Leucaena leucocephala - the Most Widely Used Forage Tree Legume

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Introduction

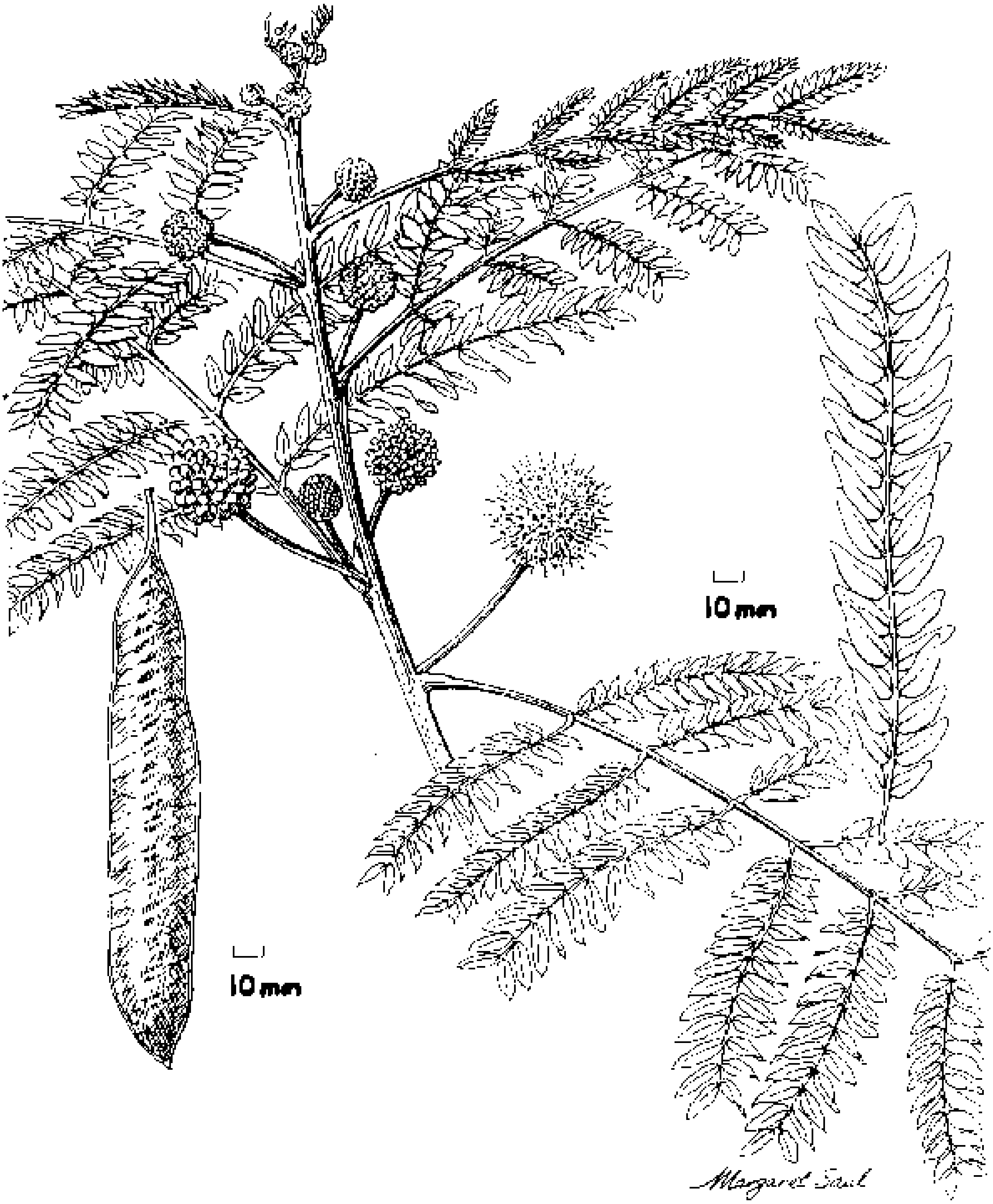
During the 1970s and early 1980s, *Leucaena leucocephala* (Lam.) de Wit (leucaena) was known as the 'miracle tree' because of its worldwide success as a long-lived and highly nutritious forage tree, and its great variety of other uses. As well as forage, leucaena can provide firewood, timber, human food, green manure, shade and erosion control. It is estimated to cover 2-5 million ha worldwide (Brewbaker and Sorensson 1990). However, a better understanding of its constraints, particularly the arrival of the psyllid insect, has now given us a more balanced view of the value of this species.

Leucaena has its origins in Central America and the Yucatan Peninsula of Mexico where its fodder value was recognised over 400 years ago by the Spanish conquistadores who carried leucaena feed and seed on their galleons to the Philippines to feed their stock (Brewbaker *et al.* 1985). From there it has spread to most countries of the tropical world where leucaena was used as a shade plant for plantation crops. It was introduced into Australia in the late 19th century and it was naturalised in parts of northern Australia by 1920 (White 1937).

Botanical Description and Genetic Variation

Leucaena leucocephala, formerly known as *L. glauca*, is a thornless long-lived shrub or tree which may grow to heights of 7-18 m. Leaves are bipinnate with 6-8 pairs of pinnae bearing 11-23 pairs of leaflets 8-16 mm long. The inflorescence is a cream coloured globular shape which produces a cluster of flat brown pods 13-18 mm long containing 15-30 seeds (Figure 2.1.1). Botanically, leucaena belongs to the family Mimosaceae; it is the best known species of the *Leucaena* genus and has a variety of common names (Table 2.1.1). There are, however, at least 14 other species recognised in the genus.

Fig. 2.1.1. Leaves, flowers and pod *of Leucaena leucocephala.*



These are *L. collinsii, L. cuspidata, L. diversifolia, L. esculenta, L. greggii, L. lanceolata, L. macrophylla, L. multicapitula, L. retusa, L. pallida, L. pulverulenta, L. salvadorensis, L. shannoni* and *L. trichodes. Leucaena leucocephala* and *L. pallida,* and one subspecies of *L. diversifolia,* are polyploids (104 chromosomes) while all other species are diploid (52 or 56 chromosomes). *Leucaena leucocephala* and the tetraploid varieties of *L. diversifolia* are self-pollinating while the others are outcrossing.

Table 2.1.1. Some common names of *Leucaena leucocephala*.) de Wit. (Brewbaker *et al. 1985*).

Common name	**Countries**
Leucaena	Australia, United States
Ipil ipil	Philippines
Lamtoro	Indonesia
Katin	Thailand
Yin ho huan	China
Kubabul, or subabul	India
Koa haole	Hawaii
Tangantangan	Some Pacific islands
Cassis	Vanuatu
Guaje	Mexico
Huaxin	Central America (Maya)

The species may be distinguished on the basis of their tree size, flower colour, leaflet size and pod size (Anon. 1990). These same authors consider the genus *Leucaena* to be an interbreeding complex capable of producing many interspecific hybrids. For instance, *L. leucocephala* crosses readily with *L. diversifolia* and *L. pallida* producing hybrids from which selection for improved growth form, psyllid resistance and cold tolerance is possible. *Leucaena pallida,* in particular, has excellent seedling vigour and hybridisation of this species with *L. leucocephala* has the potential to produce a new highly productive and psyllid resistant Leucaena (Sorensson *et al.* 1993).

There are two forms of the species *L. leucocephala* The most common is the shrubby free-seeding form or 'common' leucaena which tends to be weedy and low yielding (Jones 1979). It was this common form of leucaena which was transported around the world from the 16th to 19th centuries and is now pantropical in distribution. Australians have referred to Peruvian types which are multibranched, leafy, of medium height (3-8 m) and more productive than the common type. Cultivars Peru and Cunningham are examples released by CSIRO in Australia in the 1960s. However, we contend that these varieties are really well branched giant leucaenas. The true giant types are tall (up to 20 m) and sparsely branched with better forage and wood production than the shorter varieties. Examples are K8 and K636.

Uses

Leucaena leucocephala has a wide variety of uses and it was this multiplicity of roles that led to the worldwide reputation of the species as a 'miracle tree'.

First and foremost, the leaves of leucaena are highly nutritious for ruminants and many excellent animal production data have been published confirming the fodder value of leucaena (see Chapter 4). Secondly, leucaena can be used in cropping systems. Contour strips of leucaena have been employed for many years in the Philippines and in Timor and Flores in Indonesia. The strips serve as erosion control on steep slopes and as a form of alley cropping in which leucaena foliage is mulched into the soil to enhance yields of inter-row crops. On some islands of eastern Indonesia, thickets of leucaena are regularly burnt prior to planting crops in an advanced form of 'slash-and-bum' agriculture. The use of leucaena in cropping systems is discussed in detail in Chapter 5.

Leucaena is capable of producing a large volume of a medium-light hardwood for fuel (specific gravity of 0.5-0.75) with low moisture and a high heating value, and makes excellent charcoal, producing little ash and smoke. It also can be used for parquet flooring and small furniture as well as for paper pulp. Leucaena poles are useful for posts, props and frames for various climbing crops (Brewbaker *et al.* 1985). The low seeding varieties are used to provide shade for cacao and coffee and support for climbers such as pepper and vanilla. The high seeding types are a nuisance in this regard because of the high population of seedlings that germinate and compete with the crop. There is opportunity to produce seedless triploid hybrids by crossing self-incompatible diploid species such as *L. diversifolia* (2x) with tetraploid species such as *L. leucocephala* (Brewbaker and Sorensson 1990).

Leucaena hedges are useful as windbreaks and firebreaks, the latter due to the suppression of understorey grass growth.

Other uses include production of necklaces from seeds and the use of young leaves and seeds as vegetables for human consumption. Young green pods can be split open and the fresh immature seeds eaten raw or cooked. Only small amounts can be eaten in this way because of the presence in seed and young growth of the toxic amino acid mimosine. *Leucaena leucocephala* will occasionally produce a gum similar to gum arabic when stressed by disease or insect pests. When *L. leucocephala* was hybridised with *L. esculenta,* some segregating trees produced gum heavily in the dry season. The hybrids were seedless, had good vigour and were psyllid resistant (Brewbaker and Sorensson 1990).

Climate and Soil Adaptation

Temperature

Leucaena is a tropical species requiring warm temperatures (25-30°C day temperatures) for optimum growth (Brewbaker *et al.* 1985). At higher latitudes and at elevated tropical latitudes growth is reduced. Brewbaker *et al.* (1985) suggest that temperature limitations occur:

- above 1000 m elevation within 10°C latitude of the equator, and
- above 500 m elevation within the 10-25°C latitude zone.

Leucaena is not tolerant of even light frosts which cause leaf to be shed (Isarasenee *et al.* 1984). Heavy frosts will kill all above ground growth, although the crowns survive and will regrow vigorously in the following summer with multiple branches. There is some scope for breeding frost tolerance into leucaena Two- and three-way hybrids of *L. leucocephala* with frost tolerant *L. retusa* show promise (Brewbaker and Sorensson 1990). Kendall *et al.* (1989) suggested that populations of *L. leucocephala* originating from more elevated sites in northeastern Mexico showed greater frost tolerance than those originating from lowland sites. Leucaena growth is strongly seasonal in the subtropics with low yields in the cool months and the majority of growth occurring in the summer months (Cooksley *et al.* 1988). For these reasons the best opportunities for developing cool tolerant leucaenas lie with hybridisation of *L. leucocephala* with *L. diversifolia* and *L. pallida.* These latter two species can be found in elevated sites in Mexico and demonstrate cool tolerance. Hybrids of *L. diversifolia* (4x) x *L. leucocephala* averaged 4.5 m per year height increase in a 2 year period at Waimea, Hawaii at 850 m elevation and mean annual temperature 17°C (Brewbaker and Sorensson 1990).

Light

Shading reduces the growth of leucaena although this plant has moderate tolerance of reduced light when compared with other tree legumes (Benjamin *et al.* 1991). Leucaena seeds will germinate and establish satisfactorily under established leucaena hedgerows or under the weed species *Lantana camara* as a method of rehabilitating infested areas.

It has also been successfully grown under coconuts in Bali as a support for vanilla.

Rainfall requirements and drought tolerance

Leucaena can be found performing well in a wide range of rainfall environments from 650 to 3,000 mm. However, yields are low in dry environments and are believed to increase linearly from 800 to 1,500 mm, other factors being equal (Brewbaker *et al.* 1985). In Hawaii, it is naturalised on Diamond Head which receives only 300 mm p.a. In Australia the leucaena psyllid is much less damaging in drier areas (600-800 mm p.a.) and this is a major advantage for graziers cultivating leucaena in subhumid Queensland.

Leucaena is very drought tolerant even during establishment. Young seedlings have survived extended periods of dry weather and soil and plant studies have confirmed that leucaena exhibits better drought characteristics than a number of other tree legumes (Swasdiphanich 1992). Leucaena is a deep-rooted species which can extend its roots 5 m to exploit underground water (Brewbaker *et al.* 1972). In shallow duplex soils, roots have been observed to branch and grow laterally at only 30 cm depth due to an impermeable clay layer.

Leucaena is not tolerant of poorly drained soils, especially during seedling growth, and production can be substantially reduced during periods of waterlogging (see Figure 3.2.3). However, once established it can survive short periods of excess moisture.

Soil type

Leucaena does best on deep, well drained, neutral to calcareous soils; it is often found naturalised on the rocky coralline terraces of Pacific island countries. However, it grows on a wide variety of soil types including mildly acid soils (pH > 5.2). It is well adapted to clay soils and requires good levels of phosphorus and calcium for best growth.

Establishment

Slow establishment is still considered to be a major limitation to the expanded use of leucaena for grazing in Australia. In subhumid tropical Australia, where the psyllid has been less of a challenge, establishment failures were reported to occur in 64% of plantings made by farmers (Lesleighter and Shelton 1986). Slow seedling growth makes plants vulnerable to weed competition and attack by wildlife. In some cases, leucaena plantings in southern Queensland have taken up to 3 years to reach mature height before regular grazing could commence. Long delays before full utilisation commences adversely affects profitability. However, leucaena seedlings are not naturally slow growing and have been shown to reach 2 m in height within

14 weeks when growing in a fertile soil well supplied with water and nutrients (Ruaysoongnern *et al.* 1985).

Leucaena can therefore be established successfully and rapidly provided growth requirements are met. Full details are provided in Section 3.3 and are briefly summarised here.

Seed treatment

Freshly harvested leucaena often has a high degree of hard seed due to an impermeable waxy coat which must be broken before the seed will imbibe water and germinate. Scarification to break this dormancy usually involves treatment with hot water (boiling water for 4 s) or acid (concentrated sulphuric acid for 5-10 min). Seed must be inoculated before planting with a suitable *Rhizobium* strain. TAL1145 is recommended worldwide and in Australia was found to be more effective than the previously used CB81 to ensure effective nitrogen fixation. Lime pelleting will protect the *Rhizobium* bacteria in very acid soils.

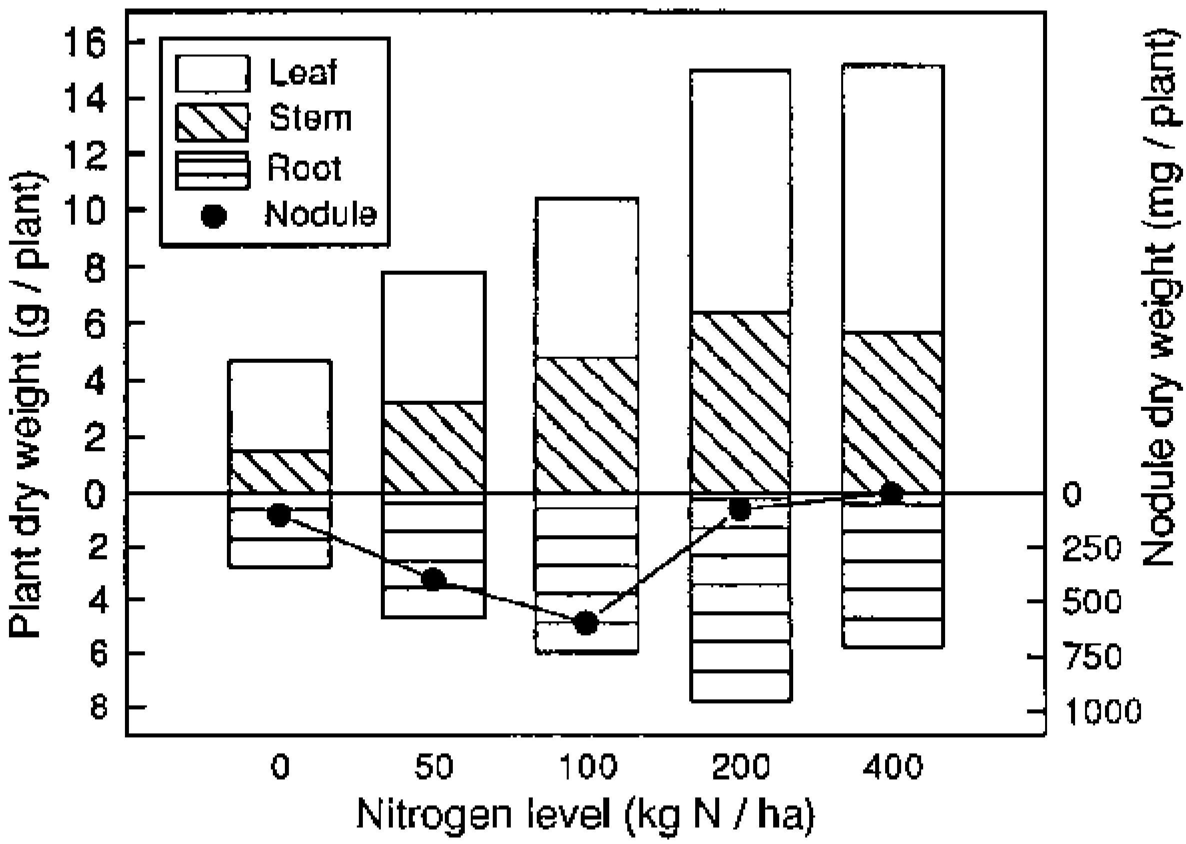
Planting

Leucaena can be planted by seed or 'bare stem' seedlings. Large areas are best planted by seed in rows into fully prepared seed beds or into cultivated strips in existing grasslands. Seeding rates of 1-2 kg/ha at depths of 2-3 cm are usually recommended in rows 3-10 m apart. Sowings are best made early in the growing season but when rainfall is reliable using good weed control measures (cultivation and herbicides) to minimise competition; leucaena seedlings are very susceptible to competition in the root zone. Trifluralin (0.5 kg active ingredient (a.i.)/ha) for grass species and Dacthal (8-10 kg a.i./ha) or 2,4-D amine (6 kg a.i./ha) for broadleaf species are recommended for pre-emergence control of weeds (Brewbaker *et al.* 1985). Fusilade (2 kg a.i./ha) and Basagran (2 kg a.i./ha) are recommended for post-emergence grass and broadleaf weed control respectively. Hand weeding or mechanical cultivation are also effective means of controlling weeds.

Fertilisation

Fertilisation at planting will be necessary on most soils to achieve vigorous seedling growth as many tropical soils are infertile following years of intensive cropping, leaching and erosion from high intensity rains. leucaena is particularly susceptible to phosphorus deficiency and is dependent on vesicular arbuscular mycorrhizae (YAM) to extend the capacity of its root system to access immobile nutrients such as phosphorus. In soils low in phosphorus, or low in natural VAM activity, quite high rates of phosphorus (100 kg P/ha) should be applied. Leucaena is also sensitive to calcium deficiency as this will reduce nodulation. Other nutrients may be necessary if soil tests indicate a deficiency, to ensure vigorous early growth of seedlings. In very acid soils (pH < 5.0), liming is necessary. In the past, 'starter' nitrogen was often applied as *Rhizobium* strains were slow to nodulate and begin fixing atmospheric nitrogen. 'Starter' nitrogen promoted both early growth and nodulation although very high rates tended to suppress nodulation completely (Figure 2.1.2). However, with the more effective *Rhizobium* strains currently available, 'starter' nitrogen should not be necessary although the use of nitrogen in nursery plantings is advised.

Fig. 2.1.2. Growth and nodulation of leucaena in response to applications of inorganic nitrogen (Sivasupiramaniam *et al.* 1986).



Planting configurations

Leucaena may be planted as single plants, single hedgerows or multiple hedgerows depending on its use. In the latter case, hedgerows may be closely spaced (75-100 cm) to achieve maximum yield per hectare for cut-and-carry feeding or more widely spaced (3-10 m) for alley cropping or grazing. Intra-row plant spacings of 25-50 cm are adequate. In widely spaced rows for grazing, grasses may be planted between leucaena rows to increase total fodder supply to animals. In Australia, green panic (*Panicum maximum* var. Trichoglume), setaria (*Setaria sphacelata*), pangola (*Digitaria decumbens*) and buffer grass (*Cenchrus ciliaris*) have been successful companion grasses for leucaena.

Productivity

Dry matter productivity of leucaena varies with soil fertility and rainfall. Edible forage yields range from 3 to 30 t dry matter/ha/year. Deep fertile soils receiving greater than 1,500 mm of well distributed rainfall produce the largest quantities of quality fodder. Yields in the subtropics, where temperature limitations reduce growth rates, may be only 1.5-10 t of edible fodder/ha/year (Brewbaker *et al.* 1985).

The most suitable cutting or grazing intervals to promote high yields vary with environmental factors. In general, longer intervals between defoliation have increased total yield; however, the proportion of inedible wood may also increase leading to a decline in forage quality. At very productive sites, harvest intervals may be 6-8 weeks and up to 12 weeks at less productive locations. Harvest height has less influence on total yield than harvest frequency.

Maintenance fertilisers are rarely applied to mature leucaena stands although nutrient deficiency can limit growth. Stands of leucaena at the Brian Pastures Research Station near Gayndah 400 km northwest of Brisbane were deficient in sulphur yet persisted and were successfully used to fatten steers. An indication of need for fertiliser application can be obtained from the chemical composition of young leaves. Table 2.1.2 shows critical nutrient values in index leaves of young seedlings and some typical nutrient concentrations in young leaves of vigorously growing leucaena plants. Concentrations substantially lower then these values can be regarded as deficient. Colour photographs of nutrient deficiencies on leucaena are shown in Smith *et al.* (1992).

Grazing management

In Australia, it is recommended that regular heavy grazing of leucaena does not commence until plants are mature and well established. This may take 1-3 years depending on growing conditions. However, light grazing can occur in the first year when plants reach 1.5 m in height especially if frosts and wildlife may damage leucaena plants during winter. Grazing promotes branching, results in a protective thickening of main stems and can remove flowers and pods which reduce growth rates.

Regular grazing of well established rows of leucaena leads to the development of quite uniform hedgerows. Taller plants or branches are readily broken and reduced in size by hungry animals. In Vanuatu and Papua New Guinea, cattle graze in leucaena thickets which may be up to 10 m in height. Cattle graze lower branches and newly emerging seedlings and the upper canopy is kept as a drought reserve. The amount of leucaena material available for grazing is reduced in this system of management. Leucaena paddocks are normally rotationally grazed with cattle moved to new areas when most leaf and edible stem have been removed and before serious damage to the wooden framework of the plants has occurred.

Appropriate stocking rates vary greatly from less than 1 beast to 1.5 ha in low rainfall environments (750 mm p.a.) up to 6 beasts/ha in fertile well watered or irrigated stands.

Table 2.1.2. Concentration of various elements in the young leaves of nodulated *Leucaena leucocephala* (Ruaysoongnern 1989, Jones 1979).

Element	**Critical concentrations in young leaves of cv. Cunningham**	**Concentrations in young leaves of cv. Peru**	
		Sample 1	**Sample 2**
N (/D)	4.1	4.1	5.4
P (%)	0.25	0.21	0.32
K (%)	2.0	1.5	2.01
S (%)	0.24	0.27	0.31
Ca (%)	0.49	0.66	0.98
Mg (%)	-	0.31	0.30
Na (%)	-	0.03	0.03
Cu (ppm)	-	7	9
Zn (ppm)	-	29	29

Mn (ppm)	325*	-	45
Fe (ppm)	-	-	164

* Critical concentration for toxicity

Animal production

Leucaena is well known for its high nutritional value and for the similarity of its chemical composition with that of alfalfa (Table 2.1.3). However, leucaena forage can be low in sodium and iodine, but is high in β -carotene. Tannins in the leaves and especially the stems of leucaena reduce the digestibility of dry matter and protein but enhance the 'bypass' value of protein.

Digestibility and intake values for leucaena range from 50 to 71% and from 58 to 85 $g/kg^{0.75}$ liveweight respectively (Jones 1979). The lower values were suggested by Jones (1979) to-be associated with the effects of mimosine on intake when pure diets of leucaena were fed.

Animal production on leucaena based pastures is excellent. In southeast Queensland, cattle on leucaena/setaria pastures gained between 310 and 430 kg liveweight/ha, approximately twice that obtained from siratro (*Macroptilium atropurpureum*) based pastures in the same environment (Jones and Jones 1984). In low frost environments, leucaena foliage can be heldover for feeding in the cool or dry season providing valuable high protein feed during stress periods for grazing ruminants. Under ideal growing conditions under irrigation on the fertile alluvial plains of the Ord River valley, leucaena/pangola (*Digitaria decumbens*) pastures produced annual liveweight gains of 273 kg/head or 1422 kg/ha at a stocking rate of 6 weaner steers/ha (Davison 1987). In central Queensland, on fertile clay soils, cattle are gaining 300 kg liveweight per head per year on leucaena pastures.

Table 2.1.3. Comparative compositions of alfalfa (*Medicago saliva*) and Malawi-grown leucaena (NAS 1977).

(a) General compositor	**Leucaena leaf**	**Alfalfa leaf**
Total ash (%)	11.0	16.6
Total N (%)	4.2	4.3
Crude protein (%)	25.9	26.9
Modified-acid-detergent fibre (%)	20.4	21.7
Calcium (%)	2.36	3.15
Phosphorus (%)	0.23	0.36
β -carotene (mg/kg)	536.0	253.0
Gross energy (kJ/g)	20.1	18.5
Tannin (mg/g)	10.15	0.13
(b) Amino acid	**Leucaena**	**Alfalfa**
Arginine (mg/gN)	294	357
Cysteine (mg/gN)	88	77

Histidine (mg/gN)	125	139
Isoleucine (mg/gN)	563	290
Leucine (mg/gN)	469	494
Lysine (mg/gN)	313	368
Methionine (mg/gN)	100	96
Methionine + cysteine (mg/gN)	188	173
Phenylalanine (mg/gN)	294	307
Threonine (mg/gN)	231	290
Tyrosine (mg/gN)	263	232
Valine (mg/gN)	338	356

These production figures are much greater than can be achieved from more traditional herbaceous legume based pastures and can be expected to be sustained over long periods. Leucaena hedgerows at the CSIRO Samford Station have been grazed for 25-30 years and continue to grow vigorously. The half-life of leucaena plants is thought to be over 50 years (Jones and Carter 1989). Such longevity is not available among herbaceous legumes. A more complete exposition of the grazing and supplementary feeding value of leucaena appears in Chapter 4.

Toxicity

The foliage and pods of leucaena contain the toxic amino acid mimosine which may reach 12% of the dry matter in growing tips but is less in young leaves (3-5% of dry matter) (Jones 1979). Although quite toxic to non-ruminant animals, mimosine is broken down by microbes in the rumen to DHP (3 hydroxy-4-(1H)-pyridone) a goitrogen, which is normally broken down further by rumen microorganisms to non-toxic compounds. The microbes are naturally present in ruminants in Indonesia and Hawaii and probably other countries of southeast Asia and the Pacific where there has been a long history of ruminant animals grazing naturalised leucaena.

However, in some countries, notably Australia, Papua New Guinea and perhaps African countries, the appropriate rumen microorganisms are not naturally present leading to an accumulation of DHP which causes goitre (enlargement of the thyroid gland) which results in listlessness, loss of appetite, excess saliva production, hair loss and loss of weight. However, this effect only occurs if leucaena constitutes a high proportion of the animal's diet (>30%) for an extended period. Details of the discovery of the microorganisms which break down DHP by Dr RJ. Jones of the CSIRO Division of Tropical Crops and Pastures are described in Lowry (1987) and in Section 4.4.

Procedures for the transfer of the appropriate rumen microbes among ruminants have been developed in Australia.

Pests and Diseases

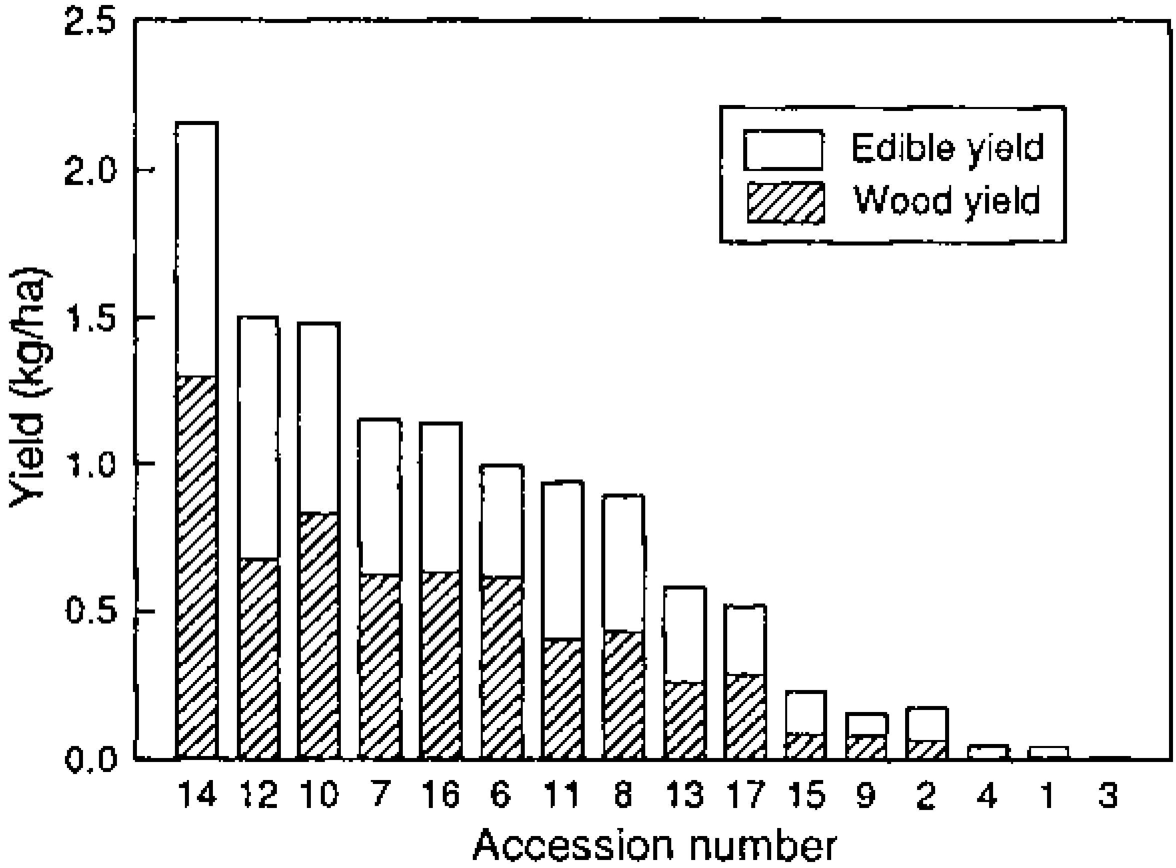
Until relatively recently, there were few pests of leucaena because of the insecticidal properties of mimosine. However, following the rapid movement of the leucaena psyllid

(*Heteropsylla cubana* westward from the Caribbean across the Pacific in 1985/86, large areas of previously productive leucaena in the Philippines, Indonesia and Australia have been affected. The psyllids or jumping lice are small aphid-like insects adapted to feeding on the young growing shoots of leucaena. Mild infestations cause distortion of leaves whilst heavy infestations result in loss of leaves and attack by secondary moulds which feed on the sticky exudate of psyllids. The psyllid is native to Central America. Bray and Woodroffe (1991) reported that psyllids reduced the production of edible material by 52% and that of stem by 79% in southeast Queensland. There is some scope for biological control from the beetle *Curinus coeruleus*, the parasitic wasp *Psyllaephagus* nr. *rotundiformus* and from resistance in the *leucaena* genus (Anon. 1990). More will be said of this problem in Section 6.1.

The most probable control of the psyllid will occur through the development of psyllid resistant hybrids. Leucaena hybridises readily with the species *L. pallida* and *L. diversifolia* both of which contain psyllid resistance. Breeding programmes to develop open-pollinated and F1 hybrid cultivars are well advanced (Brewbaker and Sorensson 1993). The yield of these psyllid resistant lines far exceeds that of susceptible *L. leucocephala* lines in high psyllid environments (Figure 2.1.3) and they are exciting prospects for future development.

A serious disease of seedling leucaena in nurseries is damping-off in moist soils caused by the fungal species *Pythium* or *Rhizoctonia* spp. (Brewbaker *et al.* 1985). This is controlled by good nursery techniques (overwatering promotes the disease) and use of well-drained soil media. The use of fungicides such as Benlate or Captan are also an option.

Fig. 2.1.3. Wood and edible forage yields of sixteen 9 month old lines of *Leucaena* grown at Redland Bay in southeast Queensland. Lines are: 1 = *L. leucocephala cv.* Cunningham; 2 = *L. leucocephala* K636; 3 = *L. leucocephala* Q25221; 4 = *L. leucocephala* CPI61227; 5 = *L. pallida* K818; 6 = *L. pallida* K803; 7 = *L. pallida* CSIRO composite; 8 = *L. pallida* K376; 9 = *L. diversifolia* K156; 10 = *L. diversifolia* CPI46568; 11 = *L. leucocephala x L. pallida* (KX2) K8xK376 (F2); 12 = *L. pallida x L. leucocephala* (KX2) K806xK636 (F1); 13 = *L. pallida x L. leucocephala* (KX2) K8xK376 (F1); 14 = *L. leucocephala x L. pallida* (KX2) K748xK636 (F1); 15 = *L. leucocephala x L. diversifolia* (KX3) K636xK156; 16 = *L. pallida* K806xK748; 17 = *L. pallida* K953 (A. Castillo and H.M. Shelton, unpublished data).



The moth *Ithome lassula* which damages leucaena inflorescences and the seed beetle *Araecerus levipennis* reduce the production and viability of seed.

Conclusions

Leucaena has played a valuable role in world agriculture over a long period of time. Its value is multifaceted and the potential for increasing and diversifying the use of this wonderful species is enormous. However, its future use in humid areas is currently in doubt because of the devastation caused by the psyllid. On an optimistic note, we hope for increasing populations of natural predators to give some biological control of the psyllid. Alternatively, the current worldwide coordinated move towards use of psyllid resistant hybrids is likely to lead to the development of genetic resistance. The future role and value of leucaena will depend on the outcome of these programmes.

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