

Use of Trees by Livestock

GLIRICIDIA

3



Use of Trees by Livestock

GLIRICIDIA

Jennison and R.T. Pinner



The scientific arm of the
Development



© Crown copyright 1993

The Natural Resources Institute (NRI) is an internationally recognized centre of expertise on the natural resources sector in developing countries. It forms an integral part of the British Government's overseas aid programme. Its principal aim is to alleviate poverty and hardship in developing countries by increasing the productivity of their renewable natural resources. NRI's main fields of expertise are resource assessment and farming systems, integrated pest management, food science and crop utilization.

NRI carries out research and surveys; develops pilot-scale plant, machinery and processes; identifies, prepares, manages and executes projects; provides advice and training; and publishes scientific and development material.

Short extracts of material from this publication may be reproduced in any non-advertising, non-profit-making context provided that the source is acknowledged as follows:

Bennison, J.J., and Paterson, R.T. (1993) *Use of Trees by Livestock 3: Gliricidia*. Chatham, UK: Natural Resources Institute.

Permission for commercial reproduction should be sought from:

The Head, Publications and Publicity Section,
Natural Resources Institute, Central Avenue,
Chatham Maritime, Kent, ME4 4TB, United
Kingdom.

No charge is made for single copies of this publication sent to the governmental and educational establishments, research institutions and non-profit-making organizations working in countries eligible for British Government Aid. Free copies cannot normally be addressed to individuals by name but only under their official titles.

Natural Resources Institute
ISBN: 0 85954 333 1
Price £2.00

LG3

This booklet is printed on paper produced using the residues from sugar-cane processing.

Contents

Foreword

Genus *Gliricidia*

Summary 1

Description and distribution 2

Fodder characteristics 3

Anti-nutritive factors 7

Management 8

Alternative uses 10

References and further reading 13



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 focussed on a limited number of introduced species. Thus there are many 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 the Publications Section at the Natural Resources Institute.

Margaret Gill
Livestock Production Programme

Genus *Gliricidia*

Family LEGUMINOSAE
Subfamily PAPILIONOIDEAE
Tribe GALEGEAE
Subtribe ROBINIINAE

Principal species *Gliricidia ehrenbergii*
Gliricidia maculata
Gliricidia sepium

Main common names Quickstick (Caribbean)
Mata Raton (Puerto Rico)
Madre Cacao (Central America)

Summary

Gliricidia has long been used for shade and physical support for a range of crops and as living fence posts. It has toxic effects on rodents and possibly horses. It can be a useful supplement for ruminants, even though palatability appears to be a problem with some accessions under certain conditions. The major drawback in many systems is its tendency to shed its leaves during the dry season, although this effect can be minimized by frequent cutting during the wet season, together with storage of surplus foliage as either sun-dried leaf meal, or as silage prepared with molasses and formic acid as additives. Presently exploited accessions represent only a small part of the existing germplasm held in international collections and there is much scope for selection within existing gene banks. There may also be scope for further collection from native populations before it becomes necessary to resort to breeding to achieve further improvements of exploitable characteristics. The tree shows potential for tropical animal production systems on relatively acid, infertile soils, particularly in sub-humid and humid regions and is deserving of further evaluation and development.



Description and distribution

Gliricidia is a genus of six to nine species of small, spreading, unarmed, fast-growing perennial shrubs or short-boled trees, reaching 5-15 m in height. They are able to fix nitrogen and nodulation has been observed and evaluated (Patil and Prasunamma, 1986). They nodulate readily, usually within three months of planting when grown from stakes, or even faster when established from seed (Chadhokar, 1982). They are deciduous, glabrous and characterized by a spreading or pyramidal crown of foliage borne on long, irregular, feathery branches that often curve downwards. They seasonally bear numerous large, showy, pink to light purplish, pea-shaped flowers which often appear before the leaves at the end of the dry season. The pods are glabrous, blackish at maturity and measure up to 14 cm long and 1.5 cm wide (Smith and van Houtert, 1987).

Native to tropical America and the West Indies, *Gliricidia* species now enjoy worldwide distribution as multipurpose trees suitable for use as living fences, for shade and soil improvement, as fuelwood and pole material, and as sources of high-protein

fodder and browse. *Gliricidia* establishes well in the tropics: it is found in lowlands and at altitudes of up to 2000 m. Although it is best suited to the wetter areas in the humid tropics where it is widely cultivated, it is native to the drier parts of Central America. Its considerable drought tolerance is due to a policy of avoidance, since it drops its leaves and becomes dormant during the driest parts of the year. The plant thrives on relatively acid, infertile soils and shows some tolerance of short-term waterlogging, conditions which are unsuitable for some of the other popular tree legumes such as *Leucaena leucocephala* (Chadhokar, 1982).

Most published data on *Gliricidia* refer to *G. sepium*, or to *G. maculata*. There is some confusion in the literature regarding the taxonomy, since authors such as Allen and Allen (1981) consider these taxa to be synonymous, while Wiersum and Dirdjosoemarto (1987) regard them as separate species. NFTA (1989) describes *G. maculata* as being native to the Yucatan Peninsula and having white flowers, rounded leaflets and relatively small pods and seeds. In contrast, *G. sepium* is considered to be native to the Pacific coast of Mexico and Central America and has pale

coloured flowers, more pointed leaves and larger seeds and pods. *G. ehrenbergii* comes from highland areas with altitudes of 1500-2000 m. It is a shrub growing to 3 m in height, with deep red-to-purple flowers and small rounded leaflets. This review will concentrate on *G. sepium* and *G. maculata*, although most published reports probably refer to the same species, due to taxonomic confusion.

Because of the ease with which the species may be vegetatively propagated, it is likely that most of the work carried out in a number of distinct countries has concentrated on a narrow gene base.

Fodder characteristics

The foliage of *Gliricidia* has been more or less accepted throughout the tropics as a source of high quality fodder. This is despite some traditional beliefs that the plant is toxic at the flowering stage, particularly to non-ruminants (Carew, 1983). Seeds or powdered bark are mixed with rice for use as a poison for rats and mice (Uphof, 1968), while the leaves are reputedly toxic to dogs and horses but not to cows and goats (Blohm, 1962). Some non-

ruminants, however, are able to tolerate it, at least at low levels of intake, since it has been successfully used in Venezuela as a replacement for *Medicago sativa* (lucerne, alfalfa), as a yolk colourant in maize-based diets for laying hens (Ford, 1987). Levels of 2-4% of *Gliricidia* leaf meal are recommended for poultry diets (NFTA, 1989). As a supplement for fish, *Gliricidia* meal has compared favourably with other leguminous fodders (Raj and Kutty, 1984).

Reports vary on the toxicity of *G. sepium*. The flowers and leaves are eaten by humans where it grows but they may be detoxified by the cooking process (Martin and Ruberte, 1975). It was claimed by Neal (1948) that plants grown in Hawaii were not poisonous. Despite the conflicting reports, it has been successfully used for feeding ruminant livestock in many tropical countries of the world.

As a browse plant, the shoots and sprouts, especially the tender twigs, together with the fruits, pods and stems, are cropped by domestic and wild animals. Fodder is also cut at varying intervals and carried to provide a high protein supplement to small and large ruminants. Its use in alley cropping is widely reported (ILCA, 1988). The trees can



withstand grazing and lopping and can be trimmed to a height of 1-1.5 m to serve as living fence posts and to provide limited forage within reach of browsing animals.

Data concerning browse productivity are few and variable and must be viewed with caution, since the age, species and size of the trees as well as the prevailing agro-climatic conditions can have considerable influences on foliage yields. ILCA (1988) cited a yield of 4475 kg/ha leaf dry matter (DM) over a 19-month period, equivalent to an annual DM yield of around 2800 kg/ha for the humid region of Nigeria,. In a similar area, a three-year old crop of *Gliricidia* yielded 1131-2703 kg/ha DM over a five month period, equivalent to annual DM production of 2700 to 6500 kg/ha. Management practices will also have an effect on yield (see page 8).

Data on the variation in yield with season are even scarcer and presumably more variable than those for annual production. Oakes and Skov (1962) reported monthly yields of 990 kg/ha for *Gliricidia* in the dry season, compared with 1480 kg/ha in the wet season. During times of stress, *Gliricidia* will shed its leaves, a

characteristic which detracts from its usefulness as a standing reserve of high quality fodder to be carried over for feeding as a dry season supplement for lower quality roughages.

The yield of fresh forage of the whole tree is closely related to the fresh weight of a single branch in both *Gliricidia* and *Leucaena*. This gives a rapid, largely non-destructive method for estimating forage yields of intensively managed plantations (Sumberg, 1984).

Typical data for proximate and fibre analyses of *G. sepium* are shown in Table 1. In general, they indicate good feeding value. NFTA (1989) confirmed this conclusion, suggesting that the foliage contained high levels of crude protein and calcium but low levels of phosphorus. Amino acid profiles (Chadhokar, 1982) compared favourably with herbaceous legumes such as *Medicago sativa*.

In a review, Smith and van Houert (1987) concluded that, in common with many legumes, *G. sepium* contained sufficiently high levels of most minerals (except phosphorus and copper) to meet tropical requirements and it would make an excellent feed during the dry season, when protein and

Table 1 Proximate and fibre analyses of leaves and bark of *Gliricidia sepium*

	Dry Matter %	Crude protein	Crude fibre	Ash	Ether extract	NFE	DMD	NDF	ADF
	(as % of dry matter)								
LEAVES									
No. of data	4	8	6	6	4	2	5	2	2
Low	20.4	15.6	14.1	3.8	2.0	43.6	51.0	44.3	27.9
High	26.1	30.0	35.0	12.2	5.9	48.2	68.2	48.7	34.2
Mean	24.3	25.5	21.4	8.0	4.4	45.9	59.4	46.5	31.0
BARK									
No. of data	0	2	2	2	2	1	0	0	1
Low		12.2	30.5	11.6	0.9	41.7			38.1
High		13.1	33.8	12.7	4.0	41.7			38.1
Mean		12.7	32.2	12.1	2.5	41.7			38.1

Notes: NFE - nitrogen free extract; DMD - dry matter digestibility;

NDF - neutral detergent fibre; ADF - acid detergent fibre.

Sources: Chadhoker (1982); Falvey (1982); Devendra (1983); Nochebuena and O'Donovan (1986); and NFTA (1989).



mineral deficiencies commonly occur. These comments apply equally to fresh foliage or to material conserved as dried leaf meal. Numerous reports consider the benefits of *Gliricidia* in terms of animal production, often as a supplement to poor quality diets (Ash, 1989). The foliage is highly degradable in the rumen (Minor and Hovell, 1979) and it is well digested (Wiersum and Dirdjo-soemarto, 1987). Although rarely offered as a sole feed, *Gliricidia* should serve to increase the digestibility of the diet when used to supplement low quality feeds (NFTA, 1989).

Despite numerous reports to the contrary (e.g. NFTA, 1989), Smith and van Houtert (1987), reviewed performance trials with both small and large ruminants, and concluded that while the feeding of *Gliricidia* had no adverse effect on growth and reproductive performance, supplementation did not improve intake of the basal diet. When readily consumed, the bulky *Gliricidia* quickly distended the rumen, cutting down on the intake of the basal ration. In contrast to this, Ash (1989) considered that feeding small quantities of *Gliricidia* leaf to goats would significantly increase total DM intake when

compared with mature tropical grass offered as a sole feed. Similarly, Chadhokar and Katharaju (1980) and Chadhokar and Lecumwasam (1982) reported increased levels of total intake when *Gliricidia* supplemented diets for dairy cattle and sheep respectively. These contrasting observations may be due, at least in part, to differences between species, or even between provenances, since little work has been done to characterize and stabilize varieties of *Gliricidia*.

Crushed *Gliricidia* leaves have been associated with a strong odour and this has resulted in palatability being described as only satisfactory to sheep (Nochebuena and O'Donovan, 1986) and unpalatable to rabbits (Raharjo and Cheeke, 1985). However, Chadhokar and Lecumwasam (1982) described *Gliricidia* as both acceptable and palatable to dairy cattle. While differences between provenances may explain some of the variability in reported animal acceptance, wilting for 24 hours between cutting and feeding appears to improve intake by reducing the odour of the foliage. The same effect can be achieved by oven drying. It has been reported that animals which initially refused

Gliricidia became accustomed to it in a few days, after which it was readily consumed. The presence of animals used to eating the foliage accelerated acceptance by others which were being introduced to it (Atta-Krah and Sumberg, 1987).

The rather conflicting data suggest that *Gliricidia* can be a useful supplement to low quality roughage diets, even if the improvement in animal performance is not great.

Anti-nutritive factors

Early reports concerning the role of *Gliricidia* as a forage refer to its toxicity and certainly the derivation of the generic name (*glis* = doormouse, *caedo* = kill) implies a toxicity to rodents. Furthermore, the powdered bark and seeds have been used as a rodent poison in the tropics and Skerman *et al.* (1988) confirmed that the roots were toxic to rodents and suggested that the leaves could poison horses.

Potentially toxic substances have been isolated from *Gliricidia*, including coumarins (Griffiths, 1962), hydrocyanic acid (Manidool, 1985), alkaloids (Glander, 1977), and tannins (Devendra, 1983).

Furthermore, it is suspected that *Gliricidia* may be a nitrate accumulator responsible for a 'cattle fall syndrome' in Colombia (Tiheebilcock, 1978).

However, whilst toxic effects have been well documented in non-ruminants, conclusive evidence in ruminants is lacking. Recent work (Ash, 1989) reported moderate condensed tannin levels in *Gliricidia* (20.5 g/kg DM), and yet the plant material was more degraded in the rumen than that of other plants of a similar tannin content. Condensed tannins may differ in type and behaviour between plant species. It also appeared that tannins could be altered by feed treatment. Oven-drying, a process by which animal acceptance has been increased, resulted in an apparent loss of tannins (Ahn *et al.*, 1989). Palatability could be improved by this process, although it could also have been modified by the destructive effect of heat on other plant components such as coumarins.

In conclusion, under practical feeding conditions, *Gliricidia* does not seem to be toxic to ruminants, although palatability may be a problem in some areas. It should be used with caution as a dietary supplement of diets for non-ruminants.



Management

Gliricidia tends to shed its leaves during the dry season and in Central America flowering and fruiting often take place while the trees are bare (February to April). In parts of Asia and the South Pacific, flowering is in the wet season and seed production is then often poor. Mature pods are strongly dehiscent, throwing their contents up to 25 m from the parent tree and creating problems for seed collection. The seeds show no dormancy, germinating readily as soon as moisture becomes available. If the opening rains are followed by a dry spell, many seedlings growing from naturally dispersed seed will die before they can become established. While there is considerable variation between individual trees, *Gliricidia* is not generally a heavy seeder (Salazar, 1986; Atta-Krah, 1987), although the seed maintains viability for well over a year when stored at 17°C and 50% humidity (NFTA, 1986). Trees grown from seed appear to produce stronger and deeper root systems than those which are vegetatively propagated, so are more suitable for use on sloping land, or where drought and high winds are potential problems.

Propagation by long stakes is easy, giving rise to the Caribbean common name of quickstick. Mature, leafless cuttings (6-12 months growth), 0.5-1.5 m long, produced a strike rate of some 85% when bark stripping was combined with regular watering (Glover, 1986). Chadhokar (1982) reported best results from fresh stakes 1.0-1.5 m in length and 3-5 cm in diameter, when about 15 cm of the stake was embedded in the soil. Coating the exposed ends with vaseline, wax, mud or polythene aided survival by reducing moisture loss.

The ease of vegetative propagation and the widespread use of *Gliricidia* as living fence posts established from long stakes, coupled with seed production difficulties, has probably resulted in the exploitation of only a small proportion of the existing germplasm. There are collections of seed held at international centres such as the Nitrogen Fixing Tree Association in Hawaii and the Oxford Forestry Institute in the UK (NFTA, 1989). Testing these seed resources should be given priority, although there would appear to be scope for further collection and selection from native populations in order to obtain provenances with desirable characteristics before the

gene base becomes further eroded. Wider use of seed would enable superior individuals to be selected from both natural and artificially established populations.

In alley cropping, in order to leave adequate space for annual crops, it is common to plant the trees in rows 4-10 m apart on flat land, reducing the spacing to 2-3 m as the slope of the land increases. In either case, spacing within the row is 10-50 cm. The trees are pruned at the end of the first year and subsequently managed with periodic cutting of regrowth to prevent excessive shading of the interplanted crops. It has been reported that delaying the age at first cutting encourages root development. Chadhokar (1982) recommended one or two harvests per year for the first two or three years, followed by an 8-12 week cutting cycle (4-5 cuts/year) to maximize the yield of foliage. Two cuts during the wet season delayed leaf fall and flowering during the subsequent dry season (Simmonds, 1951). Reduction of the leaf canopy at this time also protected trees from the ravages of storms and hurricanes in the Caribbean.

Little work has been reported on tree spacings for

forage production. Unlike *Leucaena*, which can be easily maintained as a hedge for direct grazing, *Gliricidia* does not respond well to repeated cutting close to ground level, although NFTA (1989) reported that it would tolerate a cutting height of 40-90 cm. Partly as a result of its use as living fence posts, it is common to see the trees growing with a single trunk to a height of at least 1.5 m, branching profusely above that height. This implies management under what would be basically a cutting regime and the optimum pattern and density in plantations would then be determined by the methods of harvesting and transporting the cut material. Densities in excess of 3000 trees/ha are probably rare in practice, although NFTA (1989) noted spacings of 1.0 x 0.25 m in protein banks and Wiersum and Dirdjosoemarto (1987) quoted spacings ranging from 1 x 1 m to 2.5 x 2.5 m for woodlots in Indonesia. In fence lines, spacings of 0.5-3.0 m are common.

Under a cutting regime, some of the cut material is usually fed fresh to livestock, although sun-dried leaf material is easy to store for later use. Dried foliage is well accepted. *Gliricidia* lacks the fermentable carbohydrates necessary to make high quality silage



unless it is ensiled with molasses and formic acid additives (Kass and Rodriguez, 1987). Wilting also improves the quality of the silage.

At wide spacings of 10 x 10 m in a parkland grazing system, *Gliricidia* can provide shade and foliage to animals and small quantities of nitrogen to the companion grass species without reducing grass yield through excessive shading.

Alternative uses

Gliricidia is a truly multipurpose tree with a variety of uses complementing its role as a source of fodder. Its ease of establishment from large vegetative cuttings makes it suitable for living fences where it can also act as a windbreak, or as a support for climbing crops such as yam, pepper, vanilla and passion fruit. The excessive new tree growth is browsed or lopped for fodder, while the blossoms provide pollen and nectar for honeybees during the short flowering period.

Gliricidia serves a variety of soil protection and improvement purposes. As well as the fencing and support roles noted above, it is often interplanted

with plantation crops as shade and to provide green manure or mulch. It has long been used as a shade tree in tropical plantations of tea, coffee and cocoa, with benefits including ease of husbandry and propagation, good coppicing, a canopy structure that permits a desirable level of shade and a deep, non-competitive root structure (Budowski *et al.*, 1984). Associations with annual crops provide both shade and nutrients. It is this further role as a source of nutrients in alley cropping that makes it ideally suited to the improvement of farming systems through both maintenance of soil fertility for crop production and provision of high protein feed for ruminants.

Alley farming systems, developed by the International Livestock Centre for Africa (ILCA) and the International Institute of Tropical Agriculture (IITA) for the humid regions of the developing world, employ foliage to both improve the soil and to provide animal feed. They have led to increased maize yields, due to the benefits of nitrogen fixation by the root nodules and by the addition of nutrients supplied as either green manure or mulch. Timely pruning is essential since failure to remove

superfluous foliage can cause decreased crop yields due to excessive shading, together with increased risk of trees being blown over during heavy storms. Foliage incorporated into the soil as green manure, rather than applied to the surface as mulch, results in faster leaf decomposition and nutrient release. In drier areas and areas subject to soil erosion, mulching may be more appropriate to reduce soil temperature and increase soil moisture retention. Wilson *et al.*, (1986) suggested that shrubs may be more suitable than herbaceous legumes for soil restoration in the humid tropics. The nitrogen released from decomposing plant tissue may be more important than that exuded from roots in such environments.

In numerous agroforestry systems, nutrient release by leaf decomposition is regarded as the most important factor in the restoration of soil fertility. Roskoski *et al.*, (1982) measured rhizobial activity *in situ* in a 20-year-old stand of *G. sepium* and estimated annual nitrogen fixation to be only 13 kg/ha/year. In comparison, Yamoah *et al.*, (1985) reported that prunings released 252 kg nitrogen/ha/year when *G. sepium* was intercropped with maize. This would represent nitrogen both from the soil and from

rhizobial fixation. While *Gliricidia* is known to form nodules, there is little information available regarding the efficiency of nitrogen fixation under normal farm conditions.

As a source of nitrogen and organic matter, *Gliricidia* is often added to rice fields at mudding up. *Gliricidia* compost was compared with cow, pig, goat, and poultry manure for effects on rice growth. The highest grain yield, 5.7 t/ha, resulted from the application of both *Gliricidia* and pig manure (Joseph and Kurakose, 1985).

A balance should be sought between the use of the foliage as mulch, as green manure or as fodder, depending upon the nature of the farming system. The deep rooting habit of leguminous trees is an important feature in the prevention of soil erosion, especially with increased cultivation of more precarious hillsides.

Aken'Ova and Atta-Krah (1986) noted additional benefits of improved weed control in alley cropping, while Obando (1987) indicated a possible allelopathic effect of *Gliricidia* on the common weeds *Bidens pilosa* and *Melanpodium perfoliatum* in Costa Rica. Sclerotial viability of *Rhizoctonia solani*, a pathogen of rice, is



reduced by the addition of green *Gliricidia* leaves to the soil (Lakshmanan and Nair, 1984). Hot water infusions of the leaves are used as pesticides against external parasites of livestock, including dogs, and chopped leaves placed in the nests serve a similar purpose in poultry husbandry (NFTA, 1989).

Hot compresses of *Gliricidia* leaves, bark and roots are used to treat wounds, warts and bites, and skin rashes are cured by bathing in hot water infusions of the leaves (NFTA, 1989).

The wood of *Gliricidia* is hard and heavy (specific gravity 0.75) with a coarse texture and irregular grain. It is not easy to work but finishes smoothly and is extremely durable. It is used to fashion agricultural implements and small carpentry items which show great resistance to termites and decay. While Soetrisno *et al.*, (1984) produced satisfactory wood pulps in Indonesia, Yantasuth *et al.*, (1985) considered *G. sepium* unsuitable for pulping in Thailand.

A calorific value of 4900 kcal/kg is commonly cited for *Gliricidia* when used as a fuelwood, and it has been described as an outstanding fuelwood tree by Brewbaker *et al.*, (1982)

References and further reading

Two important references which report the level of current knowledge on *Gliricidia sepium* have been recently published by the Nitrogen Fixing Tree Association in Hawaii. Where appropriate, individual contributions to these volumes have been noted in the alphabetical listing of references below. These publications are:

NFTA (1987) *Gliricidia sepium* (Jacq.) Walp.: *Management and Improvement. Proceedings, Workshop held at CATIE, Turrialba, Costa Rica, June, 1987.* Special Pub. 87-01. Hawaii, USA: Nitrogen Fixing Tree Association.

NFTA (1989) *Gliricidia Production and Use.* GLOVER, N. (ed). Hawaii, USA: Nitrogen Fixing Tree Association.

Alphabetical listing

AHN, J.H., ROBERTSON, B.M., ELLIOT, R., GUTTERIDGE, R.C. and FORD, C.W. (1989) Quality assessment of tropical browse legumes: tannin content and protein degradation. *Animal Feed Science and Technology*, **27**: 147-156.

AKEN'OVA, M.E. and ATTA-KRAH, A.N. (1986) Control of spear grass (*Imperata cylindrica* (L.) Beauv. in an alley cropping fallow. *Nitrogen Fixing Tree Research Reports*, **4**: 27-28.

ALLEN, O.N. and ALLEN, E.K. (1981) *The Leguminosae: A Source Book of Characteristics, Uses and Nodulation.* Madison, USA: The University of Wisconsin Press.

ASH, A.J. (1989) The effect of supplementation with leaves from the leguminous trees *Sesbania grandiflora*, *Albizia chinensis* and *Gliricidia sepium* on the intake and digestibility of guinea grass hay by goats. *Animal Feed Science and Technology*, **28**: 225-232.



ATTA-KRAH, A.N. (1987) Flowering and seed production of *Gliricidia sepium*. In: *Gliricidia sepium* (Jacq.) Walp.: *Management and Improvement. Proceedings, Workshop held at CATIE, Turrialba, Costa Rica, June, 1987*. Special Pub. 87-01. pp20-28. Hawaii, USA: Nitrogen Fixing Tree Association.

ATTA-KRAH, A.N. and SUMBERG, J.E. (1987) Studies with *Gliricidia sepium* for crop-livestock production systems in West Africa. In: *Gliricidia sepium* (Jacq.) Walp.: *Management and Improvement. Proceedings, Workshop held at CATIE, Turrialba, Costa Rica, June, 1987*. Special Pub. 87-01. pp31-43. Hawaii, USA: Nitrogen Fixing Tree Association.

BLOHM, H. (1962) *Poisonous Plants of Venezuela*. Cambridge, USA: Harvard University Press.

BREWBAKER, J.L. (1986) Leguminous trees and shrubs for Southeast Asia and the South Pacific. In: *Forages in Southeast Asian and South Pacific Agriculture*. BLAIR, G.J., IVORY, D.A. and EVANS, T.R.(eds). ACIAR Proceedings No 12, Canberra, Australia. pp43-50.

BREWBAKER, J.L., MACDICKENS K., and VAN DEN BELDT, R., (1982) Tropical nitrogen-fixing fuelwood trees. In: *Energy Conservation and Use of Renewable Energies in the Bio-industries*. VOGT, F.(ed). pp108-119 Oxford, UK: Pergamon Press.

BUDOWSKI, G., KASS, D.C.L. and RUSSO, R.O. (1984) Leguminous trees for shade. *Pesquisa Agropecuaria Brasileira*, **19**: 205-222.

CAREW, B.A.R. (1983) *Gliricidia sepium* as a sole feed for small ruminants. *Tropical Grasslands*, **17**(4): 181-184.

CHADHOKAR, P.A. (1982) *Gliricidia maculata* - A promising legume fodder plant. *World Animal Review*, **44**: 36-43.

CHADHOKAR, P.A. and KANTHARAJU, H.R. (1980) Effect of *Gliricidia maculata* on growth and breeding of Bannur ewes. *Tropical Grasslands*, **14**: 78-82.

CHADHOKAR, P.A. and LECAMWASAM, A. (1982) Effect of feeding *Gliricidia maculata* to milking cows: a preliminary report. *Tropical Grasslands*, 16: 46-48.

DEVENDRA, C. (1983) Physical treatment of rice straw for goats and sheep and the response to substitution with variable levels of cassava (*Manihot esculenta* Crantz.), leucaena (*Leucaena leucocephala*) and gliricidia (*Gliricidia maculata*) forages. *MARDI Research Bulletin*, 11(3): 272-290.

FALVEY, J.L. (1982) *Gliricidia maculata* - a review. *International Tree Crops Journal*, 2(1): 1-14.

FORD, L.B. (1987) Experiences with *Gliricidia sepium* in the Caribbean. In: *Gliricidia sepium* (Jacq.) Walp.: *Management and Improvement. Proceedings, Workshop held at CATIE, Turrialba, Costa Rica, June, 1987. Special Pub.* 87-01. pp3-7. Hawaii, USA: Nitrogen Fixing Tree Association.

GLOVER, N. (1986) Vegetative propagation of *Gliricidia sepium*. *Nitrogen Fixing Tree Research Reports*, 4: 62-63.

GLANDER, K.E. (1977) Secondary compounds and the feeding behaviour of leaf-eating primates. *American Journal of Physical Anthropology*, 47: 133.

GRIFFITHS, L.A. (1962) On the co-occurrence of coumarin, O-coumaric acid and melilotic acid in *Gliricidia sepium* and *Dipteryx odorata*. *Experimental Botany*, 13: 169-175.

ILCA (1988) *Annual Report*. Addis Ababa, Ethiopia: International Livestock Centre for Africa.

JOSEPH, P.A. and KURIAKOSE, T.F. (1985) An integrated nutrient supply system for higher rice production. *International Rice Research Newsletter*, 10(2): 22.

KASS, M.L. and RODRIGUEZ, G. (1987) Preliminary studies on silage making from *Gliricidia sepium* (Madero Negro). In: *Gliricidia sepium* (Jacq.) Walp.: *Management and Improvement. Proceedings, Workshop held at CATIE, Turrialba, Costa Rica, June, 1987. Special Pub.* 87-01. pp201-204. Hawaii, USA: Nitrogen Fixing Tree Association.



LAKSHMANAN, P. and NAIR, M.C. (1984) Effect of soil amendments on the viability of sclerotia of *Rhizoctonia solani* in soil. *Madras Agricultural Journal*, **71**(8): 526-529.

MANIDOOOL, C. (1985) Utilisation of tree legumes with crop residues as animal feeds in Thailand. In: *Relevance of Crop Residues as Animal Feeds in Developing Countries. Proceedings, International Workshop held at Khoen Kaen, Thailand*. pp 249-269.

MARTIN, F.W. and RUBERTE, R.M. (1975) *Edible Leaves of the Tropics*. Mayaguez, Puerto Rico: Antillean College Press.

MINOR, S. and HOVELL, D.F.D. (1979) Rate of rumen digestion of different protein sources using the *in vivo* nylon bag technique with cattle fed sugar cane. *Tropical Animal Production*, **4**: 105-106.

NEAL, M.C. (1948) *In Gardens of Hawaii*. Special Publication No.40. Honolulu, USA: Bernice P. Bishop Museum.

NFTA (1986) *Gliricidia*: its name tells its story. *NFT Highlights* 86-06. Hawaii, USA: Nitrogen Fixing Tree Association.

NOCHEBUENA, G. and O'DONOVAN, P.B. (1986) The nutritional value of high-protein forage from *Gliricidia sepium*. *World Animal Review*, **57**: 48-49.

OAKES, A. and SKOV, O. (1962) Some woody legumes as forage crops for the dry tropics. *Tropical Agriculture* **39**(4): 281-287.

OBANDO, L. (1987) Potencial alelopatico de *Gliricidia sepium* (Jacq.) Walp. sobre los cultivos de maiz y frijol y las malezas predominantes (abstract). In: *Gliricidia sepium* (Jacq.) Walp.: *Management and Improvement*. Special Pub. 87-01. pp 59-60. Hawaii, USA: Nitrogen Fixing Tree Association.

PATIL, S.D. and PRASUNAMMA, K. (1986) A preliminary evaluation of nodules from six nitrogen fixing trees. *Nitrogen Fixing Tree Research Reports*, **4**: 20-21.

RAHAJO, Y.C. and CHEEKE, P.R. (1985) Palatability of tropical tree legume forage for rabbits. *Nitrogen Fixing Tree Research Reports*, **3**: 31-32.

RAJ, S.P. and KUTTY, M.N. (1984) Food conversion efficiency and nitrogen balance in *Cirrhinus mrigala* fingerlings fed on three pelleted feeds compounded with wild legumes. *Journal of the Indian Institute of Science*, **65**(6): 59-64.

ROSKOSKI, J.P., MONTANO, J., VAN KESSEL, C. and CASTILLEJA, G. (1982) Nitrogen fixation by tropical woody legumes: potential source of soil enrichment. In: *Biological nitrogen fixation technology for tropical agriculture*. GRAHAM, P.H. and HARRIS, S.C.(eds). pp 447-454. Cali, Colombia: Centro Internacional de Agricultura Tropical (CIAT).

SALAZAR, R. (1986) Genetic variation in seeds and seedlings of 10 provenances of *Gliricidia sepium* (Jacq.) Steud. *Forest Ecology and Management*, **16**: 391-401.

SIMMONDS, N.W. (1951) Notes on field management at the Botany Department of the Imperial College of Tropical Agriculture. *Tropical Agriculture (Trinidad)*, **28**(1-6): 70-75.

SKERMAN, P.J., CAMERON, D.G. and RIVEROS, F. (1988) *Tropical Forage Legumes*. 2nd. edn. Rome: Food and Agriculture Organization.

SMITH, O.B. and VAN HOUTERT M.F.J. (1987) The feeding value of *Gliricidia sepium*: a review. *World Animal Review*, **57**: 57-68.

SOETRISNO, SAYUTI, MULIAH and EDDI, M. (1984) Pulping of *Gliricidia maculata*. *Berita Selulosa* **20**(1): 3-12.

SUMBERG, J. (1984) Alley farming with *Gliricidia sepium*. *Germplasm Evaluation and Planting Density*. Ibadan, Nigeria: ILCA Small Ruminant Program.

TIHEEBILCOCK, P.E. (1978) Nitratos totales en plantas y aguas estancadas de Cordoba y Sucre como factores causantes de "la caída del ganado". *Revista*



del Instituto Colombiano de Agricultura (Bogota),
13: 567-574.

UPHOF, J.C.T. (1968) *Dictionary of Economic Plants.*
2nd edn. Lehre, W. Germany: V.J.Von Cramer.

WIERSUM, F. and DIRDJOSOEMARTO, S. (1987)
Past and current research with *Gliricidia* in Asia. In:
Gliricidia sepium (Jacq.) Walp.: *Management and*
Improvement. Proceedings, Workshop held at CATIE,
Turrialba, Costa Rica, June, 1987. Special Pub. 87-01.
pp 20-28. Hawaii, USA: Nitrogen Fixing Tree
Association.

WILSON, G.F., KANG, B.T. and MULONGOY, K.
(1986) Alley cropping: trees as sources of green-
manure and mulch in the tropics. *Biological*
Agriculture and Horticulture, 3(2/3): 251-267.

YAMOAH, C.F., MULONGOY, K. and AGBOOLA,
A.A. (1985) Decomposition and nitrogen
contribution by prunings of selected legumes in alley
cropping systems. In: *Biological Nitrogen Fixation in*
Africa. SSALI, H. and KEYA, S.O.J. (eds.) pp482-485.
Nairobi, Kenya: MIRCEN, University of Nairobi.

YANTASATH, K., SUPATANAKUL, W.,
UNGVICHIAN, I., CHAMSAWAD, S.,
CHANTRASIRI, S., PATANAVIBUL, S.,
HYAKITKOSOL, C., PROMPETCHARA, S.,
PITHAKARNOP, N. and CHALERMKLIN, P. (1985)
V. Pulping and paper making characteristics of fast
growing trees. *Nitrogen Fixing Tree Research Reports*
3: 54-56.