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THE POTENTIAL OF LEGUME TREES FOR ANIMAL FEEDING IN THE TROPICS

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ABSTRACT

A general overview of the utilization of the foliage of legume trees in animal production systems in tropical areas is presented. The experience of their utilization in mixed type of small farm agricultural systems is emphasized for the Central American region. Three species: *Leucaena leucocephala* (Lam.) de Wit, *Erythrina* sp., and *Gliricidia sepium*, are reviewed in terms of their establishment and utilization in association with grasses or as protein banks. Results of research conducted in Costa Rica and Guatemala under different ecological conditions are discussed in terms of dry matter production, forage quality, consumption by dairy cows and rumen degradation. The main advantages and disadvantages of the use of legume trees are discussed in relation to small farm agricultural systems.

INTRODUCTION

There has been a growing interest in recent years on the utilization of leguminous trees as a source of feed and fuel in the tropical areas of the world. The Leguminosae family is of tropical origin and many of the best known tropical trees and shrubs have their origin in the American Tropics. However, the use of these trees as a component of the feeding subsystem in tropical production systems is of recent date. The presence of some toxic compounds such as mimosine in *Leucaena*, or the lack of acceptance by animals of the forage of some Gliricidias, have been some of the main constraints.

The interest on legume trees has resulted in several recent meetings with the objective to exchange knowledge and ideas on the utilization of some of these species. The importance of the work being conducted arises from the problem of deforestation and the need for conservation of the natural resources. The association of trees with crops and pastures has resulted in a reduction in pressure upon the productive resources available. Although in Central America, the foliage from trees has been used for a number of years to feed small ruminants, this practice is not widespread.

The diversification of the agricultural systems at the small farms is very large and it has been reported that especially in the hillsides, the association of trees, crops and pastures can be an alternate solution for soil conservation.

The animal production systems in the tropics have been studied following the traditional association of grasses and legumes in pastures. This practice has the advantage of supplying better quality forage with an increase in the N status of the soil. Recently, planting legumes alone to be used as protein banks, has provided the basis for managing the crop according to its own nutritional and physiological characteristics and to supply a supplement of good quality. The utilization of the forage produced by trees grown in association with crops or pastures can be particularly adequate for small farm production systems due to the hand labor required for its management.

The objective of this paper is to review data on the utilization of three legumes: Leucaena leucocephala, Gliricidia sepium, and Erythrina sp., as a potential source of feed for ruminant animals in the tropical areas of the Caribbean Basin. The agronomic practices, the nutritive value and utilization of the edible part of the biomass and the role of legume trees in some production systems will be emphasized.

Agronomic Practices in the Utilization of Legume Trees

One of the most extensively studied species is Leucaena leucocephala (Lam.) de Wit, which is a legume tree utilized for multi-purpose agriculture. There are 10 Leucaena species but L. leucocephala, the most commonly used, is highly self-fertilized which determines the use of different mechanisms for improvement (Brewbaker, 1982). This can be of great importance if adaption of the plant to the very acid Oxisols and Ultisols is to be achieved (Hutton, 1982). The Erythrinas and Gliricidias have not been studied in detail to identify the species available (Table 1). As in the case of Leucaena there is a wide diversity of factors that affect their productivity.

The establishment of some of the legume trees has followed different patterns according to their intended use. However, all of them try to grow the trees in a particular environment in a short time at the less possible cost. Some of the methods that have been studied include direct seeding, usually in rows for Leucaena to vegetative planting of species of Erythrina and Gliricidia.

In a study conducted at two different ecological conditions in Costa Rica, it has been possible to obtain plants of Erythrina and Gliricidia measuring over 2 m. in a 10-11-month period when planted from seed in the humid tropics (IICA, 1989) (Table 2). Although there is little variation in height, differences in yield result from variations in growth habits, affecting their biomass production potential. A similar tendency has been observed for Leucaena in which the varieties have been classified into common, giant and multibranched. The last group is the more recommended for pasture use (NFTA, 1985).

Table 1. Species of legume trees used in some production systems.

Leucaena species	*Erythrina* species	*Gliricidia* species
collinsii	*abissinica*	*maculata*
diversifolia	*berteroana* *	*sepium* *
esculenta	*cocleata*	
lanciolata	*costarricense*	
leucocephala *	*fusca*	
var *glauca*	*lanceolata*	
var *salvadorensis*	*poeppigiana* *	
macrophylla	*variegata*	
pulverulenta		
retusa		
shannoni		
trichodes		

* Species most commonly used.

Table 2. Growth characteristics of some legume trees at two locations in the humid tropics in Costa Rica. (IICA, 1989)*

Species	Height of plant, m(**)		Yield of forage, kgGW/tree	
	La Fortuna	Siquirres	La Fortuna	Siquirres
E. peoppigiana	2.0 ± 0.3	2.9 ± 0.7	1.7 ± 1.0	7.2 ± 5.9
E. fusca	2.3 ± 0.3	3.5 ± 1.0	2.8 ± 1.5	13.8 ± 11.3
G. sepium	2.4 ± 0.3	4.2 ± 0.8	1.8 ± 1.8	4.1 ± 2.6

(*) Based on growth period of 10-11 months, planted from seed (2 to 3 seeds/posture) at 1.5 x 4.0 m.
(**) Measured from soil surface to the highest leaf.
(***) Measured from the live material standing above 80 cm.

The establishment is a critical phase for any crop and is particularly so in the case of *Leucaena*. Studies with *Leucaena* have indicated the need of scarification, either mechanical, chemical or by water immersion for the best germination and establishment. This practice is commonly used in Hawaii. When water immersion is used the best results are obtained when the treatment is done at 80°C for periods no longer than 5 minutes (Fuentes et al., 1988). Some of the recognized difficulties to establish *Leucaena* are: a) an inherently low seedling growth rate; b) inability to compete favorably with weeds; c) delayed nodulation, and d) high palatability to native fauna.

The yields from the same variety of Leucaena in different areas of the world are highly variable depending mostly on the particular environment. The improved cultivar Cunningham has consistently produced higher yields than cv. Perú (Table 3). The yield of 26.4 ton DM/ha/year obtained in India and those obtained in the Caribbean are indicative of the high potentials of this species. Ruiz and Febles (1987) have reported that cutting intervals of 8-12 weeks do not produce yield variations, ranging from 7.2-9.2 ton DM/ha/year depending on the cutting height (Table 4). In Puerto Rico, Tergas et al. (1989) reported that the total yield of 20 accessions ranged from 7.5-15.7 ton/ha/year with big differences in DM production in the wet and dry seasons. Cultivars Cunningham and K-28 had an output of over 15 ton DM/ha/year, indicating that are well adapted tropical legumes to the local conditions.

Table 3. Annual yield of Leucaena in some areas of the world. (ton/ha/year)

Location	Leucaena cultivar	
	Peru	Cunningham
Australia (1)	5.5	7.1
Malaysia	8.5	11.4
Thailand	10.8	12.2
India	16.2	26.4

(1) Average of three locations
Source: NFTA, 1985

Table 4. Yield of Leucaena leucocephala at different intervals and height of cutting, Cuba. (ton DM/ha/year).

Height of cutting,cm	Cutting Interval, weeks		
	8	10	12
10	8.4	7.2	7.4
20	9.2	8.4	8.9
Average	8.8	7.8	8.2

Source: Ruiz and Febles (1987).

When grown in acid soils in Suriname the giant varieties of Leucaena, K-8, K-28 and K-67, have reached heights of 9.6-9.9 m in 38 months. In the first 19 months the height varied from 6.7-7.0 m showing the potential for wood production in this particular environment (Kerkoff et al., 1989).

The comparative yield of legume trees as shown by Panjaitan et al. (1989) in Indonesia varies depending on the agroclimatic zones where the plants are grown, if they received a similar management. The yield of Leucaena cv. Cunningham varied from 0.25-27.1 ton DM/ha/year depending on the location. However G. sepium varied from 2.6-27.0 ton DM/ha/year under similar conditions. These results show that the potentials of both species are similar when grown under similar adequate conditions.

The evaluation of several lines of Gliricidia carried out by ILCA in Africa indicated the potentials and good performance at a specific site as a result from primary productivity and growth and initial coppice growth vigor. The variation in growth and productivity in a relatively small collection are indicative of the vast potential space for genetic improvement (ILCA, 1987).

The Nutritive Value of Forage from Legume Trees.

The best indicator of nutritive value of a forage is the animal performance obtained under practical conditions. With highly variable materials such as the edible biomass from trees, the different constituents must be determined by chemical and laboratory means. The chemical composition, digestibility, and mineral constituents of the plant material vary depending on the species and varieties, the parts of the plant (leaves, stems, petiole), stage of maturity (before flowering or after flowering), soil factors, environmental factors (climate, temperature, rainfall, season), and management and cultural practices.

The importance of the plant parts, the chemical characteristics of forage from Erythrina sp. and G. sepium from Costa Rica are shown in Table 5. The crude protein content varies with plant portions (laminae green>stem petiole) but rumen degradability follows a different pattern (green stem>petiole> laminae).

Since the forage from these species is an important source of protein several studies have been conducted in Costa Rica to determine rumen degradability of the protein fraction. Recently, Ramirez (1990) found a protein potential degradability of G. sepium of 87.9% at four months of regrowth, but it significantly declined to 77.3% at six months when using "in situ" digestion techniques.

Several studies estimating the nutritive value of forage from tree species showed that in general they have high values of crude protein ranging from 19.7-38.3% with IVDMD of 22.7-72.0% or higher. The great variation depends on the species, age and other management aspects. However the results of these studies indicate that all species are potential candidates for feeding animals.

Table 5. Some chemical characteristics of forage from *Erythrina* *sp*. and *G*. *sepium* in Costa Rica.

Species	Part of the plant Laminae PC %	Laminae IVDMD %	Petiole PC %	Petiole IVDMD %	Green stem PC %	Green stem IVDMD %	Source
E. berteroana	27.3	54.6	7.6	42.6	8.4	41.8	Benavides, 1985
E. poeppigiana	31.3	43.9	12.2	56.4	10.7	45.3	Benavides, 1988*
E. poeppigiana	30.3		10.4		22.4		Pezo et al. 1989
E. poeppigiana	29.1	52.1	9.6	67.2			Russo, 1984*
G. sepium	26.9		12.5		18.9		Pezo et al. 1989

* Cited by Pezo et al., 1989

Animal Production Response Using Legume Trees

Animal response has been mainly studied with ruminants, although some tests have been carried out with dry leaves of legume trees in feeding poultry and rabbits. The latter will not be reviewed here.

Small Ruminants

The use of *Erythrina* and *Gliricidia* for feeding milk producing goats has been extensively studied in Costa Rica. The consumption of Erythrinas and Gliricidias forage by milking goats, ranges from 95-158 g/kg $W_{.75}$, which seems to be adequate to provide the requirements for milk production. A significant linear effect of supplying different levels of *E. poeppigiana* on milk production has been reported (Pezo et al., 1989). A partial substitution effect on the consumption of chopped grass was observed but it was not large enough to overcome the additive effect on Total Dry Matter Intake (Table 6). These same authors have found that the ruminal degradation of the nitrogen fraction of *E. poeppigiana* is very rapid and they have indicated that the microbial protein synthesis could be stimulated by adding sources of readily fermentable carbohydrates such as ripe bananas. However, the results of the research conducted so far have failed to demonstrate the advantage of using sugar as a supplemental source of energy to the nitrogen of the legume. They have indicated that the apparent adequate ratio of energy (when supplied by ripe bananas) and protein (supplied by *E. poeppigiana*) is in the order of 40g PC/MCal DE and this must be maintained for efficient milk production in goats.

Some evaluations have been made on the use of different legume trees on animal production. There is apparently little variation among species of *Erythrina* as compared to *Gliricidia* as has been reported in Southeast Asia. In Costa Rica Pezo et al. (1989), have reported a higher intake of E. poeppigiana foliage as compared to G. sepium, resulting in a significant higher milk production in goats (1260 vs 1110 g/animal/day).

Table 6. The effect of supplying different levels of Erytnrina peoppigiana on milk yield of goats.

	Level of E. poeppigiana, % BW *			
	0	0.5	1.0	1.5
INTAKE				
G. W. kg/animal/day	1.16	1.34	1.52	1.62
E. poeppigiana	0	0.20	0.40	0.55
Chopped grass	0.69	0.67	0.65	0.60
Green bananas	0.47	0.47	0.47	0.47
DM, g/kg $W_{.75}$	95	113	126	139
MILK YIELD				
g/animal/day	326	606	695	820

Significant linear effect ($P \leq 0.05$).
Source: Adapted from Pezo et al., 1989.

Cattle Production. A large amount of information on the utilization of Leucaena as a source of protein in bovine production systems comes from parts of Southeast Asia, Hawaii and recently from Cuba and other Caribbean Basin countries. The early studies of Henke in 1958, reported by Plucknett (1970) indicate that when the stocking rate was maintained constant at 1.24 steer/ha the liveweight gain per hectare increased linearly with total annual rainfall.

In a commercial production system in Hawaii, results for a 12-year period clearly indicate the potential of Leucaena for milk production. A stocking rate of 6.1 cows/ha has been maintained with an average milk production of 9770 kg per hectare/year plus 400 kg/ha of liveweight gain. The animals received liveral amounts of concentrate and produced 12.5 kg of milk/cow/day, when grazing Leucaena pastures planted at 1 m distance between rows and Guinea grass growing among the legume plants (Plucknett, 1970). Recently, Ruiz and Febles (1987) reviewed the information available on the utilization of Leucaena and indicated that in Cuba the main interest in using this forage legume was to decrease the amount of concentrates fed to milking cows. For short term trials conducted in the island, it was found that 4-5 kg of green forage of Leucaena were able to replace 4 kg of commercial concentrate. In several trials in Cuba using Leucaena as protein bank and managed jointly with different pastures, milk yield of more than 11.1 per cow/day have been obtained when the pastures were managed at stocking rates of 2.0-3.6 head/ha (Table 7). The basic pastures were Star grass, Guinea grass or Bermuda grass and the cows were allowed to graze the *Leucaena* pasture for a limited time of the day. Milk production per cow varied depending on the grasses and their management and the consumption of *Leucaena* was estimated at 2.7-3.0 kg/cow/day which is considerably less than the 11.8-23.6 kg/cow estimated by Plucknett (1970).

Table 7. Milk production from *Leucaena* with different pastures.

Pasture Type	Stocking rate cow/ha	Milk Yield kg/cow/day
Stargrass cv. Jamaica	2.0	14.9 - 16.8
Guinea grass cv. Likoni	2.0	11.7 - 12.3
Bermuda cv. Coastcross 1	3.6	11.1 - 12.4

Source: Adapted from Ruiz and Febles (1987).

The utilization of *Erythrina* or *Gliricidia* for animal feeding has received less attention so far. In Costa Rica, Pineda as cited by Pezo et al. (1989) studied the replacement of soybean meal by *E. poeppigiana* as protein supplement. The data on Table 8 show that the quality of the protein from the legume foliage was lower than that of soybean meal, but due to cost and need of cash by small farmers, there is an economical advantage if 67% of the protein requirements are supplied as foliage legume. In Indonesia, Lana et al. (1989) reported the utilization of Gliricidia plants on the preference of various parts by steers. Although there was a decrease in total Dry Matter Consumption when the animals were fed *G. sepium* (from 3%-1.7 - 2.2% bodyweight) depending on the age of the leaves, no deleterious effects were reported. A significant higher consumption of old leaves as compared to young ones was observed. This could be due to the astringent odor and flavonol content of young leaves (Table 9), and should be considered in incorporating these species into production systems.

Comparisons among species are difficult to conduct due to problems in keeping the materials uniform. However, in Guatemala, comparing *Gliricidia* and *Leucaena*, a significant higher Dry Matter intake was obtained with the former when fed *ad libitum* to milking cows in the tropical lowlands.

Table 8. The effect of substituting soybean meal by *Erythrina poeppigiana* in liveweight gain, intake and *in vivo* digestibility in Heifers.

	Protein Supplement			
	100% SBM	67% SBM 33% E.P.	33% SBM 67% E.P	100% E. P
INTAKE, % B W				
Soybean meal	0.46	0.31	0.15	0.0
E. Poeppigiana	0.0	0.26	0.52	0.79
Digestibility, %				
Dry matter	62	60	60	58
Liveweight gain, g/animal/day	410	366	372	294

Source: Pezo et al. (1989)

Table 9. Consumption of *Gliricidia sepium* forage by steers in Indonesia.

	Part of the plant			
TOTAL CONSUMPTION:	Young leaves	Old leaves	Mixed leaves	Whole Leaves
Green weight, kg/animal/day	12.9a	16.6b	13.9ac	15.2bc
Dry weight, kg/animal/day	3.1a	4.1b	3.5ac	3.9bc

Source: Lana et al. (1989)

Recently, Abarca (1989), found differences in milk production per cow, comparing fishmeal and *E. poeppigiana* as sources of protein for dairy cows grazing African Stargrass pastures in the humid tropics in Costa Rica. When *E. poeppigiana* was used, lower milk production was obtained, but the economic benefits were increased by a reduction in the variable costs. These results indicated that the use of legume trees may be a suitable alternative for small holders when they have low quality pastures. However, it was pointed out that there is a need to study the utilization of *E. poeppiginia* at a farm level, so the management in a continuous use in terms of adequate practices could be recommended (Table 10).

Table 10. Effect of protein supplement on milk production in the humid tropics

	Protein Supplement	
	Fish meal	E. poeppigiana
Milk Yield, kg/animal/day	9.0	8.2
D.M. INTAKE, % BW		
Stargrass pasture	1.93a	1.24b
Supplement	1.08b	1.55a
Total	3.01a	2.79a

Source: Adapted from Abarca (1989)

The Utilization of Legume Trees in Production Systems.

The use of trees in associations with or without crops and pastures fall into the category of agro-forestry systems and constitute an approach to sustainable agriculture in many areas of the tropics. They are of special importance in small farms in Central America, Southeast Asia and parts of Africa.

The main agro-forestry systems are three: alley farming, use of live fences, and the protein banks. Since legume trees are important for their N supply, either in the form of protein for animal feeding or as an element supply to the companion crops or pastures, a brief discussion of these matters will be presented.

1. Alley Farming

In this farming system crops or pastures are grown between hedge rows of planted shrubs and trees which are periodically pruned to prevent shading of the companion crops. Kang and Onafeko (1989) consider alley cropping as a system that uses arable crops and the pruned materials for mulch and green manure. The use of Leucaenas and Gliricidias has resulted in the improvement of soil fertility and increase of yields of companion crops, such as maize after several seasons (Shannon et al., 1989). The forage biomass produced by Erythrina poeppigiana has been studied in Costa Rica where these species are traditionally used as shade for coffee and cacao. The yield of the biomass, that may be of interest when is to be used for animal feeding, depends on the frequency of pruning. In the humid tropics of Costa Rica, the annual forage production of E. poeppigiana is inversely related to the number of prunings per year (Table 11). The leaf yield increases as the trees are defoliated more often. The nutrients produced by the trees are recycled within the system and also are affected by the frequency of pruning (Table 12). Since this system has been used for recycling nutrients, the utilization of the edible biomass for animal feeding could endanger the sustainability, because the more easily mineralizable portions are removed.

Table 11. Biomass production of *Erythrina poeppigiana* under different pruning frequencies in Costa Rica (1).

Pruning Frequency No./year	Annual Production, kg/ha		
	Leaves	Stems	Total
1	3270	15200	18470
2	3900	7700	11800
3	4340	3510	7850

(1) A total of 280 trees/ha at 6 x 6 m spacing.
Source: From Pezo et al. (1989).

Table 12. Estimated amounts of nutrients recycled from leaves of *Erythrina poeppigiana* in Costa Rica.

NUTRIENT, kg/ha/year	Pruning frequency, No. year		
	1	2	3
Nitrogen	330	269	173
Phosphorus	32	21	14
Potassium	156	150	119
Calcium	319	126	94
Magnesium	86	51	27
Total Dry Matter	22750	13714	7850

Source: Pezo et al. from Russo (1984).

From the animal production point of view, systems where the legume trees are interplanted with pastures either for direct grazing or under a cut and carry system have been studied in Costa Rica. The total annual forage yield of Stargrass increased when associated with *E. poeppigiana* and a fair amount of nutrients were cycled from fallen forage (Table 12).

2. Live Fences

The use of *Gliricidia sepium* and *Erythrina berteroana* as live fences is a common practice in the humid and wet-dry tropics of the Caribbean Basin. In a study of the cultural practices and use of *G. sepium* in Costa Rica, it was found that 67% of the farmers that use the species in live fences, utilized the edible biomass for feeding and for shade of the animals. In the southern part of Mexico, 9 out of 10 cattle farms use *G. sepium* as live fence.

The work of CATIE in Costa Rica (Pezo et al., 1989), shows that the biomass production in this system is affected by several factors such as age of the trees, distance between trees, and pruning frequency. Some results of the evaluation of G. sepium and E. berteroana in the lowland humid tropics show that the biomass yield increases as the pruning interval is longer, but the edible biomass do not increase accordingly (Table 13). Although the data come from 4 different locations, both species have a similar potential, but G. sepium tends to be more variable.

Table 13. Biomass production from live fences of Erythrina berteroana and Gliricidia sepium in the lowland humid tropics.

Pruning INTERVAL, months.	Edible BIOMASS, kg DM/km/year	Total BIOMASS, kg DM/km/year
	E. berteroana	
2	1058-2168	1058-2168
4	1769-3976	3132-6201
6	1435-4218	3189-8273
	G. sepium	
2	139-1244	139-1244
4	1001-5580	1581-7771
6	353-3546	589-7483

Range values from four different locations.
Source: Pezo et al. (1989).

3. Protein Banks

This system has been widely used with Leucaena and some results already available show the potential for small and large farm operations. An interesting aspect that needs more research comes from the idea that during the wet season, animals introduced into the bank will tend to consume the grasses associated with the legume and have little consumption of the legume tree. This can be of particular interest to small producers where the reduced farm size requires a maximum use of the land. Additional information on the utilization of G. sepium and E. berteroana as protein banks has been started at CATIE where preliminary data show that 19.4 and 27.0 ton/ha/year of dry matter can be obtained for each species, respectively (Pezo et al., 1989). A trial to study acceptance of different strains of G. sepium in Guatemala, has shown that after the initial cutting 10 months after seeding, the number of branches per tree varied from 3-14 and the trees were ready for grazing after 78 days (Roldán et al., 1990). These innovative ways of using some legume trees such as G. sepium and Erythrina sp. need further investigation to determine the adequate management of these crops.

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