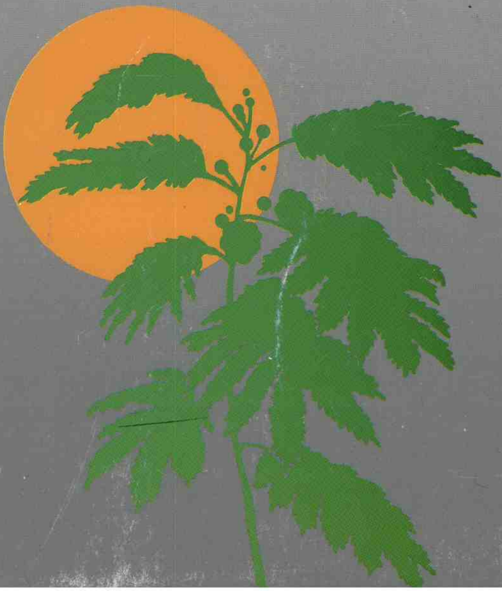
# SHRUBS AND TREE FODDERS FOR FARM ANIMALS

PROCEEDINGS OF A WORKSHOP IN DENPASAR, INDONESIA, 24 – 29 JULY 1989



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# Shrubs and tree fodders for farm animals

Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989

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IDRC
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PO Box 8500, Ottawa, Ont., Canada K1G 3H9

Devendra, C.
IDRC. Regional Office for Southeast and East Asia, Singapore SG

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# Abstract

This publication presents the results of an international meeting held in Denpasar, Bali, Indonesia, 24–29 July 1989, that focused on the use of shrubs and tree fodders by farm animals. Through 26 papers, the workshop addressed feed-resource availability, use by ruminants and nonruminants, processing methodology, economics, and development issues. These aspects and the current knowledge on shrubs and tree fodders were further highlighted by country case studies detailing prevailing situations and policy matters. A special session was held to discuss the successful development and results achieved in the three-strata forage system in Indonesia. The workshop concluded with important working group discussions on the priorities for further research and development, and on the potential for the wider use of shrubs and tree fodders in the developing world.

# Résumé

Cette publication présente les résultats d'une rencontre internationale tenue à Denpasar, Bali, Indonésie, du 24 au 29 juillet 1989 et qui a porté sur l'utilisation des arbustes et fourrages végétaux par les animaux d'élevage. Les 26 communications qui y ont été présentées traitaient de la disponibilité des ressources alimentaires pour les animaux, de leur utilisation par les ruminants et les non-ruminants, des méthodes de transformation, des aspects économiques et des questions du développement. Ces sujets et les connaissances actuelles sur les arbustes et les fourrages végétaux ont ensuite été étudiés plus à fond dans le cadre d'études de cas de divers pays exposant les circonstances particulières de chacun et les questions liées aux politiques. Une séance spéciale a porté sur la mise en place et les résultats des systèmes de production de fourrages végétaux en trois strates en Indonésie. L'atelier s'est terminé par d'importantes discussions des groupes de travail sur les priorités de recherche et de développement pour l'avenir et sur les possibilités d'utilisation élargie des arbustes et des fourrages végétaux dans les pays en développement.

# Resumen

Esta publicación presenta los resultados de una reunión internacional celebrada en Denpasar, Bali, Indonesia, del 24 al 29 de julio de 1989, y la cual centró su atención en la utilización de forrajes elaborados a partir de arbustos y árboles para alimentar a animales de granjas. En 26 trabajos presentados al seminario, los participantes abordaron temas tales como la disponibilidad de recursos alimentarios y la utilización de los mismos por rumiantes y no rumiantes, metodologías de procesamiento y cuestiones de economía y desarrollo. Estos aspectos y el conocimiento que se tiene actualmente sobre los forrajes de arbustos y árboles se vieron subrayados aún más por estudios de casos por países en los que se detallaron situaciones existentes y cuestiones de políticas. Se celebró una sesión especial para discutir el desarrollo y resultados exitosos alcanzados en Indonesia con el sistema de forraje de tres niveles. El taller concluyó con importantes discusiones de los grupos de trabajo sobre las prioridades existentes en el campo de la investigación y el desarrollo y sobre el potencial que encierra la amplia utilización de arbustos y árboles en el mundo en desarrollo.

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**Session IV: Country Case Studies**



**Session V: Processing, Methodology, and Economics**

# Potential of legume tree fodders as animal feed in Central America

D. Pezo, M. Kass, J. Benavides, F. Romero, and C. Chaves

Tropical Agricultural Research and Training Centre, Turrialba, Costa Rica

***Abstract*** — *Agroforestry systems are promising alternatives for sustainable agricultural production in the subhumid and humid tropics of Central America. Intercropping* Erythrina poeppigiana *with coffee, African star grass (*Cynodon nlemfuensis*), or king grass (*Pennisetum purpureum × Pennisetum typhoides*); live fences of* E. poeppigiana *or* Gliricidia sepium*; and monocultures of the same two legume tree species (managed as protein banks) are systems analyzed in this paper, in terms of their forage biomass production potential, herbage quality, and nutrient cycling. Data generated in the Central American isthmus on the potential of legume tree foliages (mainly* E. poeppigiana *and* G. sepium*) as protein supplements for ruminants are also presented. Some of the aspects covered are chemical composition, in vitro dry matter digestibility, rumen degradability, intake, live weight gain, and milk production responses in goats, sheep, beef, and dairy cattle. Also, some information on the conservation of the foliage of* G. sepium *as silage is included.*

***Résumé*** — *Les systèmes d'agroforesterie sont prometteurs de solutions de rechange allant dans le sens de l'agriculture durable pour les tropiques sous-humides et humides de l'Amérique centrale. Les auteurs analysent la culture intercalaire de* Erythrina poeppigiana *et du café, de* Cynodon nlemfuensis *ou de* Pennisetum purpureum × Pennisetum typhoides*; la plantation de haies vives de* E. poeppigiana *ou de* Gliricidia sepium*; et la monoculture des deux mêmes espèces d'arbres légumineux (gérés comme banques de protéines) en fonction de leur potentiel de production de biomasse fourragère, de la qualité des herbages et du cyclage des nutrients. Ils présentent les données obtenues dans l'isthme de l'Amérique centrale sur le potentiel des feuilles d'arbres légumineux (principalement* E. poeppigiana *et* G. sepium*) comme complément protéique à la ration alimentaire des ruminants. Ils abordent notamment la composition chimique, la digestibilité in vitro des matières sèches, la dégradabilité du rumen, l'ingestion, le gain de poids et la production de lait chez les chèvres, les moutons, le boeuf et la vache laitière. Également, ils donnent des informations sur la conservation des feuilles de* G. sepium *pour l'ensilage.*

***Resumen*** — *Los sistemas de agroforestación, en los trópicos húmedos y semihúmedos de America Central, son alternativas promisorias para mantener la producción agrícola. El cultivo intercalado o intermedio de* Erythrina poeppigiana *con café, grama africana (*Cynodon nlemfuensis*) o grama rey (*Pennisetum purpureum × Pennisetum typhoides*), setos vivos de* E. poeppigiana *o* Gliricidia sepium *y monocultivos de las mismas dos especies de árboles leguminosos (explotados como bancos proteínicos) son sistemas que se analizan en este estudio, en función de su potencial de producción de biomasa forrajera, calidad de pastizales y ciclo de nutrientes. Se presentan los datos obtenidos en el Istmo de América Central con relación al potencial de* *follajes de árboles leguminosos (principalmente* E. poeppigiana *y* G. sepium*) como aditivos proteínicos para rumiantes. Entre los aspectos considerados se encuentran: composición química, digestibilidad de la materia seca in vitro, la capacidad de separación de alimentos del rumen, consumo, aumento en peso vivo y las respuestas de producción lechera en cabras, ovejas, ganado vacuno y lechero. Se incluye también información relativa a la conservación del follaje de* G. sepium *como ensilaje.*

# Introduction

Agroforestry systems are a promising approach to developing sustainable, economical agricultural systems in the subhumid and humid tropics in Central America. Within this context, multipurpose nitrogen-fixing trees play an important role in smallholder farming systems. They provide fuelwood, live fences, shade for crops and animals, plant support, green manure, fodders, and medicinal and other products.

Since the late 1970s, the Tropical Agricultural Research and Training Centre (CATIE) has characterized the agroforestry systems used in the Central American isthmus and the Dominican Republic and developed more productive and sustainable systems using the agroforestry approach. CATIE has been studying several agroforestry alternatives using multipurpose nitrogen-fixing trees: intercropping trees in cocoa and coffee plantations as a source of shade and for recycling nutrients; alley cropping legume trees and annual crops; use of trees as support for trailing crops (e.g., black pepper and chayote squash); and as a source of fuelwood and posts. This paper emphasizes the potential use of *Erythrina* spp. and *Gliricidia sepium* as fodder sources for ruminants.

# Forage biomass production

Forage biomass yield has been evaluated for five agroforestry systems that include nitrogen-fixing trees: intercropping of *Erythrina poeppigiana* with coffee, African star grass (*Cynodon nlemfuensis*), or king grass (*Pennisetum purpureum* × *Pennisetum typhoides*); live fences of *E. poeppigiana* or *G. sepium*; and monocultures of *E. poeppigiana* or *G. sepium* planted as "protein banks."

The use of *E. poeppigiana* as a shade tree in cocoa and coffee plantations is a traditional agroforestry practice in many areas of the tropics (Budowski 1959; Cadima and Alvim 1967; Willey 1975). Several effects have been mentioned: soil and crop temperatures decrease; radiation is reduced, affecting photosynthesis, stomata opening, flowering, and fruit ripening; transpiration is diminished; nutrients are recycled into the soil; and nitrogen fixation occurs when legume trees are used. In this system, the biomass yields and the amount of nutrients recycled are a function of the pruning interval used for the shade tree. They also depend on the spacing of planted shade trees and the age of the plantation. Total biomass yield increases as the pruning frequency decreases. The reverse occurs for leaf yields (Table 1), indicating that the proportion of edible biomass is greater with more frequent prunings (Russo 1984).

A similar trend to that mentioned for total biomass occurs for the amount of nutrients recycled through pruned and fallen leaves of *E. poeppigiana*. The average

**Table 1. Annual biomass production (kg/ha) from *E. poeppigiana* pruned at different frequencies in a Costa Rican coffee plantation.[a]**

| Number of prunings per year | Leaves | Stems | Total |
|---|---|---|---|
| 1 | 3 270 | 15 200 | 18 470 |
| 2 | 3 900 | 7 700 | 11 800 |
| 3 | 4 340 | 3 510 | 7 850 |

Source: Russo (1984).
[a] In plantation, 280 trees/ha, 6 × 6 m spacing.

values for annual recycled nitrogen, phosphorus, potassium, calcium, and magnesium are 257, 22, 142, 180, and 55 kg/ha, respectively (Russo 1984). If all the edible biomass of *E. poeppigiana* is extracted for animal feeding, then the most easily mineralizable fractions are removed from the field. The sustainability of these systems is, therefore endangered, unless organic or chemical fertilizers are applied.

The second agroforestry system studied was the intercropping of *E. poeppigiana* with African star grass. This was compared with intercropping African star grass with a timber tree (*Cordia alliodora*) and with a control (no trees). Annual grass dry matter yield was higher when associated with the legume tree than with the timber tree (9 311 vs 4 087 kg/ha). The lowest annual yield (2 632 kg/ha) was obtained in the control plots. Also, there were broad-leaved weeds in those plots with trees. Even though the presence of trees negatively affected solar radiation reaching the grass canopy (60% of that measured in the unshaded plots), the nutrients recycled through fallen leaves and pruned branches, and nitrogen fixation occurring in the legume tree plots, favoured grass growth and prevented the invasion of weeds. A significant increase in the grass crude protein (CP) content was also observed in the *E. poeppigiana* plots compared with those plots with *C. alliodora* and without trees (9.5, 6.4, and 6.1% CP, respectively). This suggests that the legume tree effectively fixed and transferred nitrogen to the grass (Bronstein 1984).

The third agroforestry system evaluated was the intercropping of king grass (*P. purpureum* × *P. typhoides*) and *E. poeppigiana* under a cut-and-carry approach (Rodríguez 1985). In this system, the annual grass yield was not affected by the presence of trees (17.7 and 16.8 t dry matter (DM)/ha for plots with 1 666 and 3 333 trees/ha, respectively), indicating that the nutrients transferred by the legume tree compensated for the lower radiation that reached the grass canopy. Other beneficial effects of this system were the extra amount of a nitrogen-rich foliage produced annually by the legume tree (7.6 and 11.6 t DM/ha for plots with 1 666 and 3 333 trees/ha, respectively) and the slight increase observed in the CP content of the grass growing under the trees. The productivity of this system declined with time, however, because of the high removal of nutrients through the grass and legume tree biomass, which, in general, was greater in the intercropped than in the monoculture grass plots. The average annual extractions of nitrogen, phosphorus, and potassium in the intercropped treatments were 444, 71, and 396 kg/ha, respectively; the corresponding values for the control plots were 151, 59, and 345 kg/ha. This experiment has now been modified to assess the sustainability of the system, when different proportions of the biomass obtained after pruning the legume tree are returned as green manure.

The fourth agroforestry system considered was the use of legume trees (*G. sepium* or *Erythrina berteroana*) as live fences, a common practice in the humid and subhumid tropics of Central America. Different pruning intervals have been evaluated at four sites in the lowland humid tropics of Costa Rica (CATIE 1987). Several factors are known to affect biomass production in this system (Fig. 1), including age of live fence, distance between trees, and pruning frequency. In general, the total biomass yield increased as the pruning interval was delayed (Table 2), but the proportion of edible biomass declined with age. Also, tree survival was negatively affected by frequent pruning. To obtain a sustained productivity of such systems, the pruning interval has to be at least 4 months (CATIE 1987).

Because of the limited yield that can be obtained from the live fence agroforestry system, a new strategy has been tested. Stakes of *G. sepium* and *E. berteroana* have been planted similarly to sugarcane, to establish legume tree "protein banks." The average annual yields obtained during the 1st year were 19.4 and 27.0 DM/ha for *G. sepium* and *E. berteroana*, respectively (CATIE, unpublished data). Whether or not these high yields can be sustained needs to be investigated.


**Fig. 1. Measuring foliage production from a live fence of *Erythrina berteroana* in the lowland humid tropics of Costa Rica.**

Table 2. Annual biomass production (kg dry matter/km) from live fences of *E. berteroana* and *G. sepium* pruned at different frequencies in the lowland humid tropics of Costa Rica.

| Pruning intervals (months) | Edible biomass | Total biomass |
|---|---|---|
| | *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 |

Note: Results are ranges of values obtained at four research sites.
Source: CATIE (1987).

## Nutritive value

The edible biomass of legume trees is a useful protein supplement for ruminants. Efforts have been made to characterize the nitrogen fraction of these feedstuffs (Espinoza 1984). The CP content varies with plant portions (laminae green stem petiole); however, the rumen degradability of the nitrogenous fraction does not follow the same pattern (green stem petiole laminae). In general, these forages have shown higher DM rumen degradability values when in situ digestion techniques have been used (Table 3), compared with the traditional in vitro dry matter digestibility (IVDMD) method. This suggests that some antiquality factors are present, especially in the more mature laminae (Table 4). Also, the solubility of the nitrogenous fraction is particularly high in the green stem, but lower in the petiole and laminae. In all three portions, more than 75% of the soluble fraction is represented by nonprotein nitrogen (NPN) compounds (Espinoza 1984).

Most of our work on the quality of legume tree foliages has concentrated on two species: *E. poeppigiana* and *G. sepium*. More recently, however, the nutritional diversity of the genus *Erythrina* has been studied (CATIE, unpublished data). The results obtained show important variations among and within species in terms of CP content, protein solubility, acid-detergent insoluble nitrogen (ADIN) content, and IVDMD (Table 5). These results showed that the *Erythrina* species most commonly included in the agroforestry systems previously evaluated (*E. poeppigiana* and *E. berteroana*) had a higher nutritional quality than the less common *E. fusca* and *E. costarricense*, notwithstanding the variability in the nutritive value of *E. berteroana*. These results suggest the need for a better definition of the germ plasm used in different experiments, as well as the potential for genetic improvement of quality parameters in these species.

Another important aspect that needed clarification with respect to these nontraditional forages was the extent of the acceptability by animals. Benavides (1986) showed that the DM intake of *E. poeppigiana*, as the sole forage source for goats, was as high as that obtained for the herbaceous legume *Lablab purpureus* (3.24 and 3.39% body weight, respectively). Some differences among legume tree foliages, in terms of their potential intake, have been detected by Arguello et al.

**Table 3. Nitrogen fractions in different portions of the edible biomass of *G. sepium* and *E. poeppigiana* harvested at 3- and 5-month intervals.**

| Fraction | *G. sepium* 3 m | *G. sepium* 5 m | *E. poeppigiana* 3 m | *E. poeppigiana* 5 m |
|---|---|---|---|---|
| Crude protein (CP) (%) | | | | |
| Laminae | 23.8 | 26.9 | 26.0 | 30.3 |
| Petiole | 11.9 | 12.5 | 9.3 | 10.4 |
| Green stem | 20.7 | 18.9 | 17.8 | 22.4 |
| N rumen degradability (%) | | | | |
| Laminae | 79.3 | 76.7 | 67.2 | 61.8 |
| Petiole | 80.1 | 77.2 | 78.8 | 78.3 |
| Green stem | 86.8 | 81.4 | 83.9 | 89.7 |
| CP solubility (%) | | | | |
| Laminae | 23.6 | 37.8 | 26.3 | 24.4 |
| Petiole | 43.7 | 54.2 | 47.0 | 54.8 |
| Green stem | 63.7 | 70.7 | 67.2 | 60.2 |
| Nonprotein nitrogen (% soluble CP) | | | | |
| Laminae | 82.8 | 77.6 | 87.5 | 76.6 |
| Petiole | 82.0 | 78.8 | 80.4 | 80.2 |
| Green stem | 91.9 | 85.5 | 93.4 | 89.7 |
| ADIN (% total N)[a] | | | | |
| Laminae | 42.1 | 44.6 | 23.1 | 33.0 |
| Petiole | 33.6 | 32.0 | 32.3 | 38.5 |
| Green stem | 14.5 | 10.6 | 11.2 | 13.4 |

Source: Espinoza (1984).
[a] ADIN, acid-detergent-insoluble nitrogen.

**Table 4. Nutritive value of the edible biomass in *E. poeppigiana*, as a function of position in the branches.**

| Stratum (cm from branch apex) | CP (%) Laminae | CP (%) Petiole | IVDMD (%) Laminae | IVDMD (%) Petiole |
|---|---|---|---|---|
| 0–40 | 31.9a | 12.4a | 60.0a | 72.0a |
| 40–80 | 29.8b | 9.2b | 49.7bc | 66.1b |
| 80–120 | 28.8bc | 8.6b | 50.0bc | 67.0b |
| 120–160 | 26.5d | 8.4b | 48.1c | 63.3b |
| 160–200 | 28.3c | 9.2b | 52.8b | 67.4b |

Note: CP, crude protein; IVDMD, in vitro dry matter digestibility. Means followed by the same letter in the same column do not differ statistically ($P \leq 0.05$).
Source: Russo (1984).

(1986) and Vargas and Elvira (1987), using goat kids and dual-purpose cattle. In both studies, the foliage of *G. sepium* was the most readily consumed (Table 6); however, several experiments performed at CATIE have indicated that ruminants have no palatability problems with the commonly used species of *Erythrina*, whereas problems of intake have been detected in some studies with *G. sepium*. Studies to clarify the causes of this problem in *G. sepium* are needed. There is some evidence of genetic variability in the content of antiquality factors in this species; but some seasonal and age of regrowth effects may also exist.

**Table 5. Nutritive value of the edible biomass in different species and clones of the genus *Erythrina*.**

| Species | No. of clones | Crude protein (%) | Protein solubility (%)[a] | ADIN (%)[b] | IVDMD (%)[c] |
|---|---|---|---|---|---|
| *E. berteroana* | 12 | 25 | 40 | 10 | 49 |
| | | (22–28)[d] | (28–53) | (7–13) | (42–55) |
| *E. fusca* | 7 | 23 | 32 | 14 | 44 |
| | | (19–25) | (20–49) | (10–18) | (43–47) |
| *E. poeppigiana* | 3 | 32 | 49 | 9 | 52 |
| | | (31–32) | (44–60) | (7–11) | (50–54) |
| *E. costarricense* | 8 | 25 | 39 | 14 | 46 |
| | | (22–27) | (28–46) | (8–19) | (32–53) |
| *E. cocleata* | 1 | 24 | 35 | 20 | 47 |
| *E. lanceolata* | 1 | 26 | 56 | 14 | 50 |

[a] Solubility in a borate–phosphate buffer.
[b] ADIN, acid-detergent-insoluble nitrogen, % of total nitrogen.
[c] IVDMD, in vitro dry matter digestibility.
[d] Values in parentheses are the ranges of mean values for clones within species.

**Table 6. Chemical composition, in vitro dry matter digestibility (IVDMD), and voluntary intake of *Leucaena leucocephala*, *Gliricidia sepium*, and *Guazuma ulmifolia*.**

| | *Leucaena* | *Gliricidia* | *Guazuma* |
|---|---|---|---|
| CP (%) | 25.0 | 25.8 | 14.7 |
| CWC (%) | 47.8 | 43.5 | 49.5 |
| ADF (%) | 28.2 | 26.2 | 31.4 |
| ADIN (% of total N) | 7.4 | 10.7 | 25.2 |
| IVDMD (%) | 47.8 | 58.4 | 43.0 |
| DM intake[a] (% body weight) | 0.512c | 0.868a | 0.709b |

Note: CP, crude protein; CWC, cell wall constituents; ADF, acid-detergent fibre; ADIN, acid-detergent-insoluble nitrogen; DM, dry matter. Means followed by the same letter do not differ statistically ($P \leq 0.05$).
Source: Vargas and Elvira (1987).
[a] Ad libitum intake obtained in 2 h after the morning milking.

# Silage conservation

The need for protein supplementation in grazing animals is enhanced during the dry season in subhumid ecosystems. However, in many legume trees, the protein-rich leaves are unavailable for animal feeding during this part of the year because leaves are shed during the early dry season, when plants enter a flowering stage (Russo 1984). One of the strategies considered to overcome this restriction is conserving these foliages as silage. This task is not easy, however, because, in many cases, the fermentation process in legumes is dominated by Clostridia, leading to a butyrate-type silage. This has been attributed to three factors in the legumes: high buffering capacity, low water-soluble carbohydrates, and, often, low DM content. Based on these facts, different preconditioning treatments to reduce nutrient losses during silage fermentation have been tested.

Kass and Rodríguez (1987) observed that a high proportion of the nitrogen fraction was in a volatile form (ammonia) and low levels of lactic acid were detected in silages made of either fresh or wilted *G. sepium* foliage, without additives. The addition of readily fermentable carbohydrate sources, such as molasses or chopped sugarcane, decreased ammonia and increased lactic acid concentrations. Also, the addition of formic acid markedly reduced ammonia nitrogen, but did not affect lactic acid production.

Based on these preliminary results, different levels of sugarcane molasses as an additive for *G. sepium* silages were evaluated (CATIE, unpublished data). The CP content tended to decline slightly (dilution effect), but IVDMD increased as higher levels of molasses were added. A decline in ammonia concentration occurred when 2% molasses (w/w) was added to ensiled *G. sepium*, but higher levels of molasses resulted in minor changes in ammonia concentration. Lactic acid concentration increased almost linearly with molasses additions, but the highest level of molasses (10%, w/w) resulted in a silage with only 2.6% lactic acid. In all cases, the butyric acid concentration was very low (0.04%). The voluntary intake of these silages has not been measured, but observations with young female goats showed that silages made of *G. sepium* with 2% molasses as an additive were readily consumed when fed as a supplement to chopped grass.

# Animal production responses

## Small ruminants

Initial work has been done at CATIE, using goats and sheep, aimed at developing ruminant feeding systems based on the use of legume tree foliages as protein supplements. In most of these studies, the basal diet was chopped king grass (*P. purpureum* × *P. typhoides*); this has been supplemented with different energy sources, especially green bananas.

Gutiérrez (1983) compared *E. poeppigiana* foliage plus green bananas with a commercial concentrate as supplements for dairy goats receiving chopped king grass as the basal forage source. Daily milk yield was greater with goats fed the commercial concentrate than with those fed *E. poeppigiana* and bananas (1.29 vs 1.08 kg/head); however, the former showed lower daily gains (9 vs 59 g/head), and the economic analysis favoured the use of *E. poeppigiana* plus green bananas. These findings encouraged further research in this field.

Samur (1984) examined whether the use of a starch source (green bananas) would result in a milk production higher than that obtained with a sugar-rich source (ripened bananas). The rationale was not only that starch promotes microbial protein synthesis in the rumen when readily degradable protein sources are used but also that some starch escapes ruminal degradation, therefore increasing glucose availability for milk synthesis and other purposes. The results supported this hypothesis: slightly higher daily milk yields were obtained when green rather than ripened bananas were used as the energy supplement (1.28 vs 1.23 kg/head, respectively). However, this effect was more evident in two other experiments done with weaned lambs (Benavides and Pezo 1986) and goat kids (Benavides and Esnaola 1986). In both studies, the advantages of using either starch- or a mixture of sugar- and starch-rich sources as energy supplements to diets based on legume tree foliage were demonstrated.

**Table 7. Milk production and dry matter (DM) intake in goats supplemented with two levels of *E. poeppigiana* and plantain fruits.**

| Response variable | HP | | LP | |
|---|---|---|---|---|
| | HE | LE | HE | LE |
| Daily milk yield (g/head) | 1270a | 1090b | 1090b | 1110ab |
| Milk fat (%) | 3.4 | 3.3 | 3.3 | 3.1 |
| Daily DM intake (kg/head) | | | | |
| Chopped king grass | 0.77 | 0.93 | 0.96 | 0.97 |
| *E. poeppigiana* | 0.45 | 0.32 | 0.45 | 0.32 |
| Plantain fruits | 0.60 | 0.60 | 0.37 | 0.37 |
| Daily LW gain (g/head) | 170 | 50 | 20 | 50 |

Note: H, high; L, low; P, plantain fruits; E, *E. poeppigiana*; LW, live weight. Means followed by the same letter do not differ statistically ($P \leq 0.05$).
Source: CATIE (unpublished data).

Esnaola and Rios (1986) offered different levels of supplementary *E. poeppigiana* foliage to goats. Milk yield increased linearly as a response to the level *E. poeppigiana* used. Also, a partial substitutive effect of the supplement on the intake of chopped king grass was detected, resulting in an additive effect on total DM intake.

A recent factorial experiment (CATIE, unpublished data), in which two levels of both *E. poeppigiana* foliage and plantain fruits were evaluated as supplements to a chopped king grass basal diet for milking goats, showed that the highest milk yield corresponded to the combination of the highest levels of both supplements (Table 7). However, the interesting aspect of this study is that the second highest milk production was obtained for the combination of the lowest levels of both supplementary sources. As both treatments had about the same CP/DE (digestible energy) ratio, perhaps a given ratio of both nutrients should be maintained for efficient milk production.

Most of the small ruminant feeding experiments carried out at CATIE using legume tree foliages have used *E. poeppigiana*. There is one direct comparison of this species with *G. sepium* (Rodríguez et al. 1987): higher milk yields were obtained when goats were fed *E. poeppigiana*. Both tree foliages showed similar values for chemical composition, but the lower DM intake observed in the case of *G. sepium* negatively affected daily milk production (1.26 and 1.11 kg/head for *E. poeppigiana* and *G. sepium*, respectively). It is clear that there is a need for a more detailed study on the causes of limited intake in some *G. sepium* foliages, because previous work from other regions (e.g., Chadhokar 1983) has not detected this type of problem.

## Cattle

Few studies have been done at CATIE evaluating the use of legume tree foliages as protein supplements for cattle; again, *E. poeppigiana* has been the main species evaluated. The first experiment was done with weaned dairy heifers, evaluating different levels of substitution of a traditional protein source (soybean meal) with *E. poeppigiana* foliage (Pineda 1986). The replacement of soybean with increased levels of *E. poeppigiana* resulted in lower daily gains (Table 8), confirming that the protein quality of this tree foliage is less than that of soybean meal. From an economic viewpoint, however, the best results were obtained when 67% of the protein requirements were provided by *E. poeppigiana.*

Vargas (1987) fed growing bulls different levels of *E. cocleata* foliage and observed increased live weight gain when *E. cocleata* was offered at a level equivalent to 0.5% body weight (398 and 524 g/day, for the control and 0.5% body weight for *E. cocleata*). Also, 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 vs 524 g/head).

The use of *E. poeppigiana* and sugarcane molasses as supplements for milking cows grazing African star grass, instead of commercial concentrates (Abarca 1989), have consistently resulted in lower milk yields (8.4 and 8.0 kg/day, for concentrate and *E. poeppigiana* supplementation, respectively). Minor changes in milk composition were also observed. However, when *E. poeppigiana* was compared with fish meal as a protein supplement for milking cows, higher milk yields were obtained with the fish meal (Table 9), confirming that this legume tree foliage has a lower protein quality. Economic analyses of our dairy cattle experiments have indicated that there are no differences in the net profit obtained using the traditional (fish meal or commercial concentrates) or nontraditional supplements (legume tree

**Table 8. Intake, in vivo digestibility, and daily live weight gain (LWG) in heifer calves fed different proportions of soybean meal (SMB) and *E. poeppigiana* (P) foliage as a protein supplement.**

| Response variable | 100% SBM | 67% SBM, 33% P | 33% SBM, 67% P | 100% P |
|---|---|---|---|---|
| Intake (% body weight) | | | | |
| Soybean meal | 0.46 | 0.31 | 0.15 | 0.0 |
| *E. poeppigiana* | 0.0 | 0.26 | 0.52 | 0.79 |
| King grass | 2.19 | 2.04 | 1.93 | 1.80 |
| Sugarcane molasses | 0.86 | 0.97 | 1.01 | 1.15 |
| Digestibility (%)[a] | | | | |
| DM | 62 | 60 | 60 | 58 |
| CWC | 62 | 55 | 55 | 53 |
| LWG (g/head) | 410 | 366 | 372 | 294 |

Source: Pineda (1986).
[a] DM, dry matter; CWC, cell wall constituents.

**Table 9. 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 | 1.93a | 1.24b |
| Supplement | 1.08a | 1.55a |
| Total | 3.01a | 2.79a |
| Milk production (kg/head) | 9.0 | 8.2 |
| Milk compostion (%) | | |
| Total solids | 13.4b | 12.7a |
| Protein | 3.2a | 3.3a |
| Fat | 4.1a | 4.3a |

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

foliages plus locally available energy sources, such as green bananas). There is an important advantage favouring nontraditional supplements: i.e., lower cash costs. This is important for the small farmer because the availability of cash is one of the farmer's main constraints.

Another experiment, carried out by Tobón (1988), showed a linear increase in milk production as the level of *E. poeppigiana* foliage increased. The equation describing this linear relationship was $Y = 8.75 + 1.29X$, where $Y$ is daily milk yield (kilograms per cow) and $X$ is DM intake (percent body weight).

In summary, the results obtained with grazing dairy 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. These benefits include increased carrying capacity as a result of substitutive effects on grass intake and increased recycling of nutrients in the areas grazed, through richer animal excretas. These aspects need to be investigated in future work.

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