



2.2 Gliricidia sepium - a Multipurpose Forage Tree Legume

A.J. Simons and J.L. Stewart

[Introduction](#)

[Taxonomy](#)

[Ecology](#)

[Distribution](#)

[Uses](#)

[Use of Gliricidia as a Forage](#)

[Conclusions](#)

[References](#)

Introduction

Gliricidia sepium is a medium-sized leguminous tree which occurs in abundance throughout its native range in Mesoamerica. Domestication of gliricidia has been in progress for several millennia and the multitude of indigenous common names from Mayan and Quiche peoples (Pertchik and Pertchik 1951) reveals the importance of this species to early occupants of the region. Spanish colonists adapted the local vernacular in naming the species 'madre de cacao' (mother of cocoa) to describe its use as a cocoa shade tree. The toxic properties of the seeds and bark of *G. sepium* give rise to the generic epithet of this species (*Gliricidia* = mouse killer) as well as a number of common names (e.g. mata-raton). Present day uses of this species throughout the native range (e.g. firewood, living fences, shade, construction and as an ornamental) are likely extensions of early utilisation and popularity (Rico-Gray *et al.* 1991).

Gliricidia sepium has also been used extensively outside its native range in places which include the Caribbean, the Philippines, India, Sri Lanka and West Africa. These landrace populations are largely remnants of colonial introductions used to shade plantation crops although more recently they have been integrated into indigenous farming practices being used for fuelwood, living fences, animal forage, green manure and soil stabilisation.

After *Leucaena leucocephala*, *G. sepium* is believed to be the most widely cultivated multipurpose tree. In many cases, gliricidia will yield as much as or more biomass than *L. leucocephala* (Stewart *et al.* 1992). One of the reasons for its recent popularity is its complete resistance to the defoliating psyllid (*Heteropsylla cubana*) which has devastated *L. leucocephala* in many parts of the tropics. This section describes the taxonomy, ecology, distribution and general uses of *G. sepium*, as a prelude to discussion of its use as a forage species.

Taxonomy

Botanical description

Gliricidia sepium is a small to medium-sized, thornless tree which usually attains a height of 10-12 m. Branching is frequently from the base with basal diameters reaching 50-70 cm. The bark is smooth but can vary in colour from whitish grey to

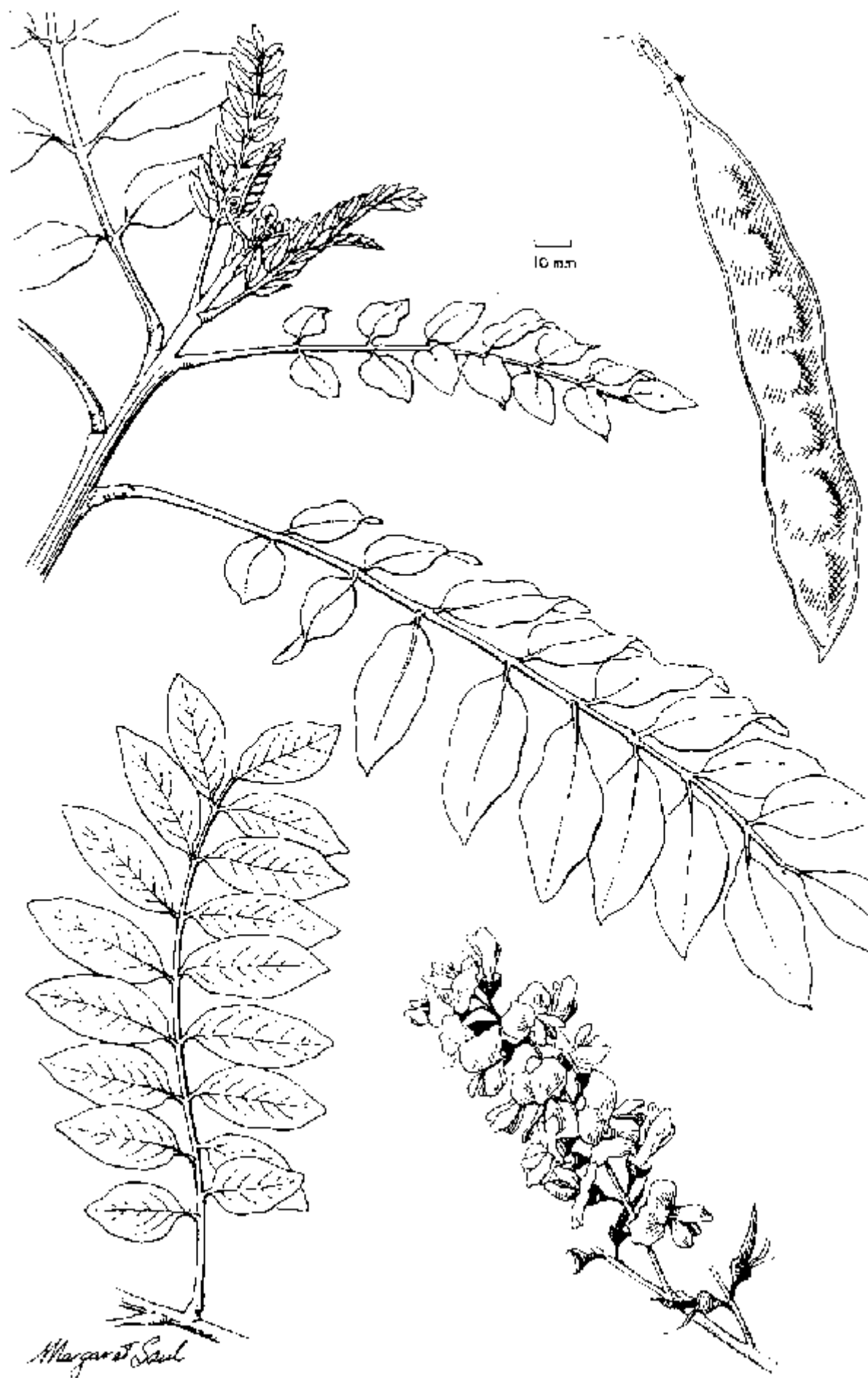
deep red-brown. The stem and branches are commonly flecked with small white lenticels. Trees display spreading crowns. Leaves are odd pinnate, usually alternate, subopposite or opposite, to approximately 30 cm long; leaflets 5-20, ovate or elliptic, 2-7 cm long, 1-3 cm wide. Leaflet midrib and rachis are occasionally striped red. Inflorescences appear as clustered racemes on distal parts on new and old wood, 5-15 cm long, flowers borne singly with 20-40 per raceme. Flowers bright pink to lilac, tinged with white, usually with a diffuse pale yellow spot at the base of the standard petal, calyx glabrous, green, often tinged red. Standard petal round and nearly erect, approximately 20 mm long; keel petals 15-20 mm long, 4-7 mm wide. Fruit green sometimes tinged reddish-purple when unripe, light yellow-brown when mature, narrow, 10-18 cm long, 2 cm wide, valves twisting in dehiscence; seeds 4-10, yellow-brown to brown, nearly round (modified from C.E. Hughes, unpublished data) (Figure 2.2.1).

Systematics

Gliricidia is a member of the sub-family Papilionoideae and lies within the tribe Robinieae (Lavin 1987). The genus *Gliricidia*, which has been previously ascribed to *Lonchocarpus* and *Robinia*, comprises a small, yet debated, number of taxa. It is most commonly known by its pink-flowered species, *G. sepium*, which is routinely observed throughout its natural range in the dry forest of the Pacific coast of Central America and Mexico (Hughes 1987). A closely related white flowered taxon, *G. maculata*, is less common although it is frequently confused with *G. sepium* despite its disjunct distribution in the Yucatan Peninsula. Most confusion of these two taxa has arisen in exotic locations where they are often treated as synonyms (see for example Falvey 1982) thus resulting in indiscriminate use of nomenclature in forestry literature (Whiteman *et al.* 1986, Reynolds 1988, Joseph *et al.* 1991).

Despite the sexual compatibility of these two taxa (A.J. Simons, unpublished data), there exists substantial evidence to confirm Rydberg's (1924) treatment of the white flowered entity as a distinct species. Lavin *et al.* (1991) showed distinction between *G. sepium* and *G. maculata* based on studies of chloroplast DNA polymorphisms. Simons and Dunsdon (1992) present 12 separate characters that can be used to distinguish these species, some of which have only recently become known (e.g. molecular markers, seed diameter, stem form) with the provision of trial material grown under uniform conditions.

Fig. 2.2.1. Leaves, flowers and pod of *Gliricidia sepium*.



Ecology

Despite the widespread present occurrence of *G. sepium* in cultivation throughout Central American countries and Mexico, it is likely to be native only in the seasonally dry forest (Hughes 1987). It is largely deciduous during the dry season which runs from January to the first rains in May. In areas where sufficient moisture prevails, however, the tree does not become leafless (e.g. Kalimantan, Indonesia; Seibert 1987). Flowering begins at the start of the dry season and can continue in some native populations until the end of March. Altitude was suggested by Hughes (1987) to exert a large influence on the onset of flowering with lower coastal sites flowering well before sites at higher altitudes (i.e. up to 1,200 m). The periodicity of pod ripening is partly dependent upon the climatic conditions and typically takes 45-60 days. *Gliricidia sepium* in cultivation in wet areas may often flower, although sets little if any fruit.

Seeds are shed from pods through explosive dehiscence with seed dispersal distances of up to 40 m (Simons and Dunsdon 1992). No scarification or pretreatment of seeds is required prior to germination, and germination rates above 90% are typical. Following germination, trees grow extremely quickly and may attain a height of 3 m before flowering at age 6-8 months (Simons and Dunsdon 1992). Its rapid growth makes it an aggressive pioneer capable of colonising secondary forest and fallow *Imperata* dominated grassland often forming dense, pure stands (Anoka *et al.* 1991).

Individual trees display vast numbers of flowers (up to 30,000) which attract a wide variety of insect visitors. Foremost amongst these is a conspicuous species of carpenter bee (*Xylocopa fimbriata*) that was suggested by Janzen (1983) and confirmed by Simons and Dunsdon (1992) to be the primary pollinator of *G. sepium*. *Xylocopa fimbriata* is a large (up to 30 mm in length), solitary bee that is principally attracted to the abundant nectar of *G. sepium*, and is capable of flight distances of several kilometres thus effecting pollen dispersal at great distances between parents. Another genus of large bees (*Centric* sp.) was also observed to visit *G. sepium* trees in Guanacaste, Costa Rica (Coville *et al.* 1986).

The temperature requirements of *G. sepium* are not too exacting as shown by the wide variation in mean monthly temperature (20.7-29.2°C) at native sites. It will, however, not tolerate frosts which partly explains its absence above 1,200 m in the native range. Whiteman *et al.* (1986) in southeast Queensland, found that trees became leafless when night temperatures fell below 15°C. *Gliricidia* can, however, be managed in a coppice system in areas with light frost, by cutting the new growth before frosts occur (Stewart *et al.* 1992).

The 30 sites sampled by Hughes (1987) in his range-wide collection of populations of *G. sepium*, represent a great diversity of soil types. Most of the soils were highly eroded, of acid reaction (pH 4.5-6.2) originating from volcanic parent material but also included sands, heavy clays and calcareous limestone soils which were slightly alkaline. At exotic locations, such as Peru, Szott *et al.* (1991) suggested that *G. sepium* was suitable for acid, infertile soils. Furthermore, Whiteman *et al.* (1986) considered *G. sepium* to be well adapted to low calcium soils in Australia, although *G. sepium* was seen to have poor survival on Indonesian soils with high aluminium saturation (Dierolf and Yost 1989).

A common feature of seasonally dry regions of Central America and Mexico is the perennial fires which burn through fallow agricultural land and secondary forest. *Gliricidia sepium* tolerates fires well and trees quickly resprout with arrival of the rains. The increased frequency of fires through deliberate burning may be responsible for the high occurrence of *G. sepium* in secondary vegetation and agricultural fallows.

Holm *et al.* (1979) report *G. sepium* as a severe weed in Jamaica, whereas Hughes and Styles (1984) consider *G. sepium* to have only a slight weediness hazard.

Distribution

Native range

Standley and Steyermark (1946) were the first to document the native distribution of *G. sepium* and recorded its occurrence up to an altitude of 1,600 m from Mexico through Central America to northern South America. Acceptance of this distribution by later reviews include those of NAS (1980) and Falvey (1982). Given Lavin's (1987) investigations, however, the higher elevation specimens may have been *Hybosema ehrenbergii*.

Hughes (1987) was the first to distinguish between native and naturalised distributions of *G. sepium* in his comprehensive genecological survey of the native range. In his tentative distribution map, Atlantic coastal populations and northern South American populations were assigned as naturalised thus restricting native sites to only the dry forests of the Pacific coast in Mexico and Central America. The sites sampled by Hughes ranged in altitude from sea level to 1,100 m, and in annual rainfall from 650 to 3,500 mm.

Exotic distribution

The earliest documented case of the use of *G. sepium* as an exotic is provided by Wiersum and Dirdjosoemarto (1987) who cite the Spaniards as taking it to the Philippines in the early 1600s. It has also been used for several centuries in the Caribbean where again the Spanish introduced it to shade cocoa (Ford 1987). *Gliricidia sepium* was introduced into Sri Lanka in the 1700s to shade tea plantations, although the Sri Lankan material came from Trinidad where it is not native. This introduction was purportedly from seed of just one tree (Hughes 1987). Liyanage (1987) records the presence of both white (*G. maculata*) and purple (*G. sepium*) flowered trees of gliricidia in Sri Lanka indicating several later introductions may have ensued. From Sri Lanka, it has spread out to India, Indonesia, Malaysia and Thailand. Similar introductions occurred in West Africa and Uganda to provide shade trees for plantation crops (Atta-Krah 1987, Tothill 1940).

Most exotic introductions are from unknown origin and are likely to be narrowly based. This supposition is supported by the findings of Bumatay *et al.* (1987) who found local seed sources from the Philippines to be inferior to the new collections made by Hughes (1987). Local landraces in Sri Lanka, Indonesia and Nigeria have also been shown to be outperformed by populations collected by Hughes (Simons and Dunsdon 1992).

Certain problems have emerged as a result of growing *G. sepium* in exotic environments. Foremost among these are pest and pathogen considerations. A number of insect pests attack *G. sepium* in the Caribbean including aphids, mealy bugs and scale (Ford 1987). In India, Subramaniam (1977) and Devasahayam *et al.* (1987) reported predation of *G. sepium* by a bud weevil and a hepialid (*Sahyadrassus malabaricus*), respectively.

Agnihotrudu (1961) reported problems with a foliar disease (*Pellicularia filamentosa*) of *Paraserianthes falcataria* being pathogenic to *G. sepium*. In addition, a root fungus attacked *G. sepium* in Trinidad although Ford (1987) did not consider this to be serious. Two foliar diseases were recorded on *G. sepium* in Nigeria, namely *Colletotrichum gloeosporioides* and *Cercosporidium gliricidiasis* (Lenné and Sumberg 1986). Lenné (1992) attributes the lack of many diseases on gliricidia to its tendency to be leafless for periods of the year thus reducing the likelihood of epidemics (Section 6.2).

Other biological problems have also arisen when *G. sepium* is used as an exotic. The lack of flowering at sites where no distinct dry season exists (e.g. Kalimantan,

Indonesia; Seibert 1987) is undoubtedly climatically induced. Where flowering occurs but no fruit develop to maturity, climate is also likely to be implicated; however, the lack of suitable pollinators may also account for this. Pod set was reported by Sumberg (1985) to be particularly low in Nigeria. Furthermore, Akkaseng *et al.* (1986) emphasised the importance of identification of suitable rhizobial strains for *G. sepium* when used as an exotic.

Uses

Few non-industrial tree species embody the concept of a multipurpose tree better than *G. sepium*. Throughout both its native and exotic ranges it is used to supply tree products such as fuelwood, construction poles, crop supports, green manure, fodder and bee forage. In addition, it is used in living fences, to stabilise soils and prevent erosion, to shade plantation crops, as an ornamental and in traditional medicine for eczema. Generally, however, it is cultivated for a particular purpose and the additional benefits are appreciated but not necessarily demanded, thus the concept of one individual tree supplying all of the above products is illusory.

A review of the main uses of *G. sepium* is given below.

Fuelwood

The easy coppicing nature of *G. sepium* contributes to its acceptability as a source of fuelwood. Fuelwood is obtained in its native range through the occasional lopping of branches or by completely coppicing trees to low levels above ground. Smaller diameter wood is not prized as much as larger diameters because of its lower specific gravity. Most wood of *G. sepium* that is collected is for self-consumption.

Wood of gliricidia burns slowly thus producing good embers, and gives off little smoke or sparks explaining its general acceptability (CATIE 1986). It has a good heating value (19.8 MJ/kg) with an average specific gravity of 0.5-0.6 (Withington *et al.* 1987).

Accumulation of woody biomass by trees of *G. sepium* is very much dependent on climate and soils, management, planting density, length of rotation and the provenance used. Salazar (1986) reports dry wood yields of up to 6.3 t/ha/year from trees in Costa Rica, whereas Wiersum (1982) quotes yields of 1520 m³/ha/year. In the Philippines, where *G. sepium* is grown in woodlots on a three-year rotation to provide wood for tobacco curing, yields of up to 23-40 m³/ha/year have been obtained (Wiersum and Dirdjosoemarto 1987).

An International Provenance Trial Series of *G. sepium* was set up by the Oxford Forestry Institute (OFI) in the mid-1980s. In total, more than 100 trials were established throughout the tropics under one of two management systems, namely (i) pure-plot plantations for wood production and (ii) hedgerow system for leaf production. The results from these trials indicated that there were marked differences between provenances with up to 500% differences in biomass production at some sites (Simons and Dunsdon 1992). One provenance from Guatemala, Retalhuleu, showed stable and superior production for both leaf and wood production across a wide range of sites. Another provenance from Guatemala, Monterrico, showed poor growth in terms of wood production yet was outstanding for leaf production. Progeny trials have now been set up of some superior provenances so that genetic parameters may be calculated with a view to converting the trials into seedling seed orchards to satisfy the demand for seed of this species.

Living fences

A distinct advantage of *G. sepium* is its ability to root from cuttings or stakes with high attendant survival. Stakes up to 2 m in length and 10-15 cm diameter can be

placed directly in the ground, a point reflected by one of its common names, 'quick stick'. The benefit of using long stakes is that they are not grazed out and compete better with other vegetation relative to seedlings. Liyanage and Jayasundera (1989), however, reported that plants of *G. sepium* grown from seed were more productive, hardier and developed a deeper rooting system than plants derived from cuttings.

Several thousands of kilometres of living fences have been planted in both dry and wet sites throughout Central America and Mexico. These are commonly pollarded at a height of 1.0-2.5 m, and generally at least once per year. Individual posts may last beyond 30 years whilst loppings provide a ready supply of replacement posts. Loppings may also be used for animal forage or firewood whilst the spreading crowns of fenceline trees give shade and shelter to livestock. Living fences are used in the native range by a wide cross-section of the community from wealthy cattle ranchers who use it for pasture fences to resource-poor campesinos who use it to mark boundaries and keep livestock out of cropped fields. Homestead gardens or domestic livestock may also be fenced off with closely spaced living fences of *G. sepium*.

At exotic locations, gliricidia has also been used extensively as a living fence. In Bali, slanting interweaved cuttings of close spacing are used to create wire-free fences (Figure 2.2.2), or alternatively, larger cuttings are used to support bamboo poles strung between them. Sri Lankans frequently use very closely spaced smaller diameter cuttings to create a dense barrier around home gardens.

Considerable research has been carried out on the appropriate age of cuttings, method of propagation, best length and diameter, and even on the optimal lunar phase when cuttings should be taken (Duguma 1988, Yamoah and Ay 1986, Withington *et al.* 1987).

Fig. 2.2.2. *Gliricidia sepium* used as a living fence in Bali, Indonesia.

Green manure

A less historic use of gliricidia but one that is increasing in occurrence is the use of leaves as a green manure; however, only isolated examples of mulching or incorporation of leaves into soil (e.g. El Gariton, Guatemala) are evident in the native range. Greater use of gliricidia as a green manure has been made outside the native range with reports as early as the 1930s in Malaysia (Anon. 1934) and Sri Lanka (Joachim and Kandiah 1934) on its benefits.

In Sri Lanka, gliricidia has been grown between rows of coconuts and found to be an excellent organic fertiliser (Liyanage 1987). In Western Samoa, taro yields have been increased by up to 54% with the addition of gliricidia leaf mulch (Kidd and Taogaga 1985). Leaf mulch of *G. sepium* increased the yield and reduced time to harvest of yam tubers in the Ivory Coast (Budelman 1989). Similarly, rice yields were boosted by up to 77% through the use of *G. sepium* mulch (Gonzal and Raros 1988). In addition, where *G. sepium* was used as a mulch in rice fields, the incidence of a rice leaf blight disease was reduced through stimulating growth of saprophytes parasitic to the causal organism (Rajan and Alexander 1988).

Patil (1989) stated that 1 tonne dry weight of leaves was equivalent to 27 kg N while Kang and Mulongoy (1987) reported that up to 15 t/ha/year of gliricidia leaf biomass could be produced on good soils in Nigeria providing the equivalent of 40 kg N/ha/year. These figures are likely to be underestimates since they do not account for nutrients arising from the sloughing of roots and nodules after pruning. Bindumadhava Rao *et al.* (1966) reported that 400 coppiced trees grown around the field perimeter could provide sufficient fertiliser for 1 ha of paddy rice.

The half-life of prunings of *G. sepium* reported by Wilson *et al.* (1986) to be 20 days, has been found to be relatively short compared with that of *Leucaena leucocephala*

and *Flemingia macrophylla* (Budelman 1988).

The timing and frequency of coppicing to produce the most biomass at the right time of year was investigated by Ella *et al.* (1989) in Sulawesi, Indonesia. They found that the optimal cutting interval of hedges of *G. sepium* was 12 weeks and that higher densities, even up to 40,000 trees per hectare, were preferable to lower densities. Widiarti and Alrasjid (1987), also in Indonesia, concluded there was no difference in biomass production from coppicing heights of 20, 40 or 60 cm above ground.

Shade

Gliricidia sepium derives many of its common names (e.g. madre de cacao) from its use in its native range to shade cocoa and coffee plantations. As an exotic, *G. sepium* has also been used extensively as a shade tree and the largest single cocoa plantation in the world (12,000 ha), in Indonesia, uses *G. sepium* as the sole shade tree (Seibert 1987). The landraces which have developed in exotic locations are largely remnants of populations chosen for their arboreal form and may not be optimally suited for other uses.

An additional benefit found from shading tea in Sri Lanka with trees of *G. sepium* was reduction in the incidence of termites (Kathiravetpillai 1990).

Use of Gliricidia as a Forage

Gliricidia is an important forage crop in cut-and-carry systems in many parts of the tropics including southeast Asia, Sri Lanka and the Caribbean (Falvey 1982, Chadhokar 1982). In other areas such as West Africa, India and the Philippines, however, its use is severely limited by apparent palatability problems (Mahadevan 1956, Trung 1989). Gliricidia is also little used as forage within its native range in Central America. This is partly because extensive grazing systems are preferred over stall feeding in Central America but there may also be a palatability constraint since little grazing of trees is evident. In Costa Rica, for example, prunings from live fences are sometimes left outside the fields, out of reach of the cattle, even where the pasture is in poor condition.

Despite these mixed perceptions of gliricidia as a forage crop, its use has been widely promoted and researched, due largely to its high productivity and quality. Interest in gliricidia for fodder has increased in recent years following the widespread defoliation of *Leucaena leucocephala* by the psyllid. Gliricidia is one of the few forage tree species capable of leaf yields comparable to those of leucaena and it will grow on a wider range of soils tolerating low pH provided that this is not associated with high aluminium saturation.

Leaf biomass production

Gliricidia resprouts vigorously after lopping and will tolerate repeated cutting. Moreover, its phenology is affected by cutting, with resprouts retaining their leaves in the dry season in the tropics when older shoots are deciduous. Management by lopping thus greatly enhances the value of gliricidia as a dry season forage.

Numerous studies have measured leaf biomass (dry matter) production under a range of climatic and edaphic conditions, and under various management regimes differing with respect to variables such as establishment methods (seedlings versus stakes of various sizes), plant spacing, lopping height and lopping frequency. Values reported for gliricidia annual leaf dry matter production generally range from about 2 t/ha/year (Wong and Sharudin 1986) to 20 t/ha/year (Sriskandarajah 1987).

Ella *et al.* (1989) found that as plant spacing was reduced, yield per plant decreased owing to competition, but total forage yield per unit area increased, as did the leaf:wood ratio. They also obtained the highest leaf yields at a planting density of 4

trees/m², the highest density tested. In hedgerow plantings, however, intra-row spacing seems to have little effect on overall yield, as lower individual tree productivity is compensated for by higher plant density. Atta-Krah and Sumberg (1987) recommended an intra-row spacing of 10 cm, but found only small differences in productivity for spacings ranging from 4 cm to 50 cm. In the same study, plants propagated from stakes were initially much more productive than those grown from seed, but by the fifth harvest (one year after the first) the difference was no longer significant.

The ease of propagation from stakes is a major advantage of gliricidia, especially as trees managed for leaf production with frequent cutting may not flower and thus set no seed. Furthermore, seed production in gliricidia depends on a marked dry season. Large (up to 1 m long) stakes are generally found to give the best establishment and subsequent growth (e.g. Adejumo 1991).

The optimum frequency of lopping for leaf production depends on the local climate; clearly trees can be lopped more frequently in the wet than in the dry season. In general, total annual biomass yield increases with less frequent cutting, but as this also increases the wood:leaf ratio the effect of cutting interval on leaf yield is less pronounced (Ivory 1990). For gliricidia grown in the humid tropics and used only for forage, a cutting interval of 6-12 weeks is usually recommended. On a subtropical site in Australia, however, Gutteridge and MacArthur (1988) obtained higher leaf yields from one harvest per year than from three to six harvests.

Nutritive value, anti-nutritional factors and palatability

Gliricidia sepium leaves have a high feeding value, with crude protein comprising 20-30% of the dry matter, a crude fibre content of only about 15%, and in *vitro* dry matter digestibility of 60-65% (Göhl 1981, Adejumo and Ademosun 1985). Panjaitan (1988) found that in Indonesia, gliricidia leaves had higher crude protein content in the wet season than in the dry season. Perera *et al.* (1991) reported high digestibility of gliricidia in the rumen relative to other multipurpose tree forages. Moreover, the dry matter digestibility was increased by the addition of energy sources such as cassava to the diet (Ademosun *et al.* 1985). Conversely, the digestibility of low quality feeds can be increased by the addition of legume leaves (Ivory 1990) (Section 4.2).

The apparent high quality of gliricidia leaves, combined with high and sustainable biomass production, should make gliricidia at least as important a forage crop as leucaena, but its use is severely limited by palatability problems, as well as by concern over possible toxicity.

The toxic effects of gliricidia are well known in its native range in Central America, where the leaves or the ground bark, mixed with cooked maize, are used traditionally as a rodenticide (Standley and Steyermark 1946). This toxicity is thought to be due to the conversion by bacteria of coumarin to dicoumerol, a haemorrhagic compound, during fermentation. There have also been reports of toxicity and growth inhibition in other monogastric animals including poultry (Raharjo *et al.* 1987) and rabbits (Cheeke and Raharjo 1987). There is little evidence, however, of toxic effects on ruminants fed either fresh or wilted leaves and gliricidia is also relatively low in tannins compared with other forage tree legumes such as *Calliandra calothyrsus*. According to Lowry (1990), the only real constraint to its feed value for ruminants lies in its palatability. Animals seem to refuse gliricidia leaves on the basis of smell, often rejecting it without tasting it, which suggests that the problem lies with volatile compounds released from the leaf surface.

The apparent variation in the acceptability of gliricidia to animals remains a major enigma. In some areas such as Colombia and Sri Lanka, there appears to be no palatability problem and gliricidia is therefore one of the most important dry season

forages in these areas. In an experiment in Guatemala, voluntary intake of gliricidia by lactating cows was higher than either leucaena or *Guazuma ulmifolia* (Vargas *et al.* 1987). Elsewhere, however, gliricidia is perceived as completely unacceptable to animals and is not used at all as forage despite its high nutritive value. In feeding trials in Nigeria where a Panicum/gliricidia mix was offered, Ndama cattle selected out the grass and left the gliricidia (J. Cobbina, personal communication). A number of methods are used to increase its acceptability. These include wilting, addition of molasses or salt, and accustomisation of the animals by prolonged exposure and/or penning with adapted animals.

Wilting gliricidia leaves for 12-24 h before feeding is found to increase intake markedly in many of the areas where gliricidia is used as forage, and is therefore recommended wherever palatability problems occur (e.g. Hawkins *et al.* 1990). The reason for this effect is not known but if, as suggested above, acceptability is limited by volatile compounds given off from the leaves, wilting presumably changes the composition of these volatiles resulting in a more acceptable odour.

Differences in management do not, however, fully explain the apparent differences in palatability. For instance, Perera (1992) reported that in Sri Lanka gliricidia cannot be used as a live fence in goat pastures because of browsing of stems and bark as well as leaves, whereas in other areas, the animals will not even eat the leaves unless they are wilted. In the Philippines, Perino (1979) found that gliricidia was seldom browsed by either wild or domestic animals. Other possible reasons for the variation in palatability in different parts of the world include climatic or edaphic effects on leaf chemical composition, differences in behaviour or in rumen flora between animals in different places (whether genetically or environmentally caused), or genetic variation in the gliricidia itself. There is some anecdotal evidence to support this last theory: according to Glander (1977), for instance, howler monkeys foraging in Costa Rica feed selectively on only a few gliricidia trees in a large population. In a 'cafeteria' trial in Nigeria using 30 provenances of gliricidia, sheep showed clear preferences for some provenances over others (A. Larbi, personal communication). The hypothesis that differences in acceptability are genetically determined is currently being tested in a project based at the OFI using a combination of analytical techniques and feeding trials. If significant differences between provenances are found, palatability should be included among the selection criteria in future genetic improvement of gliricidia.

Use of gliricidia as a feed

Gliricidia is generally used as a high protein supplement to low quality basal feeds such as grass, straw and other crop residues. Supplementation levels vary but are usually in the range 20-40%. There are numerous reports of increases in weight gain and milk production in both large and small ruminants when gliricidia forage is used as a supplement. Nochebuena and O'Donovan (1986) reported that for Tabasco sheep in Mexico, both intake and dry matter digestibility increased when gliricidia was used as a supplement, up to 30% of the diet, with grass hay. Chadhokar and Kantharaju (1980) found that gliricidia supplementation levels up to 80% increased survival and growth of Bannur ewes and lambs in Sri Lanka, and Van Eys *et al.* (1986), among others, have demonstrated an increase in live weight gain for goats fed Napier grass supplemented with gliricidia. For large ruminants, Chadhokar and Lecamwasam (1982) and Premaratne (1990) reported increases in live weight gain for milking cows and buffalo respectively on low protein diets supplemented with gliricidia, although supplementation levels over 50% are reported to cause tainting of the milk.

Carew (1983) has suggested that *G. sepium* may also be used as a sole protein source for ruminants. Indeed, in Sri Lanka during the dry season, gliricidia is commonly the sole feed of domestic goats (Perera 1992). Liyanage and Wijeratne (1987), however, found that with Sri Lankan heifers, a gliricidia/*Bracharia milliformis*

(grass) mixture (1:1) gave greater live weight gain than gliricidia alone. Kabaija and Smith (1989) concluded that *G. sepium* could also provide all livestock mineral requirements if fed as sole feed, except for Cu and P which may need to be supplemented. However, the use of pure gliricidia is unusual, even during the dry season. According to Preston and Leng (1987), the growth rate of steers in Colombia fed on King grass supplemented with gliricidia increased curvilinearly with supplementation level, with the highest growth rate at about 30% gliricidia. This result is in agreement with much of the research published to date, that about 30% is the level at which the gliricidia protein is most effectively used, in mixture with low quality basal feeds.

Conclusions

Gliricidia sepium is an extremely versatile plant which can fulfil a number of roles in smallholder agricultural production systems. It is considered by many to be the second most important multipurpose tree legume after *Leucaena leucocephala* in the humid tropics. It is a species of wide-ranging soil and climatic adaptations. Consequently, it has been transported to most tropical countries and is now pantropical in distribution.

However, its value and benefits are not universally accepted as there is still debate concerning the quality of its forage. Mackenzie (1986) suggested it may not be a really useful exotic in rural communities in West Africa despite its abundance in the landscape. Hughes (1987) suggested that one reason for its poor performance in some areas may be a result of early exotic introductions coming from a very narrow genetic base.

Nevertheless, gliricidia is an extremely valuable plant in tropical farming systems and recent provenance evaluations coordinated by the OFI have highlighted superior genotypes. These and other evaluation studies will produce material that will further improve biomass production and extend the ecological range of the plant and also help to overcome some of the perceived deficiencies within the currently used provenances.

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