NFT Highlights

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Casuarina cunninghamiana : The River She-Oak

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

Native distribution of river she-oak.

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

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

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

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

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

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

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

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

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

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

Written by Miles Merwin, International Tree Crops Institute USA, P.O. Box 4460, Davis, CA 95617 USA. Thanks to Dr. Lex Thomson, Australian Tree Seed Centre, Canberra, for his review of the manuscript.

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

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

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

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

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

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

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

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

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

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

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NFT Highlights

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

Casuarina equisetifolia : An Old Timer With A New Future

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

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

Botany

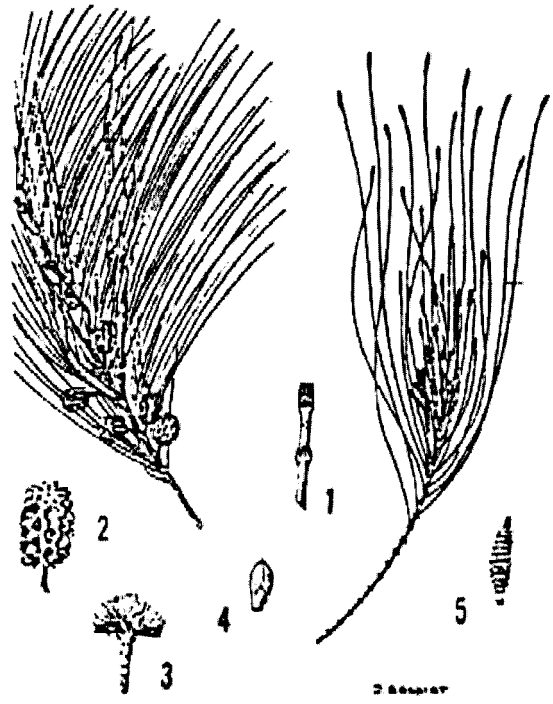
Like other Casuarinaceae, *C. equisetifolia* as a conifer-like appearance which is increased by hanging green branchlets and cone-like fruits. Casuarinas are actually typical angiosperms with simplified and reduced unisexual flowers. They are dioecious or monoecious, the proportion of male, female and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

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

Ecology

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

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



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

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

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

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

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

Written by Dr. Y. Dommergues, ORSTOM / CTFT, 45bis Avenue de la Belle Gabrielle, 94736 Nogent-sur-Marne, Cedex, France.

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

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

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

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

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

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

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

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

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

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

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

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

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Casuarina glauca : A Hardy Tree With Many Attributes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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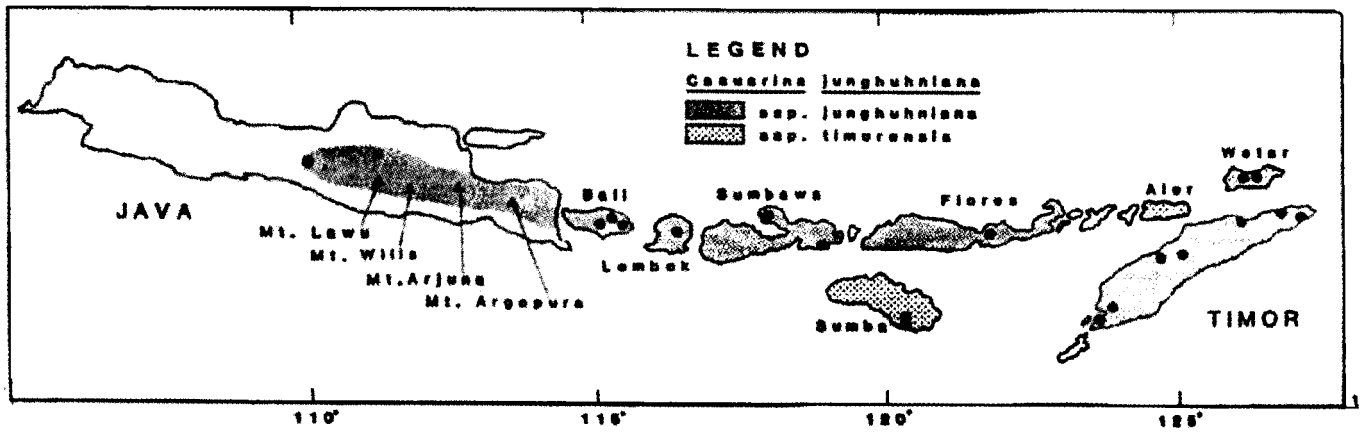
Casuarina junghuhniana : A Highly Adaptable Tropical Casuarina

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

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

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

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



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

Prepared by Khongsak Pinyopusarerk and Douglas J. Boland, CSIRO Division of Forestry and Forest Products, P.O. Box 4008, Queen Victoria Terrace, A.C.T. 2600, Australia

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

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

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

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

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

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

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

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NFT Highlights

NFTA 93-03

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

Chamaecytisus palmensis : Hardy, Productive Fodder Shrub

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

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

Botany

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

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

Ecology

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

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

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

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

Distribution

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

Uses: fodder

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

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

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

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

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

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

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

Silviculture

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

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

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

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

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

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

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

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

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

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

Limitations

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

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NFT Highlights

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

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Dalbergia latifolia : The High-Valued Indian Rosewood

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

Botany

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

Ecology

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

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

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

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

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

Leaves, flowers and pods of Dalbergia latifolia.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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NFT Highlights

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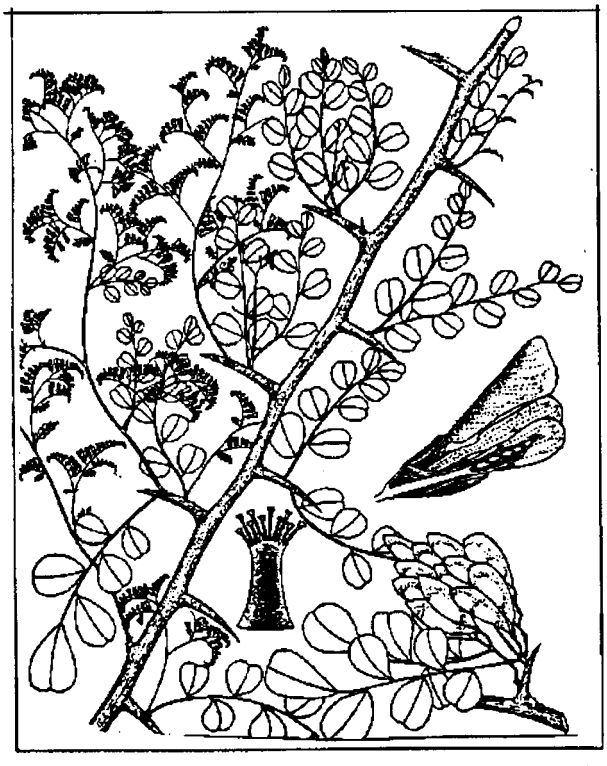
A quick guide to useful nitrogen fixing trees from around the world September 1993

Dalbergia melanoxylon : Valuable Wood From A Neglected Tree

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

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



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

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

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

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

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

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

This issue was prepared by Dr. Ladislaus Nshubemuki, Director of Forest Production Research, Tanzania Forestry Research Institute, P.O. Box 1854, Morogoro, Tanzania.

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

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

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

Silviculture

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

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

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

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

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

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

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

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

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

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NFT Highlights

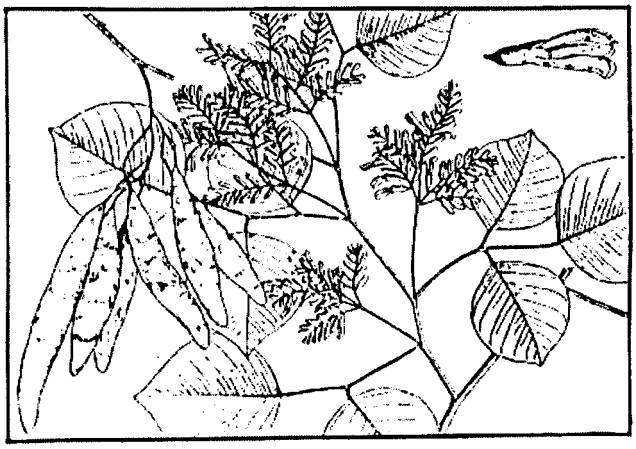
NFTA 89-07

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

Dalbergia sissoo : The Versatile Rosewood

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

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



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

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

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

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

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

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

Written by Dr. M.I. Sheikh, Director General Pakistan Forest Institute, Peshawar, Pakistan.

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

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

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

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

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

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

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

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

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

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NFT Highlights

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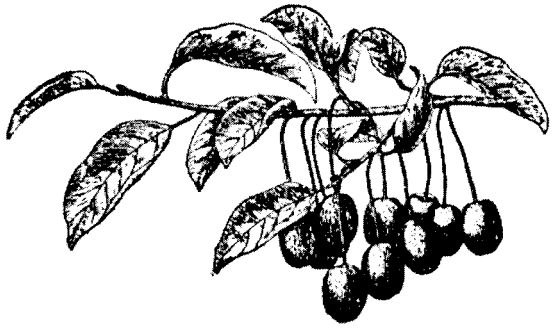
A quick guide to useful nitrogen fixing trees from around the world December 1992

Elaeagnus : A Widely Distributed Temperate Nitrogen Fixer

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



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

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

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

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

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

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

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

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

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

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

Written by Dr. Dwight Baker, School of Forestry and Enviromnental Studies, Yale University, New Haven, Connecticut 06511 USA.

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

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

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

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

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

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

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

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

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