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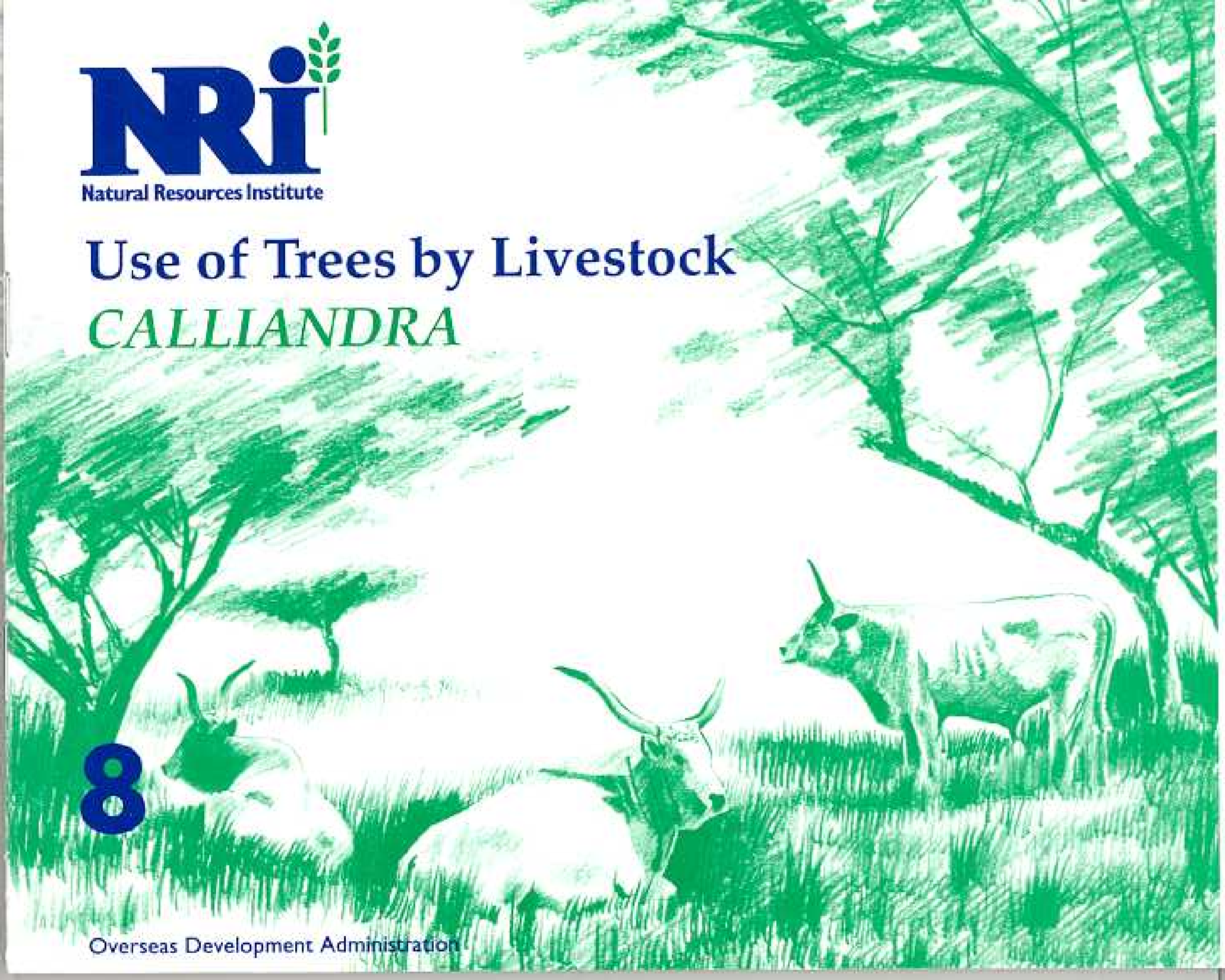
Use of Trees by Livestock

CALLIANDRA



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Overseas Development Administration

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R.T Paterson

Natural Resources Institute

Development Administration

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Contents

Foreword

The importance of trees and shrubs in the feeding of animals in the tropics and sub-tropics has long been recognized by livestock owners. In arid areas where the growth of herbaceous plants is limited by lack of moisture, leaves and edible twigs of trees and shrubs can constitute well over 50% of the biomass production of rangeland. At high altitudes, tree foliage may provide over 50% of the feed available to ruminants in the dry season, branches being harvested and carried to the animals. Even in regions of higher rainfall where grass supplies the major proportion of the dry matter eaten by ruminants, tree leaves and fruits can form an important constituent of the diet, particularly for small ruminants.

In the last two decades interest in the planting of trees as a source of feed for livestock has been encouraged by workers in research and development, but in contrast to the hundreds of indigenous species which are used as fodder, attention has focused on a limited number of introduced species. Thus there are rnany publications reporting the chemical composition of *Leucaena leucocephala* leaves and suggesting management strategies for utilization of the tree for fodder, but it is more difficult to find information on alternative genera which might be equally, or more, appropriate.

The aim of this series of publications is to bring together published information on selected genera of trees which have the potential to increase the supply of fodder for ruminants. Each booklet summarizes published information on the fodder characteristics and nutritive value of one genus, with recommendations on management strategies, where available. Further, since the leaves of woody species frequently contain secondary compounds which may have an anti-nutritional, or toxic, effect, a separate booklet summarizes the effects of a number of these compounds. It is hoped that the booklets will provide useful resource material for students, research and extension workers, interested in promoting the use of trees as a source of fodder for ruminants.

Further copies of this booklet or others in the series can be obtained by writing to Publishing and Publicity Services at the Natural Resources Institute.

Margaret Gill
Livestock Production Programme

Genus *Calliandra*

Family LEGUMINOSAE
Subfamily MIMOSOIDEAE
Tribe INGEAE

Principal species

Calliandra angustifolia
Calliandra calothyrsus (syn. *C. confusa*)
Calliandra haematocephala (syn. *C. inaequilatera*)
Calliandra houstoniana (syn. *C. houstoni, C. houstonii*)
Calliandra pittieri
Calliandra portoricensis (syn. *Zapoteca portoricensis*)
Calliandra surinamensis
Calliandra tetragolla (syn. *Zapoteca tetragona*)

Common names

Powder puff tree (or shrub)
Cabellos de angel (Central America)
Lehua haole (Hawaii)

Summary

Calliandra is a large genus of mainly tropical American shrubs and small trees. Many species produce attractive flowers and are valued by honey bees. Others are used for shade, green manure, reafforestation, fuelwood, charcoal and timber. Recently, attention has focused on its potential as a source of fodder for livestock, but published information is largely restricted to a single species, *C. calothyrsus*.

This species tolerates a wide range of soil conditions and persists in regions of low rainfall although it does best under 2000–4000 mm/year. It coppices readily and will tolerate frequent defoliation. It appears to be resistant to most pests and diseases and may become a useful alternative to *Leucaena leucocephala* in areas where psyllids are a problem.

The leaves of *C. calothyrsus* contain 20–22% crude protein and reasonable levels of minerals. It has no reported toxic effects on higher animals but its feeding quality is reduced by high levels of condensed tannins. Animal acceptance and digestibility are variable. It should be seen as a supplement for poor-quality roughage, and should be managed under systems of direct browsing or daily cutting.

Description and distribution

Calliandra is a large genus in which there is currently a degree of taxonomic confusion and synonymy (NRC, 1983). It is variously reported to consist of over 100 (NRC, 1983), some 150 (Allen and Allen, 1981), or up to 200 (Mabberley, 1987) species. It has recently been suggested that the genus should be split and species such as *C. portoricensis* and *C. tetragona* be consigned to the genus *Zapoteca*. This view is now generally accepted but for the purposes of this booklet they are treated as remaining within *Calliandra*. Most published information refers to *C. calothyrsus* but even within this species there is such a high degree of variation in agronomic characteristics and soil requirements that the accepted taxon could be considered a complex of more than one species (Netera *et al.*, 1992).

Members of the genus are frequently unarmed and usually exist as small trees or shrubs, although there are occasional large trees and perennial herbs. They are normally straggling, highly branched plants with bipinnate (compound) leaves which have a tendency to fold at night. The showy, attractive flowers, which are usually either red or white in colour, often resemble pompoms or powder puffs and give rise to the common name of the group–powder puff shrubs or trees. The pods are flat with raised margins, narrow at the base, and are elastically dehiscent from the apex. The seeds, up to 15 in a pod, are laterally compressed and germinate readily.

Calliandra spp. occur in a wide variety of habitats ranging from rainforest to dry mountain slopes. They are usually found at altitudes up to 1500–1800 m but some species such as *C. grandiflora* occur at up to 3000 m (Macqueen, 1993). Some species, and even accessions within species, appear to require fertile soils of neutral reaction, while others will tolerate infertile, acid soils with a high level of aluminium saturation. They are often good colonizers of denuded areas and will tolerate soils which are heavily compacted and poorly aerated. They persist in poorly drained, sloping, podzolic soils (Gutteridge, 1990), although Shelton *et al.* (1991) considered them to be moderately intolerant of waterlogging. They have a marked capacity to reduce soil erosion and have been successfully used for reafforestation in many areas (Allen and Allen 1981; NRC, 1983; Shelton *et al.*, 1991).

Nodulation has been validated and nitrogen fixation is assumed in 11 *Calliandra* spp. (Allen and Allen, 1981; Brewbaker *et al.*, 1990). Although estimates of the quantity of nitrogen fixed per year are largely unavailable, trees show little response to fertilizer nitrogen and they would therefore appear to be self-sufficient in nitrogen in most environments. Both fast and slow growing strains of *Rhizobium* have been isolated from *Calliandra* root nodules, and the genus appears to be promiscuous with regard to nodulation (NRC, 1983). There are reports of non-nodulating members of the genus but they are rarely substantiated and should therefore be treated with caution (Allen and Allen, 1981). The roots of naturally occurring strands of *C. calothyrsus* are usually infected by beneficial mycorrhizal fungi which assist in the absorption of phosphorus and other nutrients (NRC, 1983; Shelton *et al.*, 1991). It is not known if this is a general characteristic shared with other members of the genus.

Calliandra is considered to be native to the New World and it is well represented from the southwestern states of the USA, through Central America and into the warmer parts of South America, including Argentina and Chile. Some species are also found in India, Madagascar and West Africa (Dalziel, 1937; Uphof, 1968; Allen and Allen, 1981; Mabberley,1987). *C. calothyrsus* is widely commercialized in Indonesia and it was introduced into the region from Guatemala in 1936 (NRC, 1983; Baggio and Heuveldop, 1984).

Fodder characteristics

The species which has attracted most attention for its capacity to produce both fuelwood and foliage for either green manure or fodder is *C. calothyrsus,* a small tree which grows to about 10 m in height. It is of Central and South American origin, occurring naturally in moist, tropical regions up to an altitude of some 1500 m. While it grows up to 2000 m in Kenya, production is limited at this altitude, probably by the low temperatures (Lowry and Macklin, 1988). It appears to do best with annual rainfall in the range of 2000–4000 mm (NRC, 1983). While it will grow in areas that receive 700–1000 mm rain/year, productivity is reduced by low rainfall (Akkasaeng *et al.*, 1989). It is evergreen in humid environments but will shed its leaves during a long, dry season. Under conditions of severe drought, young stems and branches may die back, but they usually regrow when the rains return. Mature branches become brittle and may be easily broken by animals, although this is not a problem where judicious cutting is practised.

The palatability of the foliage appears to be variable but it is accepted, at least in limited quantities and when mixed with other feeds, by most livestock, including sheep, goats, cattle and water buffalo (Brewbaker *et al.*, 1983; NRC, 1983; Baggio and Heuveldop, 1984). It has been classified as unpalatable to rabbits, although they consumed significant amounts of it when mixed with grass and herbaceous leaves. Foliage of other fodder trees such as *Leucaena leucocephala* and *Albizia falcataria* were eaten in much larger quantities (Raharjo and Cheeke, 1985). In Java, *Calliandra* leaf meal is used at levels of up to 5% in diets for chickens (Panjaitan, 1988).

Until recently, most plantings of *C. calothyrsus* were based on seed from a limited number of provenances from poorly documented sites in Guatemala, Costa Rica and Honduras. In 1990, a programme was initiated by the Oxford Forestry Institute (based in UK) to collect seed over the entire natural range of this, and several other closely related *Calliandra* spp. The objective was to provide material both for testing in multi-locational trials for future breeding activities. Seed distribution for wide international assessment of provenances was expected to commence in 1993 (Macqueen, 1991; Pottinger, 1992), but was actually initiated in 1992 and greatly expanded in the following year (D. Macqueen, personal communication). Assessment is in the early stages but results of this work will become available in due course.

In Rwanda, infertile soils of pH 4.3 and 4.8, with low levels of aluminium saturation and rainfall of 1166–1564 mm/year, allowed satisfactory growth of *C. calothyrsus* in the absence of fertilizers, although there was a small positive interaction between applications of lime at 750 kg/ha and farmyard manure at rates of between 2.5 and 10.0 t/ha (Yamoah *et al.*, 1989). On acid (pH about 5), infertile soils with either high or low levels of aluminium saturation in both Australia and Indonesia, this species showed considerable promise when harvested at intervals of about threee months, outyielding both *Leucaena leucocephala* and *Gliricidia sepium*, particularly in the absence of fertilizer application (Bray *et al.*, 1989; Palmer *et al.*, 1989).

These results indicate the ability of *C. calothyrsus* to tolerate highly acidic and infertile soils.

In a pot experiment with soil limed at varying rates to adjust the acidity from pH 4.3 (no lime) to a maximum of pH 8.0, best growth of *C. calothyrsus* was obtained in the range of pH 6–8 (Hu *et al.*, 1983). Netera *et al.* (1992) showed considerable differences in growth characteristics between two lines of *C. calothyrsus* in a pot experiment on an infertile oxisol (pH 5 and aluminium saturation about 60%) from West Java. While these observations may indicate considerable genetic variation within the genus, the authors suggested that the line which showed poor adaptation to acid soil may be a species other than *C. calothyrsus*. They pointed out the need to detail the source of seed fully when quoting experimental results. This, however, is very rarely done at present.

In Java and Sumatra, at four sites between sea level and 920 m altitude, with soil pH at 5.6–6.9 and rainfall at 1200–3600 mm/year, *C. calothyrsus* produced higher yields of leaf material than seven other leguminous trees at the highest site, and was the second-best producer at two other sites (Panjaitan *et al.*, 1989). The *in vitro* dry matter digestibility as measured by the cellulase digestibility technique was relatively low however, ranging from 24.8% in a dry environment to 51.1% at a site with good rains in all months of the year. Despite the poor levels of digestibility, it was rated as the most agronomically adaptable of the species tested, comparing well with *Leucaena leucocephala, Gliricidia sepium, Sesbania* spp. and *Albizia falcataria* in terms of growth and resistance to pests and diseases.

On the island of Sumba (Indonesia), at altitudes of 500–1000 m and with shallow, clay loam soils, a series of leguminous trees was tested as potential alternatives to *Leucaena leucocephala* where psyllid *(Heteropsylla cubana)* attacks were a recurring problem. With annual rainfall of about 1000 mm spread mainly over a 5 month wet season, *C. calothyrsus* was considered to be useful, even though growth slowed dramatically with the onset of flowering, about 2 months into the dry season. With slightly higher rainfall (1200–1500 mm), *C. tetragona* (syn. *Zapoteca tetragona)* was found to be a more productive species but no information is available regarding animal production (Rourke and Suardika, 1990). In contrast to this report, NRC (1983) noted that *C. tetragona* was generally slower growing and less satisfactory than *C. calothyrsus* in

Indonesia. More work is required to clarify the situation regarding the relative merits, and perhaps even the delineation of these and other species of *Calliandra*.

There are few results available for *C. calothyrsus* planted specifically for animal production, but in an alley cropping experiment in western Samoa, cutting at 1.5 m every 4-5 months gave slightly higher yields of leaf dry matter over 13 months (12.9 t/ha) than cutting at 1 m (10.4 t/ha). Total biomass production (21.4 t/ha) was the same from both treatments and cutting height had no effect on the nutrient content of the foliage (Tekle-Haimanot *et al.*, 1991) In a separate 4-year alley cropping experiment in the same region, on a moderately fertile soil receiving annual rainfall of about 3000 mm, yields of taro *(Colocasia esculenta)* were slightly better with *Gliricidia sepium* hedges than when *C. calothyrsus* formed the hedges, even though annual applications of mulch from the *Calliandra* (9.6 t/ha DM) averaged 11% more than with the *Gliricidia* (Rosecrance *et al.*, 1992). There were no significant differences between species in terms of their effects on the physical or chemical properties of soil. On a relatively infertile soil of pH 6.3 and annual rainfall of 1250 mm in southwestern Nigeria, *C. calothyrsus* produced some 6 t DM/ha in non-wood prunings (leaves and small twigs) in four clippings per year. This provided some 200 kg/ha of nitrogen for use by plants as the mulch decomposed (Gichuru and Kang, 1989). The growth and performance of the *Calliandra* was comparable to that of *Leucaena leucocephala* as a hedge for alley cropping. It therefore represents a real alternative for regions where insect problems threaten the use of the better known species.

Crude protein (CP) contents of *C. calothyrsus* are often quoted at 20–22% (e.g. Ahn *et al.*, 1989) and some typical analyses are quoted in Table 1. In Sumatra, however, on an acid ultisol, Blair *et al.* (1988) obtained much lower CP values of 13.7%. The differences could be due to soil fertility, but they may be due to differences in accessions, or even species, of *Calliandra* since there is a degree of taxonomic confusion within the genus (Netera *et al.*, 1992). In common with several other tree genera on the acid soils of South Sumatra, the foliage of *C. calothyrsus* contained adequate levels of potassium, calcium and magnesium for animal production (Blair *et al.*, 1988), although it was poor in both phosphorus (0.11%) and sodium (0.01%). At three sites in Java, Jakarta and

Table 1 Proximate and fibre analyses of *Calliandra calothyrsus*

	Dry matter	Crude protein	Ash	Ether extract	*In vitro* DMD	NDF	Source
LEAVES	39.0	21.6			35.4		1
EDIBLE STEMS	25.1	11.7			42.8		1
LEAVES		19.5	7.5	2.4		49.0	2
LEAVES		13.7	4.9			63.4	3
LEAVES and EDIBLE STEMS	39.0	24.0	8.0	4.1		24.0	4
LEAVES		23.0	4.9		35.9 *(in sacco)*		5
DRY SEASON		17.7	5.1		49.5	46.7	6
		15.8	5.2		45.7	48.4	6
WET SEASON		17.5	4.9		51.5	52.5	6
		14.0	4.7		44.5	44.5	6

Notes: DMD – dry matter digestibility, NDF – neutral detergent fibre.

Sources: 1 Baggio and Heuveldop (1984); 2 Evans and Rotar (1987); 3 Blair *et al.* (1988); 4 Mahyuddin *et al.* (1988); 5 Ahn *et al.* (1989); 6 Akkasaeng *et al.* (1989).

North Sumatra, however, phosphorus levels of 0.16–0.19% were recorded by Panjaitan (1987), levels which appear to be marginal for beef cattle (McDowell *et al.*, 1983).

When wilted, fresh leaves and edible stems of C. *calothyrsus* were suspended for 48 hours in intra-ruminal nylon bags in steers maintained on a diet of Elephant grass *(Pennisetum purpureum)* and concentrates, DM disappearance was 51.0% (Mahyuddin *et al.*, 1988). When the material was dried, DM disappearance was reduced to 31.5–37.2% depending on the drying technique (either at differing temperatures in an oven, in the sun, or by freeze drying). Similarly, reductions in digestibility as a result of drying were measured using both *in vitro* pepsin-cellulase and rumen fluid-pepsin techniques. Oven-drying the fodder resulted in decreases in both total phenolic compounds and condensed tannins compared with freeze drying (Ahn *et al.*, 1989) and this was reflected in an increase in *in sacco* nitrogen digestibility in goats. Unfortunately, this work did not evaluate fresh, unwilted fodder.

In a recent, short-duration experiment using Merino wethers of about 27 kg liveweight, C. *calothyrsus* was fed as the sole dietary component. Daily DM consumption of fresh material (35% DM) was 5.9 kg/100 kg metabolic body weight and material wilted by a forced draught at ambient temperature (95% DM) was consumed at 3.7 kg/100 kg of metabolic body weight. These levels of voluntary intake are high, even for small ruminants, and indicate high acceptability of the foliage. In Droughtmaster steers, *in sacco* digestibility of wilted and oven-dried material was similar, and inferior to that of fresh foliage. Digestibility of fresh material was 60%, reducing to about 30% after only 6 hours of forced draught wilting (Palmer and Schlink, 1992).

These studies would appear to explain some of the conflicting reports regarding the acceptability, digestibility and feeding value of C. *calothyrsus*. The results quoted above suggest that in order to obtain maximum benefit from the feeding of this species, it should be used as a protein supplement for poorer quality roughage, either browsed direct, or offered in limited quantities to animals as soon as possible after cutting, at which time it will compare well with other tree foliage in terms of feeding quality. The species appears to have little potential for use as dried leaf meal, at least where ruminant animals are concerned, because of the rapid loss of digestibility after cutting.

Anti-nutritive factors

Toxic compounds such as alkaloids and cyanogenic glycosides do not occur in *Calliandra* spp. but a range of insecticidal, non-protein, sulphur-containing amino acids and rare imino acids have been found in the seeds and seedlings of a number of species. Only the amino acids have been isolated from mature leaves (Bleecker and Romeo, 1981, 1983; Romeo *et al.*, 1983). These compounds are known to have toxic effects against a range of leaf and seed-eating insects, and it is suggested that the seeds and tender young leaves, those parts which need most protection from the point of view of survival of the species, benefit from a dual defence mechanism comprised of both amino and imino acids. Mature leaves, which have had time to develop physical attributes such as toughness and waxiness, require only the protection conferred by the imino acids (Romeo and Swain, 1986). There are no reports of adverse effects of these compounds on higher animals.

In common with many other trees, *Calliandra* spp. appear to be characterized by high levels of phenolic compounds, including tannins. NRC (1983) reported that the level of vanillin-reacting compounds (condensed tannins) in leaves of *C. calothyrsus* seemed to be 1–3%, but in a more recent evaluation, the leaves of a single sample of this species contained 18.18% total phenolics. These compounds included condensed tannins of 11.07% when measured by the Vanillin-HCI technique, or 2.05% by the Butanol-HCI method (Ahn *et al.*, 1989). Such high tannin levels were reflected by in *sacco* nitrogen digestibility of only 35.9% in goats, a figure which confirmed *in vitro* dry matter digestibility of leaves of the same species of 35.43% (Baggio and Heuveldop, 1984). As noted above, the digestibility of *C. calothyrsus* decreases rapidly as the foliage wilts. The cause of this is not known, but it may be associated with the presence of unusually high levels of tannins (Palmer and Schlink, 1992).

Management

Calliandra spp. generally produce good-quality seed, but despite the presence of protective, insecticidal chemicals, the seed crop may be susceptible to destruction by insect pests. In Kenya, the rose flower beetle *(Pachnoda ephippiata)* and related species (*P. ancticollis* and *P. viridana)* feed on fruits, flowers and foliage of a number of trees and have been blamed for poor seed harvests of *C. calothyrsus*. Infestation appears to be aggravated by long spells of dry weather (Kaudia, 1990). In the Philippines, the larvae of an unidentified tussock moth have been reported attacking the flowers of *C. calothyrsus*. The moth has so far caused only minor damage but has the potential to become a significant pest (Braza, 1991). In both cases the tree was a recent introduction. It may be that chemical defences that evolved in the Americas proved to be ineffective against indigenous insect pests.

Seed of *Calliandra* spp. stores well, particularly under refrigeration, but this is not usually necessary as many species have long flowering periods and produce seed for most of the year. While the seed appears to germinate well without scarification, it has been suggested that germination may be speeded up by treatment with hot water, or by soaking in cold water. Recommended practices include pouring boiling water over the seed and allowing it to cool and soak for 24 hours (NRC, 1983), or immersion for 5 minutes in hot water, followed by soaking in water at room temperature. The latter method produced a germination rate of 77.3% in Costa Rica (Baggio and Heuveldop, 1984). Small seedlots may be scarified by nicking the coat of each individual seed.

As well as establishment either by direct seeding or by transplanting seedlings raised in nurseries *Calliandra* spp. reproduce readily by vegetative means. Both large stakes and young coppice with at least two nodes can be successfully rooted. Establishment is assisted by the use of indole butyric acid rooting hormone (Tomaneng, 1991), but readily achieved without chemical assistance.

After an initial establishment period, *Calliandra* spp. tolerate frequent, regular cutting. Established *C. calothyrsus* trees were pruned at intervals of 3 months over a 4-year alley cropping trial on an acid, infertile soil in West Sumatra. The trees remained productive under this management and overall survival rate was 97%, compared with 61% for *Paraserianthes falcataria Gliricidia sepium* had a survival rate of about 34% and only persisted where high levels of lime (2–4 t, had been applied to reduce the levels of aluminium saturation (Dierolf and Yost, 1989).

On an alluvial soil of pH 6 in South Sulawesi (Indonesia), trees were established from seedlings and allowed to grow in a pure stand for a year before being cut back to a height of 1 m. Subsequent regular cutting at 3-month intervals over an 18-month period resulted in 92% survival of trees of C. *calothyrsus*, while cutting every 6 weeks led to 81% survival. Leaf yield, particularly during the wet season, increased with increasing tree density in the range of 5000–40 000 trees/ha and also with the longer intervals between harvests. Overall, the cumulative yield of leaves was 8.5 t DM/ha/year (Ella *et al.*, 1989). The yield of Guinea grass *(Panicum maximum* cv. Riversdale), which was planted under the trees at the conclusion of the work described above, was reduced by the longer harvesting interval, particularly at higher tree densities. Overall, the understorey of grass produced yields of 7.2 t DM/ha/ year and the combination of grass and trees outyielded either component when grown in a pure stand. The presence of the grass did not change the behaviour of the trees. It was suggested that the grass and the trees obtained their moisture from different levels in the soil profile, and that during the dry season, the trees provided the grass with some protection from drying winds (Ella and Blair, 1989; Ella *et al.*, 1991 b).

Initial work on highly acid, volcanic soil in Costa Rica, in an area with annual rainfall of 2600 mm, suggested that trees of C. *calothyrsus* planted at spacings of 25–50 cm could be used as hedges to subdivide grazing areas. Rapid tree growth and high survival rates in the field produced plants of over 120 cm in height within 4 months of planting from seedlings raised in the nursery (Baggio and Heuveldop,1984). In general terms, the yield of leaf from fodder trees at subsequent harvests is positively related to the age of the tree at the first cutting, at least within the first year of two of its life. The yield differences are much less in C. *calothyrsus* than other tree species such as *Leucaena leucocephala* and *Gliricidia sepium*, however, and are almost negligible between 13 and 17 months (Ella *et al.*, 1991a). This would suggest that the first cutting of either hedges or individual trees could be carried out when convenient after a limited establishment period, without greatly influencing subsequent fodder production.

A range of fungal diseases including rusts, dieback, leaf blotch and pink disease have been recorded on *Calliandra* spp. in a number of countries.

They seldom become serious problems however, except where rough coppicing may allow infection to kill weakened tree stumps, particularly if they are cut too close to ground level. Scales and trunk borers are sometimes found on branches and stems, and loopers may damage some leaves. In plant nurseries, snails and rats occasionally destroy tightly packed seedlings, but in general terms *Calliandra* spp. appear to show good resistance to pests and diseases and control measures are rarely necessary (Lowry and Macklin,1988; Lenne, 1992).

Changes occur in the digestibility of the foliage in the first few hours after cutting which, together with the loss of leaves in response to severe moisture stress, highlights limitations in the selection of suitable animal management systems involving *Calliandra* spp. (Palmer and Schlink, 1992). Direct browsing or rotational harvesting programmes based on daily cutting and rapid feeding of small quantities of fodder, are favoured because of the ability of the plant to withstand frequent defoliation. Alternative sources of good quality fodder must be provided for the dry season however, when tree growth slows and there is a danger of losing the feed as a result of leaf shedding.

High levels of tannins in the foliage probably cause the relatively slow rate of microbial decomposition where *Calliandra* leaves are applied to the soil. This characteristic suggests that the species may be more effective as a mulch than as green manure in alley cropping systems (Salazar and Palm 1987).

Alternative uses

Members of the genus *Calliandra* are used for a variety of purposes in a number of countries (Uphof, 1968; Allen and Allen, 1981; NRC, 1983).

The wood is hard, heavy (specific gravity 0.5–0.8), strong but tending to become brittle at maturity, medium-textured, and easy to work, although it is not highly lustrous. Several species, including *C. formosa* (syn. *Zapoteca formosa)*, are used for small carpentry, implement handles and frames in tropical America.

The species are valued for fuel since they often exhibit high growth rates and respond well to coppicing.

The wood of *C. calothyrsus* dries rapidly and burns well, giving off 4600 kcal/kg of heat. It also makes good charcoal: in Indonesia it can produce annual yields of up to 14 t/ha of charcoal with a calorific value of 7200 kcal/kg. Some areas have been coppiced annually for more than 20 years, producing 35–65 m^3/ha/year of dry wood (NAS, 1979; Lowry and Macklin, 1988). The wood pulp is easily bleached and is used as a filler at levels of up to 10% in the making of paper.

C. calothyrsus is often used in reafforestation in Indonesia, to combat soil erosion and to recover and improve the fertility of bare and degraded land. It is attracting increasing attention for use as the hedge component in alley cropping systems (NRC, 1983; Gichuru and Kang, 1989). Although use is made of many naturally occurring *Calliandra* spp., only *C. calothyrsus* and *C. tetragona* (syn. *Zapoteca tetragona)* appear to have been planted for forestry purposes.

The bark of *C. anomala* (syn. *C. grandiflora) is* used in tanning in Central America, and the root is used to retard fermentation in the making of alcoholic beverages. In the past, the bark of *C. houstoniana* (syn. *C. houstonii)* has been marketed in Europe as a substitute for quinine, and as an antiperiodic.

Extracts from the roots of *C. grandiflora* have been used in Mexico to treat eye diseases, diarrhoea and indigestion, while in West Africa the dried and powdered leaves of *C. portoricensis* were sniffed to relieve headaches (Dalziel, 1937).

The flowering period of many species is long, and the nectar is attractive to honey bees. The honey from *C. calothyrsus* has a pleasing, bittersweet flavour and annual honey yields of 1 t/ha of tree plantation have been estimated in Java. The tree has also been shown experimentally to be a suitable host for the lac insect *Kerria lacca,* a valuable producer of shellac.

Most members of the genus produce attractive foliage and colourful flowers. Species such as *C. grandiflora, C. inaequilatera, C. surinamensis* and *C. tweedii* are particularly valued for their large flowers and these, and many other species are planted as individual trees or hedges in gardens and along roadsides and plot boundaries in many tropical countries.

Immature seeds of *C. calothyrsus* are eaten raw or fried by indigenous people in parts of Mexico (Macqueen, 1993).

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