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ANIMAL PRODUCTIVITY FROM *Brachiaria decumbens* ALONE AND WITH COMPLEMENTARY GRAZING OF *Pueraria phaseoloides* IN THE EASTERN PLAINS OF COLOMBIA

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In a randomized block experiment carried out at Carimagua, the animal output of *Brachiaria decumbens* alone and with complementary grazing with *Pueraria phaseoloides* in strips and in blocks was studied over a period of four years. The legume covered 30% of the grazing area in the grass-legume mixtures. Grazing was continuous and the stocking rate adjusted to 1.25 and 1.85 head/ha in the dry and rainy season, respectively. Mean animal output obtained from the mixture with the legume in strips, 183 kg/head, was significantly greater ($P < .05$) than that obtained with the legume in blocks (145 kg/head) which, in turn, exceeded that obtained from the *Brachiaria* alone (145 kg/head; $P < .05$). However, the effect of complementary grazing on daily weight gains was only significant ($P < .05$) during the dry season, with means of 504, 363 and 233 g/head/day for the mixture with legume in strips, the legume in blocks and the *Brachiaria* alone, respectively. Year effects were highly significant ($P < .008$), due to early rainfall in the dry season during the last two years of the experiment. This considerably increased the weight gains in the swards with *Brachiaria* alone and, to a lesser extent, in the mixtures with the legume in blocks and strips, although the interaction treatment-year was not of statistical significance ($P > .05$). This study demonstrates that the potential increase which may be obtained by using complementary grazing of *Pueraria* in blocks and strips with *Brachiaria* is 8-26% compared with well managed *Brachiaria* alone. This is chiefly due to the positive effect of the legume during prolonged dry seasons of the year.

Key words: Oxisol, *Brachiaria decumbens*, *Pueraria phaseoloides*, protein banks.

Brachiaria decumbens is one of the grasses best adapted to the conditions of the eastern plains of Colombia, not only because of its tolerance of poor natural soil fertility (Spain et al 1975), but also because of the levels of animal productivity which have been obtained and its relatively easy management (Tergas et al 1982). However, its aggressive habit is not conducive to the formation of grass-legumes associations (Loch 1977), although apparently stable mixtures have been obtained under conditions of low soil fertility and heavy grazing pressure using *Centrosema pubescens* in Bali (Rika et al 1981) and Nigeria (Akinola 1981), as well as with *Stylosanthes capitata* and *S. macrocephala* in the "cerrado" of Brazil (CIAT, 1983b).

Pueraria phaseoloides is a legume which adapts well to acid soils with low natural fertility (Kerridge 1978). The association of *P. phaseoloides* and *B. decumbens* has given very good agronomical results in the eastern plains of Colombia (Spain 1979) and has been recommended as an alternative for the infertile, acid soils of the Zulia region of Venezuela (Urdaneta 1980). Under similar soil conditions in the humid tropical region of Pucallpa, Peru, the association was well balanced in the initial stages although later the yield of the legume began to decline (Santhirasegaram 1975). The behaviour of *P. phaseoloides* with *Brachiaria ruziziensis*, which is similar to *B. decumbens* in habit and in its potential competitiveness with legumes, was related to grazing management, and it was found that 9 kg DM/100 kg LW with rest periods of 38-41 days gave best results (Coimbra 1979).

On the other hand, in cases of legumes which present management problems when they are used in mixtures, the use of small areas sown with pure stands of legumes has been proposed as a supplement for animals grazing gramineous pastures (CIAT 1980). These areas, known as a "protein banks", have given good results, using *P. phaseoloides* sown in blocks in native pastures in the eastern plains of Colombia (Tergas et al 1983) or sown in strips, even when accompanied by a stoloniferous grass as aggressive as *B. humidicola* (Marques et al 1980).

Materials and Methods

This experiment was carried out at the Centro Nacional de Investigaciones Agropecuarias (National Agricultural Research Center) -CNIA- which lies 320 km east of Villavicencio in the Department of Meta. The station is situated at 4°37' N, approximately 175 m above sea level, in an area which is representative of the well drained savannahs of the eastern Colombian plains. The soil and climate have been described by Spain (1979). The mean temperature is 26°C with an average rainfall of 2017 mm (Table 1), a potential evapotranspiration of 2195 mm and a distinct dry season from mid-December to the end of March. The soils are oxisols (Tropeptic Haplustox Isohyperthermic), acid (pH 4.5, 86% Al saturated), low in available P (1 ppm Bray II) and low in interchangeable Ca, Mg and K (< 0.2 me/100 g, each), fine clays with excellent physical condition.

The areas sown to *Pueraria phaseoloides* (kudzu) were in 6 m strips or in blocks which made up 30% of the total pasture area of 2 ha each. They were sown in 1978 with 75 kg P_2O_5 for the grass and 100 kg P_2O_5, 50 kg K_2O, 18 kg MgO and 22 kg S per hectare for the legume. In September, 1979, a maintenance fertilizer treatment of 22 kg K_2O, 18 kg MgO and 22 kg S per hectare was applied using 15 kg P_2O_5, 16 kg K_2O, 13 kg MgO and 16 kg S per hectare in all the treatments, including the *Brachiaria* alone.

Management and sampling

Grazing was started in December, 1979, using 2.0 head/ha in all treatments. However, these rates had to be adjusted according to the state of the pastures and treatments and the weighted average which resulted was 2.0 head/ha for all treatments in the dry season, and 2.0, 1.45 and 1.65 head/ha for the *Brachiaria* alone, kudzu in blocks and kudzu in strips, respectively, during the wet season. After the second year of grazing, rates of 1.0 and 2.0 head/ha have been maintained on all treatments during the dry and rainy seasons, respectively.

During the first year, grazing was interrupted for 80 days to allow recuperation of the kudzu following the maintenance fertilization. In the second year, access to the block was controlled so that grazing was allowed only 4 days each week. In 1981, access to the bank was limited for 15 days to allow recovery after the second maintenance fertilization and, since that time, access to the legume has been unrestricted.

Two yearling Criollo-Zebu crossbred steers weighing 150-170 kg at the start of the experiment were used, together with 2 more which weighed 180-200 kg and were employed to adjust the stocking rate each season. The animals were replaced by a new group of similar ones at the end of each calendar year. They all received mineral supplements and had free access

to water. In the first two years, the animals were fasted for 16 hours previous to weighing but later they were weighed directly from the field.

The amount of dry matter on offer was determined in both seasons of the year, initially by samples cut at random but later by the method of Haydock and Shaw (1976). The samples were combined and dried at 60°C for 48 hours to determine the dry matter.

Statistical analysis

The experimental design consisted of randomised blocks with 3 treatments: grass alone and grass with complementary grazing of the legume in blocks or in strips, with two repetitions. The results of the four years were analysed by analysis of variance for each year and for the four years together. The daily weight gains calculated from the final weight less the initial weight in the dry season, wet season and over the whole year were considered dependent variables and treatment(with and without legume) and year the sources of variation.

In the model used for the combined analysis over all years, the weight gains per head each year were considered to be measurements repeated in time, with the model $Y_{ijk} = \mu + R_i + T_j + (RxT)_{ij} + A_k + (T \times A)_{jk} + e_{ijk}$, where R_i = the effect of repetition i, T_j = the effect of treatment j with and without legumes in blocks or strips, $(R \times T)_{ij}$ = effect of the interaction repetition i x treatment j, A_k = effect of year k and $(T \times A)_{jk}$ = effect of the interaction treatment j x year k. The model for the analysis by year was $Y_{ijk} = \mu + R_i + T_j + e_{ijk}$, where Y_{ijk} = the weight gain of steer k in stocking rate j of the repetition i, R_i = effect of repetition i, T_j = effect of treatment j with and without legumes in blocks and strips and e_{ijk} = experimental error. Means were compared using Duncan's Multiple Range Test in cases where significant differences at the level $P < .05$ were detected.

Results and Discussion

The effect of the treatments with kudzu, compared with *Brachiaria* alone, was highly significant ($P < .01$) over all years (Tabla 2). This was mainly due to the significant effect ($P < .05$)obtained during the dry season of the year. At the same time, the treatment with the legume sown in strips was significantly superior ($P < .05$) to the treatment in which it was sown in blocks. The effect of years was also highly significant ($P < .01$), chiefly because in the years where rainfall was better distributed through the dry season, animal growth was favoured by the treatment of *Brachiaria* alone. This explains why the treatment-year interaction was highly significant ($P < .01$) only during the dry season.

During the first year, weight gains averaged 489 g/head/day and were higher on the treatment *B. decumbens* with *P. phaseoloides*, even though the difference did not reach statistical significance ($P > .05$) due the wide variability between animals. Nevertheless, the treatments with complementary grazing in kudzu were highly significantly superior ($P < .01$) to the treatment with *Brachiaria* alone in the dry season. In the following year, the results were similar to those obtained in the first, although it was necessary to adjust the stocking rate once the effect of the biomass accumulated during establishment had disappeared. Once again,

the effect of complementary grazing in the legume was highly significant only during the dry season and weight gains of 544 g/head/day were achieved which are considerable given the severity of the drought (Table 1). In 1981, no significant differences due to treatments were observed, due to the better distribution of the rainfall during the dry season (Table 1). As a result, there was an increased amount of grass leaf on offer at the start of the dry season. Animal performance was not affected and weight gains in the range 495 - 574 g/head/day were achieved (Table 2). In the final year of the experiment, the best results were observed in the treatment of kudzu sown in strips, especially during the dry season. By this time, the legume had invaded the adjacent area and formed an association with the grass. Due to the well distributed rainfall at the start of the dry season in December, 1981, and early rains in March, 1982, the effect of the legume was not so important as in the first two years of the experiment (Table 1).

Table 1:

Mean monthly rainfall at the Centro Nacional de Investigaciones Agropecuarias (CNIA) at Carimagua, eastern plains of Colombia (1972-1982).

Mes	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	P Lo
							mm					
January	*	4	4	6	11	0	6	2	0	0	0	3
February	*	0	14	43	31	8	4	0	0	58	0	14
March	*	79	9	177	63	18	94	119	107	50	100	74
April	*	123	181	30	273	81	232	362	193	359	376	200
May	*	99	371	421	241	191	308	201	260	223	234	232
June	343	443	*	389	431	458	348	207	402	281	237	321
July	336	334	179	332	430	224	276	275	252	181	355	288
August	242	321	200	321	186	196	171	201	291	352	346	257
September	241	362	242	187	320	272	194	214	318	218	380	268
October	182	251	252	241	141	161	157	359	230	122	110	200
November	116	165	161	137	57	94	105	117	59	88	74	106
December	65	14	3	147	16	18	88	60	0	164	23	54
Total	*	2195	*	2431	2200	1721	1983	2117	2112	2096	2235	2017

[1] **Meta; latitude 4°37' N; longitude 70°40' W; altitude 150 mm.**

Animal output was directly related to the mean annual weight gains (Table 3). The production per hectare of the kudzu in strips increased 17.6% compared with the *Brachiaria* alone, although no difference was obtained with the kudzu in blocks as had been the case in a similar experiment using native pastures (Tergas et al 1983). This may have been due to the excellent response of the *Brachiaria* to the first rains at the end of the dry season. The compensatory growth of the cattle would enable them to recover, and very poor growth rates would only be found in prolonged dry periods such as those observed in the first two years of the experiment.

Table 2:

Mean daily weight gain of steers on Brachiaria decumbens alone and with complementary grazing of Pueraria phaseoloides (kudzu) in blocks and in strips at Carimagua (1979-1982)

Year	Treatment	Stocking rate[1] (head/ha)	Seasonal		
			Dry	Rainy	
			g/animal/day		
1979	Grass alone	2.0/2.0	36b[2]	547a	374a
	Grass + legume in blocks	2.0/1.45	304a	429b	387a
	Grass + legume in strips	2.0/1.65	268a	602a	489a
1980	Grass alone	1.0/2.0	57c	495a	354a
	Grass + legume in blocks		320b	509a	448a
	Grass + legume in strips		544a	474a	497a
1981	Grass alone	1.0/2.0	495a	501a	499a
	Grass + legume in blocks		411a	488a	464a
	Grass + legume in strips		574a	553a	559a
1982	Grass alone	1.0/2.0	343b	379a	367b
	Grass + legume in blocks		419ab	438a	431ab
	Grass + legume in strips		631a	383a	465a
Mean	Grass alone	1.25/2.0	233b	480a	398c
	Grass + legume in blocks	1.25/1.86	363ab	466a	432b
	Grass + legume in strips	1.25/1.91	504a	503a	502a

[1] Dry season/wet season, respectively

[2] Values in each column corresponding to each year accompanied by different letters are significatively different ($P < .05$)

On the other hand, with the stocking rate adjusted to 1.25 and 2.0 head per hectare in the dry and rainy seasons, respectively, and with adequate maintenance fertilization every two years, the weight gains obtained in the *Brachiaria* alone were similar to those observed by Tergas et al (1982) and superior to those reported by Paladines and Leal (1979) when maintenance fertilizer was not applied for three years.

The weight gains obtained on the *Brachiaria* with *P. phaseoloides* in strips are similar to, or higher than, those obtained under other conditions, where rainfall distribution is similar to that at Carimagua: in Bali where the mixture was *B. decumbens* with *C. pubescens* (Rika et al 1981) and in the Cape York Peninsula in tropical Australia where *B. decumbens* was mixed with *S. guianensis* and *Macroptilium atropurpureum* (Winter et al 1977). In both cases, the soils were better, fertilization heavier and legumes used are considered superior to *P. phaseoloides*. In the humid tropics, the contribution of *P. phaseoloides* to animal output in association with *Brachiaria* spp and other legumes has been relatively small, as found in the Solomon Islands (Watson and Whiteman 1981b), or the *Pueraria* has not persisted, as was the case in a mixture with *C. pubescens* and *Neonotonia wightii* (Mellor et al 1973). On the other hand, up to 154 kg/head/year has been obtained with 2.7 head/ha in continuous grazing of *C. pubescens*, *M. atropurpureum* and *S. guianensis* with *B. decumbens* in the Solomon Islands (Watson and Whiteman 1981a).

Table 3:

Animal output on Brachiaria decumbens alone and with supplementary grazing of Pueraria phaseoloides (kudzu) in blocks and strips at Carimagua (1979-1982).

Year	Treatment	Stocking rate[1] (head/ha)	Output per: Head	Output per: ha
			kg	
1979	Grass alone	2.0/2.0	136a[2]	266
	Grass + legume in blocks	2.0/1.45	141a	255
	Grass + legume in strips	2.0/1.65	178a	327
1980	Grass alone	1.0/2.0	129a	227
	Grass + legume in blocks		163a	265
	Grass + legume in strips		181a	276
1981	Grass alone	1.0/2.0	182a	285
	Grass + legume in blocks		169a	269
	Grass + legume in strips		204a	317
1982	Grass alone	1.0/2.0	134b	221
	Grass + legume in blocks		154ab	258
	Grass + legume in strips		170a	257
	Grass alone	1.25/2.00	145c	250
	Grass + legume in blocks	1.25/1.86	157b	262
	Grass + legume in strips	1.25/1.91	183a	294

[1] Dry season/wet season, respectively

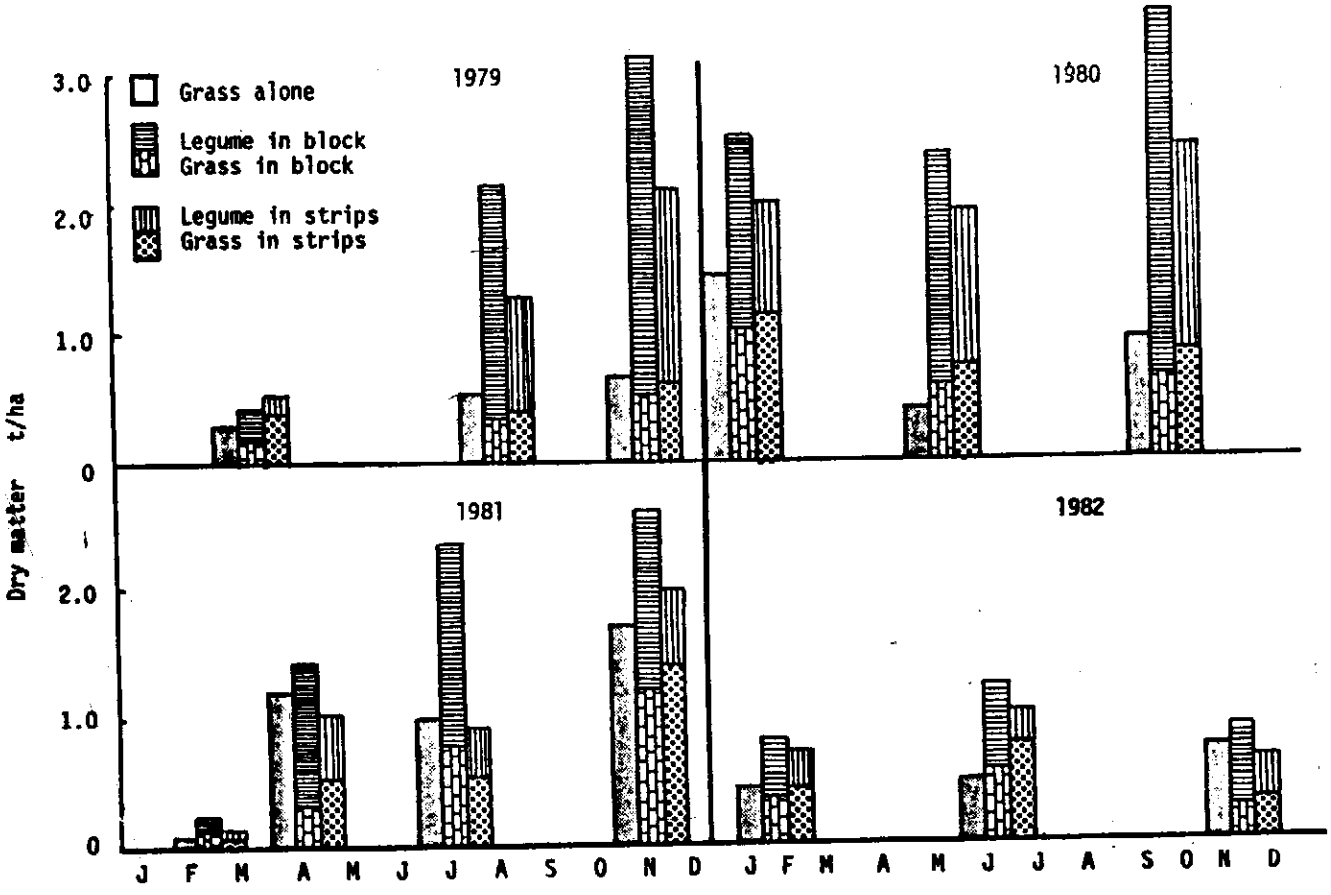
[2] Values in each column corresponding to each year accompanied by different letters are significatively different ($P < .05$)

The availability of grass and legume leaf on offer in each treatment in different years (Figure 1) shows that the greater production of green matter in 1980 was related to the fertilization of the kudzu in blocks at the end of 1979 and to the reduction in stocking rate. As a result of this management, animal output may have been favoured in the treatments with complementary grazing of legumes, especially in the dry season (Table 2), even though the drought in 1980 was as severe as in the previous year (Table 1). The production of forage in 1981 was favourably affected by the heavy rain at the start and at the end of the dry season (December and March), so that the severity of the drought was not as marked as usual. The maintenance fertilization carried out in the rainy season may also have contributed to the better distribution of leaf material throughout the year, especially in the case of the graminea, and explain the superior weight gain obtained in 1981 compared with the other years. During 1982, a reduction in the availability of leaf was observed in both species and in all treatments, and this almost certainly explains the lower animal output and suggests the need to reduce the stocking rate or apply another maintenance dressing of fertilizer in the following year.

The availability of leaf from the *Brachiaria* in the dry season (Figure 1) was almost always greater in the treatment with *Brachiaria* alone, with an average crude protein content of 5.6 - 7.7 %. The total quantity of leaf from the graminea plus the legume in the dry season was superior in the treatments with complementary grazing of *P. phaseoloides*. This greater

igure 1:

Availability of grass and legume leaf material on offer in B. decumbens *alone and in association with* P. phaseoloides *in blocks and strips at Carimagua (1979-1982)*



availability of forage, added to the mean crude protein content of 17.1% in the legume, evidently contributed to the higher animal output in these treatments in the dry period.

During the rainy season, the quantity of leaf on offer in the *Brachia ria* was always greater in the treatment with *Brachiaria* alone, followed by the graminea with legume in strips and then the legume in blocks, with an average crude protein content of 8.5%. This explains why no significant differences ($P > .05$) were found in weight gains between treatments at this time of the year (Table 2). On the other hand, it was observed that the grazing animals prefer the legume during the dry season but their preference changes markedly to the graminea during the rain season(Tergas and Lascano 1980).

Mannetje and Ebersohn (1980) pointed out that the principal factors which limit animal production from tropical and subtropical pastures are the quantity of green material available throughout the year, the amount of legume present in the sward and the chemical composition of the forage. Winter et al (1977) observed a significant correlation between the total

production of dry matter in the green forage and daily live weight gains which fluctuated markedly from season to season, and that this correlation was positive in the dry season but negative in the rainy period. Watson and Whiteman (1981a) found that highest daily weight gains of animals grazing a mixture of *B. decumbens*, *C. pubescens*, *M. atropurpureum* and *S. guianensis* were obtained when the availability of green forage on a dry matter basis was 1400 kg per head and that the growth rates increased until the proportion of legume in the sward reached 15%, with very small increases beyond that level. In general, the interpretation of the results of this experiment coincides with the main observations and conclusions of these authors with regard to the relation between green matter on offer and daily weight gain, as well as with regard to the effect of the greater amount of legume present in the blocks which did not necessarily produce higher weight gains than the quantity available in the strips.

Various authors have pointed out the importance of grass-legume mixtures in tropical pastures due to the possibility of transferring nitrogen from the legume to the grass with which it is associated, even if this is an indirect manner (Bryan 1962; Whiteman 1976). Results from trials in which the forage has been cut have given results which appear to confirm this possibility (Whitney et al 1967; Hudgens et al 1974). Although it was not the purpose of the present experiment to study nitrogen transfer under grazing conditions, no difference was observed in the crude protein content of the grass when in pure stands as compared with in association with the legume. These observations agree with Ng (1976) in Malaysia who found little evidence of nitrogen transfer from legumes in associations with *B. decumbens*.

Very little information is to be found in the literature about the results of management experiments designed to obtain persistency of *P. phaseoloides* in mixtures with tropical grasses, and which could serve as a basis for future work. In Malaysia, where the distribution of rainfall is similar to that in the eastern plains of Colombia, mean yearly weight gains per animal were only 111 kg/head in an association of *P. maximum* with *S. guianensis*, *C. pubescens* and *P. phaseoloides* with a fixed stocking rate of 2.0 animals/ha (Eng et al 1978b) and the *Pueraria* disappeared from the sward after the second year with maintenance fertilization of only phosphorus (Eng et al 1978b). In Puerto Rico, under conditions of rainfall distribution, mean yearly weight gains of 198 kg/head were obtained from a mixture of *Melinis minutiflora* and *P. phaseoloides* with a fixed stockling rate of 2.47 head/ha in rotational grazing, and over 10 years' persistence was found using a maintenance fertilization of heavy applications of potassium (Vicente-Chandler et al 1964). At Carimagua, it has been found that maintenance fertilization with potassium and magnesium is essential for *P. phaseoloides* to persist on acid soils of low natural fertility (CIAT 1983a). From this evidence, it may be concluded that maintenance fertilization with potassium is a critical factor affecting the persistency of this species under grazing.

It is also of interest that results obtained in a study of the incidence of spit bug (*Aeneolamia reducta*) in *B. decumbens*, which is another critical factor in the management of pastures containing this species,

showed an increase in the populations of nymphs and adults in three years, especially in the treatments which included the legume. In the *Brachiaria* alone, the incidence was lower and seasonal (CIAT 1983a). However, these populations are not yet considered critical and have not affected animal output from the pastures. Also, the incidence of toxicity associated with photosensitivity has been lower than in previous years in the same region (Tergas et al 1982)

Conclusions

The results of this study demonstrate the possibility of increasing animal output from *Brachiaria decumbens* pastures by 8 - 26 % by using complementary grazing of *P. phaseoloides* in the eastern plains of Colombia. The effect is mainly due to the influence of the legume on the nutrition of the stock during the dry season. Best results were obtained by using the legume planted in strips which was related to a better distribution and botanical composition of the pasture on offer throughout the year, and possibly also to a better distribution of grazing pressure over the whole sward. In the treatment using blocks, there was a tendency for the legume and graminea areas to be overgrazed in the dry and rainy seasons, respectively, due to the selective grazing of the animals.

Maintenance fertilization with K, Mg and S appears to be essential to the persistence of the legume and to animal productivity in the associations, as well as in the *Brachiaria* alone. This aspect deserves further study in soils of low natural fertility.

Although aspects of pasture management were not studied in this experiment, continuous grazing does not appear up to the present to have affected the persistence of *P. phaseoloides* negatively, and the adjustment of the stocking rate according to pasture growth rate in the dry and rainy seasons would appear to be the best form of management, as was suggested by Stobbs (1969) to avoid excessive deterioration of tropical grass-legume mixtures. It is nevertheless possible that under higher stocking rates, some kind of intermittent grazing management might be beneficial and favour the persistence of the association (Spain, personal communication).

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