NFT Highlights

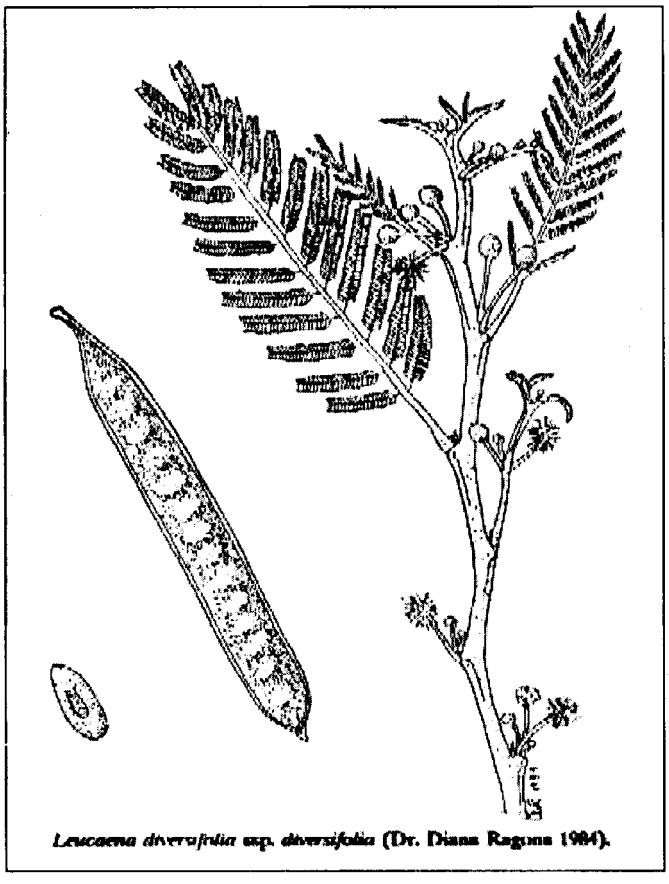
NFTA 92-05

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

Leucaena diversifolia – Fast Growing Highland NFT Species

Leucaena diversifolia is the second-best known species in the genus *Leucaena*. Through numerous international tree trials, it has gained a reputation for aggressive growth at cool or high elevation sites where *L. leucocephala* performs poorly. It is a common companion tree to coffee in much of Indonesia and Mexico. *L. diversifolia* has moderate or high resistance to both psyllids and seed beetles, and is low in mimosine. Its forage digestibility is somewhat lower than *L. leucocephala.* It produces straight boles, and is desirable for paper and charcoal production.

BOTANY. *L. diversifolia* (Schlecht.) Bentham (Leguminosae, subfamily Mimosoideae) is a medium-sized tree, often growing 10 to 20 m in height and 10 to 40 cm in diameter. *L. diversifolia* typically grows as a single stem tree with a long straight bole and slender uplifted branches that terminate in horizontal twigs. Some diploids produce branches at 180 degrees to each other, giving the trees a planar or two-dimensional appearance.



Leucaena diversifolia ssp. *diversifolia* (Dr. Diana Ragone 1984).

The leaves of *L. diversifolia* are easily distinguished from *L. leucocephala* by high numbers of small leaflets. The leaflets are 1 to 2 mm wide and nearly 1 cm long. The apex of the leaflet is usually off-center and pointed. Flower heads are borne in clusters at leaf axils and average under 1 cm diameter (0.5-1.8 cm) on the day before flowering. Unlike *L. leucocephala* flowers, the styles of *L. diversifolia* extend past the anther halo. Flowering is profuse, beginning in late spring and continuing until mid-fall. Flower color ranges from bright red to light pink. Young pods can turn bright red in the sun, accounting for the Mexican name 'guaje rojo" or red leucaena (Brewbaker 1987b).

Subspecies. *L. diversifolia* contains two subspecies. The most widely cultivated, *L. diversifolia* ssp. *diversifolia*, is like *L. leucocephala* being self-fertile and "tetraploid" (2n = 104). It is often abbreviated DIV4. The other subspecies, *L. diversifolia* ssp. *trichandra* (syn. *L. d.* ssp. *stenocarpa*) is outcrossing and has half as many chromosomes ("diploid"). It is abbreviated DIV2. The subspecific division is important as the breeding methods used to improve each subspecies are very different. DIV4 pods mature in about 90 days, while those of DIV2 mature in 80 to 160 days. *L. diversifolia* seed weigh about one third (about 20 seeds/gram) of *L. leucocephala* seed. Seeds of the DIV2 are commonly smaller than those of DIV4.

ECOLOGY. Unlike *L. leucocephala*, which frequents hot mesic lowlands (sea level to 1000 m), *L. diversifolia* colonizes higher (700 to 2500 m), cooler, and seasonally wetter sites. Its performance in highland trials is, predictably good. Biomass yields of *L. diversifolia* (DIV4) were five times that of *L. leucocephala* at Mealani, Hawaii, 850 m elevation, mean average temperature 18°C (Brewbaker et al. 1988). An Indonesian *L. diversifolia* diploid performed better than several *L. leucocephala* in Papua, New Guinea (Bray *et al.* 1988)

L. diversifolia is not frost tolerant. Early indications suggest that *L. diversifolia* is drought-sensitive. It performs best on fertile (maize-growing) soils, but also colonizes infertile ones. The species is not normally found on acid soils but some can tolerate moderate acidity (Hutton 1984). Some diploids have been discovered growing among pines near Siguatepeque, Honduras. The species does not appear to be tolerant

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of saline or sodic soils. It tolerates partial shade and seasonally heavy rain.

DISTRIBUTION. The native distribution extends from Eastern and Central Mexico (Veracruz and Puebla) south through Guatemala, Honduras and into Nicaragua. The tetraploid is native only in a small region of central Veracruz, Mexico near Jalapa. No diploids grow in this area, although they probably occur in southern Veracruz. The center of diversity of the diploids is Guatemala. Oaxacan (Mexico) diploids are different in tree form (shrubby), pollen (large) and pubescence (heavier) from their Guatemalan kin, and may withstand periodic drought.

The naturalized distribution of the species includes the Caribbean, Africa and S.E. Asia. The tetraploid was probably established in Jamaica early in this century. Diploids (probably Guatemalan) were brought into the Ivory Coast, Cameroon and Java, Indonesia in the late 1800s. The Indonesian populations appear to be agronomically superior and may be partially inbred; if so they could be invaluable in hybrid seed production.

USES. *L. diversifolia* does not have a history of cropping and much of the information on its value remains anecdotal. The primary uses of *L. diversifolia* are fuelwood, posts, pulpwood, shade and reforestation. It is also used for soil improvement and stabilization, alley cropping and agroforestry, pasture improvement and forage.

Forage. In one study, foliar digestibility of *L. diversifolia* lines were 10-20% less than that of *L. leucocephala*. The higher tannin content of the foliage may increase bypass protein levels in ruminants. Bypass protein is important to ruminants because the protein is protected from degradation in the rumen, but available for absorption in the small intestine, which is metabolically efficient. Mimosine content (1.5-2.5%) is about half that of *L. leucocephala* (4%). Levels of more than 50% of the forage in animal diets are not recommended.

SILVICULTURE. Seed can be scarified by: a 5-7 minute soak in concentrated sulfuric acid, a 3 minute soak in 75°C hot water, or mechanical scarification. *L. diversifolia* fixes nitrogen with *Rhizobium*, and has a specificity comparable to that of *L. leucocephala*. Little is known about its mycorrhizal needs; these are also assumed to be comparable to that of *L. leucocephala*. Seedling vigor of *L. diversifolia* is poor, especially of the tetraploids and small-seeded diploids (Sorensson et al. in submission). Seeds may take a week to fully germinate, and early growth rates are half that of more vigorous leucaenas. Seedlings are typically transplanted into the field eight to twelve weeks after germination, when they should be 15 to 30 cm tall. Vegetative propagation from cuttings and grafts has generally failed although tissue culture is successful.

PESTS & DISEASES. *L. diversifolia* are generally resistant to insect pests in the field. Tetraploids show moderate psyllid resistance, but defoliate during heavy pest outbreaks (Brewbaker 1987a, Bray and Woodroffe 1988). Some diploids are extremely resistant to psyllids.

Both tetraploids and diploids show high resistance to seed beetles *Araecerus levipennis* and *A. fasciculatus* (Braza 1988). Damage to unprotected seed from *A. levipennis* in Hawaii is often one-quarter that to seed of other susceptible leucaenas.

HYBRIDS. Most interspecific combinations between and within *L. diversifolia* and other species are successful (Pan 1985, Sorensson and Brewbaker in submission). The best known hybrid is that between tetraploid *L. diversifolia* and *L. leucocephala*. It is called 'KX3'. It has a broader genetic base than either parent and often outyields them. Like the parents, the hybrid is self-fertile and seedy.

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FACT 97-06

A quick guide to multipurpose trees from around the world September 1997

Leucaena leucocephala : A Versatile Nitrogen Fixing Tree

Among about 700 trees now known to fix nitrogen, none are more versatile than *Leucaena leucocephala.* This lowland tropical American legume circled the globe four centuries ago. In Latin America it served as a food source (beans). Now it serves worldwide as a source of fuelwood and charcoal, pulp for paper and rayon, leaves for fodder and green manure, timber for building and furniture and poles and crafts, shade for trees like coffee and cacao, seeds for crafts, and gum for glues.

Botany

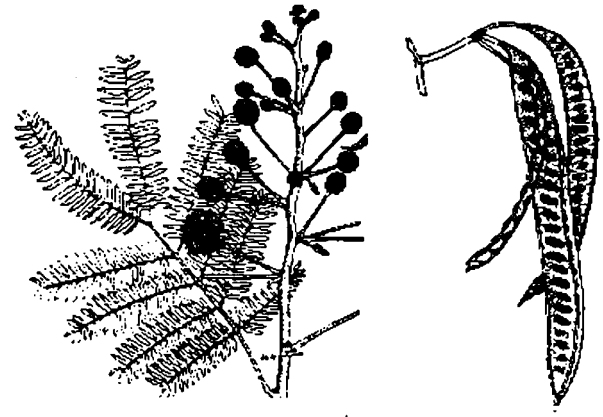
Leucaena leucocephala (Lam.) de Wit has a history of several botanical names, including *L. glauca* and *L. latisiliqua.* It was widespread in Mexico and Central America at the time of arrival of Spaniards in 1520, and by the end of the century had traveled in their galleons to the Philippines. From there it spread worldwide as shade for coffee and as fuelwood and fodder tree. Only one variety occurred worldwide prior to the 1950's, the 'common' shrubby, seedy type in the subsp. *leucocephala.* Gross misnomers exist and only add confusion; e.g., the 'Hawaiian' type is not from Hawaii, the 'Peru' type is not from Peru, the 'Salvador' type is not from El Salvador.

The species varies widely from small shrubs to handsome trees (to 20 m and 40 cm dbh). Leaves are 15 to 20 cm long and bipinnately compound. Flowers are white and in compact heads of about 150 flowers. It is fully self-fertile and rarely outcrosses, making it very seedy with 4-10 pods per head. The brown pods hang vertically, with about 15 seeds per pod. There are 10,000-20,000 seeds per kilogram.

Few countries lack a special name for this species and its relatives. 'Guaje' (Spanish) and 'huaxin' (Zapotec) are basis for the name of the State of Oaxaca, Mexico, near its origin. Other names include 'koa haole' (Hawaii), 'tangantangan' (Pacific isles), 'ipilipil' (Philippines), 'lamtoro' (Indonesia), 'yin hue whan' (China), 'subabul' or 'kubabul' (India), and 'leucaena' (international) are among the better known.

Ecology

Leucaena probably originated in calcareous lowland soils of the Yucatan peninsula (17 N) of Mexico and Guatemala. It thrives on limestone rich soils (including highly alkaline soils) and fails where pH is under 5, especially if aluminum saturation is high. Mild frosts kill back the tree, but regrowth is adequate for commercial fodder production in south Texas, USA and Queensland, Australia. Cool temperatures greatly slow leucaena's growth, and it is not a competitive legume for mid-elevations (above 1000 m) in Mexico, Hawaii, Nepal or East Africa, regions where *L. pallida* and the KX2 hybrids excel.



Source: F/FRED 1992

Leucaenas are highly drought-tolerant once established, and naturalize under rainfalls ranging from 500 to 2000 mm. They do not stand waterlogging and are replaced by *Prosopis* spp. in extremely arid areas. Nodulation and N-fixation can involve many types of *Rhizobium*, and P uptake depends entirely on activity of a wide range of VAM (vesicular arbuscular mycorrhizae).

Establishment

On most eroded tropical soils, leucaena establishment is greatly accelerated by addition of phosphorus and calcium. Seeds have a hard coat that must be scarified to permit water absorption by nicking the seed coat or soaking 3 minutes in boiling water or 15 minutes in sulfuric acid. Direct seeding requires good moisture and weed control conditions. Nursery-grown seedlings thrive in 15-cm long dibble-tubes with aerial root pruning. They transplant well in three months, after at least a month in full sunlight. Bareroot transplants have also been used. Cloning has no direct interest in the highly self-fertile *L. leucocephala*, and is difficult at best. Weed control is essential during establishment and seedlings need protection from grazing animals.

Uses

Wood. 'Instant Forests' occur when leucaenas are transplanted well, with canopy closure in 3 months. They can grow to a mature height of 13 to 18 m in 3 to 5 years. Mean annual wood increments range from 20 to 60 m^3 when population densities are high (over 5000/ha). Isolated trees can achieve dbh of 50 cm. The wood of 5-yr-old trees has specific gravity of about .52 and 46% moisture, and has a brown heartwood that reddens with age. It serves well for posts and parquet flooring, and can be used for furniture and lumber. The wood is a preferred fuelwood internationally, burning slowly with little ash or smoke, and makes an excellent quality charcoal. Varieties like K636 have erect boles more suitable for timber

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production, which can be enhanced by close spacing and pruning.

Fodder. Foliage of *L. leucocephala* has one of the highest digestibilities (60 to 70%) for ruminant animals among tropical legumes and grasses. All animals relish the foliage. Annual forage yields are very high under good management, ranging over 20 t dry matter/ha with 3-month harvest at population densities exceeding 50,000/ha. Cattle and goats make superior gains on grass supplemented with 20 to 30% leucaena. Range grazing is the most economic management, with leucaenas in rows spaced 5-8 m and grass between. Mimosine and DHP are problems overcome by ruminant bacteria (see "problems" below). Non-ruminant animals are more seriously affected by these compounds. However, leucaena is used up to 5% in poultry rations to color egg yolks.

Green manure. 'Growing Your Own Nitrogen' is a motto that deserves wide application in the tropics, as soils become increasingly eroded and impoverished. Leaf litter yields from solid plantings of leucaenas exceed 10t/ha (dry) with up to 300 kg N/ha. For alley cropping, it is planted in hedgerows and coppiced at 50 to 100 cm.

Other products. In Southeast Asia, tender vegetative shoots of leucaena are eaten, and seeds are made into tempeh (see "problems" below). Both seeds and leaves have high protein (25%) and Vitamin A precursors (400 ppm). Gums in its leaflets complicate the production of liquid protein extracts, a potentially valuable product. Exuded leucaena bark gum is an excellent substitute for gum arabic, with local use in Asia.

Genetic improvement

Leucaena leucocephala is a polyploid with 2n=104 chromosomes, probably arising as a hybrid among two of the many diploid species in the genus. Collections grown in Hawaii have revealed many outstanding varieties of *L. leucocephala*, including K584 and K636, to supplement earlier releases such as K8, K28 and K67. One new hybrid population (LxL) exploits intraspecific heterosis. However, the genus Leucaena is an interbreeding complex that permits improvement of *L. leucocephala* from any other species. Fertile hybrids occur from crosses with other polyploid species, including *L. pallida* (2n=104), *L. diversifolia* (2n=104) and *L. confertiflora* (2n=112). Among these, populations KX2 and KX3 were bred by recurrent selection in Hawaii and often lead international fodder yield trials. *Leucaena leucocephala* can also be crossed to diploid species to make fertile hybrids (e.g., *L. pulverulenta*, 2n=56) or seedless hybrids (e.g., *L. esculenta*, 2n=52). The seediness of self-fertile leucaenas is an issue of concern in a few places in the tropics (such as Hawaii), where feral animals do not exist. Seedless hybrids offer an attractive option to plantations in these areas. Seedless plantations can also be achieved by cloning any of the self-sterile leucaenas, including segregants from KX2. Since varieties of *L. leucocephala* are all self-pollinated, seed sources are few (e.g., Hawaii Agricultural Research Center) and local seed orchards are recommended.

Problems

Two problems of leucaenas dominate literature, although damage by people and animals are more important. An historic problem is that of the amino acid, mimosine, found in *L. leucocephala* around 4% dry weight in leaflets and seeds. Mimosine degrades to form DHPs (dihydroxypyridines) that are depilatory and goiterogenic. These are degraded in the rumen of ruminants by a bacterium, *Synergistes jonesii*. Such bacteria are associated only with leucaenas, thus not generally found in temperate animals, and must then be added. Mimosine also degrades due to heat and precipitates with iron salts.

The psyllid, or jumping plant louse, attracted great attention as it circumnavigated the globe between 1984 and mid-1990's. Long known throughout the Americas, *Heteropsylla cubana* Crawford can defoliate leucaenas seriously when there are no predators around. However, in Hawaii, and in most countries where it has moved, the psyllid now is under heavy predation or parasitization. It causes a problem largely where leucaenas are regularly lopped or browsed for foliage, providing a rich continuing resource of the juvenile leaflets needed by the psyllid. Useful predators that have been deployed abroad include the beetle *Curinus coeruleus* and a parasitic wasp. Breeding in Hawaii revealed rich genetic resources of resistance, now available in varieties like KX2. Within the species *L. leucocephala*, however, the best tolerance (e.g. K636, K584) is inadequate to prevent yield loss under forage management unless predation is heavy. Once established, leucaena trees do not appear to suffer yield loss due to psyllids.

Other challenges to scientists include leucaena's susceptibility to leafspot disease in South America, to rootrots caused by *Phytophthora drechsleri* and *Fusarium semitectum* in wet soils, and to aluminum toxicity in acid soils.

Resources

A Leucaena Network (LEUCNET) was established in 1994 to link scientists working with leucaenas, coordinated by the University of Queensland, University of Hawaii and Oxford University. A newsletter is published regularly, and seed sources for research listed. Contact FACT Net for more information.

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NFT Highlights

NFTA 88-05

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

Leucaena Psyllids : A Review Of The Problem And Its Solutions

Psyllids have caused severe damage since late 1982 to *Leucaena* in tropical and subtropical areas outside their native range in the Americas. Many farmers, especially in parts of South and Southeast Asia, have been particularly hurt by these "jumping plant lice" that have defoliated their fodder and green manure trees. More damage is expected as these psyllids spread around the world. However, components of an Integrated Pest Management Program - genetic resistance and biological control - are rapidly being developed and indicate that the psyllid problem is surmountable.

PSYLLID IDENTIFICATION: Leucaena psyllids, *Heteropsylla cubana* Crawford, are tiny insects (1-2 mm) in the family Psyllidae (Homoptera). Eggs are yellow, found primarily on young terminal leaves, and hatch in 2 to 3 days. Nymphs, which resemble aphids, undergo five instars over eight to nine days. Adults are two to three times the size of the largest nymphal instar. Their reported color has ranged from green to brown to whitish. They use stout legs to jump before taking flight when disturbed. Females begin laying eggs 1 to 3 days after becoming adults.

PSYLLID DISTRIBUTION: The Leucaena psyllid is native to the Caribbean, Mexico and Central and South America. Moving as uninvited passengers on aircraft or in high altitude winds, they arrived in Hawaii in 1984. By 1986, they were reported in Australia, the Pacific Islands and Southeast Asia (Thailand, Malaysia, Indonesia, Philippines). In 1987 they arrived in Sri Lanka, making their way to Burma, China and India in 1988. They undoubtedly will move into Africa.

DAMAGE: Psyllid damage is greatest when juvenile foliage development is rapid, as on hedges managed for green manure and/or fodder. Nymphs cause the primary damage by sucking sap from young foliage. Leaflets turn yellow, curl, and wilt. The deposition of honeydew encourages the growth of sooty molds. Complete defoliation of terminal shoots can occur under heavy psyllid infestation. Trees usually survive unless they are subject to other severe stresses, such as a drought. Damage usually has been the most severe just after the psyllids invade an area. Trees were almost bare in Hawaii during the first year of attack, which coincided with a severe drought. Defoliation has occurred rather cyclically since then.

POPULATION DYNAMICS: Psyllid population trends tend to vary from site to site, and seem to depend on a complex set of interactions between leucaena growth, weather (particularly moisture), psyllid mortality factors, and other influences. In a study of two sites in the Philippines, psyllid populations built up during the rainy season, but leucaena usually outgrew whatever damage occurred (Villacarlos et al. 1988). When leaf growth slowed in the dry season, the already high psyllid populations caused the most severe damage. Psyllid populations dropped to very low levels at the end of the dry period due to the lack growing young shoots. Psyllid population fluctuations and damage were much more severe at the site with a more pronounced dry season. Entomogenous fungi, which require moist conditions, apparently helped keep psyllid populations in check at the wetter site.

In Australia, the number of adults rapidly built up from almost none to large numbers within three to four days of rain (Bray and Woodroffe 1988). Adults had either been present on the lower leaves, migrated from leucaena in the surrounding area, or traveled from more remote stands. The most important environmental factor for this build-up appeared to be moisture and its effect on plant growth. Without actively growing young shoots to feed on, damaging levels of psyllids could not arise.

From July 1987 through June 1988 in Hawaii, three major defoliations occurred in a psyllid trial (Wheeler 1988). Correlations between psyllid numbers and temperature and rainfall were very low, but a higher correlation was found with rainfall. The build-ups in psyllid populations took approximately two weeks. The first indications were greater numbers of eggs on juvenile leaves, followed by higher numbers of nymphs and adults, and then defoliation.

Typical psyllid damage, top, and a psyllid nymph, bottom left, and adult.

Written by NFTA Staff

GENETIC CONTROL: The psyllid outbreak emphasizes the importance of a diversified genetic base to reduce the impact of pest infestations. Some people have developed the unwarranted belief, however, that leucaena should no longer be used. The psyllid epidemic has been caused primarily by excessive use of only one genotype of *Leucaena leucocephala*. This diverse genus has a large degree of variability in form, growth and psyllid resistance, and it still has much to offer.

Leucaena species with outstanding psyllid resistant germplasm are *L. collinsii, L. pallida L. esculenta, L. retusa* and *L. diversifolia* (Sorensson and Brewbaker 1987). *L. leucocephala* varieties that show some psyllid tolerance as mature trees are K636 and K584, "giants" from N.E. Mexico. Observations in Hawaii indicate that when these varieties are managed for wood production trees retain enough mature foliage to maintain good growth (Wheeler 1988). Tolerant *L. leucocephala* and *L. diversifolia* varieties and hybrids also have been identified in Taiwan (Pan 1987) and other countries.

The international Leucaena Psyllid Trial Network organized by NFTA has identified germplasm that is resistant under fodder management (Glover 1988, Wheeler 1988). *L. pallida* showed the highest psyllid resistance followed by the hybrids KX1 (*L. pailida* x *L. diversifolia*) and KX2 (*L. pallida* x *L. leucocephala*) and *L. diversifolia* (K784 & K785). *Leucaena diversifolia* (KI56) and the hybrid KX3 (*L. diversifolia* x *L. leucocephala)* showed resistance at some sites and susceptibility at others. The giant *L. leucocephala* varieties managed for fodder production were heavily damaged at all sites when psyllid populations were high. *L. leucocephala* K636 performed better than the other *L. leucocephala* varieties because of its ability to recover faster from psyllid damage. New hybrids are being developed at the University of Hawaii in collaboration with NFTA. New leucaena plantings should involve a number of tolerant or resistant varieties.

OPTIONAL TREES: *Calliandra, Gliricidia* and *Sesbania* spp. are among the attractive local and exotic alternatives to leucaena (IDRC 1988). Since all species have insect pests, overuse of any particular genotype should be avoided.

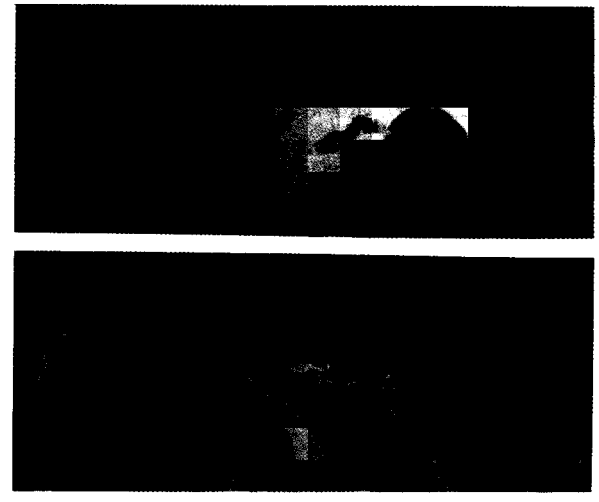
BIOLOGICAL CONTROL: Natural enemies of the psyllid normally have provided effective control in leucaena's native range (Pound and Martinez 1983). Many general predators in areas invaded by psyllids also have been observed preying on them, although it is difficult to determine how effective they are in controlling psyllid populations (IDRC 1988).

Introducing host-specific predators or parasites could help solve the problem in some regions. Two coccinellid beetles, *Curinus coeruleus* Mulsant and *Olla abdominalis* (Say), were introduced to Hawaii in the 1920s to control mealy bug infestations on coconuts. Their populations increased substantially since the arrival of the psyllid. *Curinus* larvae have contributed greatly to the reduction of psyuid populations in most localities (Funasaki 1988). It appears that *Curinus* is able to control high populations of psyllids, but it may not be able to move into an area of rapid population increase fast enough to prevent early damage to leucaena (Waterhouse and Norris 1987). The Curinus beetle has been introduced into several Asian countries with successful establishment and partial control of the pest.

Host-specific parasites are preferred over general predators for introductions, since they pose less of a threat to other insects and plants. The parasitic wasp *Psyliaephagus* sp. nr. *rotundiformis* from Tobago was released on several islands in Hawaii in 1987. Numerous parasitized nymphs have been observed at several sites since February 1988. However, two hyperparasites, which are parasites of parasites, also have been observed on this wasp (Funasaki 1988).

Entomogenous fungi also can help control psyllid populations in moist sites (Villacarlos et al. 1988, Hsieh et al. 1987).

CHEMICAL CONTROL: Chemical control has generally proven uneconomical and also eliminates predators and parasites.



Coccinellid beetles, especially the larvae, such as Curinus coeruleus, top, and Olla abdominalis, are psyllid predators.

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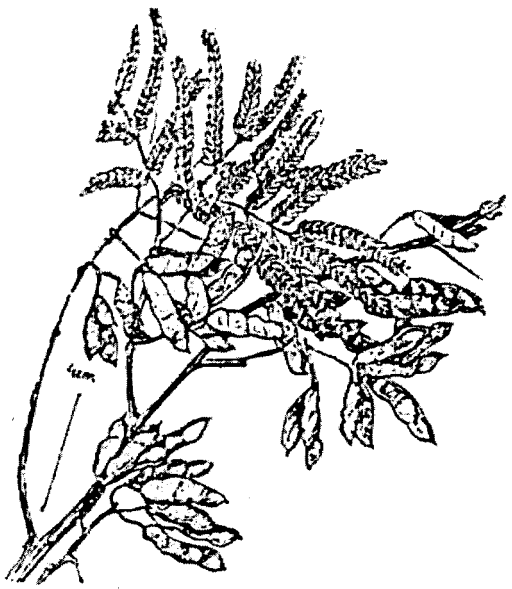
NFT Highlights

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

NFTA 88-01
March 1988

Mimosa scrabella : The Tree that Fueled the Railroads of Brazil

In the early 1900s Brazil's steam locomotives ran on wood from plantations of *Mimosa scabrella*, commonly known as "Bracatinga". Today, this fast-growing species is being planted in highland areas around the world for fuelwood, lumber, charcoal, honey, fence posts, pulp, as shade for coffee tress, and as an ornamental.



Botany

Mimosa scabrella Benth. (synonym *M. bracaatinga* Hoehne) is a member of the Mimosoideae subfamily of legumes. Mature trees reach 15-20 m in height and up to 50 cm in diameter with a straight bole and sparse, broad crown (Duke, 1981). Shrubby varieties are also found which are 4 - 7 m in height with a dense crown. The tree has small bipinnately compound leaves with tiny leafints, small white flower heads and small, narrow flat pods separated into joints that split open upon drying (Little, 1932). Throughout the year it sheds large quantities of nitrogen-rich leaves that decompose rapidly and form a very good humus (NAS, 1979).

Native to the cool, subtropical plateaus of southeastern Brazil, bracatinga thrives in low temperatures ranging from 12-18 C and tolerates infrequent frosts. It rarely occurs in areas with mean annual temperatures above 23 C. Bracatinga prefers an annual rainfall above 1000 mm with no more than four months of less than 100 nm per month. It can tolerate strongly acidic soils, pH 4.8 to 5.1, deficient in P and K with a high aluminum content (Haeffner and Salante, 1981). It will not tolerate wet soils and growth is greatly affected in compacted, degraded pastures (Campos, 1984).

Establishment

Seeds (65,000/kg) remain viable for at least 3-5 years when stored in cold chambers. To obtain rapid and uniform germaination, seeds are scarified by puring boiling water over them and stirring gently for 3 minutes. Seeds can then be soaked in tap water for 24-48 hours to accelerate germaination. Direct seeding is possible with frequent weeding (NAS, 1980).

Successful establishment is also possible with bare-root seedlings. Nursery grown plants are ready for field transplanting in 2-4 months, or when seedlings are 15-20 cm in height and 8-12 mm in diameter. There is a considerable amount of genetic variability in the species (Fonseca, 1982). Variation in growth and thickness

Written by Nancy Glover

of bark were detected between six seed sources collected in its native range. It has been suggested that *M. scabrella* is cross-pollinating.

FUELWOOD AND CHARCOAL:
Fuelwood plantations in Brazil are commonly planted at spacings of 2 x 2 or 3 x 3 m and harvested on 3-7 yr. rotations (Haeffner and Salante, 1981). Mean annual increments ranged between 8 and 36 M^3/ha for 6 year old plantations in southern Brazil (Ahrens, 1981). In the deep, fertile, volcanic soils of Costa Rica mean annual increments of 45.7 M^3/ha are reported (Campos and Bauer, 1985). Bracatinga also makes good charcoal, but it produces a large amount of ash (Lisbao, 1981).

OTHER WOOD PRODUCTS: The heartwood is hard with specific gravity reports ranging from 450 to 670 kg/m^3 and is tinted a grayish- rose color (Lisbao, 1981). Sapwood is pinkish. The wood is used for lumber and is straight-grained and medium textured with a moderately rough surface without luster. Tests of young plantation-grown wood show it can be pulped with sufficient quality for printing and writing paper. Fiber length is 1.2 mm. Stakes also are used for fence posts and in tomato production.

SHADE TREE: Highland coffee plantations in Guatemala and Costa Rica use bracatinga as a shade tree for coffee. Planted in Costa Rica at a spacing of 4 x 5 m in deep, fertile, well-drained, fertilized coffee plantations, it reaches 5-6 m in height and 8- 11 cm in diameter at breast height in 16 months (Picado, 1985).

INTERCROPPING: In its native region, bracatinga is often found growing in association with corn and beans (Barembuen, 1985). In the highlands of Kenya, has been planted along contour lines 8 to 30 m apart with corn for fuelwood production. It is not a good hedgerow species because it does not coppice.

OTHER USES: Commonly referred to as "the tree with many white feathers," it makes a beautiful ornamental, avenue tree or living fence. Abundant flowering make it excellent for honey production As a pioneer species it established pure, dense stands throughout vast areas in Brazil's Parana area after the native forests (*Araucaria angustifolia*) were cut and burned (Hoehne, 1930), indicating its reforestation potential (EMBRAPA, 1981).

RESEARCH: A comprehensive research program with *M. scabrella* was initiated in 1980 by the Instituto de Pesquisas e Estudos Florestais (IDEF) and the Departmento de Silvicultura at the Universidade de Sao Paulo, Sao Paulo, Brazil.

NFT Highlights

A quick guide to multipurpose trees from around the world

NFTA 95-03
June 1995

Myroxylon : Balsam and Much More

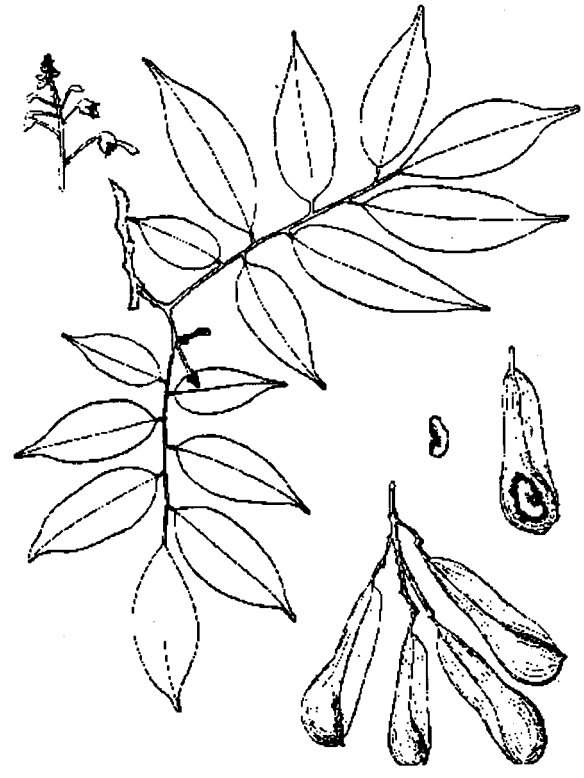
Native to Central and South America, representatives of *Myroxylon* are used in folk medicine, as shade trees for cultivated crops, ornamentals, and for fine timber. Balsam and its essential oil are used to flavor baked goods, candy, chewing gum, gelatin, ice cream, pudding, soft drinks and syrups, and as incense in churches. Balsam oil is also used in perfume, cosmetic and soap industries. Seeds are used to flavor aguardiente, a popular alcoholic beverage in Latin America (Duke 1981).

Common names include: bálsamo, palo de bálsamo (Spanish America in general), cedro chino, nabal (Mexico), chirraca, sándalo (Costa Rica), tache, tolú (Colombia), estoraque (Peru), cabreúva vermelha (Brazil), incienso, and quina (Argentina) (Chudnoff 1984).

Botany

Myroxylon balsamum (L.) Harms (family Leguminosae, subfamily Papilionoideae) grows to 34 m in height and 1 m in diameter. The bark is generally gray and spotted with yellow rough areas. The 3-11 leaves are alternate, evergreen and oddly pinnate, 6-9 cm long and 3-4 cm wide (Duke 1981), and have scattered, translucent, glandular oil dots or lines (Allen and Allen 1981). Flowers are whitish, and the corolla contains 5 petals (Fuentes, 1993). The winged pod is 8-13 cm long and 2.5 cm broad and contains one seed at the tip (Duke 1981). There is confusion about the number of species and varieties in the genus *Myroxylon*. Wiersema et al. (1990) reports two species: *M. balsamum* (L.) Harms native to southern Mexico, Central America, Colombia and Venezuela; and *M. peruiferum* L.f. native to northwest Argentina, Bolivia, Brazil, Colombia and Peru. Duke (1981) reports one species in South America *M. balsamum* (L.) Harms. In Brazil Lorenzi (1992) reports *M. balsamum* (L.) Harms and *M. peruiferum* L.f. as synonymous.

Wiersema et al. (1990) also reports two varieties: *M. balsamum* var. *balsamum* in Panama, Colombia and Venezuela; and *M. balsamum* var. *pereirae* (Royle) Harms from southern Mexico through Central America. Duke (1981) reports only one variety *M. balsamum* var. *pereirae* (Royle) Harms distributed along the Pacific Coast jungles of Central America.



Myroxylon balsamum *(L.) Harms*
Source: Duke 1981

Ecology

Myroxylon balsamum grows in areas with annual precipitation ranging from 1350-4030 mm (average 2640 mm), annual mean temperature of 23-27°C, and soils with pH 5-8 (Duke 1981). In northwestern El Salvador it grows from 450-700 m altitude in an area known as the "balsam zone" (Fuentes 1993). *Myroxylon balsamum* var. *pereirae* is reported to grow on poor but well-drained soils, at altitudes up to 600 m (Duke 1981).

Distribution

Representatives of the genus are found in southern Mexico, Central America, Venezuela, Colombia, Ecuador, Peru, Bolivia, Argentina and Brazil. *Myroxylon balsamum* var. *pereirae* has been introduced to southern Florida, Ceylon, India and West Africa (Duke 1981).

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Uses

Gum. *Myroxylon balsamum* var. *balsamum* and *M. balsamum* var. *pereirae* yield gums called tolu and Peru balsam, respectively. These gums are used mainly as a flavoring in cough syrups, soft drinks, confectioneries, ice cream and chewing gums (Duke 1981). Trees are wounded to collect gum by three methods. 1) V-shaped cuts are made in the bark taking care not to girdle the tree and cups are placed under cuts to collect gum. 2) Trees are burned at the base. Strips of bark are pulled off, crushed and placed in hot water to soften the balsam and facilitate its flow. The cooled balsam sinks to the bottom and can be separated (Duke 1981). 3) Sections of the tree trunk are beaten with a wooden club and then vertical incisions 8 cm wide are made in the bark. A few days later the incisions are heated with fire to stimulate gum flow—incisions are not burned. Rags are placed over the incisions and removed when they are saturated. Crude presses are used to extract gum from the rags (Fuentes 1993).

Gum harvesting begins on 20 to 30-year-old trees with minimum diameters of 12-15 cm (Fuentes 1993). Twenty-year-old trees yield about 3 kg of gum per year (Allen and Allen 1981). With proper management trees yield gum for 30 to 40 years. Prices per half kilogram of unrefined and refined gum in El Salvador in 1993 were approximately 17 and 24 colones, respectively (Fuentes 1993). This is US$2.00-3.00 at current exchange rates.

El Salvador, a major producer of Peru balsam, exported about 48 MT annually in the late 1970's and early 1980's. Tolu balsam is produced in Colombia, the main source, Venezuela and the West Indies (Duke 1981).

Oil. Balsam gum contains about 60% cinnamein, a volatile oil extracted by steam distillation. The oil is used in high-grade perfume, cosmetic and soap industries (Duke 1981).

Wood. Balsam wood is used for flooring, furniture, interior trim, turnery and railroad ties. It is moderately difficult to work but can be finished smoothly with a high natural polish. Heartwood is reddish brown, turning deep red or purplish upon exposure, and very resistant to attack by decay fungi. Specific gravity is 0.74-0.81. Shrinkage values from green to ovendry are very low for a wood of this density (Chudnoff 1984).

Folk medicine. Tolu balsam is used as a feeble expectorant in cough mixtures, and as an inhalant for catarrh and bronchitis. Peru balsam is used extensively as a local protectant, rubefacient, parasiticide in certain skin diseases, antiseptic, and applied externally as an ointment, or in alcoholic solutions. It is rarely used internally as an expectorant. Alcoholic extracts of tolu and Peru balsam inhibit *Mycobacterium tuberculosis* (Duke 1981).

Agroforestry. *Myroxylon balsamum* (L.) Harms is used in El Salvador as a shade tree in coffee plantations. There are no government initiatives to promote formal planting of the species—it is propagated mainly through natural regeneration (Fuentes 1993).

Silviculture

Seed collection. Seeds are wind dispersed and may be collected from the tree as they begin to mature. Balsam trees in Brazil flower from July to September and set seed in October and November. There are approximately 1,700 seed per kilogram (Lorenzi 1992).

Propagation. Seed should be planted in a mixture of clay and organic matter to a depth of .5 cm, covered with fine soil and watered daily. Germination beds or containers should be partially shaded. Seeds germinate (greater than 50%) in 15-30 days. Seedlings are ready for outplanting in 5 months. Seedlings grow to 2.5 m in 2 years (Lorenzi 1992).

Symbiosis

Allen and Allen (1981) report nodulation of *Myroxylon balsamum*. Nodulation of *M. balsamum* has not been reported in Brasil (S.M. de Faria, personal communication).

Limitations

Myroxylon balsamum (L.) Harms var. *balsamum* and *M. balsamum* (L.) Harms var. *pereirae* are attacked by a number of fungi: *Meliola xylosmae*, *Myiocopron pereirae*, *Peckia pereirae*, *Phylosticta myroxyli*, *Phomopsis* sp. and *Tabutia xylosmae* (Duke 1981).

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NFT Highlights

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

NFTA 89-01
May 1989

NFT Gums : Ancient and Modern Commercial Products

Plant gums have been important items of international trade for centuries in the food, pharmaceutical, adhesive, paper, textile, and other industries. Of the plant families that produce gums, which are contained in seeds or exuded from damaged bark, the Leguminosae is the most important. Many species in this family are already being utilized, and others produce gums of unexploited commercial potential.

Gum that exudes from the stem of **Acacia senegal** *is the source of gum arabic, a widely utilized edible gum.*

GUMS FOR FOOD USES

Gum Arabic: *Acacia senegal* (L.) Willd. is the classical, defined source of gum arabic, a highly water-soluble gum of relatively low viscosity. It is the only acacia gum toxicologically tested to establish its safety as a food additive. Applications include confectionery, medicated lozenges/pastilles, encapsulation of dried flavors/fragrances, and emulsification of citrus oils.

Acacia senegal is native to the and Sahelian regions of Africa and the Middle East (NAS 1979). Gum arabic is often the principal source of revenue for semi-nomadic African people who gather it from wild, untended plants. Trees are grown commercially ("gum gardens") or in state forests in the Sudan from nursery seedlings or in direct seeded plantations spaced at about 4 x 4 m. Tapping, which consists of slitting the bark and collecting the walnut-sized gum globules three weeks later during the dry season, begins about 5 years after planting and continues for about 15 years. An average annual yield is 250 g/tree, although production may range from a few grams to 10 kg (NAS 1979) or 0.2 to 6.7 kg (Duke 1981). Tree improvement programs and better management might increase quality and production. Gum arabic's export price in Sudan, which produces about 85% of the world's supply, was $3,450/ton (Oct. 1987), but the current trend is towards a lower price.

Commercial high tonnage gum arabic production requires severe physiological stress from water depletion and heat. Gum formation has been regarded as a natural response of trees under dehydration stress to store a strongly hydrophilic form of reserve carbohydrate. Gum is known to be formed at leaf-fall and translocated to roots even though the tree has not been "tapped."

Despite this drought resistance mechanism, two droughts (1973-75 and 1983-1985) decreased production and killed many trees. Gum shortages increased prices and led to the development of more cost effective modified starches, celluloses and biosynthetic/fermentation products that can replace or extend gum arabic. Consumption has dropped from 70,000 tons in 1972 to 20,000 tons today. For some applications, these alternative hydrocolloids are not as satisfactory as gum arabic, but research is continuing (Anderson 1987). This should not prohibit the extensive planting of *A. senegal* in and zones, however. For ecological reasons alone. *A. senegal* also produces firewood, food for animals and people, and other products (NAS 1979). There is always the possibility that some, at least, of the gum that can be collected will be marketable, especially if more systematic and widespread production decreases prices, hygiene and storage standards improve, research identifies new uses of natural gums, and the marketing strategies of the Sudan are improved with a decrease in the present excessively high rate of export tax (40%).

Gum Tragacanth: Asiatic *Astragalus* species are the defined source of gum tragacanth, widely used in pharmaceuticals and cosmetics; as a thickening agent in syrups, salad dressings and sauces; in textile sizing; and as an adhesive (Allen and Allen 1981; NAS 1979). The gum comes from bushes that grow in the arid mountains of countries from Pakistan to Greece, particularly Iran and Turkey. Plants are widely scattered and gum is usually collected unsystematically by villagers. Plants develop a mass of gum in the center of the root, which swells in the summer heat. If the stem is slit, a ribbon of soft gum is exuded. Over the past few years gum tragacanth demand and hence production has declined,

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partly because of its high cost (up to $80/kilo in 1985-87). As a result demand fell in 1988 to a few hundred tons and prices fell by up to 50%. Its deliberate cultivation in appropriate regions may be rewarding. However, little is known about the environmental and genetic factors that enhance gum yields and quality.

GUMS FOR NON-FOOD APPLICATIONS

Gums without a long history of safe use and toxicological evaluation, and not already included in international lists of permitted food additives will probably never be included (Anderson and Farquhar 1982). The cost of toxicological evaluations is prohibitively expensive -- at least $1 million -- and can take 8-10 years to complete, followed by 2-3 years evaluation by international regulatory committees with no guarantee of final approval. Although these non-food gums are of little commercial interest internationally, they may be used for local technological applications.

Gum Tahla: *Acacia seyal* Delile, a large, thorny tree of the Sahel, is one of several acacias that produces gum tahla, a water-soluble gum traditionally used for non-food applications such as lithographic formulations, textile and paper manufacture, foundry moulding sands, and explosives. Other globose-flowered acacias (e.g., *A. hockii, A. sieberana, A. ehrenbergiana, A. drepanolobium, A. abyssinica, A. nilotica,* and *A. arabica* (frequently misquoted, especially in India, as the source of gum arabic) may also contribute to the gum parcels commonly offered in West and East Africa. All such species give poor quality gum, usually dark, with a high tannin content, and of poor solubility. About 3000-5000 tons are exported annually. The October 1987 price was $1100- 1300/ton. There is currently a world surplus of poor quality, dark gum from many botanical sources in India, Africa and South America. *A. seyal* is also a useful source of firewood, lumber and sheep and goat forage in arid areas with 350 mm or more of annual rainfall (NAS 1980). Other Acacia species that produce gums with possible commercial non-food uses include *A. auriculiformiss, A. berlandieri, A. hebeclada, A. mellifera,* and *A. saligna* (NAS 1979).

Prosopis Gum: Gum from *Prosopis* species was collected and marketed in Mexico, South America, and the southwestern United States from the 1940s to the 1960s. The comparatively low viscosity of prosopis gum's aqueous solutions made it a useful substitute for gum tahla and technological grades of gum arabic. In general, the analytical parameters of the prosopis gums are similar to tahla gum (Anderson and Farquhar 1982; Anderson *et al* 1985). Mesquite (common name for *Prosopis spp.* in the Amereicas) gum is no longer readily available, probably because of eradication programs in areas where mesquite is considered a thorny pest. Nevertheless, there may be agroforestry opportunities in areas where windbreaks or soil stabilization and enrichment are desirable (Felker and Bandurski 1979).

Sesbania Gum: Some *Sesbania* species produce exudate or seed gums (NAS 1979; Evans and Rotar 1987). *S. grandiflora*, the closely related *S. formosa* and to a lesser extent *S. sesban* and other species, exude gum from cut or damaged bark. It has been used as a substitute for gum arabic in some applications. However, seeds are the best source of gum from sesbanias. India and Pakistan have investigated using *S. sesban* and particularly *S. bispinosa* as alternative sources of guar gum (produced by *Cyamopis tetragonolobus*), which is used in making textiles, paper products and for thickening and stabilizing solutions. Guar gum of specified quality is permitted for use in foodstuffs and this market is increasing steadily.

Leucaena Gum: *Leucaena* may become an important gum producer. Chemical analysis of gums from *L. leucocephala, L. pallida* and their hybrids indicate distinct similarities to gum arabic (Anderson 1986; Anderson and Douglas 1988) in terms of chemical composition, although the water-solubility of the leucaena gums evaluated so far has been greatly inferior to that of gum arabic. Further chemical analyses are in process and the study of gum production management and yields are now needed.

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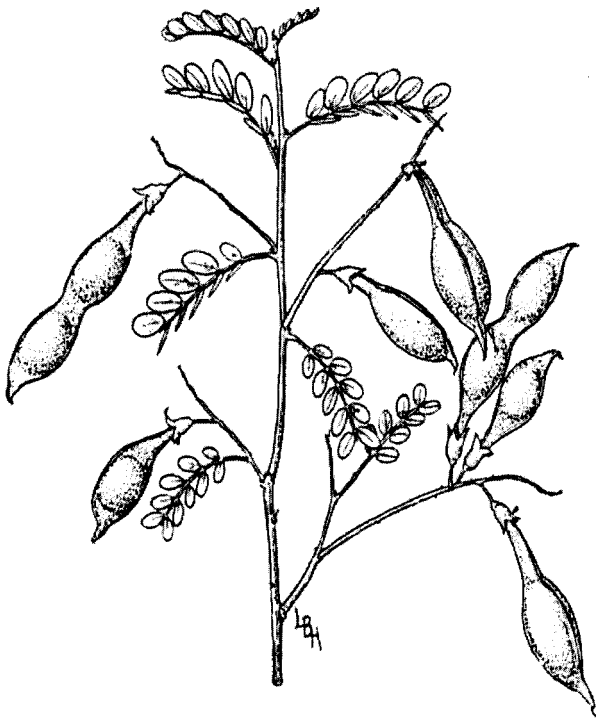
NFT Highlights

NFTA 92-08

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

Olneya tesota : A Potential Food Crop For Hot Arid Zones



Olneya tesota by Lucretia Breazeale Hamilton, from *Trees and shrubs of the Southwest Desert* (Benson and Darrow 1981).

Olneya tesota, called desert ironwood, tesota or palo fierro, is a conspicuous tree in much of the Sonoran Desert of southwestern North America. Valued for its wood, this long-lived desert tree has potential for development as a tree food crop for hot arid climates.

Botany

Olneya tesota A. Gray (Leguminosae, subfamily Papilionoideae) is the sole member of the genus *Olneya*. It grows as a small tree to 10 m in height and spread, commonly with several trunks. The trunks can attain a diameter up to 60 cm on very old individuals. Young twigs up to 10 or 15 mm thick are green. The bark of limbs is gray and smooth, becoming fissured and eventually shredding on older limbs and trunks. Painfully sharp, paired spines, 3-11 mm long occur at each node.

The foliage is cold and drought deciduous but trees in favorable locations may remain nearly evergreen. The once-pinnate leaves are up to 6 cm long with 6 to 20 grayish green leaflets. Leaflets are 7 to 20 mm long. Pink to lavender pea-like flowers, 15 mm long, appear in short, dense racemes or panicles in the late spring. In some years they cover the trees with dense masses of color. While most individual trees flower each year, flowering appears to be heavy only about two years in five. The pods ripen in the summer and contain one to several round seeds 5-6 mm in diameter. Mature pods rapidly dehisce.

ECOLOGY. *Olneya tesota* is adapted to hot and climates. Average rainfall over its range varies from 75-400 mm. The tree occurs from below sea level to approximately 900 m elevation, most often in sandy and rocky soils of plains, slopes and along dry washes. Its pH limits are unknown, but it grows well in soils with a range of 7 to 8.5.

Along its range, *O. tesota* is a dominant component of many plant communities. In the more arid portions of its range it is restricted to dry desert watercourses where storm runoff increases the available moisture. The largest individuals are found in these habitats, often forming woodlands with other desert trees including *Cercidium floridum*, *Prosopis glandulosa* var. *torreyana*, *P. velutina*, *Acacia greggii*, and others (Felger 1992). Seeds require rainfall or storm runoff during the hot season to germinate. Few seedlings which germinate away from the protective cover of other plants survive rodent predation.

Olneya tesota tolerates some freezing but generally sustains stem damage below -6° C. Prolonged exposure to lower temperatures may cause severe damage or death. It tolerates summer temperatures of 45° C. Because of its preference for warmer sites, *O. tesota* has been used as an indicator plant in choosing locations for citrus plantations (Little 1950). The trees are long-lived, perhaps attaining 200 years of age. Dead stumps can persist for decades. The trees serve as a source of food and shelter for many species of wildlife. Other desert plants, including shrubs, vines, cacti, and annuals, often grow in the microclimate beneath the canopy of *O. tesota*.

DISTRIBUTION. *Olneya tesota* is endemic to the Sonoran Desert Region. It is found in central and southwest Arizona and southeast California, USA, much of the Baia California peninsula, western Sonoran and

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extreme northwest Sinaloa, Mexico (Hastings *et. al* 1972).

USES. Human Food. The seeds of *O. tesota* have been used for food by native Americans. Fresh, uncooked seeds have a taste similar to soybeans (*Glycine max*). Felger and Moser (1985) report that the Seri Indians of Sonora, Mexico, cooked the seeds in water, emptied the water and then cooked the seeds a second time in fresh water to remove an unpleasant smell. The cooked seeds were eaten whole, or ground and salted. The seeds contain Canavalin a mild toxin (Rosenthal 1977). Roasted seeds have been used as a substitute for coffee.

Wood. The wood is very hard, dense and durable. It will not float in water. *Olneya tesota* is cut for fuelwood, charcoal and carvings. The heartwood is dark brown and takes a beautiful polish. The trees do not respond well to coppicing. Larger trees are usually killed by this practice and recovery of younger plants is slow. Widespread cutting of *O. tesota* has seriously reduced the numbers of these trees in areas of Mexico.

Other uses. Wildlife and domestic livestock browse the foliage to some extent (Allen and Allen 1981). *Olneya tesota* is cultivated as a landscape tree in hot and regions of southwestern United States. The nearly evergreen foliage, dense shade, showy flowers and attractive form make it well suited for a variety of landscape functions. Trees up to 8 m tall have been successfully transplanted by side-boxing.

Olneya tesota growing in the Sonoran Desert south of Hermosillo, Sonora, Mexico.

SILVICULTURE.

Propagation. *Olneya tesota* is propagated from seeds. Scarification of the seeds enhances uniform germination but fresh seeds will germinate without scarification. Optimum temperature for germination appears to be 25-30° C. Fresh seeds often have 80-90% germination. Emergence usually occurs in 4-12 days. Seedlings can reach 25 cm tall in their first season.

Growth. *Olneya tesota* thrives in well-drained soils with infrequent, deep irrigation. Established trees win survive on 200 mm of annual rainfall. Typically slow growing in the wild, established plants can grow up to 60 cm per year under favorable conditions in cultivation. *Olneya tesota* shows no tendency to become weedy.

Seed Production. Optimum conditions for fruit production are not fully documented. Unless supplemental irrigation is available in and regions, *O. tesota* grows slowly, prolonging the time it tales for the tree to reach flowering size.

SYMBIOSIS. Felker and Clark (1981) report that *O. tesota* seedlings grown in nitrogen free media produced nodules when inoculated with soil taken from beneath wild trees. Allen and Allen (1981) indicate that nodulation has been reported from cultivated trees of *O. tesota* in Zimbabwe.

LIMITATIONS. Desert Mistletoe (*Phorodendron californicum*) can be a serious problem on *O. tesota* in its natural range. Heavy infestations can weaken and even kill mature trees. Control can be achieved by periodically removing the clumps of mistletoe.

Young plants may be severely damaged by browsing, particularly by rodents. No significant disease problems have been reported. The plants do not appear to be fire resistant. The spiny stems can be a nuisance to people working around the plants.

RESEARCH NEEDS: Methods of vegetative propagation should be investigated to provide a convenient method of propagating selected cultivars. Trial plantings are needed to determine how this species may perform under field conditions.

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NFT Highlights

A quick guide to multipurpose trees from around the world

NFTA 95-04
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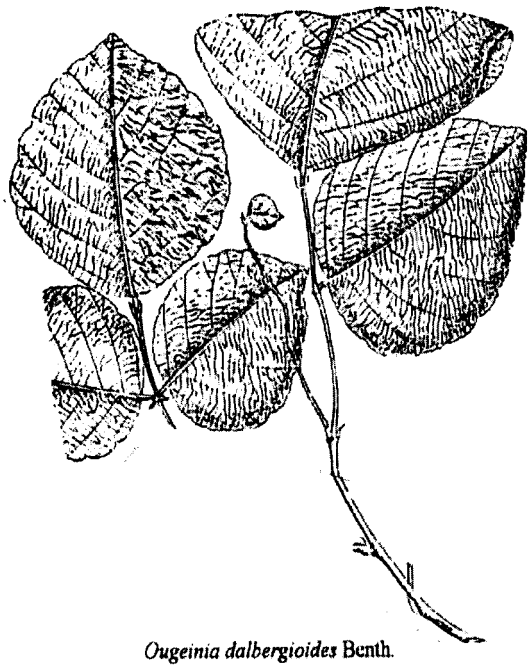
Ougeinia dalbergioides : A Multipurpose Tree for Sub-tropical and Tropical Mountain Regions

Ougeinia dalbergioides Benth. (Leguminosae, Subfamily Papilionoideae) is a monotypic genus formerly classified as *Ougeinia oojeinensis* and *Dalbergia ougeinesis*. It is a valuable timber and fodder species restricted to India. The natural forests containing this tree have been severely degraded by timber exploitation. *Ougeinia dalbergioides* is most commonly called sandan.



Ougeinia dalbergioides Benth.

Botany

Ougeinia dalbergioides is a medium-sized semi-deciduous tree, commonly attaining 40-50 cm in diameter breast height (DBH) and 7-14 meters in height (Troup 1921). The stem is often crooked, but in some areas the tree is straight. The bark, varying from pale pinkish-brown to dark bluish gray, is somewhat rough and exfoliates in irregular thin soft scales. Leaves are pinnately trifoliate, smooth above and lightly pubescent below. The obovate leaflets are generally 6-12 cm long and 2-15 cm wide, but size varies greatly. Leaf margins are entire.

The light-pink to white flowers emerge in clusters from February to May. The previous years branches generally do not bear flowers. Branches bearing flowers are leafless, while others retain leaves. Flowering trees are conspicuous and afford a beautiful sight.

Pods have a distinct seam, are 5-10 cm long and 1 cm wide. They mature and ripen in May to June and fall chiefly in June. Normally, pods remain closed until seeds germinate. Mature pods yield 2-5 viable seeds. The smooth brown seeds are 10-12 mm long and 5 mm wide. Trees do not seed heavily each year (Troup 1921).

Ecology

Ougeinia dalbergioides is native to sub-tropical regions of India. It is common at elevations of 300-1500 m. At higher elevations it remains a small tree. The optimum mean annual temperature in its habitat ranges from 20-47°C with a relative humidity from 49-90%. The optimum rainfall appears to range from 950-1900 mm. This species is not found in wet regions. Characteristic of limestone soils, sandan grows well on dry exposed sites and eroded hills (Troup 1921). It also occurs on alluvial soil, red clay, black cotton, and rocky soil. Its best growth and greatest size is attained in the lowlands on alluvial soils. Sandan is a component of mixed deciduous and sal (*Shorea robusta*) forests. It is associated with pines at the higher limits of its elevation range.

Distribution

Ougeinia dalbergioides is found in the sub-Himalayas foothill and plains of the Punjab eastwards to Bhutan. It is also common in Central and Northern India and in some parts of Southern India. It is an important species in Uttar Pradesh and Madhya Pradesh.

Uses

Wood. *Ougeinia dalbergioides* yields a valuable timber. The sapwood is grey and narrow, the heartwood is light golden brown, hard, strong, heavy and elastic-specific gravity is 0.84 and average weight is 865 kg/cubic meter. The wood air seasons slowly without much degradation. The wood can be kiln-seasoned without difficulty, but requires slow and careful drying. Planks 2-5 cm thick require 16-20 days to season (Pearson and Brown 1932; Trotter 1944). The wood does not require preservative treatment. It is difficult to work, but turns well and takes polish readily. Though originally considered difficult to peel, it is now frequently utilized for plywood. The timber of this species is superior to teak (*Tectona grandis*) in terms of shock resistance, shear strength and hardness (Pearson and Brown 1932). Sandan timber is used in the manufacture of agricultural implements, construction timbers, furniture and textile mill implements. It is also a specialty timber for marine plywood. It is a good fuel with a calorific value of 4900-5200 Kcal/kg (Krishna and Ramaswand 1932).

Fodder. The leaves are highly valued as cattle feed. Farmers lop side branches, but often spare the main limbs to assure good growth and future supplies of fodder. In

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some areas, natural stands of this species are such important fodder resources, timber harvesting is forbidden. Leaves contain 12- 15% crude protein (Singh 1982).

Other uses. Bark fibers are suitable for making rope (Pearson and Brown 1932; Trotter 1944). The bark is used as a fish poison and to reduce fevers. A sap exudate is used to make a medicine to treat dysentery. The tree is a host plant for lac producing insects. The resulting shellac is of high quality (Purkayastha and Krishnaswamy 1958).

Propagation

Ougeinia dalbergioides is readily propagated from seed. The seeds do not retain their viability for long and should be used within 12 months of maturity. Once collected seed should be properly dried and stored in sealed containers. A kilogram contains 28,000-33,000 seeds. To maximize germination, pods should be broken into fragments containing one seed and soaked in water for 24 hours before sowing (Uniyal and Nautiyal 1992). Seed should be sown 1 cm deep. Germination occurs in 3-8 days. Direct sowing is very successful and highly recommended (Troup 1921; Kadambi and Dabral 1955).

Nursery propagation accelerates seedling growth, however the large taproot of sandan makes transplanting difficult. Establishment by stump sprouts gives good results. One-year old seedlings with root-collar diameters of 5 cm are recommended. For stump production, seedlings should be cut 2-3 cm above the root-collar and 20-25 cm below. Propagation by root cuttings is successful, but stem cuttings yield poor results.

Silviculture

Young trees and seedlings need a moderate amount of shade. However, once established *O. dalbergioides* requires full sunlight for its best development. Although young trees are drought and frost sensitive, mature trees are hardy. A tree spacing of 3 x 6 m is recommended for timber production.

Mean annual growth increment averages between 3-20 mm in DBH. Trials in Srinagar indicate keeping seedlings free of heavy weed competition for 3-4 years will improve growth and survival. Under this management scheme, trees attained heights of 4-5 m and DBH of 10.5 cm in 6 years. Conversely, heavy weed competition can kill seedlings. Sandan coppices well and produces abundant root-suckers. This characteristic is particularly useful for controlling erosion along steep banks and eroded hillsides. Fast-growing coppice and root-suckers attain 7-10 m in height and 12-17 cm in DBH after 20 years. Coppice and root-suckers can be managed for timber production. In Madhya Pradesh forests are commonly managed simultaneously for sandan and teak production. The exploitable diameter for *O. dalbergioides* timber is generally 30 cm.

Limitations

Sandan is very susceptible to heart rot (*Fomes caryopnhylla*), buff brown pocket rot (*Polystictus nilgheriensis*) and white spongy rot (*Asterostromella rhodospora*). The tree is also susceptible to a number of defoliators and borers. The latter also attack dead wood (Kadambi and Dabral 1954). Timber exploitation has degraded the natural stands of this species. To reverse this condition, improved natural forest management and the establishment of large scale tree plantations are necessary.

Symbiosis

As with many other leguminous plants, *Ougeinia dalbergioides* forms nitrogen fixing symbiosis with *Rhizobium* bacteria. Reliable estimates of its nitrogen fixing capacity are not avaflable.

Genetic Variation

A variant of this species has been reported to occur at a frequency of 4% in Srinagar. Variants differ morphologically from the normal plants by producing narrower leaves with 4-6 leaflets instead of three. The morphological difference has been retained by trees established in an arboretum in 1985 (Purohit et. al 1987). These plants grow 30% slower than the normal plants. Detailed investigations on the physiology of variant plants are in progress.

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NFT Highlights

NFTA 89-05

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

Paraserianthes falcataria : Southeast Asia's Growth Champion

By whatever common or scientific names it is known, *Paraserianthes falcataria* (L.) Nielsen is a valuable multipurpose tree for the humid tropics. One of the fastest growing of all tree species, it is used for pulp and other wood products, fuelwood, ornamental plantings and shade for coffee, tea and cattle. Potential uses for which it is being tested include alley farming and intercropping in forest plantations.

BOTANY: "Falcataria" belongs to the Leguminosae (subfamily: Mimosoideae). It is most widely known by its former name, *Albizia falcataria* but it also has been called *A. moluccana* and *A. falcata*. "Falcate' means "curved like a sickle," referring to its leaflets. Leaves are alternate, bipinnately compound, and 23-30 cm long. Flowers are creamy white, and pods are narrow, flat, 10-13 cm long and 2 cm wide. This is a large tree that regularly reaches 24 to 30 m in height and 80 cm in diameter. When grown in the open, trees form a large, umbrella-shaped canopy. Crowns are narrow when this light-demanding species is grown in plantations of 1000 to 2000 trees/ha. Trees regularly produce large quantities of seeds after reaching 3 to 4 years of age.

ECOLOGY: Falcataria occurs naturally in Indonesia, Papua New Guinea, and the Solomon Islands from 10° S to 30° N. In its natural habitat it grows from sea level to 1200 m above sea level with an annual rainfall from 2000-4000 mm, a dry season of less than 2 months, and a temperature range of 22° to 34° C. Although it is likely to perform better on alkaline soils (NAS 1983), there are many examples of it growing well on acid soils.

Correlation and multiple regression analysis show that topsoil depth is the most important indicator of site quality for falcataria (Dalmacio 1987). The most productive sites had at least 19-26 cm of well drained topsoil with at least 3-8% organic matter and an exchangeable potassium of 0.36 meq/100 g of soil.

ESTABLISHMENT.- Seeds (42,000/kg) germinate easily and only require an overnight soaking in water. For more uniform germination, seeds can be treated with hot water, or dipped in concentrated sulfuric acid for 10 minutes followed by water for 15 minutes (NAS 1983). Seedlings are ready for planting in about three months and grow so fast in the field that one complete and three spot weedings during the first year are sufficient.

SILVICULTURE: A common spacing for a pulpwood rotation of 6 to 8 years is 3 x 3 in (APFN 1987). If sawtimber is desired, stands can be thinned to 6 x 6 in at 6 to 8 years and harvested at 15 years. In fertile sites a 4 x 4 in spacing for pulp is common (Tagudar 1974). In an investigation of closer spacings, Domingo (1967) found that growth at a 2 x 2 in spacing was significantly faster than 1 x 1 in.

P. falcataria is one of the fastest growing of all tree species, reaching 7 m in height in one year under ideal conditions, 15 m in height in 3 years and 30 m in 10 years. Growth averages 39 m ^{3}/ha/yr on 10-year rotations and can reach up to 50 m ^{3}/ha/yr on better soils (NAS 1983).

Liming the soil from pH 6.5 to 7.0 did not improve growth or nodulation (Ordinario 1986). Providing both nitrogen and phosphorus produced a marked increase in early growth in a red-yellow podzolic soil deficient in each nutrient (Moloney *et al.* 1986).

SYMBIOSIS: Nodulation by *Rhizobium* occurs in most soils with sufficient moisture and a pH ranging from 5.5 to 7.0. Inoculation enhanced growth and modulation in potted grassland soils. Nodulation of

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inoculated seedlings decreased with the application of 100 kg N/ha and was totally suppressed with the application of 2.00-300 kg N/ha (Garcia *et al* 1988). Falcataria also is associated with endomycorrhizal fungae, which when inoculated enhance its growth and nodulation (de la Cruz *et al* 1988).

GENETICS: At the Paper Industries Corporation of the Philippines (PICOP) plantations in Mindanao, introduced provenances performed better than local provenances. Nuevo (1976) reported that branching habits are an inherited trait. In terms of wood properties, tree to tree variation tends to be larger than variation due to stand locations and gross morphological classes.

USES: Falcataria is perhaps best known as a pulp crop (NAS 1979, Hu 1987). Other wood uses include fiber and particle board, packing cases, boxes, matches, chop sticks and light furniture. Wood is difficult to saw and not strong or durable. Its thin crown provides partial shade to coffee, tea, and cacao. It also is used as a windbreak for bananas. Trials in Hawaii have indicated its usefulness as an intercrop with *Eucalyptus*, especially in wetter areas. After four years, eucalyptus grown with falcataria in a 50:50 mixture at a spacing of 2 x 2 m were 58% taller and 55% larger in DBH than in pure eucalyptus stands (Schubert 1985). In other trials with 34 and 50% falcataria, total biomass was equal to or better than that of pure stands (Schubert *et al* 1988).

Falcataria also shows potential in alley farming. In a trial on acid soils (pH 4.2) in Indonesia, trees were managed in hedges 4 m apart and produced 2- 3 dry tons of green leaf manure/ha/yr. Application of falcataria green leaf manure doubled upland rice yields and more than quadrupled cowpea yields as compared to control plots (Evensen *et al* 1987). In 1988, however, concerns surfaced about the longevity of falcataria in alley cropping systems (Evensen, pers. comm.).

Falcataria also is grown as an ornamental, although it seldom lives more than 50 years (APCF 1987) and its brittle branches can be a problem in windy areas. Raharjo and Cheeke (1985) reported that foliage scored well in some palatability tests with rabbits and poorly in others.

Its wood is soft and generally light in color with a reported specific gravity range of 0.20 to 0.49 (NAS 1979; Little, undated). Ecotypes with denser wood have been found at PICOP plantations. Despite its low specific gravity and caloric value, its fast growth and vigorous coppicing ability make it worth considering as firewood (NAS 1983). It is used as firewood in Western Samoa, the Philippines and Java, where it is frequently planted in home gardens for fuelwood and timber with herbaceous and fruit crops. It makes a good charcoal.

DISEASES AND PESTS: Seedlings are susceptible to root rot caused by *Betrydiplodie* and *Sclerotium* (Domingo 1977). Leaf spots are caused by *Phyllachora pterocarpil* and *Pestalotia* species. Stem and branch canker is caused by *Coticum salmonicolor* (Quinones 1980, de Guzman 1974). Pests such as larvae of yellow butterflies (*Eurema* sp.) have been reported to attack plantations in the Philippines, Malaysia and Burma (Domingo 1977). The stem borer, *Kysomerafestiva* sp., is an important pest in Burma, Indonesfa and Vietnam (Domingo 1967). Shoot pruner beetles (*Callimetopus* sp.) occasionally have caused significant damage to trees in the Philippines (Braza 1988).

PROBLEMS AND LIMITATIONS: Since falcataria is easily damaged by high winds, most successful plantations in the Philippines are found in areas not frequently hit by typhoons. The tree regenerates so easily by natural seeding on any clearing that it can spread rapidly and become a pest. However, falcataria is very susceptible to herbicides. Soil erosion in falcataria plantations can be a problem, and it is not a recommended species for steep hillsides (NAS 1983).

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NFT Highlights

NAFT 95-05

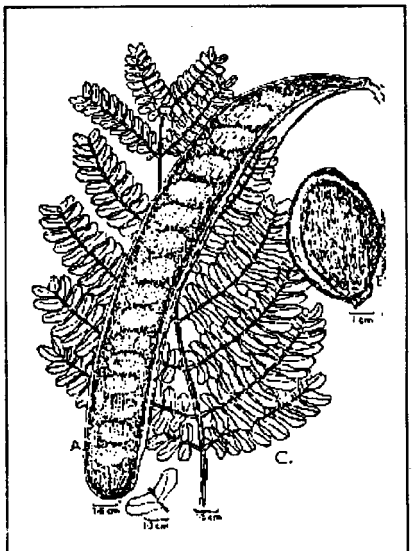
A quick guide to multipurpose trees from around the world September 1995

Pentaclethra macrophylla : A Multipurpose Tree From Africa With Potential For Agroforestry In The Tropics

Pentaclethra macrophylla Benth., the oil bean tree, is the sole member of the genus occurring naturally in the humid lowlands of West Africa. It is a leguminous tree (family Leguminosae, sub-family Mimosoideae), and recognized by peasant farmers in the southeast of Nigeria for its soil improvement properties. A related species viz. *Pentaclethra macroloba* (Wild) is native to South America (Norris 1969). *Pentaclethra macrophylla* has been cultivated in Nigeria since 1937 (Ladipo 1984) and for many years in other West African countries where its seed is relished as a food. *Pentaclethra macrophylla* was not known to nodulate until recently (Ladipo et al. 1993). With the diverse native uses of this species, and the present research effort on it, its utility could be further enhanced for agroforestry development in the humid tropics. The species is relatively fast-growing and seedlings will achieve a height of 1.5 m in the first year on good sites.

Botany

Trees grow to about 21 meters in height and to about 6 m in girth (Keay 1989). The tree has a characteristic low branching habit and an open crown which allows substantial light under its canopy. This characteristic accounts for the trees use in combination with food crops on farms and particularly in home gardens in south east Nigeria.



Pentaclethra macrophylla *A. Fruit, B. Seed, C. Leaf (Source: Isawumi 1993)*

The hole produces a reddish-orange coloration after a slash is made. Stem form is usually crooked and buttressed. Some straight-stemmed and less buttressed trees, which can pass for good timber, are occasionally seen in the forests. Bark is grayish to dark reddish brown (Keay 1989), thin and patchy with irregular pieces flaking off.

Leaves possess a stout angular petiole. The compound leaves are usually about 20-45 cm long and The hole produces a reddish-orange coloration after a slash is made. Stem form is usually crooked and buttressed. Some straight-stemmed and less buttressed trees, which can pass for good timber, are occasionally Seen in the forests. Bark is grayish to dark reddish brown (Keay 1989), thin and patchy with irregular pieces flaking off. Leaves possess a stout angular petiole. The compound leaves are usually about 20-45 cm long and

Natural distribution of Pentaclethra marcophyila *in Africa*

covered with rusty hairs giving a scurfy effect particularly along the upper surface but this eventually falls off. There are 10-12 pairs of stout opposite pinnae. The middle pairs are 7-13 cm long and also have rusty hairs along the central grove. There are usually 12-15 pairs of opposite stalkless pinnules (leaflets), each 12-15 cm long 5-10 mm broad, with the middle pairs longest. Leaflets often have a rounded tip but are sometimes notched; the base is unequal. Flowers are creamy-yellow or pinkish-white and sweet smelling. Flowering commences at variable periods within West Africa. The main flowering seasons is between March-April with smaller flushes in June and November. Fruits are available at most periods of the year because the large woody pods are persistent.

The pods are 40-50 cm long and 5-10 cm wide. Fruit splits open explosively with the valves curling up. This is the form in which they appear on most trees. Usually, pods contain between 6-10 flat glossy brown seeds which may vary in site. The seed are up to 7 cm long. This is the edible product and source of the oil; hence the name 'the oil bean tree'.

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Table 1 : Common uses of Pentaclethra marcrophylla in West africa

Uses	Part of Plant	Country
Food	Seed	Nigeria, Ghana
Salt Substitute	Pod ashes	Ghana
Edible oils	Seed	Nigeria, Ghana,Togo, Cameroon
Fences and palings	Wood	Nigeria, Ghana
Charcoal	Wood	Cameroon,Togo, Cote d'Ivoire
Carving bowls, etc.	Wood	Nigeria, Ghana
Seed craft (beadings)	Seed (beadings)	Nigeria
Dye (mordants)	Pod ashes	Ghana
Mild poison	Bark & seed	Ghana
Medicine(convulsion)	Pod	Cameroon
Medicine* (abortion)	Crushed seed	Ghana, Nigeria
Medicine (convulsion)	Smoke of burnt leaf	Ghana
Medicine* (diarrhea)	Leaf/stem bark	Ghana
Medicine* (itch)	Bark as liniment	Ghana
Medicine(lactogenicity)	Bark decoction	Ghana
Medicine	Bark as lotion	Ghana
(wound/treatment)	Whole tree	Nigeria
Ornamental		

*Abbiw (1990)

Distribution and Ecology

Pentaclethra macrophylla occurs from Senegal to Angola and also to the Islands of Principe and Sao Tome. This multipurpose tree is endemic to the humid and some parts of the sub-humid zones of West Africa. It does not occur in the highlands although, growth can be good where rainfall is adequate and temperatures are never cooler than 18°C. The annual mean temperature requirement is about 25°C and rainfall between 1000-2000 mm. After about 2-years growth in the forest, trees become relatively fire resistant and resprout readily when lopped. The natural distribution of *P. macrophylla* suggests that it is endemic to relatively acid soils. The species will also tolerate water logging as in the low altitudinal riverine areas of southeast Nigeria, Togo and Cameroon. The unusual feature of leaf loss during the wet seasons has been observed in the field on some individual trees of *Pentaclethra macrophylla* and this could be an important trait for selection for farmers. Although no provenance trials of this species have been conducted, tree phenotype in natural populations shows considerable variation in crown shape, fruit morphology and seed size.

Uses

Pentaclethra macrophylla is planted on the fringes of compound farms mainly for its edible seed. Okafor & Fernandez (1987) described the species as a major component of this agroforestry system. Its empty dry fruit pods are used as fuelwood for cooking. Leaves are shed during the dry season and farmers believe this contributes to soil fertility within the homegarden. *Pentaclethra macrophylla* wood is highly suitable for fuelwood and charcoal making (other uses are listed on Table 1). Farmers protect this species on farms because of its open crown form which does not inhibit crop plants grown under its canopy. Litter drop is appreciable. The species is believed to enhance soil nutrient and organic matter content.

The seed is large with approximately 50-80 seeds per kg. Because seeds are edible, they are not usually available for seedling production. When available in the open market, they are usually non-viable because of their short longevity (recalcitrant). Consequently seed should be planted immediately. Storage at 15°C can extend longevity for about three months. Seed pre-treatment is required. Mechanical scarification and soaking in water for 24 hours will enhance germination. Adult trees are easily marcotted (air layered), but only juvenile stem cuttings will root if treated with IBA (20 ppm). Seedlings produced in nurseries and hardened-off before out-planting make the best planting material.

Pests & Diseases

No serious pest and disease problems are known but stem borers have been recorded on some old trees and mild defoliation of juvenile seedlings is not uncommon. The species is reported to be termite resistant.

Seed Sources

- Forestry Research Institute of Nigeria, PMB 5054, Ibadan, Nigeria
- ICRAF/IRA Project P.B. 2067 (Messa), Yaounde, Cameroon

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NFT Highlights

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

NFTA 92-01
March 1992

Pithecellobium dulce : Sweet And Thorny

From Little and Wadsworth (1964)

Many N-fixing trees are alternately praised and cursed. Hardy, tenacious, seedy, and able to provide their own nitrogen, they often colonize soils and sites that are difficult or impossible for other trees. *Pithecellobium dulce* is such a tree.

Pithecellobium dulce is a thorny tree which can become weedy. In Hawaii it has a reputation as a pest in grass pastures, but normally only when fields have been left nitrogen-starved. It is a tree with many uses; food (sweet pods), firewood, honey, fodder, soap oil, tannin, hedges and shade--and it can survive hostile climates. The generic name refers to the curly pod, that mimics an ape's earring (pithekos ellobium), and the species name "dulce" refers to the sweet pod.

DISTRIBUTION: This hardy American tree is native along coasts from California through Mexico to South America, but is now found throughout the tropics. *Pithecellobium dulce* followed the Spanish galleon route (with leucaenas, gliricidias and other nitrogen fixing trees) through the Pacific and Asia to Africa. It is now common and naturalized in India and tropical Africa, especially along coasts. It is notably weedy in the Caribbean islands (including Cuba, Jamaica, Puerto Rico, and St. Croix), and in Florida and Hawaii, USA, but less so where population and animal pressure keep it contained.

BOTANY

Pithecellobium dulce (Roxb.) Benth. (family Leguminosae, subfamily Mimosoideae) is one of 100-200 species in this genus. *Pithecellobium dulce* is the only species that has become widespread outside its origin.

The height of *P. dulce* is commonly 10-15 meters, but ranges from 5 to 18 m. They are broad-spreading with irregular branches. The bark is grey, becoming rough, furrowed, and then peeling. Leaves are bipinnate, and leaflets oblong to 4 cm in length. Thin spines are in pairs at the base of leaves, and range from 2 to 15 mm in length. Leaves are deciduous. However, new leaf growth coincides with the loss of old leaves, giving the tree an evergreen appearance.

The flowers are in small white heads 1 cm in diameter. Each flower has a hairy corolla and calyx surrounding about 50 thin stamens united in a tube at the base. Flowering begins in 3-4 years and is seasonal (April in Hawaii). The pods are pinkish, 1-1.5 cm wide, about 12 cm long, and become spiral as they mature. Seeds are about 10 per pod (9,000 to 26,000/kg), black and shiny, hanging on a reddish thread from the pod. The pod splits along both margins.

ECOLOGY. *Pithecellobium dulce* thrives in dry warm climates where annual rainfall is 400 to 1650 mm. It is typical of lowlands, but can be found at elevations above 1,500 m in Mexico and East Africa. This species is found on most soil types, including clay, limestone, and sands. *Pithecellobium* species are noted for their tolerance of heat, salinity, and impoverished soils. They are also tolerant of drought conditions.

FOOD AND FODDER. Names like "dulce' (sweet) and "Manila tamarind " reflect the wide use of the pods as food. Pods contain a pulp that is variously sweet and acid, commonly white but also red. The seed and pulp are made into a sweet drink and eaten roasted or fresh. In India, the seeds are used fresh or in curries. The pods are relished by monkeys and livestock. The

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flowers are attractive to bees as source of pollen. The resulting honey is of high quality. Although the pods are attractive fodder to most animals, the leaves are browsed but not considered an important animal fodder.

WOOD: The wood of *P. dulce* is strong and durable vet soft and flexible. It can be used in construction and for posts. The reddish-brown heartwood is dense and difficult to cut. It is commonly used as fuel, although due to smokiness and low calorific values (5,500 kcal/kg) it is not of high quality. The short spines and irregular. crooked growth make it less attractive for wood uses.

OTHER USES: The tree is used extensively as a shade or shelterbelt tree with a great tolerance of arid and harsh sites. It coppices readily and can be managed as a hedge. Coppicing often increases the occurrence of thorns. This characteristic makes hedges of *P. dulce* excellent for livestock fences, but problematic for other uses.

Pithecellobium dulce is also very popular as an ornamental and is used in topiary (plant sculpturing). Trees with variegated leaflets are available as ornamentals in Hawaii. When wounded, the bark exudes a reddish-brown gum similar to gum arabic that dissolves in water to make a mucilage. The bark can also be used for tanning and produces a yellow dye. Seeds contain an oil that can be used in soap-making or as food, and the residue ran be used as animal feed. Medicinal uses are known but not common.

SILVICULTURE AND GROWTH: Seed viability is Long under dry cool storage. No pretreatment is necessary for seeds to germinate, although nicking may improve and hasten the process. Germination occurs quickly, normally in 1-2 days. Application of *Rhizobium* inoculum to seeds is suggested prior to sowing. Successful propagation by cuttings has also been reported.

Pithecellobium dulce normally competes successfully with other vegetation. It often establishes in grass ecosystems without the benefit of weed and grass control. Few data are available on its relative growth rate, but it appears to be intermediate in growth to the slower *Prosopis* spp. and the faster *Leucaena* spp. Height growth can reach 10 meters in 5-6 years under good environmental conditions.

SYMBIOSIS: *Pithecellobium dulce* forms root nodules with *Rhizobium* bacteria. Nodulation is common in all types of soil, but quantitative data on fixation has not been reported.

PESTS AND PROBLEMS: The sharp thin spines can be fierce on young shoots and often limit plant utilization. Spines are reportedly absent in some trees; a pure spireless variety would be welcomed. In pastures and cropland. *P. dulce* can be a tenacious weed. Coppice regrowth is rapid and the tree is not easily killed once established.

The tree is evidently not deeply rooted and is subject to blow-down. Superficial rooting is not common in drier soils, thus blow-down is less of a problem under such conditions. The sap is said to cause irritating skin welts and severe eye irritation (the latter is common to sap or juice from many legume trees and their fruits). The heavy smoke created by burning limits its usefulness as fuelwood. Pests include the thornbug and several boring and defoliating insects.

OTHER SPECIES OF PITHECELLOBIUM: The genus includes several other important species—*P. arboreum, P. unguiscati, P. flexicaule, P. jiringa,* and *P. parviflorum.* Commom names include "Manila Tamarind", "Madras thorn", "bread-and-cheese", "blackbeard"(English), "guamuchil", "macamtet" (Thailand), and "opiuma" (Hawaii).

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FACT Net

FACT Sheet

A quick guide to multipurpose trees from around the world

FACT 97-03
June 1997

Pongamia pinnata : A Nitrogen Fixing Tree For Oilseed

Pongamia pinnata (L.) Pierre has also been called *Derris indica* (Lam.) Bennet and *Pongamia glabra* Vent., all of these three names are still commonly found in literature. According to Lewis (1988), this species may eventually be transferred to genus *Millettia. Pongamia pinnata* is one of the few nitrogen fixing trees (NFTS) to produce seeds containing 30-40% oil. It is often planted as an ornamental and shade tree. This species is commonly called pongam, karanga, or a derivation of these names.

Botany

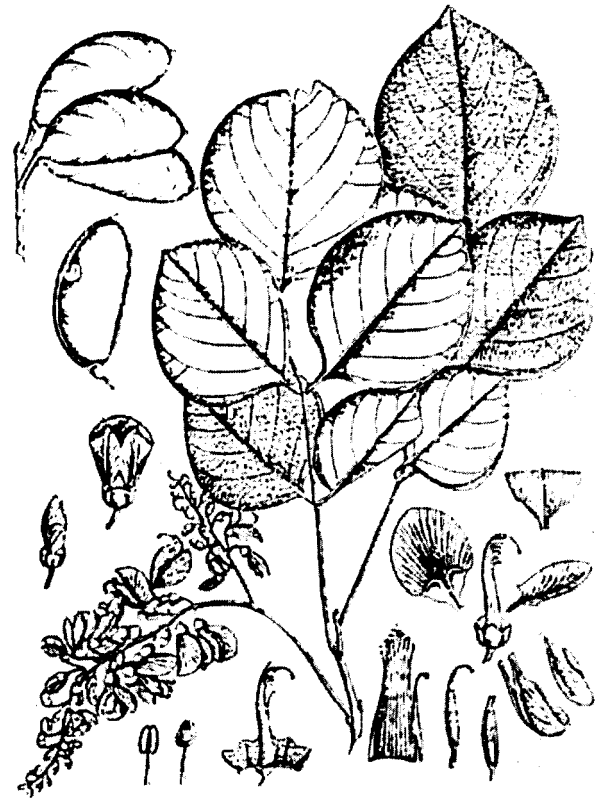
Pongam (Legunumosae, subfamily Papilionoideae) is a medium sized tree that generally attains a height of about 8 m and a trunk diameter of more than 50 cm. However, Troup (GOI 1983) reports trees attaining heights of 18 m. The trunk is generally short with thick branches spreading into a dense hemispherical crown of dark green leaves. The bark is thin gray to grayish- brown, and yellow on the inside (GOI 1983). The taproot is thick and long; lateral roots are numerous and well developed.

The alternate, compound pinnate leaves consist of 5 or 7 leaflets which are arranged in 2 or 3 pairs, and a single terminal leaflet. Leaflets are 5-10 cm long, 4-6 cm wide, and pointed at the tip. Flowers, borne on racemes, are pink, light purple, or white. Pods are elliptical, 3-6 cm long and 2-3 cm wide, thick walled, and usually contain a single seed. Seeds are 10-20 cm long, flat oblong, and light brown in color.

Ecology

Native to humid and subtropical environments, pongam thrives in areas having an annual rainfall ranging from 500 to 2500 mm. in its natural habitat, the maximum temperature ranges from 27 to 38°C and the minimum 1 to16°C. Mature trees can withstand waterlogging and slight frost. This species grows to elevations of 1200 m, but in the Himalayan foothills is not found above 600 m (GOI 1983).

Pongam can grow on most soil types ranging from stony to sandy to clayey, including Verticals. It does not do well on dry sands. It is highly tolerant of salinity. It is common along waterways or seashores, with its roots in fresh or salt water. Highest growth rates are observed on well drained soils with assured moisture. Natural reproduction is profuse by seed and common by root suckers.



Source: Beddome 1869-74.

Distribution

The natural distribution of pongam is along coasts and river banks in India and Burma. Native to the Asian subcontinent, this species has been introduced to humid tropical lowlands in the Philippines, Malaysia, Australia, the Seychelles, the United States (Little undated), and Indonesia.

Uses

Wood. With a calorific value of 4600 kcal per kg, pongam is commonly used as fuelwood. Its wood is beautifully grained and medium to coarse textured. However, it is not durable, is susceptible to insect attack, and tends to split when sawn. Thus the wood is not considered a quality timber. The wood is used for cabinet making, cart wheels, posts (NAS 1980), agricultural implements, tool handles and combs (GOI 1983).

Oil. A thick yellow-orange to brown oil is extracted from seeds. Yields of 25% of volume are possible using a mechanical expeller. However, village crushers average a yield of 20% (ICFRE, undated). The oil has a bitter taste and a disagreeable aroma, thus it is not considered edible. In India, the oil is used as a fuel for cooking and lamps.

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The oil is also used as a lubricant, water-paint binder, pesticide, and in soap making and tanning industries. The oil is known to have value in folk medicine for the treatment of rheumatism, as well as human and animal skin diseases. It is effective in enhancing the pigmentation of skin affected bv leucoderma or scabies (ICFRE undated).

Fodder and feed. Opinions vary on the usefulness of this species as a fodder. Troup (GOI 1983) reports that the leaves are eaten by cattle and readily consumed by goats. However, in many areas it is not commonly eaten by farm animals. Its fodder value is greatest in arid regions. According to Singh (1982) the leaves contain 43% dry matter, 18% crude protein, 62% neutral detergent fiber, 40% acid detergent fiber, and *in vitro* dry matter digestibility of 50%. The presscake, remaining when oil is extracted from the seeds, is used as a poultry feed.

Other uses. Incorporation of leaves and the presscake into soils improves fertility. Dried leaves are used as an insect repellent in stored grains. The presscake, when applied to the soil, has pesticidal value, particularly against nematodes. String and rope can be made from the bark fiber.

Pongam is often planted in homesteads as a shade or ornamental tree and in avenue plantings along roadsides and canals. When planted as a shade or ornamental tree, branch pruning may be necessary to obtain a trunk of appropriate height. It is a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. Its root, bark, leaf, sap, and flower also have medicinal properties.

Silviculture

Pongam is easily established by direct seeding or by planting nursery-raised seedlings or stump cuttings of 1-2 cm root-collar diameter. Propagation by branch cuttings and root suckers is also possible. In peninsular India, the seeding season is April to June, and the seed yield per tree ranges from about 10 kg to more than 50 kg. There are 1500-1700 seeds per kg. Seeds, which require no treatment before sowing, remain viable for about a year when stored in air-tight containers.

Seed germinates within two weeks of sowing. Seedlings attain a height of 25-30 cm in their first growing season. Transplanting to the field should occur at the beginning of the next rainy season when seedlings are 60 cm in height (GOI 1983). Seedlings have large root systems. Soil should be retained around the roots during transplanting. Seedling survival and growth benefit from annual weed control for the first three years after transplanting.

The spacing adopted in avenue plantings is about 8 m between plants. In block plantings, the spacing can range from 2 x 2 to 5 x 5 m. Pongam seedlings withstand shade very well and can be interplanted in existing tree stands.

This species can be regenerated bv coppice management. Information on management practices to maximize seed or biomass production is not available and should be investigated. Because it tolerates moderate levels of salinity, pongam is an ideal candidate for saline soil reclamation.

Symbiosis

Nodulation is reported in pongam (Dayama, 1985). In nurseries and in the field the presence of nodules on uninoculated pongam, seedlings is common. Therefore, this species may not be specific in its *Rhizobium* strain requirement.

Limitations

Pongam attracts many pests and diseases. Some of the important pests are *Parnara mathias*, *Gracillaria* sp., *Indarbela quadrinotata*, *Myllocerus curvicornis*, and *Acrocercops* sp. (Anon. 1994). Attacks by these insects cause whitish streaks and the formation of galls on affected leaves. The lateral spread of roots of this species, about 9 m in 18 years, is greater than most other tree species (Misra and Singh 1987). Moreover, it produces root suckers profusely. Because of these characteristics, pongam is unsuitable for agroforestry and has the potential to become a weed if not managed carefully.

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NFT Highlights

NFTA 91-06

A quick guide to useful nitrogen fixing trees from around the world November 1991

Prosopis alba and *Prosopis chilensis* : Subtropical Semiarid Fuel and Fodder Trees

Prosopis alba and *Prosopis chilensis* are native to the semi-arid regions of northwestern Argentina and northern Chile. Locally they are called *el arbol* or, the tree, because of their widespread occurrence and importance. Since these species have often been confused in the literature, it is useful to treat them together. Once leaf patterns have been observed, differences between species become obvious.

Species with the narrower spaced leaflets (left) is Prosopis alba. Species with the widely spaced leaflefts (right) is Prosopis chilensis (photo by P. Felker)

BOTANY

Prosopis alba (Grisebach) and *P. chilensis* (Molina Stuntz) (subfamily Mimosoideae, family Leguminosae) are small to medium-sized trees up to 12 m in height and 1 m in diameter. Both species have thorny and thornless variants. The most distinguishing feature between the two are the number and spacings of leaflets.

The trees have compound leaves each with numerous leaflets along several pairs of pinnae. *P. alba* usually has 2-3 pairs of pinnae (but up to 4 or 5) with 30-50 sets of 10 min long leaflets per pinnae (Burkart 1976). *P. chilensis* generally has fewer leaflets per pinnae (about 10-29) and usually no more than two pair of pinnae per leaf. In *P. alba,* the 1-2 mm wide leaflets nearly touch the pinnae, while in *P. chilensis*, leaflets are about 1 cm apart.

Abundant, greenish-white to yellow flowers occur on spike-like racemes. Pods of both species are beige to off-white, from which the species name alba, or white, originates. In contrast, other Argentine species have red-tinged to dark purple pods (*P. flexuosa* and *P. nigra*).

The pods of *P. alba* are typically 20 cm long, 4-5 mm thick, and 20-25 mm wide. They are sickle-shaped with the entire pod occurring in the same plane. Although *P. chilensis* pods are the same color, they are shorter (about 15 cm) and not as wide (about 15 mm). The pods of *P. chilensis* are seldom flat and have a tendency to be rolled up along the long axis. *P. alba* pods also usually have a thicker mesocarp indicating a greater pod sugar content. The name *P. chilensis* has been incorrectly applied to the North American species *P. glandulosa* and *P. velutina* and to the naturalized *P. juliflora* that occurs in the Sudan.

ECOLOGY

Over 20 species of *Prosopis* occur in the semiarid and and regions of northwestern Argentina, making Argentina the center of genetic diversity for *Prosopis*, although probably not the center of origin (Burkart 1976). *P. alba* is native to the plains and low sierra of subtropical Argentina, extending into Uruguay, Paraguay, southern Brazil, and Peru (Burkart 1976) up to 1,500 m elevation.

In Argentina, *P. chilensis* grows in regions that experience lower winter temperatures and lower rainfall than *P. alba* (E. Marmillon, pers. comm.). In areas with groundwater between 3 and 10 m below the surface, such as in drainage channels and along groundwater sinks, *P. chilensis* may occur in areas with less than 250 mm rainfall. If no groundwater is available, annual rainfall must exceed 350-400 mm for large trees (25-100 cm diameter) to occur. Trees of both species have been identified that grew in seawater salinity (Rhodes and Felker 1987).

Over most of the trees' range the climate is subtropical with annual temperatures averaging about 20°C. In northern Argentina along the border with Paraguay, the frosts are light (-3 or -4°C), but further south near Cordoba occasional frosts of -12°C occur. When grown in Texas, nearly all spineless trees of *P. alba* froze, to ground level with frosts of -12°C. Both species occur m areas that experience 45°C, so high temperature stress is not a problem.

USES. Wood: The wood of these trees is relatively dense (about 700-800 kg/m^3) and makes an excellent fuel whether burned directly or first converted to charcoal (Tortorelli 1956). The timber is valued for furniture, doors, cobblestones, and parquet floors. The reddish/brown wood has a volumetric shrinkage much lower (ca. 5%) than that of other quality furniture woods

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(ca. 15%). As a result, joints in furniture have much less tendency to open during conditions of changing humidity.

Fodder. The pods but not the leaves of the trees are readily eaten by domestic livestock. Pods are high in sugar (about 35%) (Oduol et al. 1986) and contain 10-12% crude protein. Seeds are sometimes ground into a concentrate for animal feed. Large trees, 40 cm in basal diameter and 7 m in canopy diameter, may produce 40 kg of pods under optimal conditions. Because of water constraints, tree spacings must be considerably greater than canopy diameters.

Food: The pods of both trees are eaten by native peoples, especially as a ground flour. Contemporary milling techniques and product formulations with *Prosopis* flour has been described (Sounders et al. 1986). Bees produce honey from the flowers.

Other uses: The large size of the trees and more rapid growth than other *Prosopis* (e.g., *P. glandulosa*) have led to widespread use of *P. alba* and *P. chilensis* for shade, windbreaks, and as ornamentals in Argentina and in Arizona and California, USA. They also contribute nitrogen and organic matter to soils (Johnson and Mayeux 1990). These trees are candidates for erosion control and soil stabilization in and lands.

SILVICULTURE. Establishment: Seeds are difficult to extract from the gummy pulp. *Prosopis* pods can be ground in a meat grinder after drying pods in an oven at 52°C overnight, which will also serve to scarify the seeds. For good germination seeds require scarification of the seed coat with a file or knife. There are about 36,000 seed/kg.

Outstanding trees have been cloned using rootings or cutting techniques that require control over light intensity and air temperatures (Klass et al. 1984). To obtain the highest survival under semi-arid controls, seedlings are grown in long (38 cm) narrow (3.8 x 3.8 cm) cardboard plant bands and planted with the container still on (Felker et al. 1988). Mechanical and chemical weed controls to maximize growth are available (Felker et al. 1986).

Yield: Biomass yields of trees grown under short rotation systems (3 yrs) on close spacings (1.5-3.0 m) have been high. Field trials in Texas, USA, using a high productivity *P. alba* clone, produced 39 dry metric tons/ha in three years at a site with 650 mm annual rainfall (Felker et al. 1989). Trees grew about 2.2 m in height per year. However, excellent weed control coupled with mechanical cultivation was required to achieve these high yields.

SYMBIOSES: A single rhizobia strain that effectively nodulated 13 *Prosopis* species (Felker and Clark 1980) is available from LiphaTech (3101 West Custer Ave., Milwaukee, Wisconsin 53209). *Rhizobium* for *Prosopis* species is also available from NifTAL through NFTA.

PROBLEMS AND PESTS. Twig girdling insects (*Oncideres* spp.) cause minor damage to these trees. An undescribed "disease" causes the terminal shoots to die. Over a period of years this necrosis gradually spreads downward and eventually may kill the entire tree. These *Prosopis* can become weeds in heavily grazed areas.

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NFT Highlights

NFTA 91-04

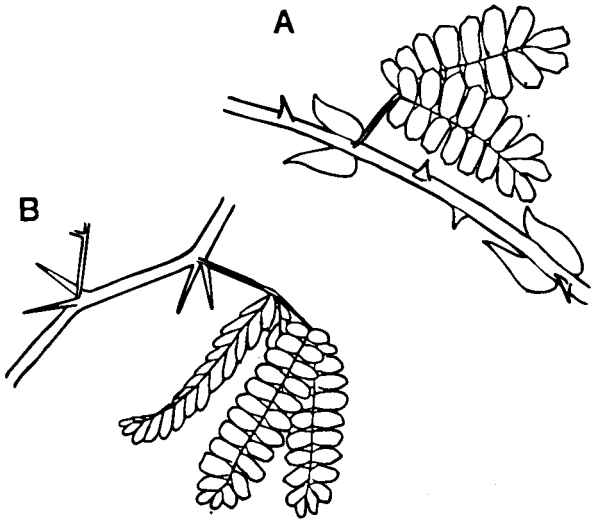
A quick guide to useful nitrogen fixing trees from around the world July 1991

Prosopis cineraria : A Multipurpose Tree for Arid Areas

Prosopis cineraria is a versatile species, providing fodder, fuel food, timber, and shade, as well as affecting soil improvement and sand dune stabilization. It is commonly used in dryland agroforestry in India and Pakistan. The tree is known locally as jandi or khejri (India), jand (Pakistan), and ghaf (Arabic). Its synonym is *P. spicigera.*

BOTANY. *Prosopis cineraria* (L.) Druce (family Leguminosae, subfamily Mimosoideae) is one of 44 species of leguminous trees and shrubs in the genus. It is a small, thorny, irregularly branched tree, 5-10 m high. Evergreen or nearly so, it forms an open crown and has thick, rough gray bark with deep fissures.

Leaves are alternate, bipinnately compound with 1-3 pairs of pinnae. Each pinna has 7-14 pairs of leaflets, 4-15 mm long and 2-4 mm broad. The thorns are straight with a conical base and distributed sparsely along the length of the stem. They first become visible when the seedlings are 6-8 weeks old. In respect, *P. cineraria* differs from the thorny New World species of *Prosopis* (e.g., *P. juliflora)* which have thorns in pairs at the nodes but thornless internodes.



Young branches of (A) *Prosopis cineraria* and (B) *P. juliflora,* showing the differing position of thorns.

The 0.6 cm yellow-green flowers are borne on 5-23 cm spike-like racemes. Up to 25 dull brown seeds, 0.3-0.8 cm long, are contained in each of the light yellow pods, which are long (8-19 cm), narrow (0.4-0.7 cm), and cylindrical. As with other *Prosopis,* rooting can be very deep; the tap root of P. *cineraria* may penetrate vertically up to 20 m or more (Mahoney 1990).

ECOLOGY. *P. cineraria* occurs naturally in the dry arid regions of India, Pakistan, Afghanistan, Iran, and Arabia. It is one of the principal species on higher and older alluvium in the Indus river valley. It is extremely drought tolerant, growing in areas with as little as 75 mm annual rainfall generally 150-400 mm (FIN 1991), with dry seasons of eight months or more (NAS 1980).

Slightly frost hardy and tolerant of temperatures up to 50°C, it grows at altitudes from sea level to 600 m. The tree is found in alluvial and coarse, sandy, often alkaline soils where the pH may reach 9.8. *In vitro* studies have confirmed the nodulation of *P. cineraria with Rhizobium.*

In areas such as the Wahiba Sands in Oman there exist isolated, ancient *P. cineraria* trees. It also grows gregariously on sand. Under less extreme conditions, *P. cineraria,* often in association with *Acacia tortilis,* may form open dry, woodlands, which are important communities within the desert ecosystem. There is considerable phenotypic variation between individuals in crown shape, growth rate, and branching. Ecotypes growing in highly saline coastal areas have also been identified.

USES. Wood: *P. cineraria* provides excellent firewood (calorific value, ca. 5,000 kcal/kg) and charcoal. Its wood is favored for cooking and domestic heating (Mahoney 1990). Hard areasonably durable, the wood has a variety of uses for house building, posts, tool handles, and boat frames, although poor tree form limits its usefulness as timber.

Fodder. The leaves are an available, excellent, and nutritious fodder, readily eaten by many animals including camels, goats, and donkeys. The tree produces leaves during the extremely dry summer months when most other trees are leafless. Leaves contain 13.8% crude protein, 20% crude fiber, and 18% calcium (FFN 1991). The pods also provide a good fodder, containing a dry, sweet pulp.

Food: Pods are eaten as a vegetable in the human diet in some areas. In Rajasthan, green pods called *sangri*

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are boiled and dried (FIN 1991). The flowers are valuable for honey production. The bark can be used in leather tanning and yields an edible gum. Bark and flowers are used medicinally (NAS 1980). In times of famine, the powdered bark has been mixed with flour and made into cakes (Bhandari 1978).

Partial lopping of khejri for goat fodder Rajasthan India.
(photo by Iqbal Hussain)

Land use: *P. cineraria* effectively stabilizes sand dunes and can withstand periodic burial (Gates and Brown 1988). Because of a deep taproot, trees are not believed to compete for moisture or nutrients with crops grown close to the trunk. During the growing season it casts only light shade and is therefore suitable as an agroforestry species. Farmers in and semi-arid regions of India and Pakistan have long believed it to increase soil fertility in crop fields. Yields of sorghum or millet increased when grown under *P. cineraria* as a result of higher organic matter content, total nitrogen, available phosphorus, soluble calcium, and lower pH (Mann and Shankarnarayan 1980). Other crops traditionally grown amid scattered *khejii* are maize, wheat, and mustard.

SILVICULTURE. Seeds (25,000/kg) remain viable for decades in dry storage and establish well with 80-90% germination (Mahoney 1990). Soaking seeds in tepid water for 24 h is recommended as a pre-germination treatment. The round end of the seed may also be scarified by scratching or nicking with a file or knife.

P. cineraria is difficult to propagate by cuttings, although treatment with rooting hormones has proved success in India. Propagation by root suckers and by air layering has been reported. Recent attention has also been given to micropropagation of this species, but it appears that *in vitro* propagation is more difficult with *P. cineraria* than with many other *Prosopis* species. The tree is also considered slower growing than other *Prosopis.*

Seedlings are raised in a nursery and transplanted when 2-3 months old at the onset of the rainy season. Trees can be planted in close lines as a hedge with 1 m spacing between trees (Mahoney 1990), but tree densities of 50-100/ha are recommended for both agroforestry and silvopastoral systems. One or two weedings are necessary during the first year owing to slow initial growth rate. Early pruning to encourage straight growth is recommended (NAS 1980). The tree responds well to irrigation, tolerating up to 50% sea water.

The tree coppices readily (NAS 1980). Maximum yields of fodder are obtained when the trees are pollarded on a three-year-rotation. Villagers traditionally lop their trees in winter and store the sun-dried leaves for dry season fodder.

YEILD. The trees reach 3-5 m high in 5-6 years with an average diameter of 6 cm. Annual firewood yields of up to 2.9 M^3 /ha have been reported (NAS 1980). A moderate sized tree may yield 45 kg of dry leaf fodder per year.

RESEARCH. Although *P. cineraria* plays a vital role as an agroforestry species in some parts of its natural range, little success has been achieved in planting it elsewhere. Further work is needed to establish the range of conditions under which it might prove useful. *P. cineraria* displays considerable genetic variation, particularly in populations close to the edge of its natural range, which are often threatened by overgrazing. Genetic conservation of this valuable resource is considered a priority.

LIMITATIONS. Desert locusts *(Shistocarica gregaria)* and *Melolonthidae* beetles attack the foliage, and bruchid beetles feed on the mature dried seeds.. Termites *(Odontoteomen obesus),* white grubs *(Halorachia* spp.), and the gallfly *(Goccidomulid galli)* are also important pests. There is little information on diseases of *P. cineraria.* This NFT is not suitable for planting in riverine areas or subhumid environments where it can become an aggressive colonizer and spread rapidly.

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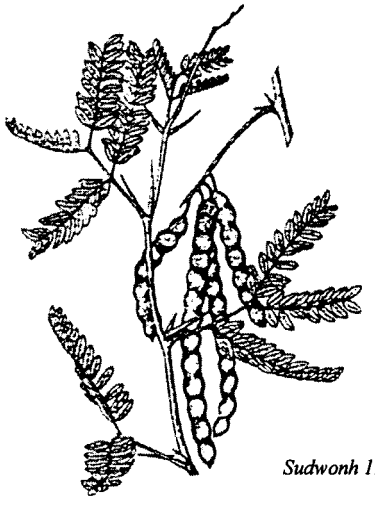
NFT Highlights

NFTA 90-07

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

Prosopis glandulosa : A Multipurpose Tree for Arid Lands

Native to North America, *Prosopis glandulosa* Torrey is a small to medium-sized tree, 3-7 m tall with two recognized varieties. *Prosopis glandulosa* var. *torreyana* grows primarily in the deserts and drylands of the southwestern United States and northern Mexico (Hilu et al. 1982). *P. glandulosa* var. *glandulosa* is found from Mexico north to Kansa and east to Louisiana (Burkhart 1976). Commonly called mesquite, or honey mesquite, this nitrogen fixing tree was a key resource of the native people, providing food, drink, alcohol, fuel, medicine, and fertilizer.



Sudwonh 1908

BOTANY. Mesquite has spiny branches and leaves with 7-18 sets of paired leaflets. Its seed pod resembles the common pea or bean, 10-30 cm long and 5-10 mm diameter. The flower is a yellow inflorescence with many spikes. Hybridization is common and the taxonomy of mesquite is difficult (Hilu et al. 1982). Genetic variability is high with good potential for selection of individuals and ecotypes and plant breeding. The trees are self-fertile.

ECOLOGY. Honey mesquite will grow in a wide range of soils and is moderately salt and frost tolerant. It thrives under very high temperatures (> 38C) and survives in areas with very low precipitation (< 200 mm annually), but it is usually found in areas with groundwater reserves. This tree has been found to occur in Death Valley with only 50 mm annual rainfall (Hilu et al. 1982). In its drier, western range it occurs along streams and in low-lying areas; in areas with more rainfall it occurs on open range or in chaparral.

USES. Food. Honey mesquite pods were a primary food of the residents of the Southwest North American deserts (Felger 1977). Pods are quite sweet and whole pod composition is 80% carbohydrate, 13% protein, 25% fiber, and 3% fat (Zolfaghari et al. 1982). The pods are easy to collect and store and, unlike most beans, are edible without cooking. Mesquite pods are still used as a food and beverage in Mexico. Processing and use is described in Meyer 1984 and Meyer et al. 1986. Pods could prove useful for production of flour, wine, tempe, and tofu products. R.S. Felger has proposed that the pods of this dryland-adapted tree will one day become as important as corn, rice, and wheat to the world food system. Bees favor the flowers. and mesquite honey is highly valued for its flavor.

Fodder. Grinding improves the use of honey mesquite pods for fodder. Sheep, goats and pigs are able to use a higher percentage of mesquite pods in their diet than are cattle and horses. In 1965, 40,000 tons of pods were used as feed in Mexico (Lorence 1970). Leaves of mature honey mesquite are browsed by cattle only on deteriorated rangeland.

Fuel: Mesquite wood (17,000 BTU/kg), chips, and charcoal are excellent fuels, and the wood smoke lends a pleasant flavor to cooked foods. Annual production on dry, low quality sites may be < 1 t/ha, but with sufficient water (even though slightly saline) trees can grow rapidly and yield > 5 t/ha/yr (Felker et al. 1983).

Hardwood. Mesquite wood is very dense, specific gravity 0.7+, and has very balanced shrinkage on drying (Rodgers 1986). These properties make it excellent for woodworking. Mesquite is also used for fencing.

Other products: Mesquite has been used for a variety of medicinal purposes, including lice control, treatment of sore throat and treatment of skin sores and ulcers (Felger 1977). Mesquite produces quality gums which may be economically valuable (Meyer 1984).

Soil improvement: The refinement of a modern management system of intercropping with mesquite based on traditional practices (Lawton and Bean 1968) should receive high priority. The deeply-rooted, open-canopied trees may provide little competition for field crops and can fix 30-40 kg N/ha with 30% canopy cover (Jarrell et al.

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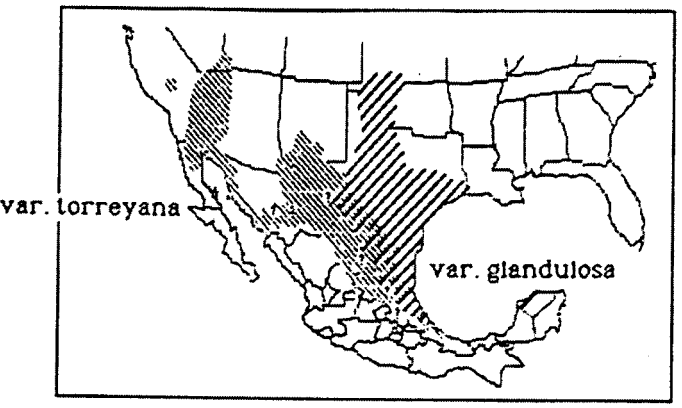

The distributional range of Prosopis glandulosa *in SW North America.*

1982). Soils under honey mesquite are enriched with nitrogen (Abrams et al. 1990). Mesquite may be established as tree crops for alley cropping, windbreaks, or timber belts.

PROPAGATION. Mesquite pods ripen simultaneously. They should be picked when the seed rattles in the pod, and stored in a dry place. Bruchid beetles can be killed by freezing or fumigating the pods. Mesquite seeds store well maintaining excellent viability for years or even decades. There are about 30,000 seeds/kg. A modified commercial meat grinder with a plate with holes 1 cm in diameter is recommended for cleaning. The seeds have a very tough coating which must be scarified for germination by chipping or cutting, acid treatment, or exposure to boiling water. Acid, however, will damage seeds if cuts in the seed coat are made by mechanical cleaning. Seeds germinate best at temperatures between 20-40'C and can germinate within six hours of wetting at 34C (Bainbridge and Virginia 1989). Preliminary studies of honey mesquite propagation from cuttings, tissue culture, and air layering suggest that these vegetative reproduction techniques are possible (Bainbridge and Virginia 1989).

Scarified or sprouted seed should be planted in a well drained soil mix If small containers are used, transplant seedlings 2-3 weeks after germination to avoid disturbing the dominant tap root. Young seedlings can have root to shoot ratios as high as 10:1 (Mooney et al. 1977). Larger transplants can be grown in deep containers (7.5 cm wide by 100 cm deep) or in plant bands (4 cm x 40 cm).

SILVICULTURE. Although mesquite is very drought tolerant best growth is achieved in areas where the root system can reach groundwater. In areas with low rainfall especially in fast-draining soils, irrigation may be required during establishment. Buried clay pot and deep pipe irrigation have considerable potential for establishing mesquite in hot desert regions (Bainbridge and Virginia 1989). Soils with compacted or hard pan layers should be deep ripped or worked with an auger to 1-3 m and planting strips cleared of competing vegetation. Direct seeding is also possible, if adequate soil moisture can be maintained for germination.

ROOT SYMBIOSES. Mesquite forms symbioses with rhizobia and VA mycorrhizae. The active root nodules can occur many meters deep (Virginia et al. 1984,1986; Jenkins et al. 1989). Nitrogen levels in the soil under plantation-grown mesquite were much higher than same-aged *P. chilensis* or *P. alba* (Abrams et al. 1990). Seedling rhizobial inoculation can be done with a liquid culture, clay or peat based inoculum, or with small amounts of soil from the active root zone under healthy, established trees nearby (Bainbridge and Virginia 1989). Fertilizer (especially phosphorus) may increase mesquite growth on poor soils, but both P and N can depress microbial symbionts and fertilization may be detrimental in the long term.

PESTS AND PROBLEMS. Pods are commonly damaged by bruchid beetles. Mesquite hosts mistletoe and infection may be extensive on older trees. Trees rarely suffer significantly from other diseases and pests, although psyllids may be a problem in some areas, and spider mites have been a problem in glasshouse studies. When planted in southern Texas, var. *torreyana* from California, but not var. *glandulosa,* is subject to stem fungal diseases (P. Felker, pers. comm. 1990). Fencing or seedling protectors will usually be needed to protect young, transplanted mesquite seedlings from rabbits or other grazing animals. To ensure good tree form, the leader should be protected against grazing. As with other *Prosopis* species, mesquite can become a serious invader on disturbed lands or overgrazed rangelands.

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NFT Highlights

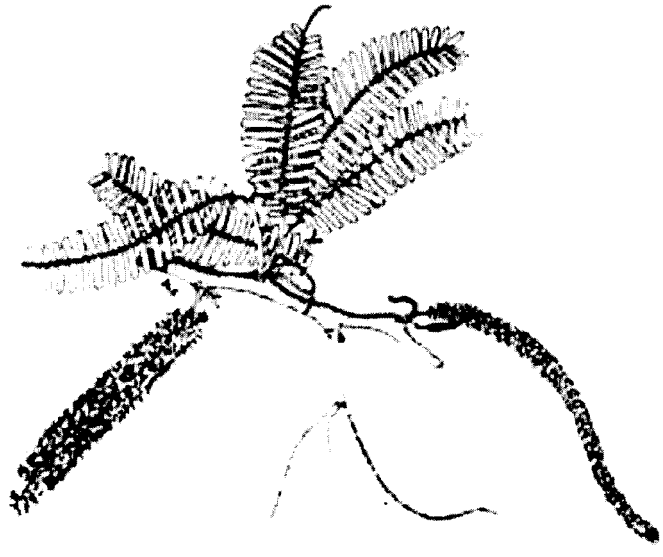
A quick guide to useful nitrogen fixing trees from around the world

NFTA 87-05
October 1987

Prosopis pallida : Pioneer Species for Dry, Saline Shores

Some trees must be valued simply because 'they are there,' filling important vacuums in nature. The hostile environment this scraggly tree occupies is hot, dry and saline. Under these conditions, *Prosopis pallida* and its sister species produce nutrient rich pods for animals and the world's finest charcoal. They also fix nitrogen to enrich the soil around them.

Native to incredibly dry coastlines of Peru and Ecuador, *P. pallida* was spread in the 19th century to African and Pacific nations and later throughout Asia. It often dominates arid, saline coastlines, while other saline-tolerant trees like the casuarinas are riverine or restricted to shores with subsoil moisture. The tiny leaflets presumably intercept fog to obtain much of their moisture along South American coasts.



BOTANY:

P. pallida (H. & B. ex Willd.) H.B.K. is one of about 40 species of this genus many of them quite similar. It is much like *P. juliflora* (Sw.) DC., a smaller Central American tree now widespread internationally and often weedy (Burkart 1978). Common names include 'kiawe' (Hawaii) and 'algarrobo' (S. America). Its better known temperate relatives are called "mesquite" it is a wide-spreading tree to 18 m in height and 80 cm in diameter with sinewy branches reminiscent of twisted ropes. On poor sites it is shrubby. Spikes of small pale-yellow mimosoid flowers are followed by abundant tan pods 12-24 cm in length. Most trees have sharp spines, but about 12% of Hawaii's trees are thornless.

FUELWOOD AND CHARCOAL:

Prosopis spp. are justly famous for charcoal and fuelwood (marketed as "mesquite" from related temperate species). Kiawe's wood is very dense (old trees to .85 specific gravity) and is challenging to cut but burns slowly almost smokeless and with little ash (NAS 1980). Its charcoal is superb.

WOOD:

Heartwood of kiawe is dark reddish-brown and sapwood is light yellow. It is used for fence posts that are durable and decay-resistant but susceptible to termite attack. Although dense and strong the wood is relatively easy to work (e.g mallets).

Contact author J.L. Brewbaker and NFTA staff

FODDER:
Mature pods of *P. pallida* produced annually, are sweet and high in energy with adequate digestibility and protein (12%). Pods can thus form a significant dry season fodder after grasses have dried down. When pods are fed as an exclusive diet, however cattle become malnourished and lose weight. Trees are largely cross-pollinated, and produce few pods when grown in isolation. The sparse thorny foliage is not a good fodder, and seeds are indigestible.

HONEY AND FOOD:
Kiawe is a source of nectar that makes an excellent honey that was once a major commercial product of Hawaii (Neal 1965). Trees flower seasonally in dry areas, but may flower for longer periods when rooted in subsoil moisture. Pods of kiawe are sweeter than most other species. They can be made into a syrup, "algarrobina," as a natural thickening for foods and beverages. They are reported also to serve as a medicinal for dysentery.

OTHER USES:
The principle use of kiawe is as cover for erosion control on arid land and shifting dunes. Thornless trees should be carefully chosen for beach parks; a thornless composite is being produced in Hawaii. Bark has been used for tanning, and exuded stem gums for glue and varnish.

SALT TOLERANCE:
P. pallida grows in highly saline soils along coastlines. It reputedly tolerates irrigation water containing up to half sea water (NAS 1980).

ECOLOGY:
Most *Prosopis spp.* tolerate drought and thrive under 250-600 mm of annual rainfall, although growth improves greatly with more moisture. Rooting is commonly shallow and spreading but can be deep in arid soils. Trees do not tolerate frost.

PRODUCTION:
Kiawe has not been widely planted. Seeds should be scarified (nicking, hot water) for best germination. Seedling growth is very slow, to 1 m annually. Natural reseeding of the species is common in low-rainfall regions with saline soils. Trees survive coppicing, but may grow back as many-branched shrubs.

PESTS AND PROBLEMS:
The bruchid beetle (*Algarobius prosopis*) often invades kiawe pods. Several other insects including psyllids, can defoliate trees. Posts of kiawe are durable, but are subject to attack by teredos, a shipworm, when used as pilings in the water. Rooting is shallow in many soils and windstorms can topple the trees. Growth is very slow compared to other trees under adequate moisture conditions. Trees rarely survive slow fires. Trees appear highly variable genetically and are almost uniformly poor in form. Taxonomy is debated, and the relationships of *P. pallid* and *P. juliflora* needs clarification.

FACT Net

FACT Sheet

FACT 99-06

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

Prosopis tamarugo : Uniquely Adapted To The Atacama Desert Of Northern Chile

Prosopis tamarugo F. Philippi is a most remarkable tree, being able to survive in one of the most inhospitable deserts in the world. In the Atacama Desert of northern Chile, decades can pass without any rain at all, and layers of salt often several meters thick lie on the soil surface. The trees produce excellent quality fuelwood, timber from larger trunks, and nutritious pods and leaves. The edible pods were a valuable source of food for indigenous populations and supported Spanish armies as they crossed the vast desert during the conquest of South America. Deforestation on a massive scale during the following centuries decimated the once-great forests. A major reforestation scheme was undertaken in recent decades, and these new forests now support large flocks of sheep and a thriving local economy. However, attempts at introducing tamarugo to other and areas have not been successful.

Source: FAO 1985

Botany

Prosopis tamarugo is one of the 44 species of *Prosopis* recognized by Burkart (1976), being in the family Leguminosae, subfamily Mimosoideae, or family Mimosaceae. It is a deciduous tree with an open, irregular crown. In favorable conditions, trees are 8–20 m in height with roots reaching subterranean water at depths of 15 m. The trunk is usually short, up to 80 cm in diameter, with dark gray and fissured bark. Typical of common legume trees, the leaves are bipinnate, with one pair of pinnae, each 3–4 cm long, and with 10–15 pairs of small leaflets 4–8 mm long. The stems are thorny, with slightly curved, spiny stipules up to 1–4 cm long. The flowers are small, 8–9 mm long, yellowish, and in spike-like racemes 3–6 cm long. The pods are hard, curved, and red-brown, 2.5–4 cm long, containing 6–8 small, brown seeds.

Ecology

The range of mean annual minimum and maximum temperatures tolerated is 12°–36°C. The annual water deficit under cloudless skies is approximately 2000 mm per year. There is often a permanent water table lying 1–15 m deep. In the natural habitat, the soil is generally very saline sandy or clay loam with surface salt encrustation up to 60 cm thick. Soil pH is between 8.0 and 8.4. The tamarugo tree has evolved a two-fold root system, made up of one or more deep tap roots and a dense, surface mat of lateral roots to exploit both deep ground water and atmospheric moisture for survival. It appears that atmospheric moisture condenses below the canopy and is taken up by the roots, rather than taken up directly by the leaves as was previously thought (e.g., Sudzuki 1969). This "reverse transpiration" process plays a negligible part in the water balance of *P. tamarugo* (Le Houérou 1999, pers. comm.). The tree grows very quickly in the early years of establishment, but annual increments decrease markedly after 20 years. Trees may live to be over 1000 years old. Unlike most *Prosopis* species, *P. tamarugo* shows less genetic variation and is thought to be at least partially self-compatible (Hunziker et al. 1975).

Distribution

The native range of the tamarugo tree is restricted to the unique environmental conditions of the Atacama Desert in northern Chile. The most extensive forests are found in the Pampa del Tamarugal, with some 1000 km^2 now designated a national reserve (19°–22°S, 68°–70°W), at an elevation of 950–1500 m. This region is typified by an almost total absence of rainfall (0.2–1.0 mm annually), intense solar radiation, a very high diurnal range in temperature (24–35°C).

Uses

Wood. The wood is very hard and difficult to work but extremely durable and resistant to decay, with a dry-weight density of 910 kg/m^3. The heartwood makes up over 80% of the stem volume, has a desirable dark brown to intense red

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color, and is very dimensionally stable (Cuevas et al. 1985). It is used for furniture, but the short, twisted, and often knotty stems are not very suitable as a source of timber. Other uses include tool handles and, more recently, for parquet flooring.

Fuelwood. The wood burns well, slowly, and with an even heat. It has a high calorific value of 5065 kcal/kg and produces an excellent-quality charcoal. It has been used extensively throughout history as the main source of fuel in the region, continuously for domestic use but also for industrial uses. Biomass production is 0.2–2.8 m^3/ha/yr from plantations at 25–188 trees/ha.

Fodder. The tree has palatable, nutritious foliage and fruit, and mature stands of 100 trees/ha are reported to support up to 26 sheep per hectare. Leaves have 50% total digestible nutrients and 14% protein and are rich in carbohydrates (Serra 1997). Leaf forage production is 20–70 kg/ha/yr from 14–22- year-old trees at 100 trees/ha. Flowering and fruiting begin when the trees are 8 years old (Stienen 1985) but then varies widely from year to year and even in the same year between individual trees (Serra 1997). The fruits have 55–65% digestibility, 10–20% protein, 20–30% carbohydrates, and are an excellent fodder source. The flowers are also a valuable bee forage.

Reforestation. Sustainable agro-ecological systems for the Atacama have been developed following large-scale reforestation, primarily with *P. tamarugo*. Beginning in 1965, the Chilean government initiated a plantation program that was responsible for the establishment of 20,000 ha of tamarugo forest by 1990. These now support extensive flocks of sheep, mainly Karakul and Suffolk Down, along with Angora goats. Hereford cattle are also raised.

Silviculture

There are 50,000–110,000 seeds per kg, which require pretreatment for rapid and synchronized germination. Untreated seeds give germination over 50%, but for >95% germination, soaking for 14 minutes in 95% sulfuric acid is required (Pasiecznik et al. 1998). Seed are sown in nursery bags and tended for 3–5 months before out-planting. Site preparation involves the digging of pits, normally at 10 x 10 m spacing (100 trees/ha), 80 cm in diameter and 40 cm deep, with another smaller pit dug into the bottom into which the tree is planted. This smaller pit is covered with a plastic sheet to maintain a saturated atmosphere. Pure sheep manure is used at planting, and superphosphate is applied at varying intervals during establishment. Trees are watered every 10 days initially, decreasing to every 30 days after the first year. Pruning improves tree vigor and increases foliage and fruit yields and is also required to allow stock to move freely between trees. Trees coppice readily when cut or lopped for fuel wood.

Symbiosis

The tamarugo tree is known to fix atmospheric nitrogen (Felker and Clark 1980), even under very saline conditions, up to salinity levels equal to sea water (Felker et al 1981), such as are found in the Atacama. Nodules appear 5–6 weeks after inoculation, generally in new secondary roots. Low growth rates have been correlated with low soil phosphorus, which has in turn been suggested as a factor limiting rates of nitrogen fixation in *P. tamarugo* under field conditions (Jarrel et al 1982).

Limitations

Following successful reforestation in the hyper-arid native range and research showing its ability to survive and grow in salinities equal to seawater (Felker et al 1981), the species was promoted as a promising multi-purpose tree for arid zones. However, after inclusion in many species trials the world over for the last 25 years, there are no records of any successful introductions. *Prosopis tamarugo,* if it survives the nursery stage, has suffered 100% mortality within the first year after planting in North America, India, and Africa (author's observation). Although reforestation in northern Chile should continue, it is not recommended for further introductions outside of its native range.

Related Species

Arboreal *Prosopis* species are dominant in many arid and semi-arid regions of the world. Several have been widely introduced, with mixed effects. While providing valuable fuelwood and animal fodder in areas where little else will grow, they have also become invasive weeds in some countries. The main introduced species are *P. juliflora* and *P. pallida* in tropical regions, and *P. glandulosa* and *P. velutina* in more subtropical climates. Other species such as *P. alba* and *P. chilensis* have been successfully introduced to several countries, and others have shown potential. *Prosopis africana, P. cineraria, P. pubescens,* and *P. tamarugo* have not been successfully introduced outside of their native range.

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A complete set of references is available from FACT Net

FACT Sheet

FACT 99-03
June 1999

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

Pterocarpus erinaceus : An Important Legume Tree In African Savannas

Pterocarpus erinaceus is a deciduous legume tree of African savannas and dry forests famous for producing one of the finest woods in its native region. It also produces leafy fodder high in protein, which makes an excellent animal feed crucial for the survival of livestock during the dry season. The tree produces showy and attractive golden-yellow flowers and has considerable potential as an ornamental. Increasing demand for its high-value timber and fodder threatens existing natural stands. However, the tree fruits abundantly and is easy to propagate, making it a good candidate for reforestation programs.

Botany

Pterocarpus erinaceus Poir. (Leguminosae, subfamily Papilionoideae) is a small to medium-sized tree 12–15 m tall with a diameter of 1.2–1.8 m. In the drier part of its range it has an open, spreading form and is low-branching, but under favorable rainfall and soil conditions, much larger specimens with clean straight boles 6–8 m long or more can be found (Lely 1925). Exceptionally tall trees reaching 35 m height have been reported (von Maydell 1983). The bark of the trunk is dark gray and rough, with scales that curl up at the ends. Its branches are light gray and smooth. The leaves are once-compound, imparipinnate, and 30 cm long. There are 10–15 alternate or subopposite leaflets, 6–11 cm long and 3–6 cm wide (Hutchinson et al. 1958, Lely 1925). The flowering tree is showy and very attractive, with masses of golden-yellow flowers that completely cover the canopy. In its native range, *Pterocarpus erinaceus* flowers from December to February (ICRAF 1998). The fruit is 4–7 cm in diameter, indehiscent, and broadly winged, giving it a "flying saucer" appearance. "Pterocarpus" means "winged fruit," from the Greek "pteron" (wing) and "karpos" (fruit). The young fruits are light green and turn light brown when dry. The seeds are kidney-shaped to oblong.

Pterocarpus erinaceus has been referred to as *Pterocarpus angolensis* DC and *Pterocarpus echinatus* DC. It is known under many common names including vene, madobia, and kino.

Ecology

Pterocarpus erinaceus is found in open dry forests of semiarid and subhumid lands with mean annual rainfall of 600–1200 mm and a moderately to very long dry season that can last 8–9 months. Mean annual temperature in the tree's natural range is 15–32°C, but it tolerates high temperatures reaching over 40°C. The tree grows at low altitudes (0–600 m) and thrives even on shallow soils.

Source: Hutchinson & Dalziel, 1958

It is drought tolerant and once established it survives yearly dry seasons. It also survives the yearly savanna bush fires and readily colonizes fallow lands. *Parkia biglobosa* and *P. erinaceus* are believed to be surviving species of the former dense, dry forest of the sudanian zone (Aubreville 1950).

Distribution

Pterocarpus erinaceus is found throughout West and Central Africa, ranging from Senegal in the west to the Central African Republic in the east. It is distributed up to 14°N but is a stunted, small tree at this latitude, where another species, *Pterocarpus lucens,* takes over and becomes more abundant. Southward, the range extends to the limit of the humid forest in Cote d'Ivoire and the humid coastal savannas in Guinea, Togo, and Benin, where a gallery-forest species, *Pterocarpus santalinoides*, is common along rivers and temporary watercourses. The species is not known to have been introduced outside its native region.

Uses

Wood and wood products. Virtually unknown to commerce outside of its native range, *Pterocarpus erinaceus* provides some of the finest wood from dry forests of the region. The wood is a beautiful, rich rose-red or dark brown, mottled with dark streaks (NAS 1979). It has a handsome, fine-grained appearance and is used for furniture (including stools and benches), decorative paneling, and parquet flooring. It is also used as construction wood and in carpentry for doors and

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window frames. It makes very good charcoal, which is highly valued by local blackmiths.

Leaf fodder in silvopastoral systems. *Pterocarpus erinaceus* provides high-quality leaf fodder with an average nutritive value in dry matter of 5.3 MJ kg^{-1} net energy, 16–19% crude protein, and 0.15% phosphorus. Pastoralists traditionally lopped wild trees in silvopastoral systems to feed their livestock during the dry season. Increasingly, this fodder is brought to urban and semi-urban markets for sale. In Bamako, the capital city of Mali, more than 1400 tons of fresh pterocarpus leaves are sold annually to feed urban livestock, especially sheep. This supply is far short of the demand; 7500–8000 tons is needed annually to feed the estimated 11,000 sheep in the city (Anderson et al 1994). Because of the huge demand, the tree is so heavily lopped that it is now difficult to find in the periphery of Bamako, where it used to be readily available. Vendors of pterocarpus fodder are now forced to travel up to 50 km to find trees that still have leaves to harvest (ICRAF 1997, Bonkoungou et al. 1998).

Agroforestry fodder bank. *Pterocarpus erinaceus* is a good species for fodder bank technology, which involves intensive coppicing through periodic cuttings. A pterocarpus fodder bank trial established at Nyenkentoumou (800 mm annual rainfall) in Mali by the International Centre for Research in Agroforestry (ICRAF) and their national partners shows that the species resprouts well when cut at a height of 50 cm at the end of the rainy season and remains green in the dry season. Trees do not resprout well when cut at ground level (ICRAF 1997). Results of biomass production from the trial indicate that a 0.25 ha fodder bank of pterocarpus can feed a herd of 6 tropical livestock units (1 TLU is equivalent to 250 kg animal live weight).

Other uses. Medicinal uses are many, including the use of leaves as a febrifuge, the bark for tooth and mouth troubles, and bark and resin as astringent for severe diarrhea and dysentery. The grated root is mixed with tobacco and smoked in a pipe as a cough remedy. The resin, kino, is used for dyeing cloth to produce a dark purple color.

Siviculture

Propagation. *Pterocarpus erinaceus* is a prolific seed producer and is easy to propagate by planting nursery-raised seedlings or rooted cuttings. The fruit, an indehicent pod, must be cracked open. There are about 3500 unshelled seeds per kg (19,800 per kg if shelled). The recommended seed pretreatment is immersion in water at room temperature for 18–24 hours, or in sulfuric acid for 30–60 minutes and then in tap water for 5–10 minutes (Roussel 1996). Germination occurs within 6–10 days. Seeds are sown in pots (2–3 seeds per pot) or in nursery beds at spacing of 20 x 30 cm or 30 x 30 cm. Watering is done twice a day, morning and late afternoon, at 10 liters per 20 m^2 of planted area. Seedlings develop a deep taproot, which must be pruned frequently, first done 6 weeks after seed sowing, then every 3 weeks afterwards. Outplanting can be done with both potted seedlings and bare-root seedlings, as stumps or entire seedlings. Rate of survival is high, but growth is slow. Diakité (1991) reported a yearly height increment in Mali of 11–15 cm during the first year and 25–42 cm the second year. The recommended size for the planting hole in dry zones is 40 x 40 cm at 5 x 5 m spacing for woodlots or 1 x 2 m for fodder banks.

Symbiosis

Pterocarpus erinaceus fixes atmospheric nitrogen through a symbiotic relationship with *Rhizobium* soil bacteria.

Limitations

Seedlings must be well protected against rodents and crickets. Newly established plantations require 4–5 years protection from browsing by livestock and wildlife. Although the species survives yearly bush fires, frequent and severe burnings may permanently scar the trunk.

Research

Strong intraspecific growth differences have been observed in several trials with *P. erinaceus,* suggesting possible genetic variability (ICRAF 1997). Domestication research to characterize the extent of variation and to develop low-cost propagation techniques is needed. The management of trees in woodlots and fodder banks is not well documented. Research to investigate the specificity of the *P. erinaceus-Rhizobium* symbiosis and the quantity of nitrogen fixed in different management systems is also needed.

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NFT Highlights

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

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Pterocarpus indicus : The Majaestic N-Fixing Tree

Pterocarpus indicus is one of the best known trees in Southeast Asia. It is known as *narra* in the Philippines, *sonokembang* in Indonesia, *angsana* or *sena* in Malaysia and Singapore, and *pradoo* in Thailand. In the Philippines, it is the national tree and the favorite timber for the manufacture of fine furniture (Duaresma et al. 1977). In Singapore, it is practically the symbol of that country's garden city planting program; many avenues are graced by this attractive species. In Malaysia, it has been planted as a shade tree for at least 200 years.

Botany

Pterocarpus indicus Willd. (Leguminosae, subfamily Papilionoideae) is a big tree, growing to 33 m in height and 2 m diameter. The trunks are usually fluted and buttressed to 7 m diameter at the base. The crowns are large and bear many long branches that are at first ascending, but eventually arch over and sometimes droop at the ends. Trees with long willowy, drooping branches are particularly conspicuous and attractive in Singapore and some parts of Malaysia and Hawaii. Elsewhere the drooping habit may not develop.

The leaves are compound-pinnate, bearing 6-12 alternate leaflets. The leaflets are rather large, 7 x 3.5 to 11 x 5.5 cm and ovate to elliptic in shape, with a pronounced acuminate tip. The flowers are yellow, fragrant, and borne in large axiuary panicles. When flowering, the buds do not open in daily sequence. Instead, as buds come to full size, they are kept waiting, to be triggered into opening.

The opened flowers last for one day. After that, several days may pass before another batch of accumulated 'ready' buds open. The nature of the trigger is unknown. Whole avenues of such trees blooming in unpredictable synchrony making a splendid display. Local drivers have learned to slow down on the flower-carpeted roads to avoid skidding. The fruits, which take four months to mature, are disc-shaped, flat, and have winged margins. About 5 cm across, the fruit have a central woody-corky bulge containing several seeds (*ptero-carpus* means winged fruit). Unlike most legumes, the *Pterocarpus* fruit is indehiscent and dispersed by wind. It also floats in water and can be water-dispersed.

There are 1-3 seeds in each fruit. The seeds are difficult to extract, but will germinate readily through built-in weaknesses in the fruit wall; hence each fruit is able to function like a seed, but produces 1-3 seedlings. There is no advantage to extracting the seeds because the germination time and percentage are practically the same between whole fruits and extracted seeds.

Pterocarpus indicus foliage and flower, taken from *Plants of the Philippines* (1980)

In a non-seasonal humid tropical climate such as in Kuala Lumpur and Singapore, the trees are generally evergreen, but in regions with seasonal rainfall, the trees are deciduous.

Distribution. The genus *Pterocarpus* consists of 20 species distributed throughout the tropics (Rojo 1977). *P. indicus* has a wide range from southern Burma to the Philippines and throughout the Malay Archipelago to New Guinea and the Solomon Islands. There is considerable morphological and ecological variation when viewed throughout its range, but because of extensive clonal propagation, the trees planted in any given locality tend to be uniform. In Malaysia, its natural habitat is by the sea and along tidal creeks and rivers. Elsewhere (e.g., Papua New Guinea), it occurs in inland forests. In the Moluccas (Manupatty 1972-1973), four varieties are locally recognized, which occupy a range of habitats from the coast to subnmontane forests and seasonal swamps.

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Propagation. *P. indicus* may be propagated by seed, which germinate in 8-100 days, but the initial growth of seedlings and saplings is relatively slow. Propagation by cuttings is preferred, especially for ornamental planting (Wong 1982). *P. indicus* is unique among big timber trees in that the capacity for rooting of stem cuttings is not lost with age. Stem cuttings can be taken from trees of any age and size. Indeed, cuttings of diameter 6 cm or larger will root better than cuttings of smaller diameter. Young leaf-bearing stems will not root at all. For roadside planting, the cuttings used are in the form of stakes 1.5-3 m long and as much as 10 cm diameter. Such stakes produce up to 10 radiating shoots at the top, making a symmetrical crown very quickly, above pedestrian height. Few species can match *P. indicus* in the ability to produce well-crowned instant trees within one or two years. If large stakes fail to root, it is usually because of water-logging or accidental movement of the stakes during the tender rooting period. These problems can be avoided by rooting the stakes in loamy soil in large well-drained containers, while tied securely to a simple supporting framework. The stakes root in about 3 months and can be reduced to as short as 10 cm length, but such cuttings would take longer to develop into trees.

Timber. The timbers of all species of *Pterocarpus* are highly valued. *P. indicus* timber is moderately hard (.52 specific gravity), moderately heavy, easy to work, pleasantly rose-scented, takes a fine polish, develops a range of rich colors from yellow to red and has conspicuous growth rings, which impart a fine figure to the wood. Remarkably, such growth rings are developed even in the non-seasonal humid tropics. In Java and the Moluccas, giant burrs on the stem give rise to finely figured gnarl wood (also called *wavy* or *curly* wood). In the Moluccas, *P. indicus* is also the source of *linggua kasturi*, a highly valued red wood with the scent of sandalwood (Burkill 1935); this is perhaps a pathological condition. Traditionally, *Pterocarpus* has been so much in demand for cabinet class furniture that nearly everywhere its existence in the wild is precarious.

Silviculture. *P. indicus* behaves like a pioneer and grows best in the open. Seedlings are slower growing than cuttings and exhibit considerable variation in vigor. A strict culling program would be necessary to ensure that only the best stocks are planted out. Rooted cuttings can be established readily on nearly all kinds of soils, from coastal sands to inland clays, in urban and garden situations, and even in quite small planting holes dug into pavements. However, establishment trials in forest areas have had mixed results and some have failed. The reasons are not clear.

With a little practice, it is easy to distinguish a healthy tree by its luxuriant foliage from one that is thinly leafed and stressed. Under favorable conditions, trees in Singapore have been known to grow an average of 13.3 m in height and 1.55 m in girth in 11 years, or an average annual increment of 1.2 m height and 14 cm girth. Urban trees in Singapore are fertilized with compound fertilizer at the rate of 0.5, 1, and 1.5 kg per tree per annum in the first, second, and third years of growth. Subsequently, they get 3-5 kg per tree per annum depending on their size. The fertilizer is spread evenly on the soil under the tree crown and is applied once a year. Where the area of the soil is smaller than the crown (e.g., for trees planted in pavements and road dividers), the fertilizer is divided into two or more smaller applications (Wong 1982). As an urban tree, *P. indicus* is relatively wind-firm and seldom suffers branch breakage.

Trees of all sizes and ages easily regenerate new shoots when lopped or pollarded. In Papua New-Guinea, logged forest trees readily regenerate new plants from the roots (Saulei 1988).

Nodulation. The seedlings nodulate readily.

Pests and diseases. *P. indicus* trees in Singapore and Malaysia suffered extensively from an unknown disease between 1875 and 1925. The leaves of affected trees withered the branches died back, and after 2-3 months the whole tree would die (Corner 1940). Sometimes, whole avenues were wiped out. Strangely, the disease then disappeared and has not recurred. There are at present no serious pests and diseases.

Other species of *Pterocarpus*. Other well-known species are *P. dalbeigioides* of the Andamans Islands in the Bay of Bengal, *P. marsupium* of India and Sri Lanka, *P. macrocarpus* of Burma, Thailand, and Indo-China, *P. officinalis* of tropical America, and *P. soyauxii* of Africa. The silviculture of some of these has been described by NAS (1979).

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NFT Highlights

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

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Robinia pseudoacacia : Temperate Legume Tree With Worldwide Potential

Very few nitrogen fixing trees are temperate, and very few of these are legumes. The genus *Robinia,* with four species native to temperate regions of North America, is noteworthy for an ability to tolerate severe frosts. *Robinia pseudoacacia* L, or black locust (family Leguminosae, subfamily Papilionoideae), is among the few leguminous NFTs adapted to frost-prone areas. It is also adaptable to environmental extremes such as drought, air pollutants, and high light intensities (Hanover 1989). Rapid growth, dense wood, and N_2 fixing ability make it ideal for colonizing degraded sites.

BOTANY. Black locust is a medium-sized tree reaching 15-35 m in height and 0.3-1.0 m in diameter. Long (20- 45 cm) pinnate leaves consist of 5-33 small oval, alternate leaflets. Sharp spines are found at the nodes of young branches but are rare on mature wood. The smooth bark becomes reddish-brown and deeply furrowed with age. White to pink, fragrant flowers in 10-25 cm long, hanging racemes appear in early summer soon after the leaves. The closed flowers require bees to force petals open for cross-pollination. The small pods contain 4-8 hard-coated seeds which can persist in the soil for many years. Seed crops occur every 1-2 years beginning at age 3; pods open on the tree in winter and early spring. Although it can occur as a polyploid, it is primarily diploid (N = 10).

ECOLOGY. Black locust is native to regions with 1,000-1,500 mm annual rainfall, yet it is drought-tolerant and survives on as little as 400 mm. Its natural distribution includes the Appalachian and Ozark mountains of the eastern US between 35°-43° N latitudes. It occurs on upland sites in hardwood forests with black oak, red oak, chestnut oak, pignut hickory, yellow poplar, maple, and with ash along streams. In the northern part of its range at 800 m elevation it occurs with *Picea rubra* and *Acer saccharum* (Keresztezi 1988b).

First introduced to France and England in 1600, black locust has become increasingly important throughout Europe and in parts of Asia (Keresnesi 1988a). It now covers 18% of Hungary's forested areas. It is grown in temperate and subtropical regions in the US, Europe, New Zealand, India, China, and Korea. It has even been grown at higher, cooler elevations in the tropics (e.g. in Java). Trees tolerate temperatures from 40° C to –35° C. It is found on a variety of soils with pHs of 4.6 to 8.2, but grows best in calcareous, well-drained loams. Trees do not tolerate water-logging.

An old-growth black locust tree growing in Nice, France.

Extremely intolerant of shade, the trees are pioneers on disturbed soils or burned sites, often reproducing prolifically from root sprouts (Fowells 1965). Black locust dominates early forest regeneration in many native forest stands where it occurs (Boring and Swank 1984).

SILVICULTURE. Propagation: Black locust seeds (35,000-50,000 seeds/kg) require scarification for good germination. Treatment with concentrated sulfuric acid for 20-50 min is most effective. Seeds can also be nicked, soaked in boiling water for several minutes, or washed in aerated cold water for 2-3 days.

Trees sucker readily from roots and also graft easily. They can be propagated, with difficulty, from hardwood cuttings (15-30 cm long and 1-2 cm diameter) collected in winter or early spring. Treatment with indole acetic acid improves rooting. The tree responds well to tissue culture and has been mass propagated by this method. In nursery culture black locust is either direct seeded or root sections (5-8 cm long) planted. *Robinia pseudoacacia* seed is available from NFTA; improved seed is available from James Hanover (MSU).

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Growth and yield: The species has one of the highest net photosynthetic rates among woody plants. Black locust grows rapidly, especially when young. Trees can reach 3 m tall in one growing season and average 0.5-1.5 m height and 0.2-2 cm diameter growth per year. Trees attained 12 m ht in 10 yrs and 20 m ht in 25 yrs in Kashmir (Singh 1982), and 26 m ht and 27 cm diameter in 40 yrs in the US. Intensive management combined with genetic selection gave experimental dry weight yields up to 40 t/ha/yr under short rotation. On fertile sites it can yield more than 14 m^3/ha/yr (9.5 t/ha/yr.) on a 40-yr rotation with only moderate management. On poor sites, such as strip mines in the US, oven-dry biomass yields range from 3.1 to 3.7 t/ha/yr. Timber volume in a 20-yr-old stand ranged from 63 to 144 t/ha (Keresztesi 1988a), and aboveground biomass in a 38-yr-old native mixed forest stand in N. Carolina, US, was 330 t/ha (Boring and Swank 1984). Fuelwood plantations in S. Korea coppice readily and are lopped annually for fuel (NAS 1983).

TREE IMPROVEMENT. *R. pseudoacacia* has been cultivated for over 350 years. Natural variation in numerous traits has often been observed and many cultivators described. Surles et al. (1989) showed a high degree of polymorphism (71%) for 18 enzyme systems in black locust. Most of the diversity resided within seed sources with low geographic variation. Cultivators vary in crown and stem form, growth rate, growth habit (upright vs. prostrate), leaf shape, thorniness, flowering characteristics, and phenology. Clonal selection, early pruning, and close spacing have been effective means of producing straight-stemmed black locust in plantations, especially in Eastern Europe. Comprehensive germplasm collections and plantings for provenance tests were begun in 1982 at Mich. State Univ. Efforts in crossbreeding are under way to improve the tree for growth rate, borer resistance, stem form, thorn-lessness, or other traits (Hanover et al. 1989). In Hungary, a large array of tall clones is in commercial use (Keresztesi 1983), based on seeds from trees of "shipmast locust" originating from Long Island in New York State.

USES. Wood. Black locust wood is strong and hard with a specific gravity of 0.68, yet it has the lowest shrinkage value of US domestic woods. The wood makes a good charcoal. Wood energy yield is typical of temperate broadleaf trees, about 19.44 x 10^6 J/kg (Stringer and Carpenter 1986). The beautiful light to dark brown wood is used to make paneling, siding, flooring, furniture, boat building (substitute for teak), decking, vineyard or nursery props, fruit boxes, and pallets. It is also a preferred wood for pulp production. Black locust wood is highly resistant to rot (Smith et al. 1989).

Fodder. Black locust has become an important tree in the Himalayas where it is heavily lopped for fodder (Singh 1982). Leaves have a crude protein content of 24%. However, tannins and lectin proteins found in leaves and inner bark can interfere with digestion in ruminants and in nonruminants (Harris et al. 1984). Tannin levels are high in young leaves but decrease as leaves mature.

Honey. Bees harvest *Robinia* nectar to produce a honey regarded as one of the world's finest. Tree improvement specifically for late flowering and high nectar sugar content is ongoing in Hungary and the US.

Other. The tree is used extensively to rehabilitate surface mine tailings in the US. In Hungary, black locust is often grown for wood on small private farms (Keresztesi 1986). A dense growth habit makes black locust suitable for windbreaks, a use most common in China. Black locust may even prove useful for alley cropping in temperate climates. Researchers at the Rodale Research Center in Pennsylvania are experimenting with intercropping black locust with vegetables. Numerous reports indicate the beneficial effect of this NFT to associated plants through improved soil fertility. Mixed plantings of black locust and conifers, however, can lead to reduced growth or death of the slower growing conifers because of shading and over-topping.

PESTS AND PROBLEMS. The most serious pest to black locust in the US is the locust borer, *Megacyllene robiniae* (Forster). There is some evidence for genetic resistance to the borer. Another insect confined to trees in the US is the locust twig borer, *Ecdytolopha insiticiana* (Zeller). Aphids, *Nectria* cankers, leaf miners, and *Rimosus* heart rot also affect the tree (Hoffard and Anderson 1982). Its propensity to root spout aggressively can also cause problems.

RHIZOBIUM. *Robinia* is fairly specific in its *Rhizobium* requirements. Although it will form nodules with a variety of exotic strains, for effective N-fixation, strains from native trees work best. Newly introduced trees require inoculation; inoculum may be gotten from the soil of black locust stands, or from NFTA. The tree's fine roots are also colonized by VA mycorrhizae.

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A full list of highlight references is available from NFTA.

FACT Net

FACT Sheet

A quick guide to multipurpose trees from around the world

FACT 99-04
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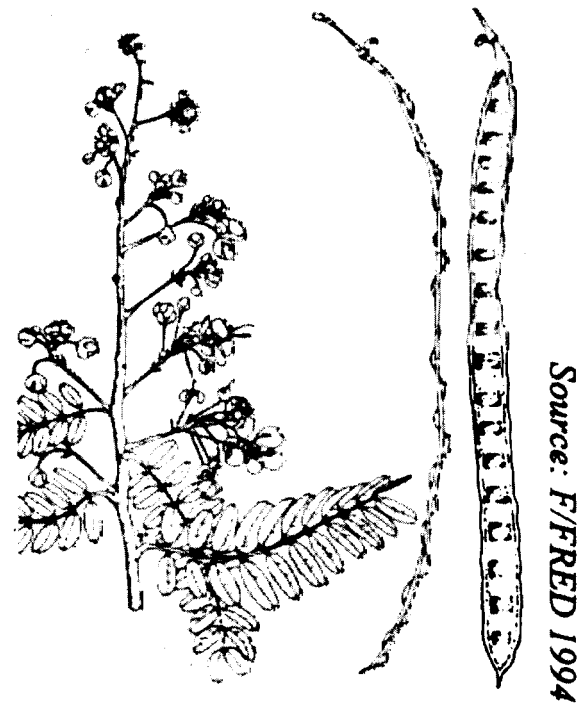
Senna siamea : A Widely Used Legume Tree

Senna siamea Lamk. (synonyms: *Cassia siamea* Lamk., *C. florida* Vahl.; *Senna sumatrana*, Roxb.) is a nonnitrogen-fixing leguminous tree in the subfamily Caesalpinoideae of the family Leguminosae. It has been widely planted in many Southeast Asian countries for erosion control, windbreaks, shelterbelts, fuelwood, and polewood. It is a good ornamental tree for planting along roadsides, and it is also used in alley cropping, intercropping, and hedgerows. It is planted as a shade tree in cocoa, coffee, and tea plantations. It is commonly called Thailand shower, minjiri, or kassod and has many regional names (Brandis 1906, F/FRED 1994).



Source: F/FRED 1994

Botany

Senna siamea is a medium sized evergreen tree attaining 5 m height in and conditions (F/FRED 1994). It rarely exceeds 20 m height and 50 cm diameter at breast height (Jensen 1995). It has a dense, evergreen, irregular, spreading crown, a crooked stem, and smooth, grayish bark that is slightly fissured longitudinally. Its young branches have fine hairs. The leaves are pinnately compound with an even leaf arrangement of 7-10 pairs of ovate-oblong leaflets 7-8 cm long and 1-2 cm wide. Its flowers are yellow, borne in large terminal panicles that are often 30 cm long. The flowering period is long, and flowers may often be found at various seasons (Troup 1921). The fruit is a flat pod 15-25 cm long, thickened at both sutures, containing many seeds (Gutteridge 1997).

Ecology

Senna siamea grows well in many environments, but it grows particularly well in lowland tropics having mean annual rainfall of 500-2800 mm (optimum about 1000 mm), mean minimum temperature of 20°C, and mean maximum temperature of 31°C. In semiarid environments with mean annual rainfall of 500-700 mm it will grow only where its roots have access to groundwater and where the dry season does not exceed 4-6 months. Best growth occurs in deep, well drained, rich soils with pH 5.5-7.5. It tolerates well drained lateritic or limestone soils and moderately acid soils (pH 5.0). It is susceptible to cold and frost and generally does not grow well above 1300 in. It requires full sun (Gutteridge 1997, Davidson 1985).

Distribution

Senna siamea is native to South and Southeast Asia, from Thailand and Myanmar (Brandis 1906, Gamble 1922) to Malaysia, India, Sri Lanka, and Bangladesh (Khan and Alam 1996). It has been cultivated worldwide and is naturalized in many locations (Gutteridge 1997).

Uses

Wood. *Senna siamea* wood is used for furniture, poles, small timber, and fuelwood. It is hard, with specific gravity of 0.6-0.8. The sapwood is whitish, and the heartwood is dark brown to nearly black, with stripes of dark and light (Gamble 1922). The fuelwood and charcoal are highly regarded (calorific value of 4500-4600 Kcal/kg), but the wood produces a lot of smoke (F/FRED 1994).

Other uses. *Senna siamea* is used in intercropping systems, windbreaks, and shelterbelts. It is also used as a shade tree in cocoa, coffee, and tea plantations (F/FRED 1994). The tree produces an extensive root system in the upper layer of the soil and, in intercropping systems, can aggressively compete for nutrients and water (Gutteridge 1997). The leaves and seeds can be eaten by ruminants (Sahni 1981) but are toxic to non ruminants such as pigs and poultry. The young leaves and flowers are used in curry dishes. The species is also used for the production of honey and tannins.

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Silviculture

Propagation. *Senna siamea* is usually propagated by seed, and plantations are often established by direct seeding (Gutteridge 1997). Mature pods should be collected from the tree when they turn brown, but mature, half opened pods may be collected from beneath the trees (Siddiqi and Ali 1994). After collection, the pods should be dried in the sun for a few days. The seeds are small and greenish-brown, and there are about 37,000-43,000 seeds per kilogram (Katoch 1992, Hor 1993). Clean seeds can be stored in air-tight containers at room temperature for years with little loss of viability. Fresh seeds generally do not need any treatment, but soaking them in cold water for 12 hours accelerates germination (Siddiqi and Ali 1994). Germination is complete within 7-20 days and germination percentage typically exceeds 70 percent. Katoch (1992) dipped the seeds in hot water for 1 minute before soaking them in cold water for 24 hours, and obtained 98 percent germination in 28 days.

In the nursery, seed may be sown in containers, or nursery beds and trays and transplanted to containers after germination. Polybags 10 x 15 cm are widely used in Bangladesh for raising seedlings. Well drained sandy- loam soil (preferably forest topsoil) mixed with manure or well-decomposed compost in a ratio of 3:1 is recommended for nursery use. In addition, 500 g each of triple superphosphate and muriate of potash may be added to every cubic meter of nursery soil. In each polybag, 2-3 seeds should be sown at a depth of 0.5-1.0 cm and covered with a thin layer of sand. Seedling growth is favored by loose soil, sufficient soil moisture, full sunlight, and absence of weeds.

Seedlings are kept in the nursery for 12-14 weeks or until they have attained a height of 25-30 cm. Root pruning and hardening off the seedlings before outplanting is beneficial. Containerized seedlings generally have better survival than direct-sown seedlings, particularly under heavy weed competition. *Senna siamea* can also be planted as stumps (Evans 1982).

Management. Plantations can be managed by coppicing, lopping, or pollarding (F/FR.ED 1994). For fuelwood, the recommended spacing is 1 x 1 in to 1 x 3 in, with the first harvest in 5-7 years. In hedges for alley cropping or shelterbeits, spacing between plants within rows should be 25-50 cm. For mulch or leaf production, the first cut may be 12-18 months after sowing, followed by 3-4 cuts per year thereafter (Gutteridge 1997). A small dose of NPK fertilizer in the first year helps the seedlings' initial growth; the fertilizer level varies with the site quality. In the field, weed control is essential during the first 1-2 years. The first weeding should be 2 months after plantation establishment, or depending on the intensity of the weed growth. Weeding of noxious plants such as climbers, creepers, and vines is recommended, but less harmful weeds may be left in the field.

On good sites, *S. siamea* can grow to a height of 8 in and a root collar diameter of 20 cm in 40 months. In a tree trial in southern Sumatra, the species produced 1200 g of leaves per plant per year. Total yield of wood for timber, poles, and fuelwood may reach 10-15 m^3/ha/year (Gut- teridge 1997).

Symbiosis

Senna siamea does not nodulate or fix nitrogen through symbiosis with *Rhizobium* bacteria.

Limitations

No significant pest or disease damage has been recorded, but minor damage can be caused by the wood rot *Ganoderma lucidum* (Khan and Alam 1996). Insects that damage seed include *Caryedon lineaticollis* and *Bruchidius maculatipes*. Seed-borne fungi reported in Thailand include *Aspergillus niger* and *Curvularia pallescens* (Hor 1993). The fungus *Phaeolus manihotis* occasionally causes damage to the root system (Gutteridge 1997).

Research Needs

Studies are needed to evaluate *Senna siamea* for timber production and to evaluate its potential as a fodder crop for ruminants.

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FACT Net

NFT Highlights

A quick guide to multipurpose trees from around the world

NFTA 94-05
June 1994

Sesbania grandiflora : NFT For Beauty, Food, Fodder And Soil Improvement

Sesbania grandiflora is a tree that grows rapidly, provides light shade, and is often grown as an ornamental. This soft-wooded tree's leaves are used as fodder and its flowers as food. Grandiflora is planted in gardens for its intercropping compatibility and soil-improving properties.

Botany

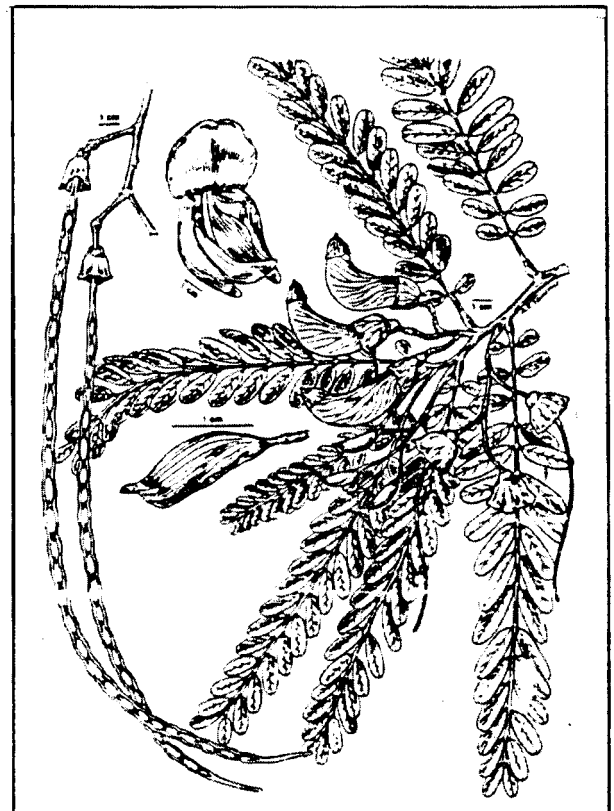
Sesbania grandiflora (L.) Poir. is a tree that grows to 8-10 m in height. The pink-red or white flowers of this papilionaceous (pea-like flowered) legume are unusually large (5-10 cm in length and about 3 cm wide before opening); this novelty may be the principal reason for grandiflora having been distributed by man throughout the tropics and subtropics. Within its genus, *S. grandiflora* is a member of the subgenus Agati, and it is thus more closely related to the unusual littoral sesbanias of Pacific islands than to the more typical sesbanias of subgenus Sesbania, such as the perennial *S. sesban* and the annual sesbanias grown for green manure (such as *S. cannabina*).

Grandiflora's pinnate leaves may be 30 cm long, with 12-20 pairs of oblong, rounded leaflets averaging 3-4 cm long and about 1 cm wide. The leaves are borne at the terminals of branches, and the canopy is open, with a thin crown which produces light shade. Its racemes bear 2-3 flowers. The pods are usually 30-50 cm long by about 8 mm wide. The seeds are tan to red-brown, 6-8 x 3-5 mm, 14-20 weighing 1 g. The trunk may reach 25 cm diameter at breast height. Grandiflora may live 20 years or more.

Grandiflora is very closely related to the endemic Australian species, *S. formosa*. This relationship supports the supposition that grandiflora may have originated in Indonesia. *S. formosa* bears white flowers and is often indistinguishable from grandiflora to the casual observer. The two species appear to have similar growth habits and adaptivity, and it is possible that *S. formosa* also can be used for the purposes described here for grandiflora.

Distribution

Grandiflora is found in cultivation throughout the tropics and subtropics.



Sesbania grandiflora, from Sachet, M.-H. 1987. The littoral species of *Sesbania* (Leguminosae) in the South Pacific islands and its relatives. Bulletin du Museum National d'Histoire Naturelle, section B, 4th series, Adansonia 9:3-27. (Focuses on subgenus Agati.)

Ecology

Because wild populations of grandiflora are unknown, its natural habitat is uncertain. Grandiflora is grown most successfully in the lowland tropics (below 1000 m elevation) and warm, frost-free subtropics. It can be grown in regions with as little as 800 mm rainfall or as much as 2000-4000 mm. It seems to prefer a bimodal rainfall distribution, growing rapidly during wet seasons but capable of withstanding prolonged dry seasons of up to nine months. Grandiflora is tolerant of soil salinity and waterlogging, and withstands occasional short periods of flooding. It is well adapted to heavy clay soils.

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Uses

Fodder, food, and soil improvement are the principal uses for grandiflora.

Fodder. Grandiflora is valued as a fodder in many regions. In south central Lombok, Indonesia, grandiflora grown around rice paddy bunds provides up to 70 percent of the diets of cattle and goats during the annual eight-month dry season (Mudahan Hazdi, personal communication). The leaves contain as much as 25-30 percent crude protein. Although ruminants readily consume grandiflora fodder, and its digestibility is high, some feeding studies have indicated that antinutritional factors are present. Until further research provides clear guidelines, caution should be used in feeding *S. grandiflora* to ruminants and other animals, and restricting feeding to less than 30 percent of dry matter intake is suggested. Grandiflora leaf is toxic to chickens and should not be fed to them or other monogastric animals.

Soil improvement. Grandiflora is often maintained in gardens and around crop fields for its contribution of nitrogen. The light shade cast by its canopy does not block much light, allowing the growth of companion plants. Falling leaflets and flowers recycle nutrients to the ground. Seedlings grow rapidly enough that they have been used similarly to annual green manure crops. For example, grown around paddy bunds for incorporation before planting the subsequent rice crop.

Wood. The wood is rather light and not ideal for firewood or pulping; the bark is thick and corky and is a further detriment to either of these uses. The trunks may be used as poles for temporary shelters and sheds, but they may not last very long due to rots and insect infestation.

Food. Leaves, seed pods, and flowers of grandiflora are prepared as food. The young, tender pods are cooked similarly to other green beans. In South Asia the young leaves are chopped and sautéed, perhaps with spices, onion, or coconut milk. In the Philippines, unopened white flowers are a common vegetable, steamed or cooked in soups and stews after the stamen and calyx have been removed. Selection of white-flowered varieties that flower profusely has resulted from this use in the Philippines.

Other uses. Grandiflora has been used to shade nurseries and some crops, such as turmeric, as support for climbing crops such as pepper and betel vine, and as an element of windbreaks. The leaves of the tree have various uses in the herbal medical lore of certain regions.

Culture and Management. Grandiflora is grown from seed, which may be planted without scarification. Stored seeds lose viability within a year or two. Seeds may be direct-sown or transplanted from nurseries; bare-rooted transplants are usually successful. Seedling growth of grandiflora may be very rapid. Under harsh conditions or neglect, however, seedling survival may be poor. The leaf canopy is open and casts only light shade, hence its popularity in gardens.

Grandiflora cannot be coppiced or pollarded. Harvesting leaves for fodder must be done selectively, to avoid complete defoliation, and cannot be done more than a few times per year. More intensive harvesting, such as managing as a hedgerow, reduces the life of the tree. For example, cutting at 1 m high five times a year can result in tree mortality. Because grandiflora establishes so rapidly, frequent replanting is a management option if heavy harvesting results in tree decline.

Where flowers and pods are harvested for consumption as vegetables, the structure of the tree is shaped by pruning so that the canopy remains low, within reach for convenient harvesting.

Symbiosis

The rhizobia strains that nodulate sesbanias are somewhat specialized and may not be present where sesbanias have not been grown previously. Test plantings should be done to see if infective rhizobia are present in the soil, or if use of a rhizobia seed inoculant at planting will be necessary.

Limitations

Grandiflora's soft wood is susceptible to damage by insects. Fodder cuttings cannot be severe. Seed recovery may be limited by pod pests. Seed viability declines after one year.

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NFT Highlights

A quick guide to multipurpose trees from around the world

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June 1994

Sesbania sesban : Widely Distribute Multipurpose NFT

Sesbania sesban is a many-branched, soft-wooded tree that grows rapidly and is useful for fodder and green manure. This species has long been used for browse and soil improvement in India and Africa. Recent interest in multipurpose, nitrogen fixing trees has caused it to be collected, studied, and recommended for fodder "banks" and alley cropping.

Botany

Sesbania sesban (L.) Merrill is a tree that grows to 8 m height. This papilionaceous (pea-like flowered) legume bears racemes of 4-20 yellow flowers that may be lightly to heavily streaked with purple. Sesbans have pinnate leaves with 20-50 opposite pinnules on a rachis 3-12 cm long. The leaf rachis and the underside of the leaflets are often pubescent. The pods are usually 10-20 cm long and contain up to 40 seeds that are brown, or dark green mottled with black. The trees usually have one main stem, but they may develop many side branches if they have space. Sesban's many branches often give the tree a shrubby appearance. It tends to have a spreading habit due to its wide branching angle (as wide as 45-60°).

Within its genus, sesban is classified in the subgenus Sesbania, and thus is more closely related to the annual sesbanias grown for green manure (such as *S. cannabina*) than to the other well known perennial species of the genus, *S. grandiflora*, which is in the subgenus Agati (Evans 1990). Several varieties of sesban are recognized. The botanical distinctions among sesbanias are often difficult for non-botanists to see, and sometimes sesban is confused with the annual types of sesbania.

Ecology

Sesban occurs naturally in semiarid to subhumid areas with 500-2000 mm of rainfall. It seems to do well under bimodal rainfall distributions, where heavy rains and even flooded conditions are followed by a progressively drier season. It grows from sea level to 2000 m elevation, but the upper limit is uncertain. It does not tolerate frost. It is uniquely well adapted to periodic waterlogging and flooding. Soil alkalinity and salinity is tolerated to a considerable degree. Some research suggests that certain sesban types may grow well on acidic soils.

Sesbans are relatively short-lived, and under intensive browsing or cutting management will not last more than 3-5 years. Their rapid seedling growth is conducive to short-term fallows and to replanting if management should reduce growth vigor.

Distribution

Sesban is found throughout the tropical and subtropical parts of Africa, Asia, and Australia. It is not widely distributed in the Americas. Africa is its center of diversity, and sesban probably originated there; its former name is *S. aegyptiaca*. From northeastern Africa, *S. sesban* var. *sesban* and its variants were spread across southern Asia, possibly by man. Within Africa, *S. sesban* var. *nubica* is the type most commonly found, and there are several sesbanias closely related to sesban, such as *S. goetzei* and *S. cinerascens* (Gillett 1963).

From A. Cronquist (1954), "Galegeae," *in* Flore du Congo Belge et du Ruanda-Urundi, Vol. 5, p. 77, Brussels.

Uses

Sesban is mostly used as fodder and for soil improvement, its wood is used only to a lesser extent (Evans and Macklin 1990).

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Fodder. The leaves and tender branches of sesban are high in protein (20-25% crude protein) and have high digestibility when consumed by ruminants, such as cattle and goats. Anti-nutritional factors are suspected to be present in sesban fodder. Feeding sesbania fodders to monogastric animals (such as chickens, rabbits, and pigs) is not recommended.

Reports of feeding sesban to ruminants conflict. Trials in Australia feeding sesban to heifers showed live weight gains, but trials with young goats in Samoa found a lack of weight gain. Until further research provides clear guidelines, caution should be used in feeding ruminants with sesban fodder at more than 10-20 percent of diet.

Soil improvement. Sesban establishes quickly and grows rapidly. In Africa it is often allowed to grow scattered throughout annual crop fields for the nitrogen it provides. It has been used in experimental alley cropping systems to provide mulch and greenleaf manure to intercrops. Sesbans can be somewhat shallow rooted, and may compete with adjacent crops.

Wood. Sesban's wood is light in weight compared to the woods of *Calliandra* and *Leucaena*, but it is often harvested for firewood in Africa and India. It has been used in India to make charcoal. The wood is not durable and should not be considered for timber use. The branches have been used as poles in temporary structures such as sheds and mud daub huts.

Because sesban grows so rapidly, it has potential for pulpwood production. Plantings at about 10,000 trees/ha have produced 15-20 tons of woody biomass (dry weight) in one year.

Food. Flowers of sesban are known to be added to stews and omelets in some regions, perhaps mainly as a decorative element.

Other uses. Various medicinal uses for sesban have been recorded in Africa and Asia (Evans and Rotar 1987, Evans and Macklin 1990). The leaves and flowers are used in medicinal poultices and teas, which are said to have the effect of astringence, or contraction of body tissues. Bark exudates from sesban produce a gum of medium commercial quality.

Culture and Management

Sesban is generally propagated from seed, although it has been rooted from cuttings, and research has revealed that it can be established by tissue culture. Seed scarification usually improves germination. Recommended hot water scarification is a 30-second dip in water heated to just below boiling. Seed weights range from 55-80 per gram for *S. sesban* var. *sesban* to 80-130 per gram for var. *nubica*.

Plants grown for fodder production can be placed as close as 30-50 cm apart in rows 1 m apart. appropriate distances between rows in alley cropping will depend on the variety grown, the ecology of the site, and intensity of management.

Experimental fodder cutting trials have yielded 20 tons/ha dry matter in the first year. However, sesban cannot be managed with the severity that *Leucaena* tolerates in fodder and wood biomass production systems. If sesban is cut too low (below 50-100 cm) or too frequent (more than 4-6 cuttings per year) death of the plants can result. When cutting sesban it is recommended to leave 10-25% of the foliage on the plants.

In some climates, such as the highlands of Kenya, sesban may have a sparse canopy and weed competition can be a problem. This characteristic makes sesban a good intercrop. Sesban has been grown with the fodder grass *Brachiaria mutica* in India, and to provide shade to young coffee plants in Kenya. In climates where sesban grows more vigorously, weeds are shaded out and companion plants may be adversely affected; this type of growth has been observed in Hawaii and Jamaica (Roshetko et al. 1991).

Symbiosis

The rhizobia strains that nodulate sesbanias are somewhat specialized and may not be present where sesbanias have not been grown previously. Test plantings should be done to see if effective rhizobia are present in the soil. If not, use of a rhizobia inoculant at planting will be necessary.

Limitations

Sesban is not a tree for timber or reforestation in the ordinary sense of forestry or silviculture. Because the range of its ecological adaptability is not yet well known, test plantings should be done before large-scale plantings are planned. Sesban has been observed occasionally to die back under cutting management; fungal infection may be the cause. Leaf-feeding insects sometimes limit production. Seed chalcids can reduce seed recovery.

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FACT Sheet

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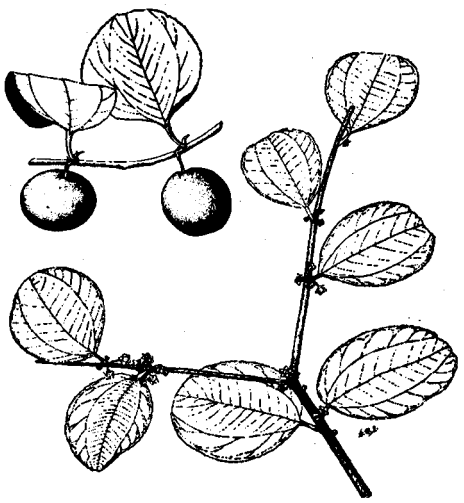
June 1998

A quick guide to multipurpose trees from around the world

Ziziphus mauritiana : A Valuable Tree for Arid and Semi-arid Lands



Source: Little and Wadsworth 1974

The use of *Ziziphus mauritiana* in India can be traced back to as early as 1,000 BC. This species which is also known as ber, Indian jujube, Indian plum, or desert apple, is an evergreen, medium-sized, thorny tree, whose greatest quality is its ability to thrive and produce fruits in arid or semi-arid regions.

One idealist describes this species as "a gift of mother nature which symbolizes the productive capacity of the seemingly infertile ecosystem". An apt description of its value is that ber produces the three vital "f's" that desert dwellers require—fruit, fodder, and fuel (Vashishtha 1997).

Ber belongs to the Rhamnaceae family. Of the well-known species of the genus *Ziziphus*, ber (*Z. mauritiana)* is the most common in the tropical and sub-tropical regions, while *Z. jujuba* is well known in temperate parts of the world. Extensive research on ber was first undertaken in India. Research on this species has expanded to Israel, Malawi, Senegal, and Zimbabwe.

Botany

Ber is a medium sized tree that grows vigorously and has a rapidly developing taproot, a necessary adaptation to drought conditions. The species varies widely in height, from a shrub 1.5 to 2 m tall, to a tree 10 to 12 m tall with a trunk diameter of about 30 cm. Ber tree may be erect or wide-spreading, with gracefully drooping thorny branches.

The leaves are alternate, ovate or oblong elliptic, with 3 veins at the base, and are usually about 2.5 to 3.2 cm long and 1.8 to 3.8 cm wide. The flowers are yellow, 5-petalled and are usually in twos and threes in the leaf axils. This quick growing tree starts producing fruits within three years. It will not set fruit by self-pollination. Fruits vary in shape and size. They can be round, oval or oblong; large, medium or small. Most are round to oval. Size can be as small as 1.8 to 2.5 cm for fruit from wild trees or as large as 5 cm (plum sized) from improved cultivars. Ber fruits are first green, turning yellow as they ripen. The ripe fruit is sweet and sour in taste. Both flesh texture and taste are reminiscent of apples.

Ecology

Commercial cultivation of ber usually extends up to 1,000 m. Beyond this elevation trees do not perform well and cultivation becomes less economical. This species is able to survive temperatures as high as 50°C. In India trees survive minimum shade temperatures of 7° to 13°C. However, this hardy fruit tree does not tolerate frost well. Native to the tropical and sub-tropical regions, ber can grow where annual rainfall ranges from 125 to 2,225 mm, but is more widespread in areas with an annual rainfall of 300 to 500 mm. It is known for its ability to withstand adverse conditions, such as salinity, drought and waterlogging. Studies report that this species flourishes in alkaline soils with a pH as high as 9.2. However, deep sandy loam to loamy soils with neutral or slightly alkaline pH are considered optimum for growth.

Distribution

Early studies indicate that the center of origin of ber is Central Asia. This species is indigenous to north Africa; from Afghanistan through north India to southern China; Malaysia; and Queensland in Australia. However, ber is now widely distributed and has become naturalized in tropical Africa, Iran, Syria, Sri Lanka, Burma, Barbados, Jamaica, Guadeloupe and Martinique, and parts of the Mediterranean.

Uses

Fruits. Ber fruits are very nutritious and are usually eaten fresh. Relatively unknown, this fruit is a rich source of vitamin C. It is second only to guava and much higher than citrus or apples. It contains 20 to 30% sugar, up to 2.5% protein and 12.8% carbohydrates. Fruits are also eaten in other forms,

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such as dried, candied, pickled, as juice, or as ber butter. In Malawi, dried fruit is used to make a potent distilled alcoholic beverage. Yields of 80 to 130 kg/tree/year have been reported in Africa (von Maydell 1986).

Fodder. In parts of India and north Africa, the leaves of ber are used as nutritious fodder for sheep and goats. Analysis of the chemicals constituents on a dry weight basis indicate the leaves contain 15.4% crude protein, 15.8% crude fiber, 6.7% total minerals, and 16.8% starch. In India, the leaves are also gathered as food for silkworms (Gupta 1993).

Wood. Ber timber is hard—with a specific gravity of 0.93— strong, fine-grained and reddish in color. It is most often used to make agricultural implements. The branches are used as framework in house construction. Ber makes good charcoal with a heat content of almost 4,900 kcal per kg. In addition, this species is used as firewood in many areas.

Other uses. This thorny tree makes good live fencing and is an excellent agroforestry tree to use in hedges. In India, ber trees are a host for the lac insects *Kerria lacca*, which are found on the leaves and makes an orange-red resinous substance. The purified resin makes a shellac used to produce sealing wax and vanish. High quality ber shellac is used in fine lacquer work.

Silviculture

Natural reproduction is through seed, stump, root suckers and coppice. Many existing silvicultural practices were developed in India, where domestication work began as early as the 1950's.

Propagation. Scientists in India have standardized propagation techniques for ber establishment. Budding is the easiest method of vegetative propagation used for improved cultivars. Different types of budding techniques have been utilized with ring-budding and shield-budding being the most successful. Wild varieties of ber are usually used as the rootstock. The most common being *Z. rotundifolia* in India and *Z. spina-christi* in Africa. Seedlings to be used as rootstock can be raised from seed. Several studies indicate that germination can be improved by soaking seeds in sulfuric acid. Germination time can also be shortened to 7 days by carefully cracking the endocarp. Ber seedlings do not tolerate transplanting, therefore the best alternatives are to sow the seeds directly in the field or to use polythene tubes placed in the nursery bed. Seedlings are ready for budding in 3 to 4 months. In addition, seedlings from the wild cultivars can be converted into improved cultivars by top-working and grafting. Nurseries are used for large scale seedling multiplication and graft production.

Spacing and fertilizer requirements. For orchard establishment recommended spacing is 7 x 7 m or 8 x 8 m. The wider spacing is preferred in areas with high rainfall where canopy development is vigorous.

Many studies in India recommend the application of both farmyard manure and commercial fertilizers to maximum production. In Africa, the recommended fertilizer application is 20 to 120 kg N, 100 to 120 kg P, and 20 to 50 kg K per hectare. Fruit production begins in the 4th year with full production in the 10th to 12th year (von Maydell 1986).

Training and pruning. It is essential to train ber trees during the first 2 to 3 years to build a strong frame. Otherwise, these trees have a tendency to grow horizontally and downwards. If untrained, trees develop into a spreading bushy form with long slender branches. Yearly pruning is also important because fruits are produced on current season's growth. Regular pruning induces sufficient new growth to produce a good fruit crop annually. Removing 25% of the growth is usually sufficient. Pruning should occur when plants are dormant.

Limitations

Pests and diseases. The most serious pest of ber are the fruit flies, *Carpomyia vesuviana* and *C. incompleta*, which attack the fruits at the "pea" stage. Susceptibility generally differs by cultivar. Control of the pests can be attained by regular spraying of insecticides. Powdery mildew is the most important disease and results in premature defoliation and fruit drop. The disease can be effectively controlled by using chemicals.

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FACT Sheet

A quick guide to multipurpose trees from around the world

FACT 98-02
January 1998

Improving Markets for farm Forestry Products

Traditionally, forestry development programs have focused on improving production and not on the products and their marketing. These programs have successfully raised production levels, but have not been successful in helping farmers meet marketing needs. Producers often lack understanding of basic marketing fundamentals and how best to market their products. To find and penetrate markets effectively, one must have knowledge of critical market information such as supply and demand, and other factors affecting markets for products (Sullivan et al 1991).

Many forest farmers are not aware of markets available and the means of getting their products to these markets. The result is that farmers often receive lower prices, are not aware of new or different market opportunities, or have little information to use for planning. Traders visiting local areas are often the only outlets. Producers do not know how to price their products, or determine demand, especially in new or distant markets. This lack of knowledge makes producers ineffective when dealing with middlemen.

Increased availability of market information will help producers strengthen their marketing skills and get higher prices, and lead to increased awareness of important marketing practices.

The Basics

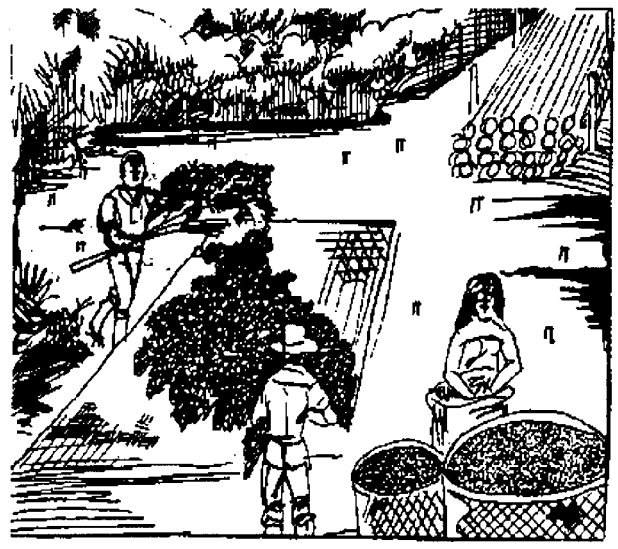
Marketing involves the many aspects of moving a product from the farm to market (see basic marketing text such as Kotler and Armstrong 1996). Prior to planting the markets for all potential products should be discussed. This may be difficult for products not ready for market until several years in the future, such as timber or fruits.

Producers should understand how to promote their products in the market. They should know how to store products to ensure they do not lose value. Sorting by quality or grade, and packaging products together with similar characteristics will help the product sell quickly and for a higher price. Proper harvest, storage, and transport will help assure that the maximum amount of product reaches market and that the farmer receives the maximum possible return.

Efforts to increase production of agroforestry products should be balanced and should look at all levels of production and handling of products. Producers often suffer from decreased revenues when marketing needs are not addressed.

Increasing markets through improving market information

One key way to improve markets for local producers is to increase access to market information. This can be accomplished by organizing a locally operated market information collection system. The cost of collecting information can be minimal and the importance of marketing reinforced if the producers collect information about the market while on regular marketing or buying trips.



Local farmers need to identify ways to improve marketing of their existing products and plan for future products. A market information checklist included here (see outline in box) is a good place to start. It was developed in the Philippines and tested in several Asian countries (Hammett 1994), and should help producers obtain the information they need to increase returns on current products and help plan for future crops.

First, an assessment of local market information needs, and the identification and evaluation of existing market information sources should be completed. A lack of local marketing expertise and market information for agroforestry products can make this task challenging. Most farmers produce only at the subsistence level; what little they produce in excess of their own needs is sold locally by the roadside or in nearby weekly markets. When surplus production occurs, farmers usually sell to traders or middlemen and do not have the capability to market products in other markets.

Market information should not only provide farmers with support for their marketing efforts, but help them optimize the selection of and mixture of forest and agriculture crops. Increased market information results in increased value for products, more efficient marketing, and improved production levels where further local processing may become feasible.

Guidelines for improved access to market information

The guidelines include steps needed to collect, assemble, and disseminate market information at the local level. The suggested sequence of these steps can be adjusted for other products and sites, and may be adapted to suit evolving farmer needs.

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A market information system checklist

1. Assess local market information needs
   - Identify and organize a group of producers
   - Set goals for the group to improve marketing
2. Analyze the local situation
   - Determine what types of market information are needed
   - Select products appropriate for marketing promotion
   - Assess available market information (price, quality, volume, seasonal)
   - Determine other marketing needs of the group
3. Establish market information system
   - Develop system by which information is collected and disseminated
   - Delegate collection and dissemination duties
   - Keep simple records
4. Develop framework for sustaining the system
   - Determine the support needed to continue the system
   - Locate sources of support needed
   - Seek support from programs or activities of local organizations
5. Keep the program focused on local needs
   - Include community input on a continual basis
   - Ensure that the system will suit the changing needs of the producers
   - Allow for the expansion of the system

It is important to identify existing markets for local products by interviewing key informants in local markets (at farm gate or roadside) within a village or locality where friends or casual acquaintances are sellers and buyers; regional markets (nearby towns or city markets) in which local products are sold; and nearby weekly markets (identify days of these markets). Major traders or large scale industrial buyers in the region can also be key sources of information.

Individual farmers may wish to join a local farmer's association to collect marketing information. This increases their access to information and helps ensure that collection and dissemination processes are sustained. It is crucial that any existing (formal or informal) market information system be identified and used. Informal sources of market information, such other farmers returning from selling their products, are also valuable. Presence of a central location for information dissemination and close proximity to potential markets are also important.

One should assess the type and frequency of information needed and the timing needed for market information. Longer term production decisions will need historical market data (monthly, and/or yearly), predictive information, and less frequent reporting. For certain perishable products, daily (or hourly) fluctuations may determine the need for more frequent information. One can determine if daily, weekly, or fortnightly price information is necessary.

Appropriate channels of communication for local producers to learn about markets may include relevant producer associations. In Pakistan, a tree farmer association helps individual forest farmers market their products.

It is important to identify a mechanism by which a system can be sustained without outside support. Location of other sources of market information may help save local resources and make the system more sustainable. The potential for involvement and support by participating groups such as farmer associations or cooperatives should also be considered. It is also important to incorporate the needs of local farmers within an existing market information system. Such linkages will save valuable resources and help farmers easily expand the area and products not otherwise included.

Clear, simple records of all market information collected need to be kept. This information will be useful when planning future marketing or production activities. Local users' ability to comprehend presented information will be an important indicator for determining appropriate dissemination techniques. It is important to select appropriate techniques to transmit information to the target users. This will include determining the appropriate media, such as blackboards posted at major intersections as was used in the Philippines (Hammett 1994). Consideration must also be given to location of dissemination points so that the maximum number of users have access to the information.

It is helpful to determine the effects of any system on producers' marketing activities. The system should be evaluated in such a manner that increased production and markets can be analyzed and understood by the farmers. Results of such an evaluation would also be useful to extension workers and program planners.

Observations

Developing a locally appropriate system to collect and disseminate market information can be implemented after modest commitment of resources and is suitable for many farm forestry products. Collaboration by farmers as a group and with input from other organizations is important—it saves small producers' time and valuable resources.

Marketing needs to be flexible enough so that it can be adapted to changing needs of the market place. The testing of farm forestry products before they are produced or marketed is usually not possible. However, through increased knowledge of markets, important indications of product marketability can be gained before valuable resources are committed.

Training in marketing and planning is critical, but often missing from many programs. Exchange of new product ideas and information about markets among farmers will give indications of skills and knowledge needed.

Organizing and implementing a market information system is not complex and is feasible—even for small, local producers. In the Philippines, local farmers now train other farmers how to improve marketing and how to collect and use market information. An increased focus on marketing will make a difference, especially for small forest farmers needing increased incomes and better planning.

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A list of related marketing references is available from FACT-Net.

Section 2.

AIS Technologies and Species Factsheets

Agroforestry for the Pacific Technologies

A publication of the Agroforestry Information Service

Number 1 **December 1992**

Why Agroforestry ?

Agroforestry land-use technologies are nothing new in the Pacific Island region, or the world for that matter. In a loose sense, agroforestry began when Man first turned from a hunting and gathering lifestyle and took up plant culture. Though maybe not purposefully integrated, trees and farm crops have always occurred together in systems where subsistence was the primary farming objective.

Social trends and economic development forces of more recent times have placed a huge amount of importance on short-term product and thus profit maximization. Cash, rather than subsistence crops have been the focus of more advanced societies. Economic rationale tells the farmer to maximize production of the crop that gets him/her the most money at the market. Agroforestry system were often replaced with crop mono-culture where trees were seen to interfere with crop yield

Today, many agree that the rapid agricultural conversion that went on during the "green revolution" was short-sighted indeed. Intensive mono-cropping systems, though perhaps more profitable for a time, are much more risky and costly in the long run. Risky because crop prices are always changing_and pest infestations can destroy entire harvests. Costly because these intensive farming practices degrade most soils rapidly; and thus require expensive chemical and fertilizer inputs to sustain productivity.

The scattered and isolated nature of Pacific Island countries is a mixed blessing. The region, has been, excluded from most global trade activities and international market pressures. Most countries have not been driven to costly mistakes in attempting to maximize short-term export income. Multi-cropping agroforestry systems remain intact over much of the landscape.

The region is not without its problems. Arable land has never been in abundant supply Growing population pressures and modern land ownership uncertainties make land scarcities increasingly apparent. The most common traditional agroforestry systems of the swidden variety, are no longer sustainable where a shortage of land forces farmers to reduce fallow periods. Root crops, staples in most cultures, require that the soil be disturbed twice in a single rotation. Shortened fallows do not allow soils to recover. They quickly lose their productive potential and become highly erodible.

Traditional agroforestry systems must be improved so as to increase subsistence and market produce from limited land areas over time. In more modern, more intensive agroforestry systems, trees are not just tolerated or passively allowed to regenerate during fallows. They are planted, arranged, managed, and harvested alongside agricultural crops and/or farm animals in a way that optimizes overall farm productivity in the short and long term. Trees are used to create a more favorable and sustainable environment for crop and/or animal production while providing additional products themselves.

Why are Agroforestry Systems more Productive?

They use limited resources more efficiently

- **SUN**: Multi-storied cropping systems absorb sunlight at all levels.
- **SOIL NUTRIENTS:** Deep tree roots take up soil nutrients and moisture that are out of reach of root crops.
- **WATER:** Trees shelter crops and soil surfaces from drying winds and intense sun. Tree-leaf mulch retains moisture in upper soil layers.
- **LAND:** Trees serve to continuously sustain rather than periodically rebuild soils. Fallow requirements are reduced, leaving more land in production at any one time.

They provide a more favorable environment for sustained cropping:

- **SHADE**: Filtered shade keeps topsoil cool, increasing beneficial soil microbe activity and reducing soil water loss.
- **WIND PROTECTION**: Trees protect the soil and crops from damaging, erosive, and drying winds.
- **SOIL ANCHORING:** Tree roots bind soil, preventing down-slope erosion during rains.

- **SOIL BUILDING/MAINTENANCE**: Tree leaf litter becomes organic humus that builds good soil structure. The stronger soil is more resistant to erosion and more able to absorb/hold water.
- **NUTRIENT CYCLING:** Trees draw nutrients from below crop root reach and then release them on the soil surface as leaves fall or branches are pruned.
- **HABITAT DIVERSITY:** Trees provide habitats for animals and birds that eat crop pests and insects.

PROMISING AGROFORESTRY SYSTEMS
for PACIFIC ISLANDS

They provide a more continuous flow of *more* products over time.

- **SHORT-TERM PRODUCTS:** Root and grain crops, tree nuts and fruits, fuelwood, posts, animal fodder, medicines, and livestock.
- **LONG-TERM PRODUCTS:** Valuable construction timber, larger fuelwood, and other wood products such as pulp and veneer.

Why is Agroforestry so Necessary in the Pacific?

- **TRADE WINDS:** Crops and soils need protection from wind damage, drying, and erosion.
- **ROOT-CROP CULTIVATION:** Methods expose and disturb soil twice in a rotation.
- **INTENSE RAINS:** On sloping terrain, frequent, intense rains wash soil away rapidly if it is disturbed and unprotected.
- **VOLCANIC SOILS**: Soils derived from volcanic rock and ash are commonly acidic and thus more subject to nutrient loss/leaching.
- **LAND SCARCITY**: Arable land is the most scarce and thus valuable natural resource.

Agroforestry is arguably a more sustainable and optimal way of farming in most resource-limited environments. This seems to be especially true in the Pacific, where growing and developing populations are confined to relatively small and scattered areas.

Successful agroforestry though, requires careful planning and usually more labor Trees and crops must be arranged and managed properly if overall productivity is to be increased and sustained. Left unmanaged, trees can out-compete crops, and reduce yields.

Pacific Island farmers appreciate the worth and function of trees in agricultural systems. They did not traditionally, however, manipulate and manage the tree component to the degree that most modern agroforestry practices require. They must be convinced that the products and benefits will justify their added time and labor inputs.

The active promotion of agroforestry in the Pacific, through information transfer, demonstration, and on-farm research, is without question a worthwhile and timely task.

Agroforestry for the Pacific Technologies

A publication of the Agroforestry Information Service

Number 2 December 1992

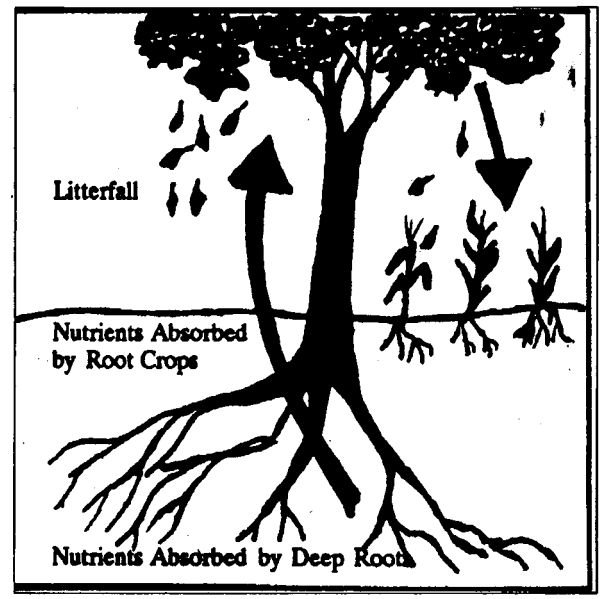
Hedgerow Intercropping With Upland Root Crops

Root-crops, primarily taro, sweet potato, and cassava, are important subsistence and market foods in most Pacific Island cultures. Traditional upland root-crop cultivation included lengthy soil restoring fallows between short croppings. After just 2 to 3 years of root-crop production, lands were typically left to rest for 10 to 15 years. Farmers have always recognized that the planting and harvesting of root crops disturbs soils more than does the farming of above-ground crops. Root crops must be dug in and dug out.

Unfortunately, modern population pressures and land-ownership uncertainties are creating situations of land scarcity that make long fallows infeasible for most. The soil degradation resulting from shortened fallows is affecting productivity and increasing dependencies on food imports such as rice and flour in many areas.

Hedgerow intercropping (HI), the practice of farming annual crops in the spaces or 'alleys' between rows of multipurpose trees is a promising alternative to the traditional fallow system. Trees planted and managed in hedgerows provide the same products and services as those that were allowed to grow during traditional fallow periods. Trees cycle nutrients from deeper in the soil profile by shedding organic matter on the surface as leafy and woody litter or 'green manure'. Litter rebuilds a soil's structure making it less erodible and more able to absorb and hold water. Hedgerows also yield other products such as fuelwood and fodder. They create a more favorable micro-climate for crops by shielding them from drying winds. Hedges planted on slopes, also anchor soil and form terraces, preventing the loss of precious topsoil by heavy rains and the overland flow of water.

Traditional systems combined trees with crops on the same piece of land in a time sequence. Hedgerow intercropping; combines trees with annual crops on the same piece of land at the same time. The tree and crop components are managed so as to be complimentary rather than competitive. The succesful HI system maximizes the product per unit of land over time. To accomplish this, competition between the crops in the alleys and the trees in the rows must be minimized. This requires the orderly spatial arrangement and rather intensive management of the tree component. It could be said that traditional systems require a large land input whereas HI systems require more labor input. Where land is more scarce than labor, this agroforestry practice makes good sense.



Hedgerow intercropping; does not necessarily eliminate the fallow requirement. Because the tree component of the HI system is kept on the land during crop production, one could say that it performs a "semi-fallow" function continuously. This means that cropping cycles can be lengthened and fallows shortened without degrading the soil and reducing system productivity over time.

The trees recommended for these systems are chosen for their multipurpose/multiproduct characteristics. They provide soil-improving services, are fast-growing, and produce a number of useful products.

In short, the primary benefit of HI over traditional systems, is a more continuous, more sustainable flow of both tree and food products from one piece of land through time.

I. TREE SPECIES SELECTION

HI trees provide desired products/services while competing as little as possible with neighboring crops. Characteristics of good HI trees are:

- ***Rapid growth and biomass production***: More leafy biomass and small branch production means more litter/mulch accumulation, more fodder, and/or more fuelwood.

- ***Smaller, bushy form:*** Smaller, multi-stemmed trees normally produce more biomass of a higher leaf: stem ratio than larger, single stemmed species.

- ***Deep-rooting***: Take-up nutrients and water out of reach of root-crops.

- ***Easy to establish:*** Trees are easy to raise from seed either directly field-planted or in pots. Cuttings develop more rapidly but produce only lateral roots that compete more with neighboring crops

- ***Repeated coppicing and/or re-sprouting ability:*** Stems and leaves grow back again and again after pruning or topping.

- ***Nitrogen Fixing:*** Nitrogen fixing trees are able to 'fix' atmospheric nitrogen and contribute this to the system in leaf litter fall/break-down.

- ***Free from pests and diseases:*** Trees should not be hosts to crop-damaging insect or fungus pests.

- ***Easily controlled:*** Trees that become weedy and will spread into alleys or neighboring fields are not desireable.

- ***Widely adaptable and stress tolerant***: Trees should be adapted to a range of soil characteristics and tolerant of environmental diversities such as high winds and periodic drought.

- **Multipurpose:** To provide an adequate return to land and labor inputs, trees must produce a number of useful products and services.

The multipurpose tree species so far identified as being very promising for Pacific Island use are: *Calliandra calothyrsus, Gliricidia sepium, Flemingia macrophylla,* and *Erythrina subumbrans. All* grow rapidly and produce. lots of soil enriching 'green manure', good fuelwood, and fodder. *Calliandra* and *Gliricidia* can both produce fuelwood diameter limbs within one year. *Flemingia* and *Erythrina* usually produce smaller diameter stems early-on, but more leaf litter than the other two. On very acid soils (<pH 5), *Calliandra* does the best. *Flemingia* litter takes longer to break down which can be an advantage in the tropics where some humus build-up is desired. All have done well on both basalt and coral derived upland island soils.

Less tried but also promising are, *Albizia saman Pithecellobium dulce, Paraserianthes falcataria, Cajanus cajan,* and some *Acacia, Leucaena,* and *Prosopis* spp.

Albizia, Acacia, and *Prosopis* spp. all have a tendency to become weedy on islands. *Leucaena* species are also considered weeds in most situations and are attacked by psyllid insects when pruned repeatedly as in HI systems. *Paraserianthes falcataria* and *Cajanus cajan* tend to die back after 3 or 4 years of repeated pruning. These species do not coppice very well in general. *Parasetianthes* is also very susceptible to wind damage.

HEDGEROW TREE SPECIES
FOR PACIFIC ISLAND UPLANDS

Calliandra calothyrsus	*Gliricidia sepium*
Flemingia macrophylla	*Erythrina subumbrans*
Albizia saman	*Leucaena leucocephala*
Pithecellobium dulce	*Leucaena diversifolia*
Cajanus cajan	*Paraserianthes falcataria*

Wise tree species selections cannot be made without considering planting site characteristics. Species all have unique sets of tolerances and preferences for certain soil types and climates. The following site factors must be examined so that, suitable tree species are selected:

- Mean annual precipitation.
- Mean annual temperature.
- Length and frequency of yearly droughts.
- Yearly/daily minimum and maximum temps.
- Incidence of frost.
- Topography: elevation, aspect, and %slope.
- Soil pH, texture, and depth.

II SPATIAL ARRANGEMENT

***Orientation*:** The ideal tree row would be oriented east to west, perpendicular to prevailing winds, and parallel to slope contour. This orientation provides maximum "alley' (crop) sun exposure and maximum erosion control. Obviously, this is not always possible. Tree rows should be oriented to provide the most benefit and the least competition given the particular environment. Where there is slope, it is always best to plant along contours.

'Alley' Width: The most important HI system design decision is alley width. Alley width will determine the ratio of tree products/services to crop product and the degree of competition between the root-crops and trees. If alleys are too narrow, root-crop yields will drop off dramatically as tree hedges grow If alleys are too wide, the soil improving role of trees is reduced and long fallows will still be required. Based on tried systems, a 5 to 6 meter width is recommended.

Within row spacing: The recommended hedge consist of two lines of trees 50 cm. apart. Trees within the lines should be at 30 to 50 cm. spacings. Close spacings encourage more leaf and smaller branch production. In general HI systems of 2-row hedges and wider alleys are more productive than those of 1-row hedges and narrower alleys. With 2-row alleys, there is less tree-crop interface (competition).

Root-crop spacing: Root-crops should be planted at traditional spacings. The space between crop plants and any one tree row should be at least 0.5 m.

EXAMPLE HEDGEROW ROOT-CROP INTERCROPPING LAYOUT

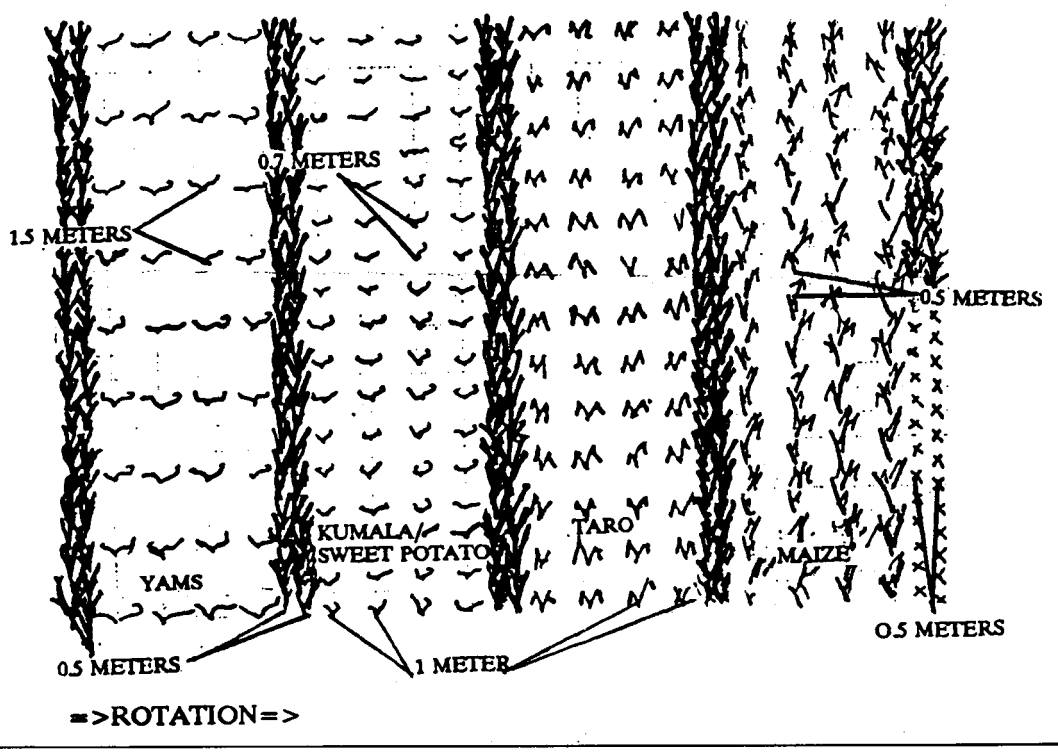
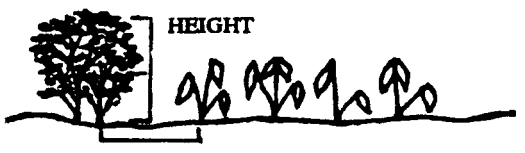


DIAGRAM ADAPTED FROM WORK OF NFTA ASSOCIATE CHARLES ROGERS, VANUATU

III. MANAGEMENT AND PRODUCT HARVESTS

Hedge Pruning: Periodic hedge pruning is necessary to prevent trees from shading-out your crop. The amount/frequency of pruning required will depend on the shade tolerance of a particular root crop at a particular stage in development. Most root-crops are very light demanding but will benefit from some shade during the first couple months of development. Shade also discourages weeds. A good rule is to maintain a hedge height equal to the distance between the hedge and nearest crop row (50cm to 1m).



Hedge Height Relative to
Distance Between Hedge and Crop Row

Pruning frequency will also depend on the product mix desired. More frequent pruning adds more 'green manure' to the soil. Less frequent pruning will produce more fuelwood-diameter branches.

The timing of prunings is more important in tropical environments where leaf decomposition and organic matter mineralization occur rapidly. Prunings should be timed so that applied litter is releasing nutrients when the root crops are most demanding - during rapid corm development.

Crop Rotations and Fallows: Continuous cropping may be possible in some very productive HI systems where organic matter and nutrients are continually returned to the soil in large enough quantities.

It is likely though, that some fallow between the normal 3 to 4 year cropping period will be required. Two years seems to be a reasonable period. After a 2-year fallow, during which hedges are left alone, a major fuelwood harvest can be expected. Crop yields are the best indicator of the fallow requirement. Once the hedgerows are in place, the farmer should experiment with different fallow lengths to find the combination that yields the most while maintaining the site's productivity. Different sites will require different management strategies. In any situation, continued, close observation of crop performance is essential.

PRODUCTS AND SERVICES PROVIDED BY TREE HEDGEROWS

- NUTRIENT CYCLING FROM DEEPER SOIL LAYERS
- GREEN MANURE AND MULCH BENEFIT COMPANION FOOD CROPS
- MULCH AND SHADE SUPPRESS WEEDS
- FAVORABLE CONDITIONS FOR BENEFICIAL SOIL ORGANISMS
- BARRIER TO CONTROL SOIL EROSION
- BARRIER TO DRYING WINDS
- PRUNINGS FOR ANIMAL FODDER
- PRUNINGS FOR FIREWOOD AND POLES
- SUPPLY BIOLOGICALLY FIXED NITROGEN TO SYSTEM

ACKNOWLEDGEMENT

The technical guidelines offered here are based largely on information collected by the AIS Information Officer during field visits and personal interviews with project personnel. The following research projects are especially noteworthy and continue to provide useful information on this subject for all those interested:

EC/Pacific Region Agricultural Program **Agroforestry Trials** at USP Alafua, Apia, Western Samoa. Stephen Rogers, IRETA Research Fellow.

Plantation Training **Center, Integrated Smallholder** ***Cropping/Livestock Trials,*** Montmartre, Port Vila, Vanuatu. Charles Rogers, Project Manager.

GTZ/Fiji-German Forestry Project, PO Box 14041, Suva, Fiji. Martin Homola, Chief Forestry Advisor, and Wieland Kunzel, Technical Advisor.

Agroforestry for the Pacific Technologies

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Managing Organic Matter : Composting and Mulching

Many farming activities interfere with-or even prevent the natural processes of nutrient and organic matter cycling. Some harvesting practices remove plant material or organic matter year after year while returning none to the soil. The inevitable result is a rapid decline in soil productivity. In some cases inorganic store-bought fertilizers are then added in larger and larger quantities to sustain crop yields. In other cases, farmers must allow a soil to fallow or 'rest' for several years between relatively brief cropping periods. Both of these methods of soil maintenance are very costly, especially where land and/or cash is in short supply.

Agroforestry strategies that integrate trees with crops provide a variety of products and services depending upon species included, management techniques, etc. They do share one common objective-sustaining the soil organic matter component.

The trees in all agroforestry systems, make continuous organic matter contributions to the soil. Scattered trees in fields, windbreaks, and live-fences all shed leaves and branches. Trees in hedgerow intercropping systems are usually chosen and managed purposefully to maximize their organic matter contribution. Leaf material is frequently pruned and applied to cropping soil as *green manure.*

Some grasses and annual 'cover-crops' are seeded and grown seasonally in fields to provide organic matter or 'green manure'. Various *Crotolaria* and *Sesbania* species are grown in this way and then plowed into soils between cropping periods.

Organic matter management-returning organic matter to a soil as it is removed-can do wonders to increase and sustain a soil's productivity. All of the properties of a highly productive soil are dependent upon the presence of organic matter:

- **Soil fertility:** Organic matter adds plant nutrients to the soil as it breaks down. It also provides sites for nutrients to bind to, holding them in upper soil layers where plants can use them.
- **Soil structure:** The slimes and microbial gums produced by decomposing organic matter bind soil particles. The result is a stronger, granular, more permeable and workable soil.
- **Soil water holding capacity:** A soil with good structure is more permeable and porous. Water infiltrates more easily and is held in small soil pores.
- **Soil pH**: Organic matter additions reduce the pH of excessively alkaline soils. The decomposition process releases hydrogen ions, increasing soil acidity.

Without regular organic matter addition, soils become drained of essential plant nutrients and unable to absorb or retain water. As their structure is weakened, soils are much more susceptible to the forces of wind and water erosion.

All trees, regardless of how they are arranged or managed, can be regularly harvested for organic matter. This plant material can then be applied to the soil surface around crops as mulch-or mixed with the soil in piles or pits to form compost.

Mulching

Mulching is the spreading of any material-green or dry on the soil surface.

What are the benefits of mulching?

- **Mulch controls weeds:** A good layer of mulch shades the soil and prevents weeds from germinating.
- **Mulch conserves soil moisture:** It creates a barrier against the drying effects of sun and wind.
- **Mulch fertilizes soil:** As mulch breaks down, it releases essential plant nutrients.
- **Mulch builds soil structure:** As mulch breaks down, it makes the surface soil permeable and increases its water holding capacity.
- **Mulch stops soil erosion:** It protects soil from the erosive forces of wind and water. It shields soil from heavy raindrops and slows runoff water that flows over the soil surface.

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What materials can you use for mulch?

- **Plant** materials: Leaves, small branches, coconut husks and stems, and wood chips all make good mulch. Whenever possible, cut or crush materials into small pieces. Smaller sized pieces produce a more effective mulch.
- **Animal residue** such as manure. Do not use fresh/wet manure as this can burn plant roots.

How do you apply mulch?

- **Before planting:** If you want to apply mulch before planting, spread the plant material about 4 cm thick over individual rows-or the entire area. Then just clear small areas for seed/seedlings and plant as usual. Do not cover newly sown seeds with mulch.
- **After planting:** If you want to mulch after planting just take care not to damage seedlings. If the plants or trees are already established, just pile mulch around the bases of trees in 1 m diameters.

Composting

Composting is the practice of mixing and piling plant and/or animal material with soil to form partially decayed, smaller particles of organic matter-or ***humus***. Composting practices favor the micro-organisms that ***work***-or break organic matter down into the proteins, starches and sugars of humus. Humus contains chemical and mineral substances in forms that plants can use immediately. Humus is also the form of organic matter that most directly adds to a soil's productive properties.

What are the benefits of composting?

Composting simply speeds the organic matter breakdown process that occurs over time in nature when the same materials pile up in layers on the soil surface as mulch. Composted organic matter can be placed in direct contact with plant roots as a soil amendment or bedding material. Compost improves soil properties just as mulch does-just more immediately and extensively. Compost is really just partially decomposed mulch. A soil that contains a lot of compost or organic matter is said to have a "spongy structure". Such soil resists compaction and erosion. It captures and holds water, oxygen, and essential plant nutrients.

What materials can you use for compost?

- **Plant materials:** Leaves from trees or grass, animal manures, twigs, sawdust, wood-ash, and kitchen scraps all make good compost ingredients.
- **Animal residues:** Dry or wet manure can be used for composting.

How do you make compost?

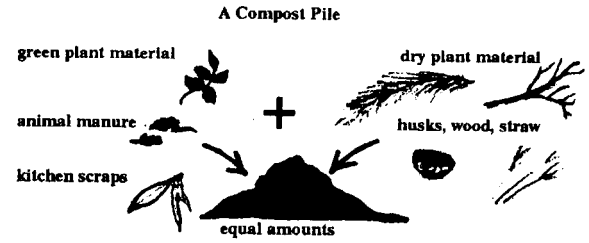
Quite simply, you make compost by throwing of organic matter-and some soil-into a big pile or pit.

Many consider composting an art and recommend special composting structures and various material layering

techniques. Most recommend gathering all needed materials at once to form a complete pile. These techniques demand lots of time and labor.

You may not have enough material on-hand to build a complete pile at once. You can also create a good compost pile over time, bit by bit. Making a good compost is not that tricky but there are some simple steps that will greatly speed the whole process:

- **Add an equal ratio of green to dry material:** Add dry stems, leaves and soil to your pile in equal measure with green plant material and manure.
- **Keep compost moist:** Build your compost pile in the shade and keep it covered with large leaves, coconut fronds, or a mat. If it rains often enough you should not have to add any water. It is best to check the pile every few days to make sure it stays moist. It should not be too wet-just moist.
- **Keep compost aired-provideoxygen:** urn/mix your pile once a week. The microbes that work the compost need oxygen.



All of the above will speed the process of organic matter decomposition by favoring the activity of the microorganisms responsible. A compost made and maintained like this will be ready for use about 6 weeks after the last ingredients are added.

How do you use the compost?

You can use the finished compost as a potting mix, a bedding mix, or a soil amendment. If your soil is really poor, you may want to raise demanding food crops such as vegetables, in beds or pots of only compost. This is a common practice on atolls where soil is often completely lacking in organic matter. You can also add compost to existing soil or dig it into the soil surrounding a plant.

You can also just dig holes next to fruit trees and periodically throw organic matter into them. This works where soils are well drained. If too wet, these pits may lack the oxygen required by the composting microbes.

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Nitrogen Fixing Trees as A Toll Soil Builders

Atoll soils form from coral reefs that grew on the tops of subsiding volcanoes during various periods--throughout the Pacific. Most of these soils are quite young in geologic terms and thus still similar in property to this coral parent material. Coralline soils are extremely nutrient deficient and highly alkaline. They are especially lacking in iron, potassium, and nitrogen. The so-called "soil" of atolls is really not soil at all since it is not made up of the usual components of soil: mineral sand, silt, and clay. Organic matter is all that really does distinguish most atoll soil from crushed coral.

Atoll farmers have always practiced mulching and composting to some degree. Most consider regular organic additions integral to any agricultural activity. Organic matter management--more on atolls than anywhere-is crucial to sustained food production. Organic matter holds nutrient ions, retains precious soil moisture, and buffers soil pH. In all soils, it builds and maintains good soil structure and provides essential plant nutrients. In atoll soil, it must also take the place of the missing clay component in providing nutrient cation exchange sites that are crucial to nutrient cycling processes.

Atoll farmers and gardeners typically make compost by piling-up rotting coconut shells/stems, household rubbish, and any green material they can find. Most simply pile this material next to a target crop or tree as a mulch. The mulch then breaks down into compost over time. Many actually make compost first-and then purposefully place it into garden trenches, holes, and taro pits as bedding material.

Although composting has always been part of the farming/gardening routine on atolls, one key ingredient is in very scarce supply-Fresh/green organic matter. As a result, mulch and compost are often spread too thinly to yield significant benefits. Compost formation is slowed drastically in piles with too high a dry: green (carbon:nitrogen) ratio of organic material.

Nitrogen-fixing trees are gaining recognition as promising atoll agroforest/garden additions and renewable sources of soil-building organic matter. Anyone who knows a bit about the unique characteristics of these trees should not find this surprising.

Why Nitrogen Fixing Trees?

Nitrogen-fixing trees are able to "fix" or take-up atmospheric nitrogen (N2) that is not available to other trees. They do this through a symbiotic relationship with certain bacteria (*Rhizobium* and *Frankia*) that form nodules in their roots. When the leaves and branches of these trees drop off, or are harvested, this nitrogen becomes available to other plants or animals in the ecosystem.

Most nitrogen fixing trees are "pioneers"-They establish easily on poor or degraded sites. These tenacious trees also grow rapidly, and produce large amounts of nitrogen-rich green foliage in some rather harsh environments.

Good mulch/compost producing nitrogen fixing trees for atolls also have the following characteristics:

- **A high leaf nitrogen concentration**
- **A tolerance to excessive soil alkalinity**
- **A tolerance to excessive soil salinity**
- **A relatively high leaf tannin content:** Many nitrogen fixing trees---such as Acacia spp.--contain tannins that slow the decomposition process. This is desireable in very humid, warm environments where the rapid break-down of organic matter prevents the build-up of a protective mulch or humus layer.
- **Repeated and vigorous resprouting/regrowth after pruning**: Many nitrogen fixing trees can be pruned or lopped as often as four times a year.
- **Multi-purpose/multi-product**: In addition to compost/fertilizer, many nitrogen fixing trees produce human-food, firewood/charcoal, pig or goat fodder, and timber or poles for construction.

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Establishing and Integrating Nitrogen Fixing Trees
Because land-area is so scarce on atolls, it is especially important that selected trees be easily integrated into existing systems. Depending on local needs and preferences, a variety of tree planting and maintenance schemes are possible:

Living fences and hedges protect crops from roaming **animals and human foot-traffic.** Trees are arranged densely or planted as fence posts.

Windbreaks are single or multiple rows of trees planted on windward field boundaries. Windbreaks slow wind, reducing physical damage to crop's and fruit trees. Placed on the windward side of atolls, they can also prevent salt-spray from reaching the interior and reduce coastal erosion.

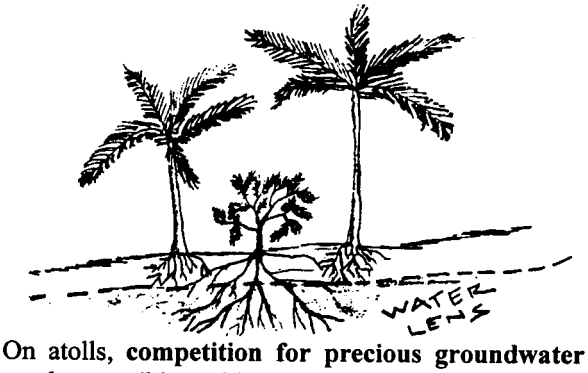
Hedgerows are dense single or multi-row plantings of trees within fields or among fruit tree plantations. Trees are arranged to minimize competition with the associated crop and pruned regularly to add compost or 'green manure' to the farming or garden system.

Shade and support are attained quickly from fastgrowing nitrogen fixing trees. Shade provides protection from the hot, drying sun. Living, soilenriching support is quickly established for vine crops such as beans, potatoes, yams, and pepper.

Home garden plantings of nitrogen fixing trees provide soil organic matter/fertility while yielding edible fruits, leaves and flowers.

If a nitrogen fixing tree is being introduced to a site for the first time, seed or soil inoculation may be required. Seed inoculation is the process of coating seeds with the nitrogen fixing bacteria prior to planting. The inoculant is just a material that contains the bacteria. Inoculation is required when the proper bacteria is not already living in the soil where the tree will be planted. Most nitrogen fixing bacteria tolerate adverse environmental conditions such as soil alkalinity, to the same degree as the host tree. Inoculant for various nitrogen fixing tree species can be obtained from the *NifTAL* Center, 1000 Holomua *Road, Paia, HI USA 96779.*

Problems/Limitations with Nitrogen Fixing Trees
Weediness is a potential problem with nitrogen fixing trees, especially on small atolls with few native species. These trees, because of their nitrogen fixing capability, establish easily, grow rapidly, and tend produce large quantities of seed. Genetic improvement research has produced several varieties of many species such as *Leucaena leucocephala.* These improved varieties have less tendency to become weedy and are more compatible with crops. They are thus safer for introduction. All species introductions should be made with considerable caution.

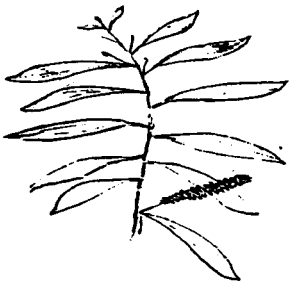


On atolls, **competition for precious groundwater** is another possible problem where nitrogen fixing trees are planted into fields or fruit-tree plantations. Proper spacings and management techniques-such as periodic pruning-should reduce this problem.

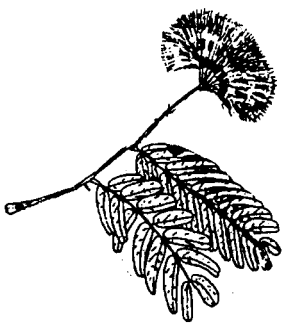
Promising Nitrogen Fixing Trees for Atolls

The following nitrogen fixing trees are those that are proving themselves in harsh atoll conditions as good, renewable sources of nitrogen-rich mulch/compost material. All of these trees are tolerant to high soil pH. Those that are especially tolerant to soil salinity are noted for this. Each brief profile includes a list of outstanding characteristics and primary uses. All are easily propagated by seed and recommended seed-treatments are listed.

Acacia auriculiformis



- Low to medium sized tree 8 to 20 m in height
- Thornless, heavily branched, short, crooked stem
- Open, spreading crown
- Tolerates droughts of 4 to 6 months
- Tolerates poor drainage/waterlogging
- Used for fuelwood, construction
- Boil seed for 30 seconds-let soak overnight or scarify



Albizia lebbeck

- Moderate to large deciduous tree
- Reaches 30 m in height with enough rain
- Straight bole when grown in dense forests
- Spreading and low branching in the open
- Produces an abundance of seed, unless coppiced frequently
- Tolerates droughts up to 8 months
- Highly tolerant of salt-spray
- Shallow roots-subject to wind-throw
- Leaves and young twigs make good livestock fodder
- Wood good for construction and fuel
- Soak seed in cool water 24 hrs or scarify

Calliandra calothyrsus

- Multi-stemmed shrub to 6 m
- Tolerates droughts to 6 months
- Used for fuelwood, fodder (fresh), honey
- Does not tolerate waterlogging
- No treatment necessary
- Soak seed in cool water 24 hrs or scarify

Source: Little, 1982

Casuarina equisetifolia

- Tall tree to 30 m
- Conifer-like appearance
- Thrives in sea-spray zones
- Tolerates droughts to 8 months
- Not tolerant to brush fires
- Relatively short-lived-40-50 years
- Used for fuelwood, charcoal, windbreaks
- No seed treatment necessary

Gliricidia sepium

- Small, branching tree to 10 m
- Tolerates droughts to 8 months
- Tolerates saline soils
- Coppices and re-sprouts vigorously
- Used for fodder, nurse tree, live-fencing, windbreaks
- Leafless sticks root easily
- No seed treatment necessary

Source: Little and Wadsworth, 1964

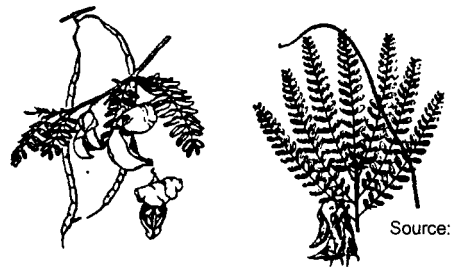
Pithecellobium dulce

- Medium, thorny tree to 15 m
- Broad-spreading with irregular branches
- Coppices vigorously
- Shallow roots--subject to wind-throw
- Used for fuelwood, honey, fodder, edible po
- Highly tolerant of soil salinity
- Tolerant to drought
- No seed treatment necessary--or scarify

Source: Little and Wadsworth, 1964

Sesbania grandiflora

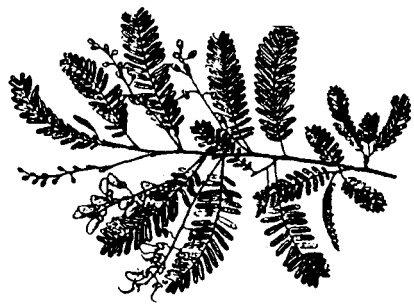
- Medium tree to 12 m
- Tolerates droughts to 7 months
- Highly tolerant of soil salinity
- Tolerates poor drainage/waterlogging
- Susceptible to wind damage
- Used for fodder, edible flowers
- Scarify or soak seed in cool water 24 hrs



Source: Verdcourt

Sesbania sesban

- Small, shrubby tree to 6 in
- Tolerates droughts to 8 months
- Tolerates periodic flooding and waterlogging
- Regenerates rapidly after pruning
- Used for fodder, firewood, edible flowers/leaves, windbrea
- Scarify or soak seed in cool water 24 hrs



Source: A. Cronquist, 1954

Illustrations

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Windbreaks for Pacific Islands

Windbreaks are single or multiple rows of trees planted to protect an area from prevailing winds. Windbreaks are planted along the windward boundaries of fields to provide a more favorable environment for crop growth. Windbreaks are also established to protect and improve the environments around homes, gardens, and villages.

Windbreaks are especially important on Pacific Islands where stiff trade winds blow throughout the year and tropical storms occur frequently. Salty maritime winds affect the most interior areas of exposed smaller islands.

Why slow the wind?

Wind can be very destructive, especially when combined with high temperatures, drought conditions, or salty sea air.

- **Wind damages crops:** Strong winds break stems, strip leaves, and tear fruit from crop plants.
- **Wind sucks moisture from plants:** When wind blows against crop plants, it dries the air immediately surrounding them. When this ***boundary*** air is dry, more moisture is pulled from the plant through ***transpiration***. This is why plants wilt in high winds.
- **Wind sucks moisture from the soil**: Wind dries the soil surface, pulling moisture from soil pores.
- **Wind removes fertile top-soil:** Even moderate winds can remove tons of topsoil annually from fields that are exposed during cultivation and harvesting. The topsoil is the most organic and fertile soil layer.
- **Wind carries salt:** Along coastal zones and on small islands wind can deposit tons of salt per hectare annually. In soil, salt draws moisture away from plants. Deposited on some plants, salt burns leaves and kills plant tissue.
- **Wind affects the health/performance of livestock:** Animals exposed to cold or hot winds can become stressed and much less productive.
- **Wind affects human environments:** Strong winds can disrupt or damage human households. Wind-borne dust may be a human health hazard.

Because they slow the wind, windbreaks conserve plant and soil moisture, prevent crop damage, prevent soil erosion, and reduce salt-spray. They also enhance animal welfare/performance and create a more habitable environment for humans.

Windbreaks made up of well-chosen multi-purpose tree species may also provide a variety of household and marketable products including fodder, fuelwood, timber, poles, fruit, mulch/compost, spices and medicine.

Windbreak Design

There are a few important windbreak design considerations:

Orientation: Correct windbreak orientation is crucial. You should obviously plant your windbreak on the windward side of the land-area or field you want to protect. You must also plant your windbreak in lines that are perpendicular to the prevailing wind direction. This may not be so obvious. If the wind direction changes from season to season you need to decide when it is most important to provide protection. This might be when the crop is most susceptible to wind damage, when the soil is exposed, or during the most windy season. In most Pacific locations, trade winds blow from a fairly constant direction so orientation should not be difficult or risky.

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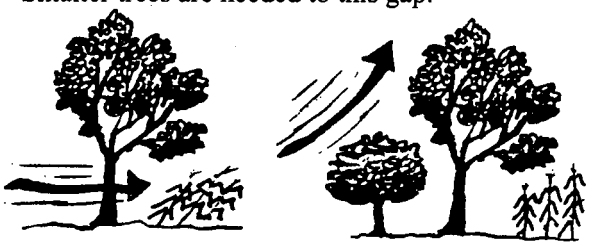
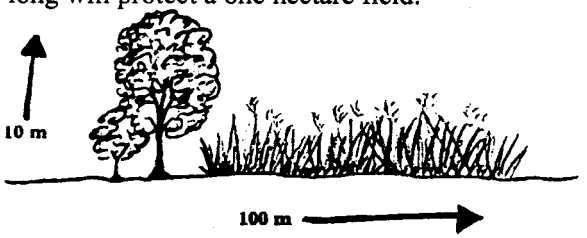
- **Multiple versus single row:** To be most effective, your windbreak should include at least two rows of trees. This is because you want a wind barrier from the ground, up. Tall trees will protect a larger area of field, but they have high canopies and will thus leave an understory gap. Smaller trees are needed to this gap.



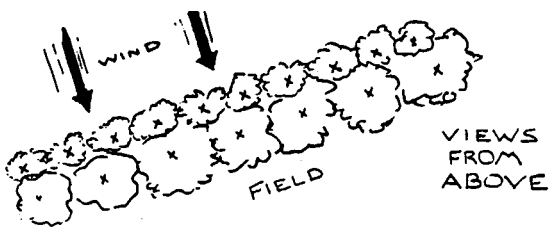
Understory gap Effective windbreak/barrier

If you cannot sacrifice the land-area that a multirow windbreak requires, plant a single-row windbreak. A single row of trees can form a reasonable windbreak-and it is certainly better than nothing.

- **Windbreak height and between windbreak spacing:** For every 1 m of height, your windbreak will protect 10 m of field area. A windbreak that is 10 m high will protect a field area 100 m downwind-so a windbreak 10 m high and 100 m long will protect a one hectare field.



- **Individual tree spacing and placement:** Plant trees closely enough within rows so that tree mature tree crowns will overlap. The best spacing for medium sized trees is 3 to 4 m. Plant smaller trees at 2 to 3 m spacings and larger trees at no more than 6 m spacings.



Individual tree/tree-row spacing and placement

You can use the same range for between-row spacing. Again consider tree canopy size. Do not space the rows so closely that the larger row will shade-out the smaller row.

Always plant trees in each row so that they are in-line with gaps between trees of parallel rows. This staggering produces more effective windbreak sooner.

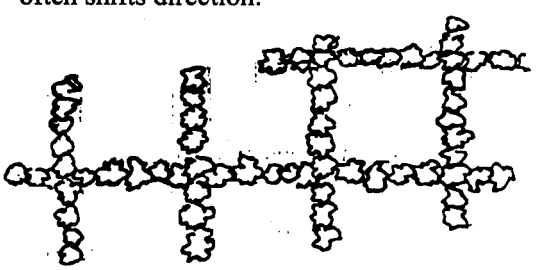
- **Species selection:** You can plant your windbreaks with a variety of species. Obviously, trees used for windbreaks should be wind-strong, and deeply rooted. The best species for windbreaks also have branching habits and relatively narrow crowns.

Choose species that are well adapted to your particular site and suited to your needs. If you need more fodder for your animals or fuelwood for your home, choose species tolerate strong winds while also yielding fodder and fuelwood. For consistency in height and ease of management, you should include only one species in each single row.

If you are able to plant a double-or multi-row windbreak, choose smaller trees for the most windward row and medium to larger trees for the next row.

The area protected will be larger if the windbreak is partially permeable rather than too dense. This is because too-dense a barrier can result in more turbulent air movement downwind. Some species make ideal windbreaks because their foliage filters rather than blocks the wind. The conifer-like foliage of *Casuarina* is one example.

- **Grid design:** This rather new windbreak technology is gaining popularity. Single-row windbreaks are laid out in a grid pattern on a field creating several smaller cells or squares. This technique is especially effective where the wind often shifts direction.



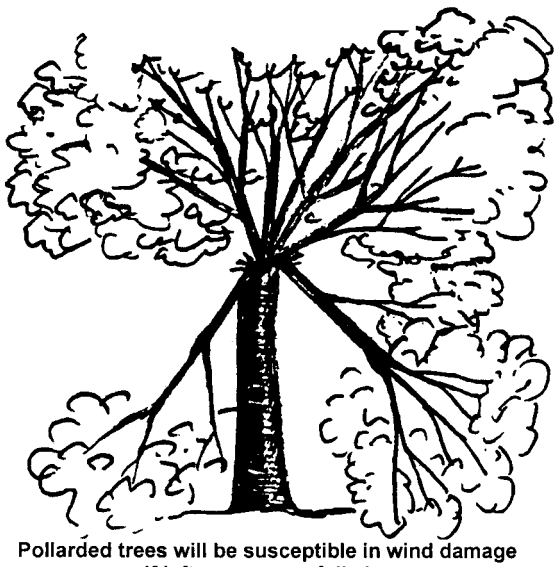
Windbreak grid-pattern layout

Windbreak Management

You will not necessarily have to manage your windbreak once it is established. Depending on the species you include however, you can prune, pollard, or otherwise treat trees in various rows to provide alternative products or maintain a more desirable height relative to other rows.

The management or harvesting practices you choose for each row will obviously influence the height and form of that row relative to the others. You should plan accordingly. For example, you can use shorter rows for things like fodder or fuelwood production because you will be pruning or pollarding them regularly. You can leave the taller rows alone to grow to their maximum height. You can also use the taller trees in ways that do not reduce their height-for fruit, nut production.

Management treatments can affect a tree's resistance to strong winds. Shoots that grow up from a pollarded stem, will be very susceptible breakage at the stem joint once they reach a certain size. If you pollard the most windward row of your windbreak for several years and then leave it alone to grow in height, sprouting branches will probably break in strong winds.

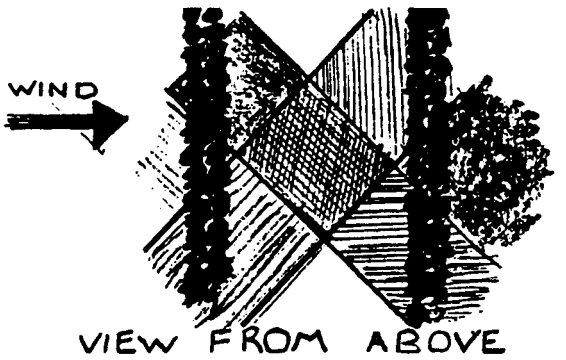


Pollarded trees will be susceptible in wind damage if left to return to full size

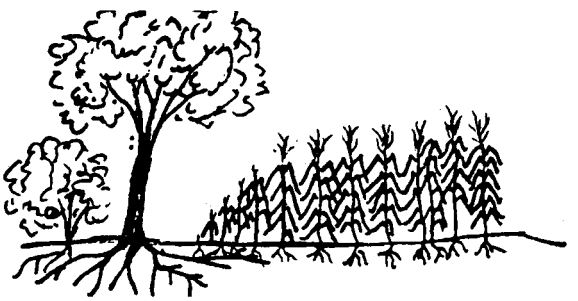
You can even harvest complete rows in you windbreak on a rotational basis if the trees are good timber producers. In this case, you would plant a new row to be functional at the time the mature row is harvested.

Problems/Limitations and Alternatives

Field boundary conflicts: It is unlikely that the ideal orientation for your windbreak will conform perfectly to your field boundary. If the boundary is nearly perpendicular to the prevailing wind, you can simply plant a windbreak as a form of boundary planting. If it is not, a boundary planting will not protect your crop from the wind. It may in fact, speed wind in your field because the wind may be forced along-rather than against it. The most effective windbreaks are those that stretch across boundaries and are the cooperative efforts of a number of farmers.



Loss of land: Windbreaks of two or more tree rows will take a substantial portion of your land out of crop production. Most successful windbreaks though, boost crop yields enough to compensate for this loss of area. Once your windbreak is in place, you may even be able to grow a more marketable or valuable crop/variety.

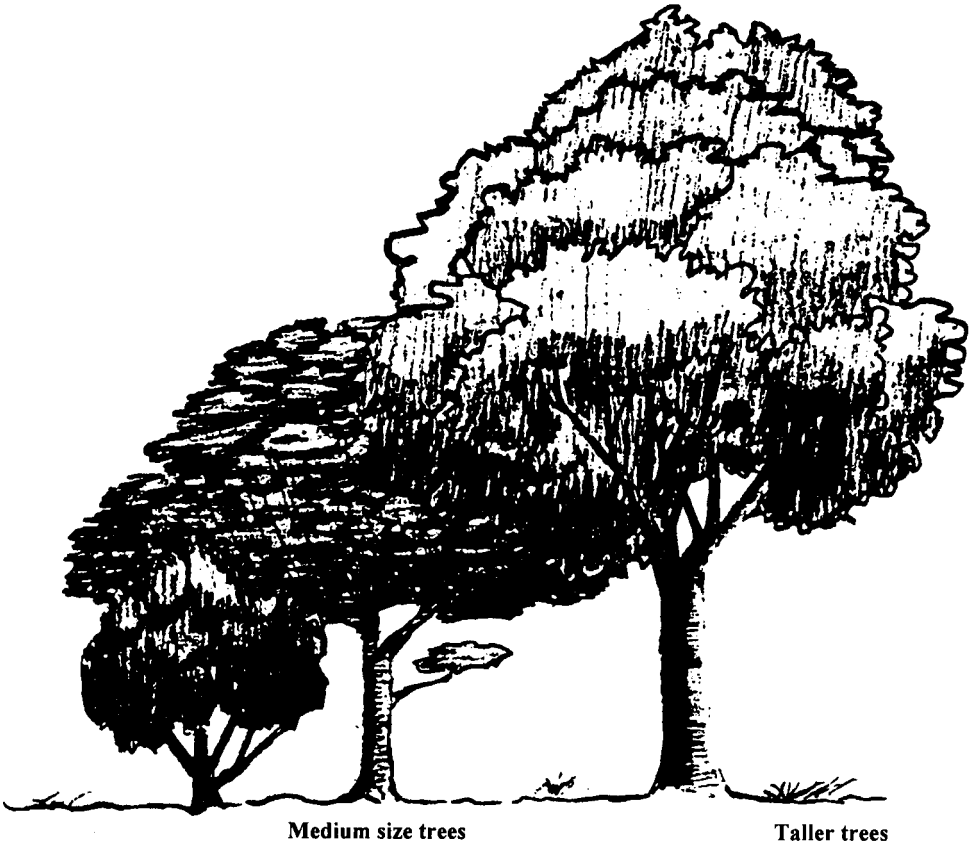


Competition with crops: Windbreaks may reduce the yield of crop plants in the area immediately next to them. This is due to competition for sunlight or water. Again, the increase in yield resulting in field interiors should compensate for this.

Pest problems: Some trees make nice homes for birds that will eat some crops-especially grains.

The following are species which have proven themselves as effective windbreak components. They are grouped by typical size at maturity. For each, common additional uses are noted.

The species in **bold** are especially tolerant to salt spray.
Species with asterisk * are more shallow rooted and may blow over in typhoons.



Smaller trees

- *Sesbania sesban*-green manure, animal fodder
- ***Sophora tomentosa***-fuelwood, nitrogen-fixing
- ***Tournefortia argentea***-fuelwood, shade

Medium size trees

- *Acacia auriculiformis**-fuelwood, shade
- *Acacia confusa*-shade, firewood, nitrogen-fixing
- *Acacia mangium*-fuelwood, nitrogen-fixing
- *Albizia lebbeck**-timber, nitrogen-fixing
- *Azadirachta indica* (neem)- fuelwood, timber, insecticide
- *Cassia fistula*: fuelwood
- ***Casuarina equisetifolia***-fuelwood, poles, nitrogen-fixing
- ***Erythrina poeppigiana***-green manure, shade, nitrogen fixing
- *Erythrina variegata*-green manure, nitrogen-fixing
- *Gliricidia sepium*-green manure, animal fodder, fuelwood, nitrogen fixing
- *Intsia bijuga*-sturdy construction timber
- ***Melia azedarachta***-fuelwood, timber, tools, shade
- *Pinus caribaea*-timber, shade
- *Pithecellobium dulce*-fuelwood, animal fodder

Taller trees

- ***Calophyllum inophyllum***-boat-timber, lamp-oil, shade, medicine
- *Cassia siamea*-fuelwood, small timber, animal fodder (toxic to pigs), edible leaves & flowers
- *Cordia alliodora*-timber
- ***Cordia subcordata***-timber, edible seed
- *Tamarindus indica* (tamarind)- edible pods, charcoal, animal fodder, nitrogen-fixing