Lessons from main feeding experiments conducted at CATIE using fodder trees as part of the N-ration

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INTRODUCTION

In the tropics, the quantity and quality of forages (mainly grasses) traditionally used by the smallholders to feed ruminants vary with rain precipitation patterns, causing periods of nutritional stress and a consequent reduction in animal productivity. Supplementing animals in periods of feed shortage is a common practice among farmers but, most of the time, this extra feed is barely enough to fulfil the animals maintenance requirement. The high cost of supplements for ruminants, especially protein, and the competitiveness of their use by monogastrics are perennial problems to many farmers in developing countries, leading researchers to look more aggressively for non-conventional protein sources.

In recent years, there has been growing interest in many regions throughout the developing world in exploring the possibilities of including shrub and tree foliages in ruminants diets.

Laboratory methods traditionally used to estimate the nutritive value of forages (proximate analysis, neutral and acid detergent fibre, *in vitro* and *in vivo* digestibility) do not give very consistent results when assessing tree and shrub foliages (Shelton, 1991; Kass and Ruiz, unpublished data) because of the presence of secondary compounds (tannins, alkaloids, etc.). There is therefore little knowledge about the characteristics of these forages as feeds. However, the ultimate indicator of nutritive value is the measurement of the animal production response.

TABLE 1. **Summary of the research carried out by CATIE on shrub and tree foliages as protein supplement to growing small ruminants.**

Foliage species	Crude protein %	IVDMD[1] %	--Dry matter intake-- Foliage % BW	kg/day	Total % BW	Energy Source	ADG[2] g/head	Animal Species	Reference
Stemmadenia donell smitii	24.5	49.4	2.0					goat	Benavides (1991)
Sambucus mexicanus	24.3	75.8	1.9					goat	Benavides (1991)
Malvabiscus arborescens	21.0	68.3	1.8					goat	Benavides (1991)
Hibiscus rosa-sinensis	19.9	71.2	1.2					goat	Benavides (1991)
Guazuma ulmifolia	36.3	50.0	1.0					goat	Benavides (1991)
Eugenia jambos	34.2	33.4	0.6					goat	Benavides (1991)
Erythrina berteroana	25.0	49.0		0.6		green bananas	54	lamb	Arguello *et al.* (1986)
Morus sp.	24.2	89.2	0.5	0.1	3.7	green bananas	75	lamb	Benavides (1986)
Morus sp.	24.2	89.2	1.0	0.2	4.0	green bananas	85	lamb	Benavides (1986)
Morus sp.	24.2	89.2	1.5	0.3	4.3	green bananas	101	lamb	Benavides (1986)
Gliricidia sepium	26.9	58.0		0.6		green bananas	60	lamb	Arguello *et al.* (1986)
Gliricidia sepium[3]	19.9	56.0		0.3		green bananas		goat	De la Fuente (1990)
Gliricidia sepium[4]	19.4	56.3		0.2		green bananas		goat	De la Fuente (1990)
Erythrina poeppigiana	29.0	52.0		0.5		green bananas	35	lamb	Arguello *et al.* (1986)
Erythrina poeppigiana	26.0	51.9	3.5			green bananas	74	lamb	Benavides and Pezo (1986)
Erythrina poeppigiana	26.0	51.9	3.2			molasses	92	lamb	Benavides and Pezo (1986)
Erythrina poeppigiana	26.0	51.9	3.3			green bananas	112	lamb	Benavides and Pezo (1986)
Erythrina poeppigiana	26.0	51.9	3.0			yam	128	lamb	Benavides and Pezo (1986)
Erythrina poeppigiana	25.6	53.7	3.3			yam		goat	Esnaola y Benavides (1987)
Erythrina poeppigiana	26.1	53.5	2.7			green bananas		goat	Rodríguez *et al.* (1987)

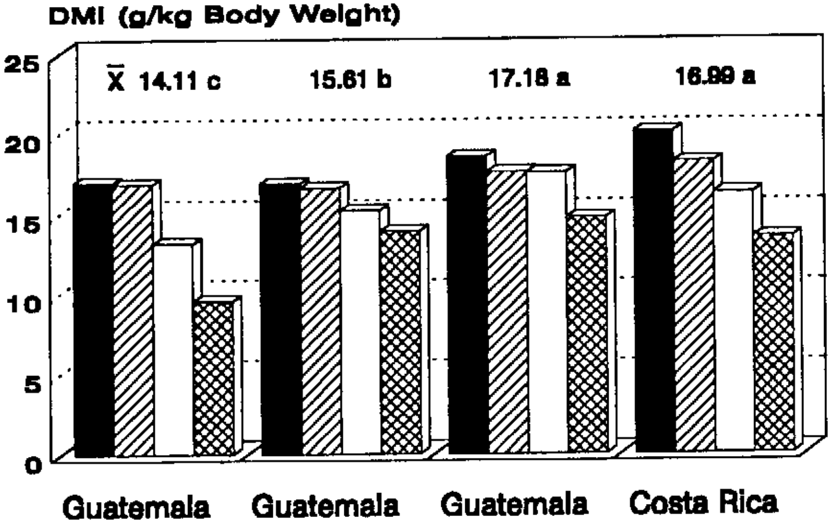
[1] In vitro Dry Matter Digestibility
[2] Average Daily Gain
[3] G. sepium silage from Turrialba, Costa Rica
[4] G. sepium silage from Guapiles, Costa Rica

TABLE 2. Summary of the research carried out by CATIE on shrub and tree foliages as protein supplement to milking goats fed on chopped *Pennisetum purpureum*.

Foliage species	Crude Protein%	IVDMD[1]	Dry matter intake: Foliage % BW	Dry matter intake: kg/day	Dry matter intake: Total % BW	Energy source	Milk Yield kg/day	Reference
Gliricidia sepium	25.4	57.3	0.9		3.6	green bananas	1.1	Rodriguez *et al.* (1987)
Erythrina poeppigiana	24.8	53.1	0.6			ripe bananas	1.1	Gutierrez (1983)
Erythrina poeppigiana	25.3	55.0	0.6			green bananas	1.3	Samur (1984)
Erythrina poeppigiana	25.3	55.0	0.6			ripe bananas	1.2	Samur (1984)
Erythrina poeppigiana	23.7	52.6	0.5	0.2	3.6	green bananas	0.7	Esnaola and Rios (1986)
Erythrina poeppigiana	23.7	52.6	1.0	0.4	4.0	green bananas	0.8	Esnaola and Rios (1986)
Erythrina poeppigiana	23.7	52.6	1.5	0.6	4.4	green bananas	1.0	Esnaola and Rios (1986)
Erythrina poeppigiana	27.8	54.0		0.5	3.9	green bananas	1.3	Castro (1989)
Erythrina poeppigiana	27.8	54.0		0.5	3.8	green bananas	1.1	Castro (1989)
Erythrina poeppigiana	27.8	54.0		0.3	4.0	green bananas	1.1	Castro (1989)
Erythrina poeppigiana	27.8	54.0		0.3	3.6	green bananas	1.1	Castro (1989)
Malvabiscus arborescens	21.0	68.3	1.3	0.6	5.2		1.8	Hernandez and Benavides (unpublished data)
Morus spp.	24.2	89.2	1.3	0.6	5.4		2.2	Benavides (unpublished data)

[1] *in vitro* dry matter digestibility.

FIGURE 1. **Dry matter intake (DMI) of different families and individual plants within the same family of *Gliricidia sepium*.**



Guatemala	Guatemala	Guatemala	Costa Rica
16.94	16.86	18.53	20.07
16.82	16.58	17.60	18.18
13.15	15.16	17.56	16.26
9.53	13.85	14.70	13.44

SMALL RUMINANTS

In 1980, CATIE began to develop goat and sheep feeding systems utilizing tree foliages as protein supplements to grasses diets, together with several energy sources, especially green banana fruits. The results have been extensively described by Pezo *et al.* (1990) and Benavides (1991), and are summarized in Tables 1 and 2. From these initial studies several conclusions can be drawn.

Dry matter intake (DMI) by goats of several Central American shrub and tree foliages was shown by Benavides (1991) to be very high. However, *Gliricidia sepium* foliage was found to produce an erratic DMI (De la Fuente, 1990; Rodriguez *et al.*, 1987). More recently, the nutritional diversity of this species has been studied by Kass and Ruiz (unpublished data), indicating important variation in DMI among provenances, families within provenances and individual plants within the same family (Figure 1). In spite of the negative relationships between foliage DMI and NDF, ADF and tannin content, these correlations were lower than those found with traditional forages (Table 3), indicating that other factor(s) is(are) responsible for DMI variation in *G. sepium* foliage.

The supplementation of *Pennisetum purpureum* and green banana fruits with increasing amounts of *E. poeppigiana*, *Morus* spp. and *Malvabiscus arborescens* foliages enhanced milk yields and daily gains in goats and lambs respectively. Although a partial substitution effect on king grass DMI was detected, the total DMI increased (Benavides, 1986; Esnaola and Rios, 1986).

The addition of an energy source to grass diets supplemented with *E. poeppigiana* improved the daily weight gain of lambs (Benavides and Pezo, 1986) and daily milk production in goats (Samur, 1984). However, starch sources such as green banana fruits and yams gave better results than soluble carbohydrate sources like molasses and ripe bananas, indicating either more microbial synthesis in the rumen when readily degradable energy sources are used and/or more bypass feed energy with starch supplements. Also, the crude protein:digestible energy ratio was shown by Castro (1989) to be more important than levels of foliage and energy for milk production by goats fed on grass (*P. purpureum*) and supplemented with *Erythrina poeppigiana* foliage and green banana fruits. Nevertheless, *Morus* spp. and *M. arborescens* foliages, used as the only feed to dairy goats, showed high DMI and milk production without energy supplementation (Benavides, unpublished data; Hernandez and Benavides, unpublished data). However, it is interesting to note that both foliages showed very high *in vivo* dry matter digestibility (64% and 81% for *M. arborescens* and *Morus* spp. foliages, respectively).

Milk yield from goats supplemented with *E. poeppigiana* was lower than commercial concentrate supplements with the same level of crude protein, confirming that the protein quality of this tree foliage is less than that of traditional protein supplement. But the economic analyses favoured the use of *E. poeppigiana*.

TABLE 3. **Correlation coefficients between foliage dry matter intake and chemical composition of *Gliricidia sepium* families.**

	Correlation coefficient	P F
Dry matter %	0.31	0.24
IVDMD[1] %	0.06	0.81
Crude Protein %	-0.04	0.86
NDF[2] %	-0.50	0.05
ADF[3] %	-0.48	0.06
Soluble phenolics %	-0.62	0.03
Insoluble proanth.	-0.36	0.16

Source: Kass and Ruiz (unpublished data)
[1] *In vitro* dry matter digestibility
[2] Neutral detergent fibre
[3] Acid detergent fibre
[4] Insoluble proanthocyanidins.

CATTLE

It was only in 1986 that CATIE's began studies on the utilization of tree foliage as nitrogen supplement to cattle. Pineda (1986) evaluated different levels of substitution of a traditional protein source (soyabean meal) with *E. poeppigiana* foliage to dairy heifers (48 kg live weight) fed on king grass (*Pennisetum purpureum*). The replacement of soyabean meal with increased levels of *E. poeppigiana* resulted in a linear decrease in daily gains and grass dry matter intake (Figure 2).

However, these effects were more evident in another experiment carried out by Abarca (1989). When *E. poeppigiana* and sugar cane molasses were compared with commercial concentrates as protein supplements to milking cows grazing African star grass, the foliage supplementation consistently resulted in lower milk production and pasture DMI (Table 4).

FIGURE 2. Average daily gain and dry matter intake of *P. purpureum* as influenced by the level of *E. poeppigiana* intake.

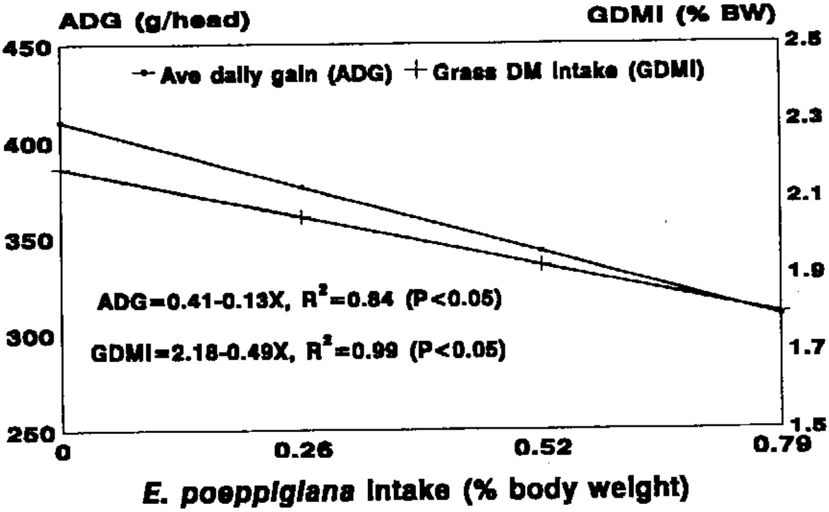


TABLE 4. Dry matter (DM) intake and daily milk production in cows grazing African star grass, supplemented with either fish meal or *E. poeppigiana* foliage as the protein source.

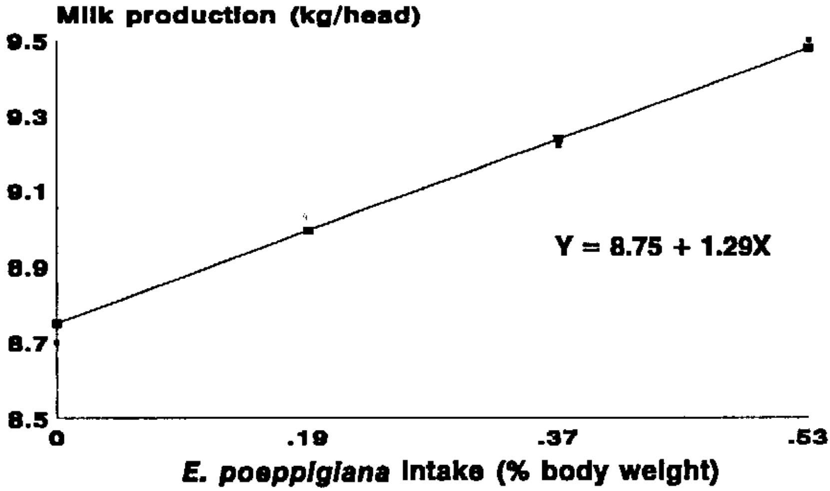
	Fish meal	*E. poeppigiana*
DM intake (% body weight)		
African star grass	1.93[a]	1.24[b]
Supplement	1.08[a]	1.55[a]
Total	3.01[a]	2.79[a]
Milk production (kg/head)	9.0	8.2
Milk composition (%)		
Total solids	13.4[b]	12.7[a]
Protein	3.2[a]	3.3[a]
Fat	4.1[a]	4.3[a]

Source: Abarca (1989)

Note: Sugar cane molasses was the energy supplement. Means in the same row followed by the same letter do not differ significantly ($P < 0.05$).

Following this finding, Vargas (1987) fed grazing steers different levels of *E. coleata* foliage and observed increased average daily gains when *E. cocleata* was offered at a level equivalent to 0.05 x body weight (398 and 524 g/day for the control and tree foliage). The addition of an energy supplement (green banana fruits) to the same level of *E. cocleata* resulted in a slight increase in daily gain (579 v. 524 g/head), but, again benefit/cost relationship favoured the foliage as the only supplement. The same beneficial effect of tree foliage supplementation was observed by Tobon (1988) when milking cows grazing African star grass (*Cynodon nlemfuensis*) and receiving a constant level of energy (1 kg molasses/head/day) where supplemented with increasing levels of *E. poeppigiana* foliage (Figure 3).

FIGURE 3. **Milk production of grazing cows in relation to levels of *E. poeppigiana* intake.**



Although the protein quality of *Erythrina* spp. was shown in both experiments to be less than that of traditional protein supplements, the economic analyses indicated that the net profit obtained using the foliage supplement plus locally available energy sources, such as sugar cane molasses, was better than concentrates. This is important to the small farmer because the availability of cash is one of the farmer's main constraints.

Taking into account this situation and in view of the fact that the addition of energy improves milk production, Corado (1991) carried out a study utilizing another locally available feed resource, rice bran, as a supplement to grazing dairy cows receiving a constant level of *E. poeppigiana* foliage equivalent to 0.05 x BW. The results, showed in Table 5, indicated that increasing the level of rice bran supplementation increased milk production. Although there were very little differences in crude protein and digestible energy intakes between the control diet and rice bran supplementation equivalent to 0.02 x BW, daily milk yield increased from 8.7 kg/head to 9.7 kg/head, with a net marginal increase of 266%, showing that bypass nutrients (protein and energy) are needed to obtain higher milk production when *E. poeppigiana* foliage is the nitrogen source.

TABLE 5. **Crude protein and digestible energy intakes and milk production in grazing cows supplemented with *E. poeppigiana* (0.5 % BW) and different levels of rice bran.**

	Rice bran intake (% BW)			
	0	0.2	0.4	0.6
Crude protein intake (g/day)	1037	1071	1159	1262
Digestible energy intake (Mcal/day)	24.4	24.1	26.7	28.9
Milk yield (kg/head/day)	8.8	9.7	9.9	10.5

Source: Corado (1991)

There is an evident need for protein supplementation during the dry season in sub-humid systems, when low quality and low protein forages (mature grass, crop residues or sugar cane) are the main feed resources. Alagon (1990), comparing *E. poeppigiana* foliage with conventional nitrogen sources with different rumen degradation rates (urea, fish meal and soyabean meal) as protein supplements to dairy cows fed on chopped sugarcane plus rice bran, concluded that daily milk yields in cows supplemented with this tree foliage were similar to urea but inferior to soyabean meal and fish meal (Table 6). Also, animals supplemented with *E. poeppigiana* foliage and urea had a lower sugar cane intake than fish meal and soyabean meal supplements. However, urea-supplemented diets resulted in inferior milk composition and the cows lost weight in the experimental period, as compared to *E. poeppigiana* supplementation. Although the crude protein degradability was the same for *E. poeppigiana* foliage and soyabean meal (68%), *E. poeppigiana* was shown to contain high amounts of nitrogen in the ADF fraction, which could be influencing its bypass protein availability. The different protein supplements did not effect the total income but the variable costs were lower for diets where tree foliage and urea were the nitrogen sources.

TABLE 6. **Sugar cane intake and milk production and composition in cows fed on sugar cane supplemented with *E. poeppigiana* foliage and traditional nitrogen sources.**

	Erythrina poeppigiana	Fish meal	Soyabean meal	Urea
Sugar cane intake (% BW)	1.45	1.61[a]	1.64[a]	1.49[b]
Milk yield (kg/day)	9.60[a]	11.02[b]	10.54[b]	9.29[a]
Milk composition (%)				
Total solids	12.58[a]	12.43[a]	12.48[a]	11.96[b]
Fat	3.63[a]	3.37[b]	3.50[ab]	3.59[b]
Protein	3.27[b]	3.42[a]	3.38[ab]	3.05[b]
Average daily gain (g/head)	468[ab]	892a	287[b]	-461[c]

Means followed by the same letter do not differ statistically ($P > 0.05$).

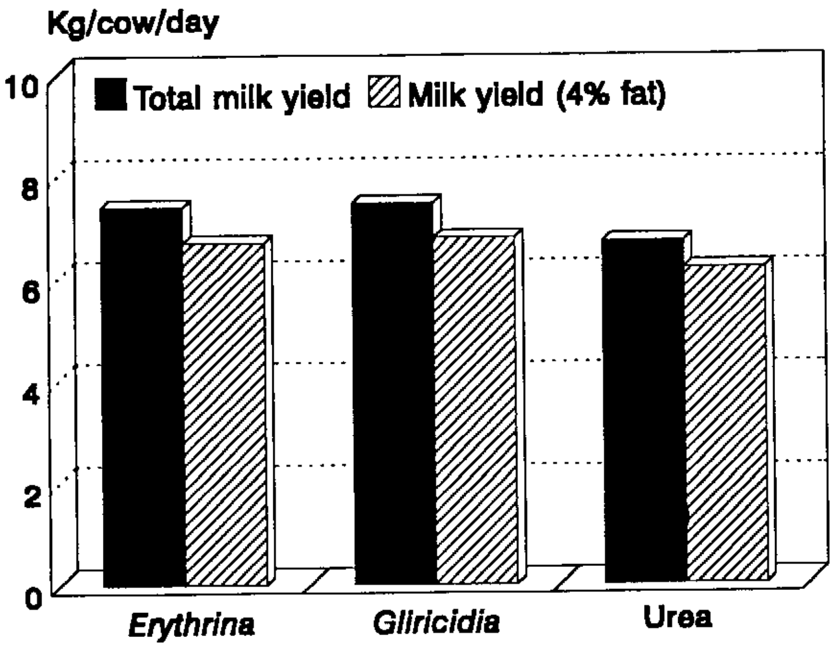
Source: Alagon (1990).

However, when the same diets were used for growing daily heifers (Vasquez, 1991), daily gains of 763, 648 and 592 g/head were obtained for fish meal, *E. poeppigiana* edible biomass and urea, respectively. The supplementation with tree forage decreased sugarcane DMI, but increased total DMI, and had no effect in the sugar cane dry matter disappearance from the rumen, in spite of increased rate of passage of the diet in the gastro-intestinal tract.

In the dry season, crop residues and hays with very low nutritive values play a major role in the feeding of livestock. Traditionally, these feed resources are supplemented with urea and molasses which slightly improves feed intake and digestibility of the diet but has very little effect in the animal productivity. Camero (1991) showed that the supplementation of *Hyparrhenia rufa* hay (3% crude protein and 35% *in vitro* dry matter digestibility) with *E. poeppigiana* or *Gliricidia sepium* foliages improved the milk yield as compared to urea supplementation (Figure 4). Also, the animals were in better body condition and had higher dry matter intakes with foliages supplementation.

In summary, the results obtained with grazing daily cows under lowland humid tropical conditions suggest that the direct benefits on milk production derived from the use of *E. poeppigiana* foliage are small but that there might be important indirect benefits such as increased carrying capacity as a result of substitution effects on grass intake and increased recycling of nutrients in the areas grazed, as a result of richer animal excreta. But, in sub-humid systems, supplementation of poor quality roughages with tree foliage seems to be an attractive method of improving animal productivity.

FIGURE 4. **Milk production in cows fed H. rufa hay and supplemented with *G. sepium, E. poeppigiana* and urea.**



total milk yield	7.33	7.44	6.68
milk yield (4% fat)	6.68	6.75	6.16

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