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Nitrogen Fixing Trees Highlights (Winrock, 1990-1997, 100 p.)

- *(introduction...)*
- Acacia koa - Hawaii's most valued native tree
- Acacia leucophloea - shade and fodder for livestock in arid environments
- Alnus acuminata: valuable timber tree for tropical highlands
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- Pithecellobium dulce - sweet and thorny
- Pterocarpus indicus - the majestic n-fixing tree
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- Acacia nilotica - pioneer for dry lands

Sesbania grandiflora: NFT for beauty, food, fodder and soil improvement

Acacia aneura - a desert fodder tree

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Nitrogen Fixing Tree Associaton

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- **Pongamia pinnata : a nitrogen fixing tree for oilseed**
- **Guazuma ulmifolia: widely adapted tree for fodder and moreli**
- **Faidherbia albida - inverted phenology supports dryzone agroforestry**
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Pithecellobium dulce - sweet and thorny

Pithecellobium dulce

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, especiaIly 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. Pithecellobian. 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 26,00.0/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 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 yet 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 Hawai. 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 soapmaking or as food, and the residue can 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 spineless 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 blowdown. 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. Common names include "Manila Tamarind", "Madras thorn", "bread-and-cheese". "blackboard" (English), "guamuchil", "quamachil" (Spanish), "kamachile" (Phillipines), "macamtet" (Thailand), and "opiuma" (Hawaii).

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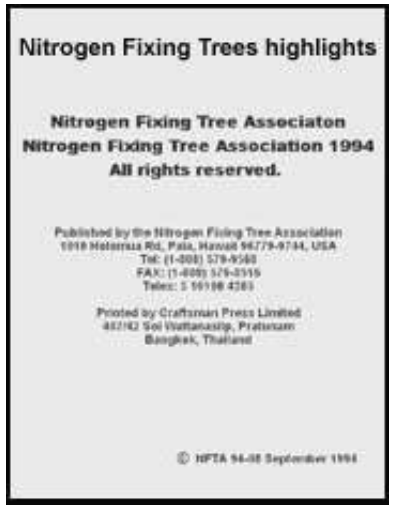

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Pterocarpus indicus - the majestic n-fixing tree

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 furhiture (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 axillary 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 discshaped, 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 19721973), four varieties are locally recognized, which occupy a range of habitats from the coast to submontane forests and seasonal swamps.

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 leafbearing 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 wellcrowned 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 guise 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 luxuiant 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 Pteroarpus.

Other well-known species are P. dalbergioides 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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A complete list of references is available from NFTA.

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Nitrogen Fixing Trees Highlights (Winrock, 1990-1997, 100 p.)

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 fixing ability make it ideal for colonizing degraded sites.

BOTANY.

Black locust is a medium-sized tree reaching 1535 m in height and 0.3-1.0 m in diameter. Long (2045 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 reddishbrown 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 1,0001,500 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 (Keresztesi 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. 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).

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 38yr-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 cultivars 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. Cultivars 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 Rhizabium 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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Nitrogen Fixing Trees Highlights (Winrock, 1990-1997, 100 p.)

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Acacia nilotica - pioneer for dry lands

Acacia nilotica (L.) Willd. ex Del. (Leguminosae, subfamily Mimosoideae) is one of about 135 thorny African Acacia species. Variation is considerable with nine subspecies presently recognized, three occurring in the Indian subcontinent and six throughout Africa (Brenan 1983.) They are distinguished by the shape and pubescense of pods and the habit of the tree.

BOTANY.

In habit A. nilotica varies from a shrubby tree with wide spreading crowns in savanna habitats (ssp. subalata, leiocarpa, adstringens, hemispherica and kraussiana), to a 20 meter tree (ssp. nilotica, tomentosa, and indica) in riverine situations. Ssp. cupressiformis has ascending branches like a poplar.

Acacia nilotica is easy to recognize by its bright yellow flowers in round heads, straight stipular spines often slightly deflexed, and dark indehiscent pods compressed over the seeds. Flowering is prolific, and can occur a number of times in a season. Often only about 0.1% of flowers set pods (Tybirk 1989.) The taxa form a polyploid complex: most are tetraploids (2n=4x=52); but higher numbers have been found in ssp. nilotica (2n = 8x= 104) & ssp. tomentosa (2n = 16x= 208) (Nongonierma 1976.)

ECOLOGY.

There are two very distinct ecological preferences in the African subspecies. Subspecies subalata. leiocarpa and adstringens occur in wooded grassland, savanna and dry scrub forests. Subspecies nilotica and tomentosa are restricted to riverine habitats and seasonally flooded areas. Subspecies kraussiana prefers dry grasslands and savannas, especially on compacted sandy loam, shallow granite or clay soils along drainages and rivers, but away from flooding.

On the subcontinent, ssp. indica forms low altitude dry forests usually on alluvium and black cotton soils. It has been widely planted on farms throughout the plains of the subcontinent. The species grows on saline, alkaline soils, and on those with calcareous pans. Subspecies hemispherica is restricted to dry sandy streams beds near Karchi, ssp. cupressiformis has similar preferences to ssp. indica though is less resilient to weed competition.

A. nilotica occurs from sea level to over 2000 m. It withstands extremes of temperature (-1 to 50 C), but is frost tender when young. Annual rainfall varies from 250 1500 mm. Trees are generally deciduous during the dry season, though riverine ssp. can be almost evergreen.

DISTRIBUTION.

The species is naturally widespread in the drier areas of Africa, from Senegal to Egypt and down to South Africa, and in Asia from Arabia eastwards to India, Burma and Sri Lanka. It has also been cultivated elsewhere, including Australia, Cape Verde islands, Indonesia, Iran, Iraq, Nepal, Vietnam' and the West Indies.

USES.

Wood.

Since the time of the Pharoahs, large timber trees have been exploited from the riverine forests of the Nile. At present the Sudan forests are managed on a 20-30 year rotation producing termite resistant timber especially suitable for railway sleepers. In India and Pakistan riverine plantations are managed on a 15-20 year rotation for fuelwood and timber.

The dark brown wood is strong, durable, nearly twice as hard as teak, very shock resistant, and is used for construction, mine props, tool handles and carts. It is best carved in a green state. It has a high calorific value of 4950 kcal/kg, making excellent fuelwood and quality charcoal. It burns slow with little smoke when dry.

Fodder.

The pods and leaves contain 8% digestible protein [12.4% crude protein], 7.2 MJ/kg energy, and are rich in minerals (Le Houerou 1980). In part of its range smallstock mainly consume it, but elsewhere it is also very popular with cattle. Pods are used as a supplement to poultry rations in India. Dried pods are particularly sought out by animals on rangeiands. In India branches are commonly lopped for fodder. Pods are best fed dry as a supplement, not as a green fodder.

Agroforestry.

Babul (ssp. indica) is a popular farm tree of the central plains of India. More recently interest has centred on the fastigiate form (ssp. cupressiformis). This

subspecies makes an ideal windbreak surrounding fields; its narrow crown shades less than other windbreak species.

Land Rehabilitation.

In India this species is used extensively on degraded saline/alkaline soils, growing on soils up to pH 9, with a soluble salt content below 3%. It also grows well when irrigated with tannery effluent, and colonises waste heaps from coal mines. Over 50,000 hectares of the Indian Chambal ravines have been rehabilitated with A. nilotica by aerial seeding (it is one of the 3 most frequently used trees for this purpose).

Tannins.

The bark of ssp. indica has high levels of tannin (12-20%) which are used for tanning leathers. Ten year old trees yield 35-40 kg of bark. The pods of ssp. nilotica have been used for tanning in Egypt for 6,000 years. Subspecies adstringens is used for both tanning and dye making. Deseeded pods from ssp. indica have 18-27% tannin levels, whereas ssp. tomentosa and nilotica reach up to 50%.

Other Uses.

The tannin also contributes to its medicinal use as a powerful astringent. It is also a powerful molluscicide and algicide. Fruits added to ponds in Sudan kill snail species which carry schistosomiasis without affecting the fish.

There are many other reported uses (Fagg & Greaves 1990). The tree makes

effective live fencing, a good host plant for growing sandalwood, and an important source shellac in the Sind. The gum is used in paints and medicines and has been collected for a millennia. It has similar properties to gum arabic (from A. senegal) and is frequently used in calico printing in India.

SILVICULTURE.

Propagation.

It is a pioneer species, easily regenerated from seed. The nutritious indehiscent pods have evolved for animal dispersal. A mature tree can produce 2,000-3,000 pods in a good fruiting season, each with 8-16 seeds, yielding 5,000 - 16,000 seed/kg depending on the subspecies.

Hard coated seeds can be extracted by pounding the pods or collected from animal pens after the pods have been eaten (Sheikh 1989). Pretreatment is needed. Mechanical scarification works best for small seed lots. Acid scarification from 60 - 120 minutes (depending on seed provenance or age), or pouring boiling water over the seeds and allowing them to cool are also effective.

Seed from natural populations of some subspecies are available from India and some Sahelian countries. A broader range of germplasm and Rhizobium inoculum is available from the Oxford Forestry Institute (Oxford OX1 3RB UK) for field triels.

Management.

The species can be direct seeded or established by seedlings. In the nursery long poly tubes (20 x 7 cm) should be used so as not to restrict rapid tap root growth.

Frequent root pruning is advised. Nursery grown seedlings are usually outplanted after 6 months, but in some cases stay in the nursery up to a year.

Establishment varies depending on the site. Seedlings are shade intolerant. In irrigated plantations in the Sind and Punjab, 10-15 seeds are spot sown at 2x3 m spacing on the tops of trenches. They are thinned to 3-4 seedlings after 34 months. Further thinning occurs at 5 year intervals. Rotations are 20-25 years. In the Thal desert, Pakistan (250 mm of rain), promising growth resulted from irrigation on a 10 day interval. Growth rates varied considerably depending on the sites, with maximum mean annual increment of 13 m^3/ha at 20 yrs old and 10.5 m^3/ha at 30 years recorded.

LIMITATIONS.

A wide range of pests and diseases affect this species. Of economic importance is the stem borer Cerostema scabrator on young plantations in India. Euproctis lunata & E. subnotata occasionally defoliate patches of forest in Sukkur and Hyderabad. Bruchid beetles attack the seeds, destroying up to 70 %. Buprestid beetles cause a dieback disease in Sudan. Fungal rots (Fomes papianus & F. badius) attack unhealthy trees, and powder post beetles (Sibixylon anale & Lyctus africanus) attack the sapwood of felled timber.

Acacia nilotica can become weedy when introduced out of its native range, particularly in more humid zones. Thorniness can be a problem when introduced to areas where people do not traditionally use thorn trees.

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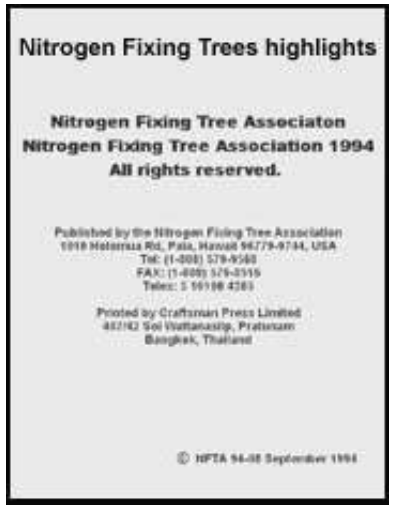

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Acacia saligna - for dryland fodder and soil stabilization

Acacia saligna is a small nitrogen fixing tree native to the southwest of Western Australia. It is commonly known as golden wreath, orange wattle, or blue-leafed wattle and was formerly known as A. cyanophylla. It is fast growing and tolerant of a wide range of soils, including calcareous and slightly saline types in temperate climates. Acacia saligna is planted in North Africa and the Middle East for fodder, fuelwood, sand stabilization, and as a wind break. In Australia it is most commonly used as an ornamental, but is being increasingly planted in agroforestry systems for fodder production and soil conservation.

BOTANY.

A. saligna (Labill.) H. Wendl. is a dense and multistemmed, thornless, spreading shrub or singlestemmed small tree up to 9 m in height. The bark is smooth and grey to red-brown on branchlets. Young plants become dark grey and fissured with age. Dark green to blue-green phyllodes with conspicuous midribs are long and narrow to lanceolate and 8-25 cm long. Flower heads are globular and contain 2555 (up to 78) bright yellow, five-parted flowers. The pods are narrow, 4-6 mm wide and usually 8-12 cm long. The seed is 5-6 mm long x 3-3.5 mm wide, dark brown to black and shiny (Maslin 1974); there are 14,000-25,000/kg. Acacia saligna is 2n=26 and outcrossing.

ECOLOGY.

In its native range A. saligna is confined to southwest Western Australia. It has become naturalized in parts of eastern Australia, from Victoria to southeast Queensland. In its natural habitat, A. saligna occurs where the mean annual

rainfall is 300 to 1,000 mm. In drier areas it normally receives additional run-on water.

Mean maximum temperature of the hottest month is 23 to 36°C and mean minimum of the coldest month is 4 to 9°C. Much of the area of natural distribution is frostfree but occasional light frosts occur in inland areas (Hall and Turnbull 1976). A. saligna is sensitive to frosts and damage is likely to be severe if the temperature falls below -4°C. The tree ranges from sea level to about 325 m elevation.

Trees are common on alkaline, infertile sandy soils. In many places A. saligna is more or less restricted to creeks and rivers and disturbed roadsides. It is moderately common along the south coast of Western Australia, but is best developed in the deep sands and loams along the water courses throughout the area. Further inland, in the wheatbelt, populations occur at the base of many of the large, granitic rock outcrops.

Acacia saligna

On coastal dune systems it often forms dense thickets in the hollows between sand hills (Maslin 1974).

USES.

Wood:

A. saligna wood is used as fuel and charcoal, and for vine stakes and small agricultural implements (Michaelides 1979). It has been successfully processed into particle board in Tunisia (El-Lakany in Turnbull 1987).

Forage:

The phyllodes, young shoots, pods and seeds, whether fresh or dry, are protein rich and non-toxic and palatable to both sheep and goats (Michaelides 1979). According to Woodward and Reed (1989), however, the phyllodes are not suitable for ruminants. This feed is especially valuable seasonally when other forage is scarce. The chemical composition shows the following ranges: dry matter (50-55%), crude protein (12-16%), crude fiber (2024%), crude fat (6-9%), and ash (1012%) (El-Lakany in Turnbull 1987). Analysis of phyllodes from trial plantings in southeast Queensland indicate a moderately low digestibility (36.5% predicted in vivo) but high levels of crude protein (18.3%) (Vercoe in Boland 1989). The low Ca/P ratio of 4.1 should enable efficient use of phosphorus supplements.

Windbreaks:

The tree is used extensively for coastal sand dune fixation in North Africa, the Middle East, and South Africa and for gully erosion control in Uruguay. In Australia it has been used in the rehabilitation of sand mining areas (Hall and Turnbull 1976).

Other Uses:

Trees were planted in the past for tannin production from the bark (Hall and Turnbull 1976). The damaged bark exudes copious amounts of gum that is very acidic. Such acid-stable gum has promise for use for pickles and other acidic foodstuffs (Michaelides 1979). A. saligna is also widely planted as an ornamental.

ESTABLISHMENT.

Prior to sowing, seed should be immersed in boiling water for 1 min to remove

seedcoat dormancy. Seed coats can also be scratched or nicked with a file or nail clipper. Seeds are available from NFTA. Treated seed should be planted to a depth of 0.5 cm. Seedlings can be produced either by direct seeding or in a nursery. A nursery phase of 10-12 weeks is recommended. Soil should not be allowed to dry between sowing and germination. Young plants require protection from grazing animals.

GROWTH.

In trials in southeast Queensland, A. saligna attained an average height of 6.2 m after only 41 months (Ryan and Bell in Boland 1989). The tree is tolerant of drought, light frost, alkalinity, and salt (Simmons 1981). Successful irrigation trials (6 liters/tree every 2nd day) have been undertaken at the Desert Development Center, The American University in Cairo. A. saligna coppices well and fodder biomass production is optimized by regular, annual harvesting (El-Lakany in Turnbull 1987). Trees grow poorly in tropical areas, except at high altitudes. In such areas the species A. ampliceps, a valuable alkaline soil fodder tree, may prove a more acceptable alternative.

SYMBIOSES.

The tree nodulates with certain strains of Rhizobium (Roughley in Turnbull 1987). In common with many other acacias, it forms associations with VA mycorrhizal fungi (Reddell and Warren in Turnbull 1987).

PESTS AND DISEASES:

Older plants are susceptible to gall rust, Uromycladium tepperianum, and various

gallexploiting insects. In parts of Western Australia more than 90 percent of A. saligna trees bear conspicuous woody galls (Van den Berg 1978). Trees are susceptible to white scale insects (Coccidae) which attack the leaves and stems. Rodents sometimes attack the roots. Termites may cause serious problems in tropical countries (Michaelides 1979).

WEEDINESS.

Caution is advised using A. saligna. The tree has become a major weed in South Africa by invading and displacing the indigenous vegetation (Roux and Middlemiss 1963). The species was introduced to South Africa in the first half of the nineteenth century. It has spread to waterways and irrigation channels. The seed has also spread in river sand transported for road and dam construction. Its hardiness and ability to coppice rapidly after fires or from trunks has also led to widespread establishment (Stirton 1980).

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Acacia senegal: gum tree with promise for agroforestry

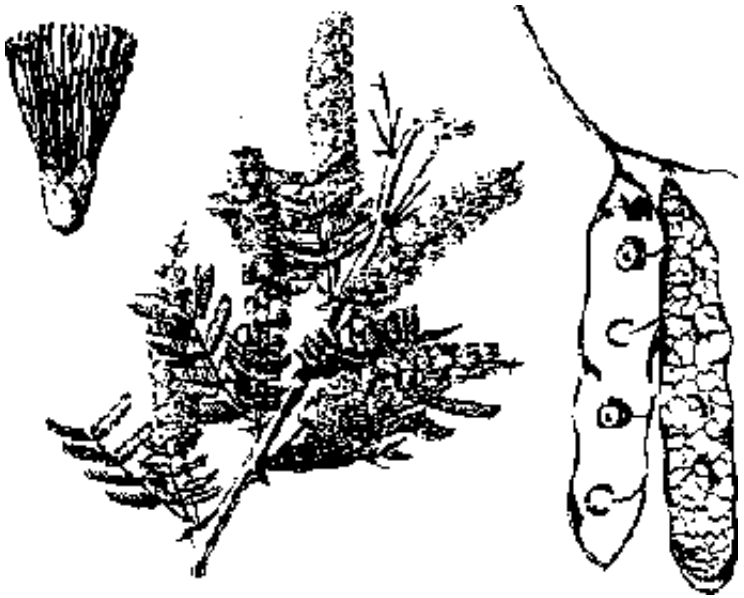
Acacia senegal is a multipurpose African tree (subfamily Mimosoideae, family Leguminosae), highly valued for centuries for gum arabic production. Today, A. senegal is grown primarily for gum, but plays a secondary role in agricultural systems, restoring soil fertility and providing fuel and fodder.

BOTANY.

A deciduous shrub or small tree, Acacia senegal (L.) Willd. grows to 2-6 m (occasionally to 15 m) tall, with a flat to rounded crown. The tree has many branches and erect twigs spreading within the upright part. The bark is typically yellow/brown and smooth on younger trees, changing to dark grey, gnarled, and cracked on older trees. The branchlets have thorns just below the nodes: either three thorns with the central one hooked downwards and laterals curved upwards, or a single thorn with laterals absent. Leaves are small, gray-green, alternate, and bipinnate. Pinnae occur in (2-)3-8(-12) pairs, and leaflets in 7-25 pairs. The rachis sometimes have prickles. The white or cream colored flowers occur on 2-12 cm long spikes. Pods are dehiscent (open by splitting at maturity), yellowish to brown, flat, papery, and oblong (2-19 cm long by 1-3.4 cm wide). Seeds are nearly round to flat, olive brown, and 8-12 mm in diameter. The tree flowers during the rainy season.

Varietal differences in Acacia senegal are based on variation in natural distribution

as well as differences in morphological characteristics such as: presence or absence of hair on the axis of the flower spike, color of the axis, shape of pod tips, number of pinnae pairs, occurrence of a distinct trunk, and shape of the crown. Four different varieties of Acacia senegal are recognized: var. senegal, var. kerensis Schweinf., var. rostrata Brenan, and var. Ieiorhachis Brenan.



Acacia senegal flower, flowering branck and mature pods. (from Flora of West Tropical Africa)

DISTRIBUTION.

Acacia senegal var. senegal is found in Mauritania, Senegal, Gambia, Ghana, Burkina Faso, Cote d'Ivoire, Mali, Niger, Nigeria, Cameroon, Zaire, Central African Republic, Rwanda, Chad, Sudan, Ethiopia, Somalia, Uganda, Kenya, Tanzania, Mozambique, Oman, Pakistan, and India. It has been introduced into Egypt, Australia, Puerto Rico, and the Virgin Islands. Var. kerensis is found in Ethiopia,

Somalia, Uganda, Kenya, and Tanzania. Var. rostrata occurs in Somalia, Uganda, Kenya, Mozambique, south to Zimbabwe, Botswana, Angola, Namibia, and South Africa. Var. Ieiorhachis occurs in Ethiopia, Somalia, Kenya, Tanzania, southern Zambia, Zimbabwe, Mozambique, Botswana, and South Africa (Transvaal).

ECOLOGY.

Acacia senegal is very drought resistant. It grows on sites with annual rainfall between 100-950 mm, mainly between 300-400 mm, and 5-11 month dry periods. It tolerates high daily temperatures (mean maximum temperatures of up to 45°C or more), dry wind, and sandstorms. Generally it cannot withstand frost. Acacia senegal prefers coarse-textured soils such as fossil dunes, but it will also grow on slightly loamy sands and skeletal soils such as Lithosols. Although generally soils are welldrained, there are exceptions: in the Kayers region, SouthKordofan, East Sudan, A. senegal grows on heavy clay soils with approximately 800 mm annual precipitation. The best sites have pH of 5 to 8. The tree ranges from 100-1700 m elevation in the Sudan to 1950 m around Nakuru in Kenya.

USES.

Gum:

Acacia senegal and its close relatives are the defined source of commercial gum arabic for food purposes. A. senegal produces the only acacia gum evaluated toxicologically as a safe food additive (Anderson 1989). The gum from other Acacia species (A. seyal etc.) is available commercially as gum tahla (approx. 10% of all acacia gum marketed) for technological applications. Gum arabic has been

used for at least 4,000 years by local people for preparation in food, in human and veterinary medicine, in crafts, and as a cosmetic. Today, gum arabic's applications are manifold. Formerly the international trade market largely absorbed all gum available, though recently international demand has declined together with gum prices.

Gum arabic is used in the food industry as ;m:avor fixative and emulsifier, to prevent crystallization of sugar in confections, as a stabilizer in frozen dairy products, for its viscosity and adhesive properties in bakery products, and as a foam stabilizer and clouding agent in beer. In pharmaceutics, it is used as a stabilizer for emulsions, binder and coating for tablets, and as an ingredient in cough drops and syrups. A soothing and softening agent, gum arabic is extensively employed in folk medicines. Among many other uses, it is used internally for coughs, diarrhea, dysentery, hemorrhage, and externally to cover inflammed areas. Gum arabic is used in cosmetics as an adhesive for facial masks and powders, and to give a smooth feel to lotions. Industrially, gum arabic is applied as an a&esive, as a protective colloid and safeguarding agent for inks, sensitizer for lithographic plates, coating for special papers, sizing agent for cloth to give body to certain fabrics, and coating to prevent metal corrosion. Gum arabic is also used in the manufacture of matches and ceramic pottery.

Wood:

Acacia senegal wood is locally valued for fuelwood and charcoal, although biomass yield per unit land area is not sufficient to plant A. senegal purely for fuelwood. Wood is used in local construction for poles and fenceposts, the lightcolored wood for tool handles and dark heartwood for weaver's shuttles.

Strong ropes are made from the bark fibers of the tree's long surface roots.

Food and fodder:

Dried and preserved seeds of A. senegal are used by people as vegetables. The foliage and pods are browsed by sheep, goats, camels, impala, and giraffe. Leaves contain 10%-13% digestible protein and 0.12%-0.15% phosphorus, while the pods contain 15% digestible protein and 0.12%-0.14% phosphorus.

Dune stabilization:

Acacia senegal is important for desertification control through sand dune stabilization and wind breaks.

Agroforestry:

Acacia senegal is grown in agroforestry systems especially in the Sudan in "gum gardens" for gum as well as to restore soil fertility. Five-year-old trees are ready for tapping, and production peaks between 7 and 15 years. In Sudan, a traditional bush-fallow system is followed with a 20year rotation during which time Acacia senegal is grown for 15 years. Agricultural crops are grown for five years (millet, sesame, sorghum, groundnuts), followed by five years with young, unproductive A. senegal trees, which later produce gum during the last 10 years of the rotation. Corresponding to this rotation, 1/4 of the land is kept in agricultural crops, 1/4 in young unproductive trees, and 1/2 in productive trees. Controlled grazing is practiced after the trees have reached age four and under productive trees after the gum has been harvested. Wild trees are harvested during the dry season for gum exuded from cracks in the bark.

PROPAGATION.

Seed should be harvested before pods have dried for easy collection and to avoid insect attack. Seed is easily extracted by hand. Freshly extracted seed should immediately be dusted with an insecticide. Seed will remain viable for 3-4 years if kept in opaque, airtight containers. There are 10,000-30,000 seeds/kg. Fresh seed requires no pretreatment if sown immediately after harvest. Seed collected in previous seasons, however, requires pretreatment to break seed dormancy. Soaking seed in water for 12-24 hours gives good results and is simple to apply. Seeds can also be nicked.

A. senegal is usually raised in the nursery in polyethylene pots, 2-4 seeds per pot, thinned to one seedling after 4-6 weeks. Direct seeding (5-8 seeds in 30 x 30 x 30 cm pits or larger) can also be used. Strict protection from fire and livestock grazing, and efficient control of weed competition during at least the first two years is important to seedling survival. Minimum spacing for block planting is 4 x 4 m. At 10 x 10 m spacing, agricultural intercropping is possible, for example, interplanting with millet, beans, or groundnuts.

PESTS AND DISEASES.

The buffalo treehopper (Stictocephala bubalus) may destroy seed crops. Spiders (Cyclops sp.) can smother young growing apices. Larval stage of Coleoptera (bruchids), Lepidoptera, and Hyrnenoptera damage the seed. Locusts (Acridium melanorhodon) can defoliate vast areas overnight. Acacia senegal is also attacked by the fungi Cladosporium herbarium, Fusarium sp., Ravenelia acaciae-senegalae and R acaciocola.

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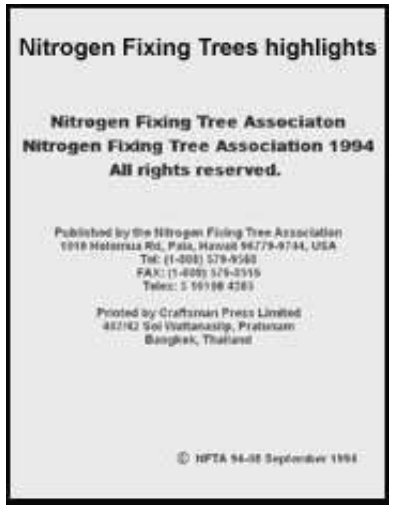

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Acacia seyal - multipurpose tree of the Sahara desert

One of few strongly gregarious Sahelian tree species, Acacia seyal combines tolerance of periodically inundated heavy clays with major roles in fuel and fodder production in countries at the southern edge of the Sahara desert, especially Mali, Chad and Sudan. A gum (gum talha) is collected from the tree and a proportion enters international trade. The epithet seyal derives from an Arabic word for "torrent" used for the species in Egypt and denotes association with water courses.

Botany

Acacia seyal Delile (family Leguminosae, subfamily Mimosoideae) is one of over 60 African acacias referred to the Uniseriae group of subgenus Acacia. The species usually reaches 9-10 m in height at maturity and in well-formed individuals a flat-topped crown develops. There arc two varieties, differing primarily in whether or not pseudogalls ("ant galls") develop and in bark color. In var. seyal there are no pseudogalls and a reddish bark color prevails, although periodic bark exfoliation exposes a pale powdery surface which darkens slowly. In var. fistula pseudo-galls arc present and the powdery bark typically remains whitish or greenish-yellow. Both varieties have paired, straight, strong, pale-colored, stipular spines up to 8 cm long which in var. fistula are often fused at the base into the inflated pseudo-galL The leaves arc bipinnate - usually with 48 pairs of pinnae, each of which bears 10-20 pairs of close-set, obscurely veined leaflets. Individual leaflets are 1-15. mm wide and about 5-8 mm long. Small bundles of up to 5 pedunculate capitate inflorescences arise in axillary positions on the young parts of shoots. Each inflorescence is vivid yellow in color, about 15 mm in diameter, and is borne on a peduncle 34 mm long. The dehiscent pods arc flat and somewhat curved, brown and up to about 20 cm long and 5-10 mm wide when ripe, with slight constrictions between the seeds. In a well-developed pod 6-10 seeds arc present, each 69 mm long, 4-5 mm wide and about 2 mm thick - in 1 kg there arc 20,00025,000 seeds. The chromosome number of 2n = 52 suggests tetraploidy.

Distribution

The range of A. seyal extends from Senegal eastwards to western Somalia and the coastal lowlands east of the Red Sea, and from the Nile valley of southern Egypt to

southern Zambia. The two varieties differ markedly in their ranges-var. seyal extends westwards from central Sudan and north of latitude 18°N and var. fistula extends south of latitude 10°S. The ranges overlap mainly in the upper Nile catchment, the Lake Victoria basin and the Ethiopian and East African rift valleys. Occurrence beyond the natural range is limited to arboreta (e.g. Iraq, Portugal) and experimental studies (e.g. India).

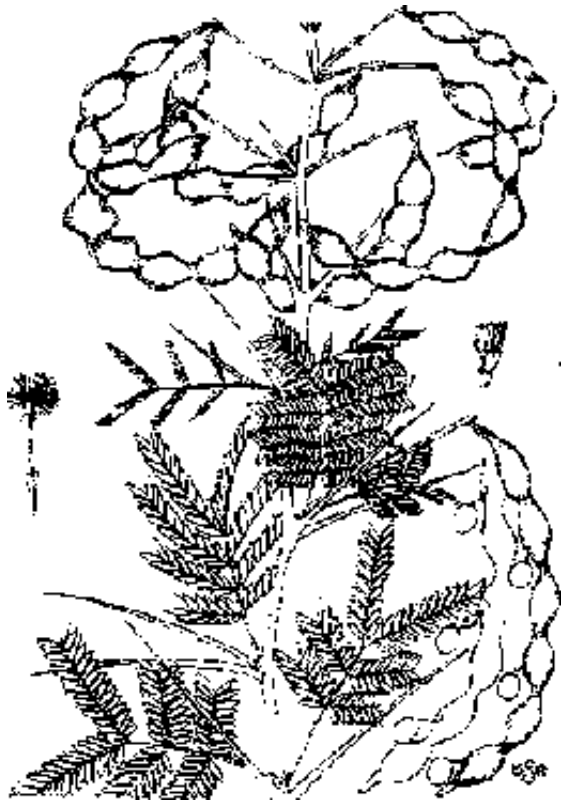
Ecology

Given suitable climatic and edaphic conditions closed, and essentially pure, stands of A. seyal develop but admit sufficient light for grass to grow in the understory.

Through the greater part of the range of A. seyal mean annual rainfall is 500-1200 mm and there is a well-defined 6-8 month dry season with mean annual rainfall less than 50 mm. Occurrences in more arid climates arc associated with the presence of water in addition to direct rainfall The phenological cycle relates closely to the rainfall regime. Where there is a well defined unimodal rainfall pattern, leaf fall takes place by the middle of the dry period and trees remain leafless for 4-7 months, depending on when the subsequent wet season begins. Leafless periods are briefer in bimodal equatorial rainfall regimes. Flowering is concentrated in the middle of the dry season and ripe fruits arc present about 4 months later.

Temperature regimes vary through the range, particularly for var. seyal which is subject to mean annual temperatures of 18-25°C. Var. fistula occurs mostly where mean annual temperatures are 20-25°C, but also in cooler climates in Ethiopia, at the upper elevation limit (1700-2000 m). Relationships with extreme

temperatures follow a similar pattern - in parts of West Africa where var. seyal is present, absolute temperature maxima are 50-55°C. Absolute minima through the range of the species are generally 5-10°C but below Sac at the northern limit and at altitudes >1800 m. The distribution pattern overall is indicative of a frost-sensitive species.



Acacia seyal var. seyal from F.E.M. Booth and G.E. Wickens. 1988. Non-timber uses of selected arid zone trees and shrubs in Africa. FAO.

Relationships with soil are well-defined. There is an unusual degree of adaptation for deep, heavy soils (pH 6-8) accumulated a, low points in a landscape or formed directly from fine-grouned rocks, such as shales, and readily weathered volcanic

materials. In communities containing both varieties, var. fistula displays greater tolerance of waterlogging and occupies lower positions in depressions and along drainage lines. Saline soils are not suitable.

Uses

Fuel.

Var. seyal, especially, is an important source of rural energy as both fuelwood and charcoal. Stands managed on a 10-15 year rotation yield 10-35 m³ ha-1 of fuelwood.

Fodder.

Both varieties of A. seyal are viewed favorable as forage. Dry matter net energy contents are high: 6-8 MJ kg- 1 (foliage) and 4-7 MJ kg1 (fruits). The associated digestible protein levels are also :gh: 100-150 g kg1 in the foliage, and higher in the fruits. For both foliage and fruits, analyses indicate a well balanced supply of minerals and very favorable qualities in terms of proximate fractions (e.g. crude fiber 10-20%; ether extract <7%). The foliage of var. seyal has been shown to contain secondary metabolites but experience suggests that levels are not a matter of serious concern.

Gum talha.

Gum talha has not been toxicologically evaluated and is not listed as an approved food additive. It contrasts with gum arabic in several significant respects, being strongly dextrorotatory, of high molecular weight and low in nitrogen (0.06-

0.24%) and rhamnose (<4% sugar composition). Ash contents of cobalt, copper, iron, nickel and, especially, aluminum (>6000 ppm) are high and tannin is present (2%), restricting acceptable use to such applications as a binder for foundry molding and a sizing agent in the textile industry.

Management of natural stands

Both varieties of A. seyal are noteworthy for occurrence in the undisturbed state in seral, even-aged stands. Reconstitution of an exploited var. seyal stand depends not on coppice shoots but on the presence of abundant seed and its exposure to a mild fire which enhances the germination of var. seyal but checks the regeneration of competing species. Stands 15 years old when harvested are likely to have produced a seed reserve sufficient to regenerate the stand. However, individual trees or uncut patches of the original cover should be left as seed sources to insure abundant regeneration. Where management for fodder production is concerned, evaluation of responses to lopping and cutting of var. seyal indicate limited recovery capacity in mature trees. Beating branches to detach leaves and fruits without damage to axillary buds is therefore preferred to exploit these as dry season resources.

Propagation

Unopened, full-sized fruits are gathered off the trees and allowed to release seed. After cleaning, seed stores well in cool, dry conditions, remaining viable for up to 8 years. Pretreatment in the nursery is advantageous, although not essential, to accelerate the germination rate. Scarification and acid treatments have proved favorable. However, germination rates have rarely exceeded 30% in 7 days. Seeds

can be pregerminated in contact with moist cotton wool or filter paper to allow rapid identification of viable non-dormant seed. Transfer to containers filled with a silt-rich medium. Seedlings require shade until the second leaf expands and watering at intervals of 1-3 days as necessary to keep the medium moist but not waterlogged.

Formal stands

Stands of var. seyal have been established in Sudan, often by direct sowing of pretreated seeds to prepared planting spots. Sowing seed in batches ensures a high proportion of spots become occupied. Competition from weed growth is overcome by using taungya, with mechanized site preparation and sowing. Sesamum or Sorghum is intercropped among widely spaced (ca 4 m) rows of trees. For poles and fuelwood a 20 year rotation is projected. Initial stocking is 1000 stems ha $^{-1}$. Thinnings after 10 and 14 years reduce stocking to 675 and 450 stems ha $^{-1}$, respectively.

Nodulation

Nodulation occurs in natural populations. In artificial regeneration it has been achieved by pelleting seed with culture of bacterial isolates, sowing into an infected medium or germinating in unsterilized soil. Uninfected seedlings have been inoculated successfully by treatment with a suspension of a symbiont. Rhizobium strains from A. mellifera and A. senegal and Bradyrhizobium from the latter have proved to be effective symbionts.

Pests

Over 40 species of insects are reported associated with A. seyal. These include 10 species of bruchid beetles which may damage high proportions of stored seeds. Beetles of various other families attack the wood, the postrychid Sinoxylon senegalense being the most notorious and swiftly locating and infesting freshly cut wood, especially if lying on the ground. Attacks are much reduced if the bark is removed and the cut stems stacked upright Subsequent creosote treatment ensures extended durability.

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For a complete set of references contact the author or NFTA.

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Acacia tortilis: fodder tree for desert sands

Acacia tortilis, often called the "umbrella thorn" for its distinctive spreading crown, is one of the most widespread trees in seasonally dry areas of Africa and the Middle East. The umbrella thorn is the dominant tree in many savanna communities and provides an important source of browse for both wild and domesticated animals.

BOTANY.

Acacia tortilis (Forsk.) Hayne (subfamily Mimosoideae, family Leguminosae) is one of about 135 African acacia species. Unlike the Australian acacias, African acacias are armed with thorns and produce highly palatable pods. A. tortilis is a variable species, with six infraspecific taxa including four recognized subspecies: tortilis, spirocarpa, heteracantha, and raddiana (Brenan 1983). Although some French and Israeli authors consider ssp. raddiana a separate species (A.

raddiana), recent revisions treat it as a subspecies (Brenan 1983, Ross 1979). As with other African acacias, A. tortilis is a polyploid complex most are tetraploids (2n=4x=52); ssp. raddiana is an octoploid (2n=8x=104).

Acacia tortilis varies from multi-stemmed shrubs (ssp. tortilis), to trees up to 20 m tall with rounded (ssp. raddiana) or flat-topped (ssp. heteracantha and spirocarpa) crowns. The presence of very long thorns and two thorn types, longstraight and shorter-hooked, distinguishAcacia tortilis from other acacia species in Africa. The alternate leaflets (usually < 1 mm wide) are smaller than those of most bipinnate acacias. White or pale-yellow fragrant flowers cluster in 1 cm diameter round heads. Flowering is prolific with up to 400 flowers/meter twig. Flowers later develop into bunches of spirally twisted, indehiscent pods. Straight pods also occur, though rarely (Somalia and Kenya). Pods vary considerably in size depending on provenance but range from 8 to 12 cm long.

ECOLOGY.

Acacia tortilis occurs throughout dry Africa, ranging from Senegal to Somalia and down into South Africa. In Asia, trees occur in Israel, southern Arabia, and Iran. A. tortilis is found in all countries fringing the Sahara and is often the tree that extends furthest into the desert. Young A. tortilis forms natural thickets in heavily overgrazed savanna in southern Africa. The tree was introduced from Israel in 1958 into the district of Rajasthan, India, where it showed the greatest promise of 277 tested species. It is now widely planted in Rajasthan and has also been planted in Pakistan and on the Cape Verde Islands.

Acacia tortilis occurs from sand dunes and rocky scarps to alluvial valley bottoms,

avoiding seasonally waterlogged sites. A very drought resistant species, the umbrella thorn grows in areas with annual rainfall as low as 40 mm and as much as 1200 mm, with dry seasons of 1-12 months. The tree favors alkaline soils but will colonize saline and gypseous soils. A. tortilis forms a deep tap root in sandy soils; the solitary landmark Tenere tree in the southern Sahara had roots reaching 35 m deep. On shallower soils and in arid sites, it can develop hose-pipe subsurface roots extending over twice the width of the crown. The umbrella thorn ranges from 390->2000 m elevation. It survives sites where temperatures regularly reach 50 °C at mid-day and fall to near freezing at night. Older trees (>3 m tall) can withstand frosts and light grass fires.

NODULATION.

A. tortilis nodulates frequently over its natural range. Considerable variation in nodulation levels has been found under controlled environmental conditions. Fastgrowing Rhizobium strains have been isolated at Dundee University.

USES.

Forage:

In semi-arid areas,Acacia tortilis provides a staple browse especially for camels and goats. Forage is available throughout most of the dry season when other sources are scarce. In the Turkana region of Kenya, large riverine trees (called ekwar) are individually owned. Pods are collected for sale in markets, such as in Lodwar (Turkana) and Msinga (South Africa), both as animal and human food. Pods are also fed to lactating animals to increase milk yields. Pods and leaves

have a good level of digestible protein (mean = 12%) and energy 6.1 Ml/kg DM (Le Houerou 1980), as well as being rich in minerals. Seeds are high in crude protein (38%) and phosphorus, an element usually scarce in grasslands. The pods require milling to increase digestion in cattle. Over 90% of the tree's flowers abort and drop from the trees, providing an additional important forage (Kayongo Male and Field 1983).

Few studies have quantified A. tortilis fodder production but an estimated 1 dry ton/ha/yr shoot and leaf growth was available in semi-deciduous bushland in the Tugela Dry Valley, South Africa (Milton 1983). Yields from young plantations in India indicate similar productiviry: 2.5 kg/tree/yr (at 400 trees/ha), discounting pod (1 kg/tree/yr by age 7) and fuelwood production (Gupta and Mohan 1982).

Silvipasture:

A. tortilis provides shade for animals. Some of the most palatable grass species grow beneath its canopy (Walker 1979). In Turkana, Kenya, soil nutrients and herbaceous plant productivity and diversity were significantly greater under than away from the tree canopy (Weltzin and Coughenour 1990).

Sand dune stabilization and shelterbelts:

A. tortilis has been used with some success to stabilize sand dunes in Somalia, United Arab Emirates, and Rajasthan, India. In India it has been grown successfully in shelterbelts with Azadirachta indica.

Wood:

The dense, red wood of A. tortilis makes very good charcoal and fuelwood (4360 Cal/kg) (BOSTID). It burns slowly and produces little smoke when dry. Poles are commonly used in hut construction and for tools. The wood of ssp. heteracantha is durable if water-seasoned. The tree resprouts vigorously when coppiced and is managed for fuelwood in natural woodlands in Sudan. In plantations in India, trees are planted at 3 x 3 m spacing and coppiced for fuelwood. After 10-12 years over 50 tons/ha wood can be harvested. In other areas the trees are not cut, to avoid reducing pod yields.

Other uses:

In traditional, pastoral societies every part of Acacia tortilis is used. The high value held by local people for the tree is reflected in the detailed nomenclature given to its cycles of development. In Oman, for example, local people call A. tortilis by more than a dozen different names in Dhofari arable.

Flowers provide a major source of good quality honey in some regions. Fruits are eaten in Kenya, the Turkana make porridge from pods after extracting the seed, and the Masai eat the immature seeds. The bark yields tannin and the inner bark cordage. Thorny branches are used for enclosures and livestock pens; roots are used for construction of nomad huts (Somali and Fulani). Leaves, bark, seeds, and a red gum are used in many local medicines. Two pharmacologically active compounds for treating asthma have been isolated from the bark (Hagos et al. 1987).

PROPAGATION.

A. tortilis is a pioneer species easily regenerated from seed. Pods are best collected by shaking them from the canopy. In East Africa, a mature tree can produce over 6000 pods in a good year, each with 8-16 seeds (10,000 - 50,000/kg depending on the subspecies).

Seeds are often extracted by pounding pods in a mortar followed by winnowing and cleaning. The hard-coated seeds remain viable for several years under cool, dry conditions. They require pretreatment for good germination. Mechanical scarification works best for small seed lots. Soaking seeds either in sulfuric acid for 20-30 minutes. or in poured. boiled water allowed to cool. are both effective treatments (Fag" and Greaves 1990).

Seed are planted in the ground in 1 cm deep holes or in the nursery in 30 cm long tubes. Rapid tap root growth requires frequent root pruning. Seedlings are ready to be planted out after 3-8 months. On marginal sites, initial seedling growth is often slow but quickens once roots have reached a water source. For best growth, plants should be weeded and protected from browsing animals for the first three years. At Jodhpur, India (320 mm annual rainfall) average height of 20 selected 2.5-yr-old plants was 3.8 m.

Limited seed supplies are available from natural populations in a number of countries, primarily in Sahelian Africa, and from landraces in India. A broader range of germplasm is available from the Oxford Forestry Institute (South Parks Road, Oxford OX1 3RB, UK) for establishment of field trials. Small quantities of seed from Kenyan provenances are also available from NFTA.

PESTS AND LIMITATIONS.

A large number of insects have been recorded to attack living trees. but only bruchid beetles are of economic importance. They can destroy over 90% of seeds produced in any year. The buprestid beetle (Julodisy sp.) defoliated over 50% of a plantation in Rajasthan. Acacia tortilis is also susceptible to nematodes, mistletoes (Loranthaceae), and galls. Large numbers of insects and mammals feed on the flowers. In India, powder post beetles (Sinoxylor. spp.) can reduce the wood of felled timber to dust over a period of weeks. A further consideration is in humid to subhumid areas where A. tortilis can become weedy if it is not being used (BOSTID 1979).

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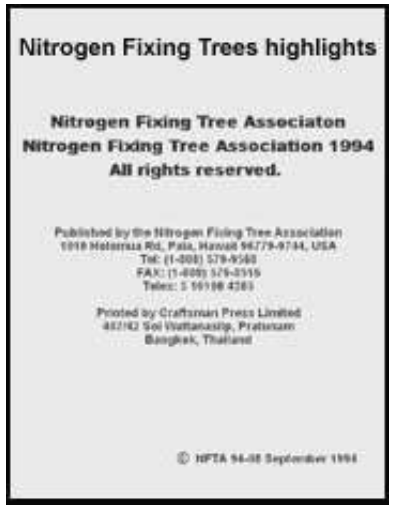

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Alnus nepalensis: a multipurpose tree for the tropical highlands

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

BOTANY.

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

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

ECOLOGY.

A. nepalensis occurs throughout the Himalaya at 500-3000 m elevation from Pakistan through Nepal, northern India, Bhutan and Upper Burma to southwest

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

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

USES.

Utis wood is moderately soft with densities of 320370 kg/m³ (NAS 1980) to 480-590 kg/m³ (Lamichhaney 1984). Wood calorific value is low (18,230 kJ/kg - Hawkins 1982, or 20,480 kJ/kg - Webb et al. 1984), but utis wood, like that of other alders dries rapidly and burns easily. Although not among the best construction timbers, utis has an even grain, seasons fairly well, and is easy to saw and finish by hand or machine. The wood preserves fairly well, but is perishable if subject to alternately wet and dry conditions. The wood is also subject to discoloration by oxidation and fungal sap stain. It is suitable for boxes, splints and matches (Dey and Ramaswami 1960) and for newsprint (Guha 1965).

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

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

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

ACTINORHIZAL SYMBIOSIS.

Alnus nepalensis forms symbiosis with N-fixing actinomycetes of the genus Frankia. Although the biochemistry and physiology of the "alder-type" symbiosis with Frankia are not fully understood, cell-free preparations of nitrogenase have been obtained from Alnus nodules (Postgate 1979). Studies in West Bengal indicated that nitrogenase activity was highest in young nodules irrespective of tree age and concluded that A. nepalensis is capable of fixing significant amounts of nitrogen (Sharma and Ambast 1984). Sharma et al. (1985) investigating soil

properties under five stands in the Eastern Himalaya found that total soil N increased with increasing stand age.

PROPAGATION.

The species is readily propagated from seed (1.6 to 23 million seeds/kg, if pure). It is orthodox and will retain viability for at least a year if properly dried and stored in sealed containers. No pretreatment is needed. Germination starts 1-2 weeks after sowing and is completed 2 weeks later. Transplanting into containers can begin 4-5 weeks after germination. Below 1200 m elevation seedlings should reach planting size (25-35 cm) in 4-5 months, but above this altitude they may take as long as 11 months (Napier and Robbins 1989). Young seedlings are liable to damage by ants and defoliation by frost and are very often killed.

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

SILVICULTURE.

Alnus nepalensis has a wider range of site tolerance than its natural distribution

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

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

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

PROVENANCES.

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

PESTS AND DISEASES.

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

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Casuarina equisetifolia: an old-timer with a new future

Casuarina equisetifolia Forst. & Forst. (syn. C litorea L), is the most widespread ant well-known member of the family Casuarinaceae, ant has many names: casuarina, ironwood, coast she-oak, horsetail, Australian pine, whistling pine, beefwood, agoho (Philippines), ru (Malaysia), filao (Vietnam, West Africa, West Indies) ant nokonoko (Fiji). All the casuarinas are nitrogen-fixing. Casuarinas support an actinorhiza symbiont in their root nodules, as opposes to the rhizabium 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 alone the coast of Queensland and northern New South Wales. Var. equisetifolia is a tall (10-40 m) tree fount on seacoasts from Malaysia to subtropical Australia, Melanesia, Micronesia, the Philippines ant Polynesia.

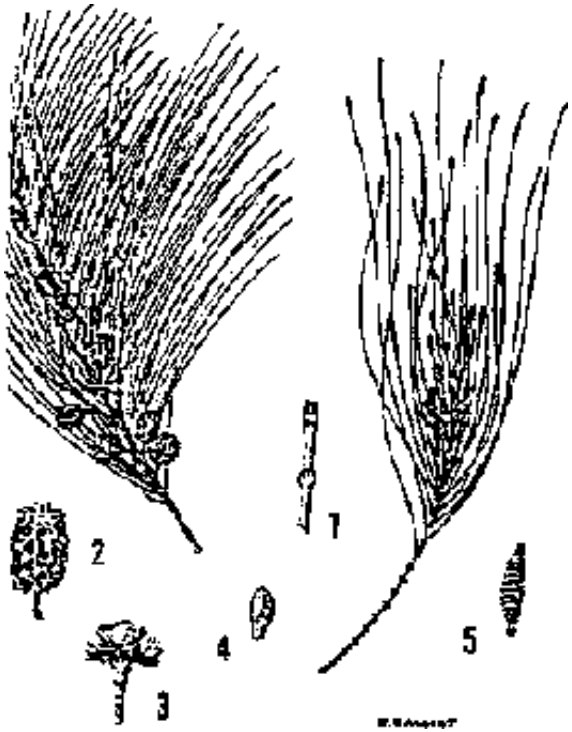
BOTANY.

Like other Casuarinaceae, C equisetifolia has a conifer-like appearance which is increased by hanging green branchlets ant cone-iike fruits. Casuarinas are actually typical angiosperms with simplified and reduces 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-growt plant body; ant determinate deciduous branchlets (incorrectly called cladodes), about 15-25 mm in diameter. These branchlets are the major photosynthetic organs of the plant (Torrey ant Berg 1988). The leaves are reduced to white or brown scales fuses laterally at the base in whorls that define notes on the branchlets.

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

ECOLOGY.

Casuarina cquisetifolia 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.



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

C equisetifolia tolerates a wide range of moisture availability. C equisetifolia grows best along the coast, where sea spray supplements moisture from the water table in arid ant semiarid climates with average annual rainfall <300 mm. C equisetifolia's N2-fixing ability seems to depend wholly on the availability of adequate soil moisture.

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

USES.

The wood of C equisetifolia is dark brown, very hart (density 1000 kg/m3), ant 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 equsetifolia is used for house beams ant 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.

Because of its resistance to salt-laden winds. C equisetifolia is widely used to stabiles 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 se. 1989). Inoculation with crushed nodules, which is sometimes practiced, should be discouraged because of the risk of introducing nonnodulating or poorly effective strains and disseminating soil-borne pathogens like Pseudomonas solanacearurn, a bacterium that causes casuarina wilt. Prolonged waterlogging inhibits nodule development.

As in other actinorhizal plants, spontaneous endomycorrhizal (YAM) 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 rootless 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 3040% 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 in 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 (15-25

m/yr), then gradually declines. In general, the volume yield reaches a maximum at age 15-20 years (7-10 m /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, Schistocerca gregaria), defoliators (Lymantria xylina), stem borers (spate monachus) and sap feeders (Icerya spp.). The major root diseases are caused by Pseudomonas solanacearum, Trichosporium vesiculorum and Rhizoctonia spp.

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Acacia koa - Hawaii's most valued native tree

Koa (Acacia koa Gray.) is unquestionably Hawaii's most prized tree species culturally, ecologically and economically. Hawaiians have always valued koa for its exceptionally beautiful and durable wood. It remains the premier Hawaiian timber for furniture, cabinetry, interior work and woodcrafts. Equally important, native koa forests provide unique wildlife habitat, critical watershed recharge areas and recreational opportunities. Unfortunately, forest clearing for agriculture, cattle grazing and feral pig activity have much diminished Hawaii's once extensive koa forest. The scarcity of koa wood is reflected in its ever increasing price-high enough now to economically justify helicopter logging.

Botany and Ecology

Acacia koa is a large, evergreen broadleaf tree and the only Acacia native-and endemic-to Hawaii. Trees occurring in dense, wet native forest stands typically reach heights of 25 m and stem diameters (DBH) of 150 cm, while retaining a straight, narrow form.. In the open, trees develop more spreading, branching crowns and shorter, broader trunks. Koa bark is gray, rough, scaly and thick. Observations indicate that koa has one main tap root - and an otherwise shallow,

spreading root system.

Koa belongs to the thorn-less, phyllodinous group of the Acacia subgenus Heterophyllum (Whitesell 1990). Like other phyllodial species, mature koa trees do not have true leaves. Instead they produce phyllodes, or flattened leaf petioles. Young seedlings have bipinnate compound true leaves with 12 to 15 pairs of leaflets. Where forest light is sufficient, seedlings stop producing true leaves while they are small less then 2 m tall.. True leaves are retained longer by trees growing in dense shade.

Phyllodes are sickle-shaped and often more than 2.5 cm wide in the middle and blunt pointed on each end. Investigations suggest that true leaves promote more rapid early growth when moisture is adequate, whereas phyllodes are better adapted to drought Phyllodes transpire only 20 percent as much as true leaves, and their stomata close four times faster after dark. Phyllodes typically hang down vertically, a position that enhances their ability to capture light during early morning and late afternoon hours. Seedlings are able to switch back from phyllode to true leave production when the sunlight reaching them is reduced (Walters and Bartholomew 1990). This adaptation allows them to survive and grow under a wide range of light regimes.

Observations suggest koa can flower a]most any time of year, depending upon local weather conditions. The inflorescence of koa is a pale yellow ball averaging 8.5 mm in diameter, one to three on a common stalk. Each inflorescence is composed of many bisexual flowers. Each flower has an indefinite number of stamens and a single elongated style. One known pollinator of koa is the honeybee (Apis mellifera). Koa appears to be fully self-fertile (Brewbaker 1977).

Koa pods are slow to dehisce and about 15 cm long and 2.5 to 4 cm wide. They normally contain between 6 and 12 seeds that vary from dark brown to black. Pods reach maturity at 4 to 6 months, depending on location and weather conditions. Insect larvae of many species typically destroy a large proportion of the mature seeds before they dehisce.

Seed production typically begins when trees are 5 years old. Koa bears seed often and abundantly. Seeds are seldom dispersed far from the tree and remain viable in the soil for up to 25 years. Thus remnant koa stands are capable of dominant regeneration under favorable conditions. Koa seeds do not require sunlight to germinate, but seedling growth is slow in dark understories or in thick grass. The species thus requires large forest gaps, such as those created by storms, to successfully regenerate.

Acacia Koa, from E.L. Little and R.G. Skolmen. 1989. Common forest trees of Hawaii (native and itroduced). Agricultural Handbook 679. Washington, D.C.: USDA, p. 131.

Distribution

Acacia koa occurs at elevations from 180 to 6000 meters between 19 and 22 latitude on all of the major Hawaiian islands. It prefers an annual rainfall of 1900 to 5100 mm, and well drained acid soils. However, koa adapts to almost any of Hawaii's diverse environments indicating its potential elsewhere in the Pacific. Koa is found on all volcanic soil types of all geologic ages. It grows well in moderately to well-drained, medium to very strongly acid soils on both flatland

and steep slopes. On dry, shallow, poorly drained soils koa's growth is slow and its form generally poor.

Occurring in both pure and mixed forest stands, koa is most commonly associated with the native ohia (Metrosideros polymorpha). IL is also a codominant in several other major forest types including: Koa/Mamane (Sophora chrysophylla) Montane Dry Forest and Koa/Ohia/A'e (Sapindus soponaria) Forest (Wagner et al, 1990). Today Acacia koa stands are fragmented and concentrated in areas between 600 and 1800 meters elevation (Whitesell 1990). This distribution is largely the result of land conversion to agriculture and ranching. Cattle avidly graze koa seedlings, preventing regeneration.

Silviculture

Propagation is most successful from seed. One study recommends air-layering as the best vegetative propagation technique (Skolmen 1978). Koa seeds are durable and easy to store. They germinate after many years of storage if kept in a cool, dry place. The most effective method for improving seed germination is mechanical scarification. However, hot water soaking works well and is a more practical method. Boil water and remove it from the heat source. Soak seed in the boiled water for 24 hours. Once treated, seeds are typically sown m nursery beds. One week after germination, seedlings are transplanted into nursery tubes or bags. Seedlings are ready for transplanting into the field when they are approximately 20 cm tall-after 3 to 4 months in the nursery. Observations suggest that heart rot problems may be partially caused by root damage during transplanting. Therefore, establishment by direct seeding or encouragement of natural regeneration is recommended. On favorable sites, planted seedlings typically grow to 9 m m 5

years time (Judd 1920).

Koa's wide branching form is the result of open growth. Trees with long clear boles-called "Canoe trees" by native Hawaiians are now rare, but still found in forest gaps created by fallen trees. Dense stocking of seedlings, which mimics the competitive environment where superior "canoe trees" grow, encourages straight and rapid height growth. Initial spacing of 1.2 x 1.2 meters is currently recommended. Observation indicates that effective self-thinning will result in an adequate number of potential crop trees by age 25.

Where scattered koa cover is adequate, plantation establishment is most easily and successfully accomplished through the stimulation of natural regeneration. Pasture soils are scarified and competition from grasses reduced by the application of a contact herbicide. Gaps in the regeneration are filled with planted seedlings. Fertilizers are applied to give seedlings an initial "boost". Plantation thinning prescriptions should be based on desired products and management capabilities. The most important factors to consider in picking koa crop trees is stem form and height. Research on koa plantation management and various spacing and thinning regimes is direly needed.

Uses

Wood.

Koa heartwood is highly valued by furniture and crafts people throughout Hawaii, and consumers the world-over, for its unique grain, varied color and workability. It seasons well without serious warping or splitting. Curly-grained wood, the

result of both stress and genetics, is preferred over straight-grained wood. Wood color ranges from a subtle yellow to a striking dark red-purple. The specific gravity of koa wood averages 40, but with curly-grained wood can be as high as.65. Mature koa boles are commonly forking or fluting and often suffer from heart rot. These characteristics and wide branch angles limit its value as a large timber. Fortunately, these defects may be corrected through silviculture.

Forage and Wildlife Habitat.

Cattle, sheep and pigs browse koa foliage aggressively, especially its juvenile leaves. Koa is spread geographically throughout Hawaii and thus offers a variety of wildlife habitats of diverse moisture regimes, soils and vegetative compositions. An overlay of a koa forest area map onto a forest bird "habitat island" map produced by Walker (1986) shows remarkable correlation.

Land Reclamation.

Most koa plantations in Hawaii have been established to provide vegetative cover on sites degraded by decades of intense grazing. Where scattered koa already exists, seed stored in the soil will likely germinate if the soil is scarified and grass competition controlled.

Symbiosis

Acacia koa is nodulated by the slow-growing Bradyrhizobium spp. common in tropical soils. It nodulates heavily in a variety of soils, suggesting it is effective with a wide variety of Bradyrhizobia strains.

Pests and Diseases

Banana poke (Passiflora mollissima) is a fast growing vine that commonly outgrows and smothers young koa trees. Kikuyu grass (Pennisetum clandestinum), a dominant and extremely aggressive highland grass in Hawaii, is a major deterrent to the emergence of koa seedlings on cleared or formerly grazed lands. Successful koa plantation monoculture has historically been difficuIt to achieve due to associated insect and disease problems. Examples include the defoliating koa moth (Scotorythra paludicola) and a lethal "koa blight" first observed in 1988 on the island of Oahu.

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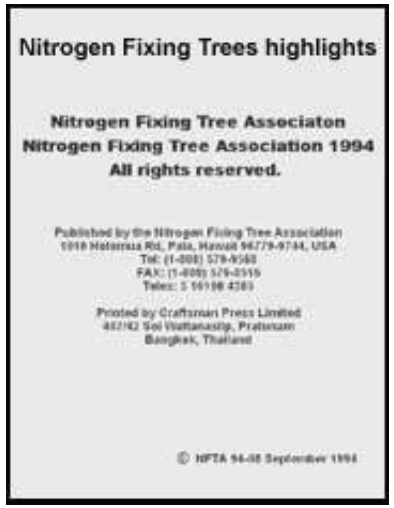

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Casuarina glauca: a hardy tree with many attributes

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 plantationgrown 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 mm 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 small, 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 (ElLakany 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 cunninghamiana 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 (ElLakany 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/l 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, saline to calcareous, and dry to waterlogged soils. Trees grow on very dry sites with saline soils in Israel and flourish 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.

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 NFTA.

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 (ElLakany and Youness 1985). Biomass productivity of 12year-old irrigated plantations was estimated at 496 t/ha of which wood volume was 294 m^3/ha (Megahed and ElLakany 1986). Provenance testing is underway in California, USA for frost colerance (Merwin 1990). Irrigation is required to establish trees in desert areas.

SYMBIOSIS.

C glauca forms a symbiosis with actinomycetes 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 waterlogged 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 waterlogging, 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 East, 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 se. 1983) kg/m³. Timber is used for handles, fence rails, 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 branchlets. 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 se. 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 arid zone cities. Like other casuarinas, the dense canopy and slow-todecompose 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 pestfree except for Stromatium fulvum, a wood borer which makes the stem susceptible to wind-damage and rot.

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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 tong. 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 seal 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 sandysurfaced 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.

Composition.

The foliage has a composition similar to bestquality 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.

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.

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 (Borers 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 ail 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 5 m 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 mizobia 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 tour 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's requirement for fertilization to maintain high levels of productivity and nutrient content poses a management limitation for resource-

poor farmers.

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