Contribution of *Erythrina* protein banks and rejected bananas for improving cattle production in the humid tropics

[1]*MA Ibrahim,* [2]*F Holmann,* [3]*M Hernández and* [1]*A. Camero*

[1]***Area of Agroforestry, CATIE-7170, Turrialba, Costa Rica***

[2]***Pasture Program, CIAT, Cali, Colombia***

[3] ***Ministry of Agriculture, Los Diamantes Experimental Station, Guápiles, Costa Rica***

Corresponding author : ***MA Ibrahim, Area of Agroforestry, CATIE-7170, Turrialba, Costa Rica.***
Fax : (506) 556-1576, email: mibrahim@catie.ac.cr

Key words: Dry matter production, botanical composition, coppice, sprouts browsing, crude protein, *in vitro* dry matter digestibility, silvopastoral systems

Abstract

The effect on cattle productivity of browsing a forage legume shrub, *Erythrina berteroana* Urban (poro) grown in a protein bank as a grazing supplement and/or diet supplementation with green banana (*Musa* AAA) was measured in a long term grazing trial. Measurements were also made of pasture and poro productivity. Daily LW gains were measured and samples of all feed material were analyzed for crude protein and *in vitro* dry matter digestibility. Pasture availability was high, averaging 0.17 t DM ha day^{-1} over the grazing period. The main grass species were *Paspalum fasciculatium* Poiret, *Axonopus compressus* Swartz and to a lesser extent African star grass (*Cynodon nlemfluensis* Vanderyst). Dry matter yields of poro declined significantly with time (> 50%) when it was managed with a two- month resting period but remained higher when subsequently managed with a three- month resting period. Average daily liveweight gain of animals was 21 to 26% higher with 2 hours daily browsing of poro than for animals only grazing pasture. Highest liveweight gain was achieved when diets were supplemented with banana and there was no additional benefit when poro was fed in addition to banana. This suggests that fodder banks of poro or supplements with green banana can improve cattle nutrition in the humid tropics.

Introduction

Cattle production is a major land use in the humid tropics of Costa Rica and the rest of Central America (Kaimowitz, 1996). Cattle rearing is generally carried out in a very extensive way with little use of inputs and on pastures dominated with native grasses and weeds. Low pasture productivity has been identified as the main cause for the low biological and economic efficiency of cattle ranching in the humid tropics (Jansen et al., 1997).

At present more than 80 % of these pastures are in an advanced stage of degradation with unproductive grass species of low quality such as ratana grass (*Ischaemum ciliare* Retz), *Paspalum notatum* Flueggé and *Axonopus compressus* Swartz (Ibrahim and Mannetje 1998). Carrying capacities of native and or naturalised pastures in the humid tropics of Costa Rica rarely exceed 1.0 AU ha^{-1} (AU = animal unit; 1 AU = 400 kg LW) and mean annual liveweight gains are typically less than 170 kg ha^{-1} (Jansen et al., 1997).

Leguminous (e.g. *Gliricidia sepium* (Jacq) Walp , *Leucaena* spp and *Erythrina* spp) and non-leguminous (e.g. *Morus* spp. and *Trichantera* spp.) woody forage perennials with high DM production and nutritive value (crude protein > 20% DM basis) for feeding ruminants have been identified in Central America (Pezo et al.,1990). Among these, the legume trees *Erythrina berteroana* Urban (poro) and *Gliricidia sepium* (madero negro) have shown high potential for increasing cattle production in the humid tropics (Kass et al., 1992; Benavides, 1994). Both species are well adapted to the climatic and edaphic conditions of humid tropical lowlands and are found in the fence lines of more than 90%

of cattle farms in the humid tropics of Central America (Budowski, 1987).

Agronomic studies conducted at the Los Diamantes Experimental Station, Guaplies, Costa Rica showed that annual edible dry matter (DM) yields of poro were greater than 11 t ha^{-1} when it was managed as a protein bank with pruning every four months (Ibrahim et al., 1998). In addition to high yields, crude protein concentration of edible biomass of poro is greater than 17% of DM (Kass *et al*., 1992) which satisfies protein requirements of highly productive dairy cows**.** Nutritional studies conducted at the experimental farm of CATIE showed that Jersey crosses grazing African star grass (*Cynodon nlemfuensis* Vanderyst) and supplemented with poro (1.4 to 2.0 kg DM animal day^{-1}) had daily milk yields of 8 to 9 kg cow^{-1} (Pezo et al., 1990). Nevertheless, there is little experience on the management of these tree species when they are browsed.

The use of green bananas **(*Musa* AAA)** as a supplement represents another alternative for overcoming nutritional deficiencies observed on native or naturalized pastures in the humid tropics of Central America (e.g. Costa Rica, Honduras, Nicaragua and Belize), especially since more than 15% of bananas produced for exportation are being rejected (Keus, pers comm.). Nutritional studies at CATIE with green bananas showed that *in vitro* dry matter digestibility of bananas was more than 85% and steers grazing *Panicum* pastures gained more than 0.7 kg day^{-1} when they were supplemented with green bananas compared to less than 0.35 kg day^{-1} obtained on a grass monoculture (Cubillos et al*.,* 1975).

The main objective of this study was to determine the effect of browsing on the productivity of a poro protein bank. A second objective was to measure live-weight gains

of grazing animals with access to the protein bank and /or diet supplementation with green bananas.

Materials and methods

The experiment was established at the Los Diamantes experimental station, Guáplies, Costa Rica; which is located at 10º 13' Latitude North and 83º 47' Longitude West; at an altitude of 250 m. The mean annual precipitation of the experimental area is 4 332 mm and mean daily temperature is 25 ^{o}C. The soil is classified as a well-drained loamy Eutric Hapludand (Soil Survey Staff, 1990) with medium to high fertility: 10.5% organic matter, 5.5 pH (H_2O), 1.83 mg P l^{-1} and 0.32 cmol K l^{-1}.

The treatments consisted of 1) Pasture only; 2) Pasture + green banana; 3) Pasture + poro; and 4) pasture + poro + green banana, in a completely randomized block design with two replicates. Thirty two Nelore steers weighing between 220 and 240 kg LW animal^{-1} were randomly assigned to the two replications of each of the four treatments (four animals per replicate) in August 93, and their experimental regime ran from September 93 to January 94. A second group of steers were similarly assigned in January 94, and they were on the experiment from February to November 94. The animals selected for both groups were 10 to 12 months old.

Animals of each replicate grazed separate pastures. An area of 8 ha of pasture was divided equally into two paddocks (replicates) and each paddock was subdivided into seven plots to establish a rotational grazing cycle of 24 days resting and four days grazing. The mean stocking rate of the pasture was 2.25 AU.

In the corresponding treatments green banana was fed in stalls at the rate of 1.1 kg DM 100 kg LW day $^{-1}$ (this was roughly equivalent to feeding 15 kg green banana animal day $^{-1}$) during the entire experimental period. Two replicates of poro protein banks were established and animals in each replicate grazed separate plots for a period of two hours daily.

Establishment and management of protein bank

The protein banks were established during September 1991 using mature stems (8 – 10 cm diameter) of poro planted horizontally in furrows dug at 2 m intervals and this resulted in a mean plant density of 15 700 stems ha^{-1} with rows 2 m apart. 10 kg P ha^{-1} was applied during establishment but no fertilizer application was made during the experiment.

After a seven month establishment period, the poro plants were pollarded at 50 cm height. Two paddocks (blocks) of poro protein bank each with an area of 3 000 m^2 were delimited for browsing. Each paddock was subdivided into three plots (1 000 m^2 $plot^{-1}$) to establish a one month browsing (two hours per day) and a two month resting period. This grazing regime was carried out from March 1992 to December 1993. The trees were pollarded at a height of 50 cm after every browsing period.

From January 1994 the protein bank was managed with a three months resting period because of a significant reduction in DM production. This was achieved through the inclusion of one additional plot (same age and size) in each paddock to complete the rotation. Animals browsed the protein bank two hours daily (07.00 to 09.00) and in the corresponding treatments they were fed bananas immediately after browsing (09.00 to 11.00).

Measurements

Botanical composition and DM production of the pasture were measured by the BOTANAL method developed by Hargreaves and Kerr (1992). This measurement was taken during the period of maximum (July) and minimum (February) precipitation of each year. The production of edible biomass of poro was measured before each browsing period from April 1992 onwards by cutting five random samples each comprising all the edible material in 1 m of a row. Poro biomass sampled was separated into edible biomass and woody stems, in this paper results are presented as edible DM production. In the

poro plots, the number of sprouts plant^{-1} was counted on six trees tagged in each plot before each browsing period.

Hand-plucked samples, selected to represent what the animal was consuming on the pasture and protein bank were collected during the period of maximum and minimum precipitation for the analysis of crude protein concentration and *in vitro* dry matter digestibility (IVDMD) (Tilley and Terry, 1963).

Steers were weighed individually every 30 days to estimate live-weight gains (LWG) for the different treatments from the beginning of September 1993. Before weighing, the animals were fasted for 12 hours with access only to water.

Statistical analysis

An analysis of variance was carried out separately for each of the two grazing regimes (two- and three- months resting) of poro and for the two groups of animals to determine treatment effects on the variables measured. For each group of animals mean daily liveweight gain was estimated using a regression model described by Jones and Sandland (1974). Least significant difference (LSD) and Duncan's Multiple Range test were used to determine statistical differences between treatment means.

Results

Production of pasture and protein bank

Pasture

Mean DM yield remained high (> 4 t ha^{-1}) though it was over 20 % lower ($p < 0.05$) in the drier season than the wetter one (**Table 1**). DM content of pasture was, however, higher in the dry season. The main species dominating the pasture were the unpalatable *Paspalum fasciculatum* Poiret, *Axonopus compressus* and to a lesser extent *Cynodon nlemfluensis* which tended to invade the plots (**Table 1**). There was little variation in the pasture composition during the experimental period.

Mean daily forage allowance for the pasture was 362 and 287 kg DM $head^{-1}$ for the wet and dry season respectively.

(Insert table 1)

Poro

Edible biomass of poro declined by more than 50% ($p < 0.05$) between June 1992 and December 1993, as the protein bank was progressively browsed with two month resting periods (**Table 2).** However, edible DM yields more than doubled when the resting period was subsequently switched from two to three months (**Table 2**).

Browsing every two months resulted in a linear decrease in the number of sprouts per plant^{-} which fell by about 30% between June 92 and December 93 (**Table 2**). On the other hand the number of sprouts increased when the protein bank was subsequently managed with a three month resting period. DM content of poro averaged 23.4% for the two months and 26.8% for the three months resting period providing a mean daily allowance of edible biomass of 3.3 and 5.4 kg DM head^{-1}.

(Insert table 2)

Quality of feeds

Mean IVDMD of green banana was 889 g kg DM^{-1} whereas those of hand-plucked pasture and poro samples were only 545 and 555 g kg DM^{-1}, respectively (**Table 3**). *In vitro* dry matter digestibility of pasture was 5.7% lower ($p < 0.05$) in the dry season than the wet season but IVDMD of poro was not affected.

CP concentration of poro was more than double that of pasture and four times that of green banana.

(insert table 3)

Live-weight gains

Mean daily live-weight gains were over 20% higher ($p < 0.05$) when animals were allowed to browse the protein bank two hours daily than in the pasture control (**Table 4**). The highest daily gains were observed with banana supplementation and there was no additional benefit from the inclusion of poro to this diet. The overall daily liveweight gain of the second group of steers was higher ($p < 0.05$) than the first group.

Cumulative liveweight gain animal^{-1} at the end of the 460 days grazing period was 210 kg for the pasture control treatment and 255 kg for the pasture+poro treatment, and above 290 kg for the banana treatments **(Figure 1**).

(INSERT TABLE 4)

(Insert figure 1)

Discussion

Productivity and management of poro

Edible DM yields of browsed poro when it was rested for two -months was less than half of what it was when subsequently rested for three months suggesting that more frequent browsing was detrimental for long term sustainability of this species. This is consistent with depletion of carbohydrate reserves reducing the production of new photosynthetic tissues after defoliation (Miyanishi and Kellman, 1986). This is evident in the decline of the number of poro sprouts under the two -month resting regime. Studies conducted by Erdmann et al. (1993) showed that soluble carbohydrates of stem bases and roots of *Gliricidia sepium* were higher for plants pruned every six weeks compared to those pruned every three weeks. Frequent defoliation may also be associated with a reduction of root biomass which could have negative effects on the mobilization of nutrients from the soil and plant vigour (Stur et al., 1994). On the other hand high DM yields of over 0.04 t ha day^{-1} were maintained with the three month resting period, indicating that this browsing management was sustainable for poro under these experimental conditions. Studies conducted by Russo and Budowski (1986) showed that dry matter yields of *Erythrina poeppigiana* grown in coffee plantations were higher when the plants were pollarded twice per year (11 800 kg ha^{-1}) compared to three times per year (7 850 kg ha^{-1}).

Livestock productivity

DM digestibility of available forage on pasture was lower during the months of low rainfall and this may be because of a higher proportion of lignified senescent biomass at this time (Humphreys, 1991). Mean IVDMD of poro was 554.5 g kg^{-1}. Studies conducted with poro under humid tropical conditions and volcanic soils showed that IVDMD of edible biomass of poro (with a 4 to 6 months pruning interval) varied between 490 and 560 g kg^{-1} (Arguello et al. 1986; Benavides 1994).

Live-weight gains were over 20% higher when the steers browsed the protein bank than in the pasture control, demonstrating the potential to improve animal production in traditional livestock systems by using shrubs. In this experiment, pasture production was twofold higher than is typical of traditional pasture systems in the humid tropics so forage banks may have a larger impact on traditional systems than was observed in this trial. Results obtained on commercial dairy farms in Rio Frio showed that daily milk yields of *Ischaemum ciliare* pastures were increased from 8.2 to 9.2 l cow^{-1} with two hours daily browsing of a protein bank established with poro (Ibrahim, unpublished data). In Central America dual purpose cattle production is the dominant production system in the humid tropical lowlands and the use of leguminous fodder trees such as poro, as a supplement for milk cows, may be higher than for beef cattle because dairy cattle have a higher protein requirement (Preston and Leng 1986).

Cumulative liveweight gains per animal were highest for the banana treatments, attributable to the high energy supply of banana (Cubillos et al., 1975). *Invitro* dry matter digestibility of banana was significantly higher (31 to 37 %) than both poro and pasture.

Green banana has a high starch content (Preston and Leng, 1986) and nutritional studies showed that starch diets have a high proportion of by-pass energy to the intestines which may explain high liveweight gains observed with banana diets in this study (Preston and Leng, 1986; Kass et al., 1992). The low energy content of forages is often considered one of the main reasons for low animal productivity on pastures in the humid tropics (Archibald, 1984). In Central America banana cultivation is carried out on fertile soils in the humid tropical lowlands and rejected banana can be used as a supplement for livestock especially for dual purpose cattle farms that are located in close proximity to banana plantations (Bouman et al., 1999). These results can also be applied to Caribbean countries where banana cultivation is the major land use system.

Unexpectedly, the inclusion of poro in addition to banana did not result in any beneficial effect on daily LW gains. LW gains were lower though not significantly so, when poro was offered with banana which could be a result of animals without access to poro having a higher intake of energy from green bananas.

The second group of animals grazed most of the time in the peak rainfall period when DM yields of the pasture were high and this together with high poro yields occurring with the three month resting interval may explain differences in daily LW gains between the two groups of animals. This is consistent with results of Watson and Whiteman (1981) which showed that daily LW gains on *Brachiaria* and *Panicum* pastures increased as the amount of green DM increased from 200 to 2000 kg animal^{-1}.

Conclusion

In Central America poro is commonly planted as a shade tree and for soil improvement in

coffee plantations . Additionally, it is widely used as a live fence post especially on livestock farms (Budowski, 1987). In Honduras, Costa Rica and Guatemala, many farmers are currently harvesting poro foliage from these agroforestry systems to supplement the diets of their cattle and small ruminants (Pezo et al., 1990). In South America, CARDI (Caribbean Agricultural Research Development Institute) is promoting the use of forage trees for supplementing ruminants (Munoz, pers. Comm.). The use of fodder trees such as poro for supplementing animals is expected to increase because of the rising cost of commercial supplements, the need for conservation of natural resources and the demand for organic livestock products. This study confirms that poro can be effective in improving cattle diets and productivity in this context.

References

Archibald KA (1984) Dairy cattle feeding in the humid or high rainfall tropics. In Smith AJ, ed, Milk production in developing countries; proceedings of the conference held in Edinburgh, 1984. Edinburgh, pp 110-132.

Arguello R, Benavides J and Esnaola MA (1986) Evaluación de las ganancias de peso y consumo de alimentos en cabritos alimentados con distintos follajes de arboles suplementadas con banano verde de desecho. In: Resumen de las investigaciones realizadas con rumiantes menores en el proyecto de sistemas de producción animal. Tropical Agricultural Research and Training Center (CATIE), Turrialba, Costa Rica. Informe Técnico No. 67: 28-32.

Benavides JE (1994) La investigación de arboles forrajeros. In: Benavides JE, ed, Arboles y Arbustos forrajeros en América Central volumen 1, Turrialba, Costa Rica, CATIE, pp 3- 28.

Bouman B, Nieuwenhuyse A and Ibrahim M (1999) Pasture degradation and its restoration by legumes in humid tropical Costa Rica. Tropical Grasslands (*In press*).

Budowski G. (1987) Living fences in Tropical America, a widespread agroforestry practice. In Gholtz E, ed, Agroforestry: Realities, Possibilities and Potentials, Dordrecht (Holland), p 169-178

Cubillos G, Vohnout K and Jimenez C (1975) Intensive cattle feeding under grazing systems. In: Potential to increase beef production in the tropical America, Series CE (10), pp. 131 -47, CIAT, Cali, Colombia.

Erdmann TK, Nair PKN and Kang BT (1993) Effects of cutting frequency and cutting height on reserve carbohydrates in *Gliricidia sepium* (Jacq.) Walp. Forest Ecology and Management, 57 (1-4): 45-60.

Hargreaves JN and Kerr JD (1992) BOTANAL - A comprehensive sampling and computing procedure for estimating pasture yield and composition. 2. Computational Package. Tropical Agronomy Technical Memorandum, CSIRO, Australia, Number 79, 83 pp.

Humphreys LR (1991) Tropical pasture utilisation. Cambridge University Press, Cambridge (UK), 202 pp.

Ibrahim MA and Mannetje Lt (1998) Compatibility, persistence and productivity of grass-legume mixtures in the humid tropics of Costa Rica. Tropical Grasslands 32(2): 1-10

Jansen GP; Ibrahim MA; Nieuwenhuyse A (1997) The economics of improved pasture and silvopastoral technologies in the Atlantic Zone of Costa Rica. Tropical Grasslands 31: 588-598.

Jones RJ and Sandland RL (1974) The relation between animal gain and stocking rate. Derivation of the relation from the results of grazing trials. Journal of Agricultural Science 83: 336 - 342.

Kaimowitz D (1996) Livestock and deforestation trend in Central America in the 1980s and the 1990s: a policy perspective. CIFOR, Bogor, Indonesia. 52 p.

Kass M; Benavides J; Romero F; Pezo D (1992) Lessons from main feeding experiments conducted at CATIE using fodder trees as part of the N-ration. In: Speedy A and Pugliese P, eds, Legume tree and other fodder trees as protein sources for livestock. Proceedings of the FAO Expert Consultation held at the Malaysian Agricultural Research and Development Institute (MARDI) in Kuala Lumpur Malaysia, 14- 18 October 1991, FAO, pp 161 -175.

Miyanishi K and Kellman M (1986) The role of root nutrient reserves in regrowth of two savanna shrubs. Canadian Journal of Botany 64 (1): 1244-1248.

Morales Jl (1992) Distribución del pasto ratana (*Ischaemum ciliare*) en las tierras de pastoreo de Costa Rica. In: El pasto ratana en Costa Rica. Alternativa O Problemática en nuestra Ganadería. Seminario/Taller de Dos Pinos, San Carlos, Costa Rica, 23 pp.

Pezo D, Kass M, Benavides J, Romero F and Chaves C (1990) Potential of legume tree fodders as animal feed in Central America. In: Devendra C, ed, Shrubs and tree fodders for farm animals. Proceedings of a workshop in DENPASAR, Indonesia 24 -29 July, 1989, IDRC, Canada, pp 163 - 175.

Preston T and Leng R (1986) Matching livestock production systems to available resources. ILCA, Addis Ababa, Ethopia. 331 p.

Russo R and Budowski G (1986) Effect of pollarding frequency on biomass of Erythrina poeppigiana as a coffee shade tree. Agroforestry systems 4: 145 – 162.

Soil Survey Staff (1990). Keys to Soil Taxonomy, fourth edition. SMSS technical monograph no.6. Blacksburg, Virginia, 422 pp.

Stur WW; Shelton HM; Gutteridge RC (1994) Defoliation management of forage tree legumes. In: Gutteridge RC and Shelton HM, eds, Forage Tree Legumes In Tropical Agriculture, CAB International, UK, pp 158 - 167.

Tilley JM and Terry RA (1963) A two-stage technique for the *in vitro* digestion of forage crops. Journal of British Grassland Society 18: 104 -110.

Watson SE and Whiteman PC (1981) Grazing studies on the Guadacanal Plains, Solmon Islands. 2. Effects of pasture mixtures and stocking rate on animal production and pasture components. Journal of Agricultural Science 97: 669 – 676.

Table 1. Mean dry matter yield and botanical composition of pasture during the high and low rainfall period.

	Rainfall		
	High	**Low**	**Se**
DM (%)	19.3 a	23.2 b	1.3
Production, DM (t ha cycle^{-1})	5.8 a	4.6 b	0.3
Botanical Composition (% DM)			
Paspalum fasciculatum	61.4 a	58.2 a	6.4
Axonopus compressus	25.7 a	30.6 a	9.4
Cynodon nlemfluensis	12.9 a	11.2 a	5.1

Values with same letter in the same row are not significantly different at $P < 0.05$
Se = Standard error

Table 2. Effect of browsing on dry matter content, edible biomass and number of re-growth plant^{-1} of poro managed with 2 and 3 months resting.

Date of measurement	DM (%)	Edible biomass (kg DM ha^{-1})	Re-growth plant^{-1} (N°)
	2 months resting		
June 92	23.4 a	3942 a[1]	11.3 a
December 92	24.5 a	2963 b	10.7 ab
July 93	22.7 a	2120 c	9.7 b
December 93	22.9 a	1931 c	8.0 c
Se	1.3	225	0.31
	3 months resting		
April 94	26.9 a	4830 a[1]	9.3 a
August 94	25.7 a	4760 a	11.2 a
December 94	27.8 a	4496 a	11.3 a
Se	1.2	120	1.06

[1]Values with the same letters within a column and for the same resting period are not significantly different at $P < 0.05$.

Se = standard error

Table 3. Mean *in vitro* dry matter digestibility (IVDMD) and crude protein (CP) concentration of pasture, poro and banana measured in the high (HR) and low (LR) rainfall seasons.

Feed	IVDMD (g kg^{-1} DM)		SEM	CP (g kg^{-1} DM)		Se
	HR	LR		HR	LR	
Pasture	561 a[1]	529 b	19.3	104 a	98 a	14.1
Poro	562 a	547 a	32.3	227 a	231 a	28.2
Banana	883 a	896 a	28.2	47 a	46 a	3.6

[1]Means in the same row with the same letter are not significantly different at $P < 0.05$.
Se = standard error

405

Error! Bookmark not defined. **Table 4**. Effect of browsing on poro protein banks and supplementation of green banana on mean daily liveweight gain of animals grazing unimproved pastures.

Error! Bookmark not defined.**Treatment**	**Mean daily liveweight gain**	
	Period 1	**Period 2**
	kg day^{-1}	
Pasture alone	0.401 c[3]	0.476 c
Pasture + poro	0.486 b	0.598 b
Pasture + banana	0.614 a	0.700 a
Pasture + poro + banana	0.582 a	0.671 a
Mean	0.518	0.612
Se	0.042	0.051

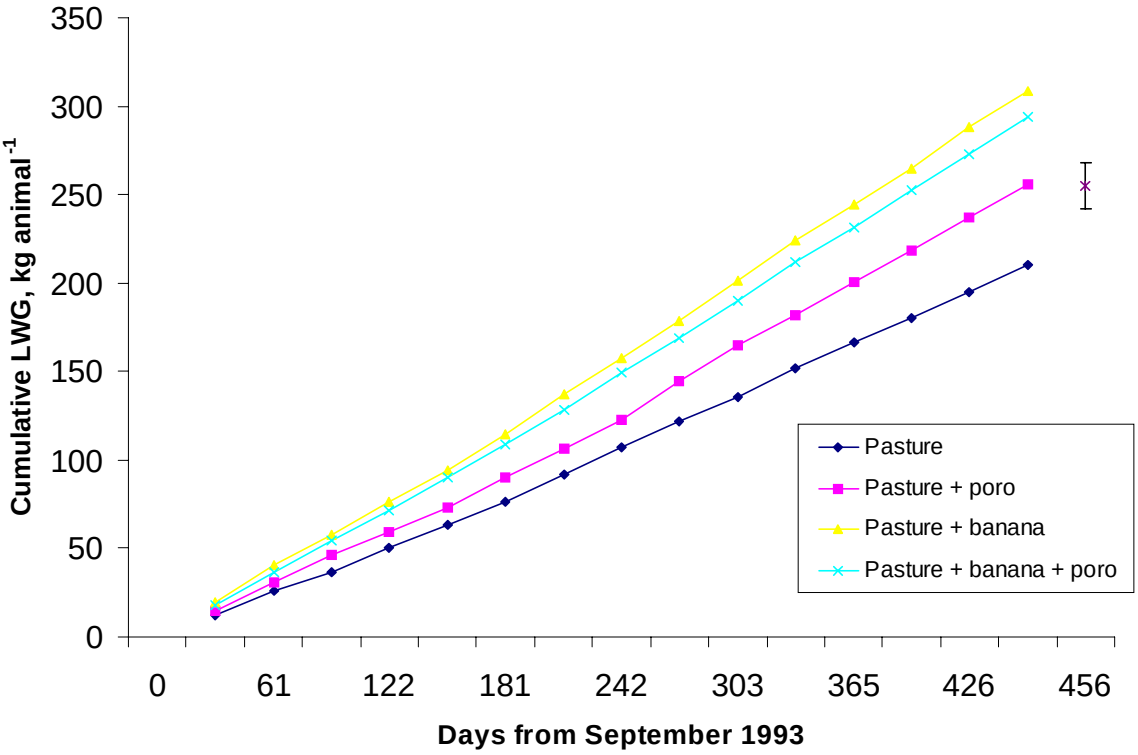
[1] Period 1 = September 93 - January 94; [2] Period 2 = February 94 - November 94

[3] Means with the same letter in the same column are not significantly different at $P < 0.05$; Se = standard error

Figure caption:

Figure 1. Cumulative liveweight gains (kg/animal) of animals grazing pasture alone and or with browsing poro and banana supplementation (error bar is shown for last measurements on liveweights).

420


Cumulative LWG, kg animal-1
350
300
250
200
150
100
50
0
0
61
122
181
242
303
365
426
456
Days from September 1993
Pasture
Pasture + poro
Pasture + banana
Pasture + banana + poro