JARQ 38 (1), 61 – 67 (2004) http://www.jircas.affrc.go.jp

Compatibility of Mixed Seedings of Tropical Legumes and Grasses on a South American Tropical Savanna

Yoshimitsu SAITO[1]*

Animal Production and Grassland Division, Japan International Research Center for Agricultural Sciences (JIRCAS) (Tsukuba, Ibaraki 305–8686, Japan)

Abstract

The compatibility of two tropical grasses (*Brachiaria humidicola* (Bh) and *Panicum maximum* (Pm)) and three legumes (*Arachis pintoi* (Ap), *Stylosanthes capitata* (Sc) and *Stylosanthes guianensis* (Sg)) were examined at two fertilizer application levels in a tropical South American savanna region. Pairs consisting of one grass and one legume were planted on a reclaimed Colombian lowland. Changes in biomass over time, growth patterns, and the relative palatability of these species indicated by grazing preference were measured. Among the two grass species, Bh showed strong growth, even under the low fertility condition, while Pm required the high fertilizer application level for establishment and growth. Among the legumes, Sg grew vigorously, even at the low fertility level, and could compete with Bh in biomass production. Sc was less vigorous than Sg, but was preferred by cattle. The growth habit of Ap was stoloniferous and it required a long time period to make a dense sward, because its seeding rate was low due to the bigger seed size. Among the three legume species, Ap was most preferred by cattle, and Sg was the least, but was nevertheless eaten by cattle if no other legumes were present. Considering the compatibility of these grasses and legumes, the mixture of Sg and Bh produced a higher level of herbage biomass than the other grass-legume mixtures examined in this study. The Ap and Pm mixture also had good compatibility, and its palatability to cows was higher than the other mixtures.

Discipline: Grassland
Additional key words: competition, palatability, pasture production

Introduction

Low fertility acid soils and long dry seasons are among the obstacles to crop production in the tropical savanna regions of Central and South America[1,4]. In these regions, since pasture productivity per unit area is low, livestock must graze across wide areas to obtain sufficient forage. To improve animal productivity in tropical savannas, introduction of more productive grass and legume species is essential[3]. Furthermore, improvement in grassland management technologies would help to enhance the sustainability of grass-legume mixtures. Legumes in grasslands also represent a rich source of protein[2].

Though many legumes in tropical areas are classified as perennial plants, their persistence in pastures is largely affected by the aggressiveness of grass species in mixed plantings, as well as grazing pressure, fertilizer levels, soil physical conditions, and other environmental factors. Therefore, the compatibility of newly introduced grass and legume mixtures should be examined in each local environment, for selecting appropriate combinations of these mixtures, and for enhancing the sustainability of pasture production systems.

This study aims to examine the compatibility of some typical and newly developed tropical grasses and legumes, based on their growth characteristics and associated cattle grazing preferences for 3 years. Several new combinations for the South American savanna are proposed based on the results of this research.

Present address:
[1] Department of Mountainous Grassland Farming, National Institute of Livestock and Grassland Science (Miyota, Nagano 389–0201, Japan).
*Corresponding author: fax +81–267–32–2318; e-mail yoshimi@affrc.go.jp
Received 1 November 2003; accepted 23 December 2003.

Materials and methods

1. Investigation site and climate

The experiment was undertaken in Carimagua (4º37'N., 71º36'W. and 200 m alt.), one of the investigation sites belonging to CIAT (Centro Internacional de Agricultura Tropical), situated in the province of Meta, Colombia. The area of Carimagua is in the so-called “Los Llanos Orientales”, and the natural vegetation is a typical South American savanna.

In Carimagua the dry season lasts for 4 months, beginning in December and lasting to the end of March (Fig. 1). Precipitation during this period is less than 50 mm per month. The rainy season extends from April to November, during which time rainfall is 100 to 400 mm per month. The rainy season brings the annual total precipitation to 2,200 mm. The annual mean temperature of the site is 26.2ºC. The lowest temperatures are during the middle of the rainy season (July, 24.5ºC), and the highest are in the middle of the dry season (February, 28.3ºC).

2. Reclamation of the experimental area

In an 8,400 m^2 (60 × 140 m) area of natural savanna the native vegetation was cut down using machinery in April of 1995, and then thoroughly burned to ashes after a few days.

After exterminating the ant colonies in the area with a pesticide, dolomite (containing Ca and Mg) was spread at 150 kg/ha (low fertilizer level) and 300 kg/ha (high fertilizer level). On the same day the site was plowed and the fertilizer was mixed into the soil, after which the soil was crushed by machinery and prepared for planting.

3. Materials tested and fertilizer levels

(1) Grasses:

Brachiaria humidicola (CIAT6133) (Bh)
Seeding rate: 3 kg/ha

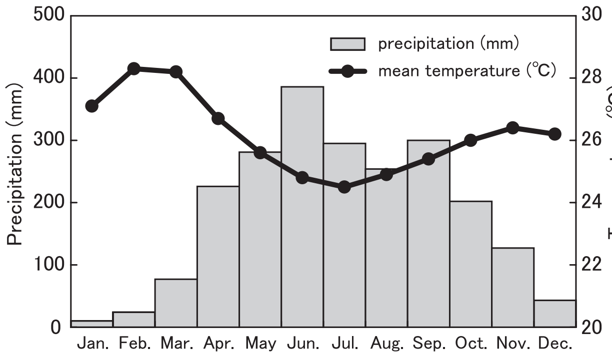

Fig. 1. Monthly precipitation and monthly mean temperature in Carimagua

Panicum maximum (CIAT36000) (Pm)
Seeding rate: 6 kg/ha

(2) Legumes:

Arachis pintoi (CIAT22160) (Ap)
Seeding rate: 8 kg/ha

Stylosanthes capitata (CIAT10280) (Sc)
Seeding rate: 8 kg/ha

Stylosanthes guianensis (CIAT11833) (Sg)
Seeding rate: 4 kg/ha

(3) The levels of fertilizer for the high and low fertility conditions were set as follows:

High Fertilizer Levels (H); P:40 kg/ha, K:40, Ca:68, Mg:28, S:20, and micronutrients (Zn, Cu, B, Mo).

Low Fertilizer Levels (L) (half of the set High Fertilizer Levels); P:20 kg/ha, K:20, Ca:34, Mg:14, S:10, and micronutrients (Zn, Cu, B, Mo).

(4) The fertilizer was spread on June 12, 1995. On the following day, 5 plant species were manually sowed. After that, over the following 2 months, additional sowings of Bh, Pm and Ap were carried out in bare areas where germination had not taken place. In April 1997, additional fertilizer was spread only on H levels in the amounts of P:40 kg/ha, K:40, Ca:68, Mg:28, S:20, and micronutrients (Zn, Cu, B, Mo).

4. Test design and measurements

A block of 16 plots was established with three replications, combining two grass species (Bh and Pm), 4 treatments of legume species (Ap, Sc, Sg and no legume), and two fertilizer treatments (H and L). Within the plots (10 × 10 m), rows of one grass and one legume species were planted alternatively. The space between the rows was 25 cm.

The reclaimed experimental area, including the plots of the grass-legume mixtures, was grazed during three time periods, April to May, July to August, and November to December respectively, in each year. The grazing periods lasted for 2–4 days with 13–20 adult zebu cows for each grazing. Normally, animal days (stocking rate × days) were 50–95 (heads × days /ha) at each grazing. It was the lowest (26 animal days) in April 1997, and the highest (162 animal days) in August 1997.

The measurements were carried out as described below:

(1) Biomass: The grasses and legumes in an area of 0.5 × 1 m were cut at a residual height of 10 cm with two or three replicates in each plot at intervals of 15–28 weeks. Harvested plant materials were then separated into grass, legume and weeds, and oven-dried to determine the forage biomass of each group.

(2) Productive structure: To examine the physical growth patterns of each species, plants within a single arbitrarily

selected area of 25 × 50 cm within each plot were cut at 10 cm intervals above the ground. This plant material was also separated into leaf, stem and flower, and then weighed separately.

(3) Evaluation of palatability: The total biomass of an arbitrarily selected area measuring 0.5 × 1 m within each plot was measured two times in the experiment, before and after grazing.

(4) Plant coverage: Plant coverage was assessed by visual inspection of a single square meter area selected at random within each plot.

Results and discussion

1. Changes in mean biomass

Fig. 2 and Fig. 3 show the changes in mean biomass of the two grass species and three legume species respectively. After germination, Bh and Pm grew more rapidly under the high fertility condition than under the low fertility condition (Fig. 2). From the second year, the biomass of Bh under the high fertility condition appeared to increase gradually. Pm under high fertility and Bh under low fertility maintained stable biomass levels from the second year. In contrast, under low fertility, Pm biomass levels gradually declined from the second year to the third year. This result indicates that the nutrient requirement of Pm was larger than that of Bh.

The growth of Sg was vigorous both under high and low fertility conditions, increasing with time without regard to grazing effects or dry season (Fig. 3). This result suggests that Sg adapted well to the highly acidic and low fertility soil of the Colombian savanna. The biomass of Sc changed seasonally, and decreased sharply after grazing following the dry season both in the first and second year. The initial growth of Ap was slow, and this was caused by the larger size of the Ap seed (18.0 g/100 seeds) compared to Sg or Sc (Sg: 0.22, Sc: 0.36 g/100 seeds). This result indicates that Ap requires a longer time period to cover the ground.

2. Biomass of each species in the mixture

Fig. 4 and Fig. 5 show the changes in biomass production of each grass and legume mixture. Fig. 4 shows the biomass of Bh together with the three legumes or without legumes, under the high fertility condition. In the combination of Bh and Ap, the growth of Ap was so slow that Ap fell quite far behind Bh. On the other hand, the mixture of Bh and Sg showed vigorous growth, although competition between the two species may have occurred. Sc was less vigorous in growth than Sg, and produced less biomass.

For the case of Pm under the low fertility condition

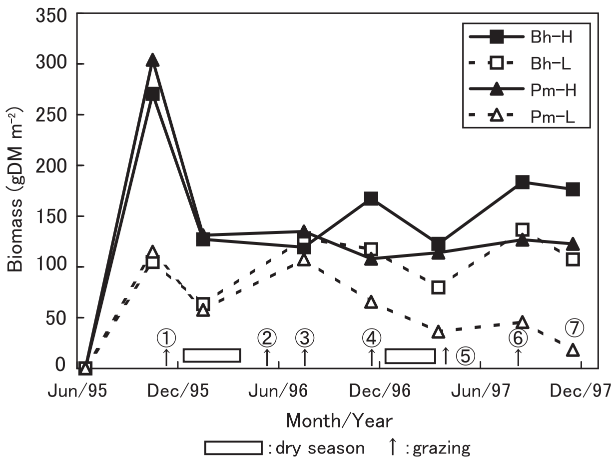

Fig. 2. Changes in grass biomass

Animal days: ① 87, ② 50, ③ 71, ④ 95, ⑤ 26, ⑥ 162, ⑦ unknown (head × days/ha).

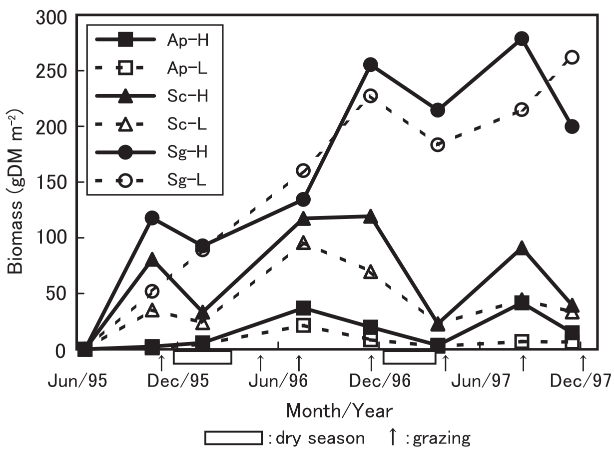

Fig. 3. Changes in legume biomass

(Fig. 5), the mean biomass of Pm-L tended to decline with time as shown in Fig. 2. In the combination of Pm and Ap, the growth of Ap was relatively more vigorous than in the combination with Bh-H. For the combination of Pm and Sg, Sg growth easily outstripped that of Pm, resulting in the complete elimination of Pm by the second year. In the combination of Pm and Sc, Sc outgrew Pm only in the third year.

The biomass of Ap was low under both high and low fertility conditions. To investigate the growth of Ap in detail, ground coverage was examined (Fig. 6). When coexisting with Bh, Ap showed clear signs of stunted ground coverage under both high and low fertility conditions, indicating that Bh inhibited Ap growth. However, when paired with Pm, Ap demonstrated significantly broader coverage, attaining coverage of 40% under the high fertility condition (in the third year). Thus, this species grows poorly when planted with Bh, but coexists

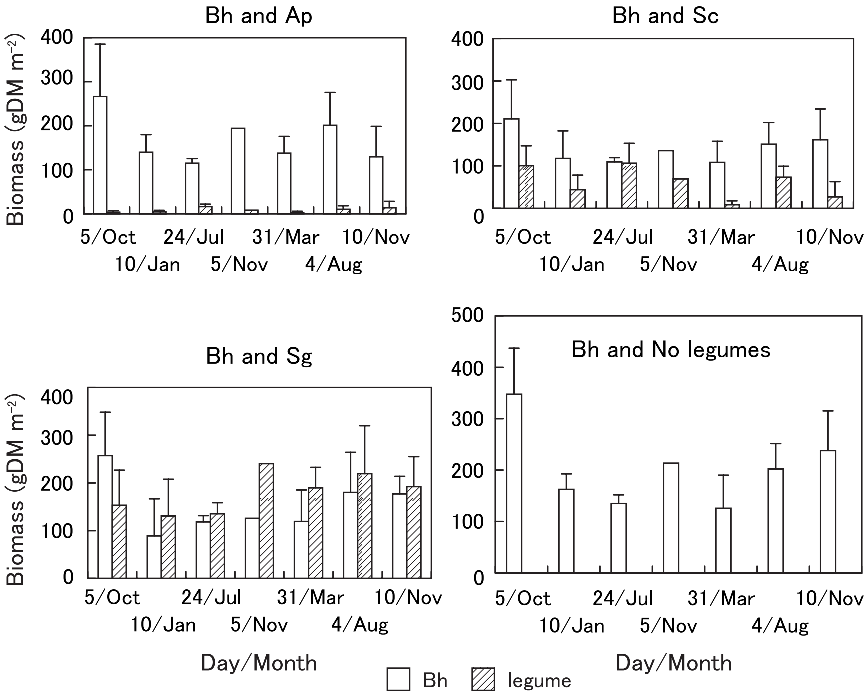

Fig. 4. Grass and legume biomass for Bh-H

Vertical bar indicates the SD of mean values.

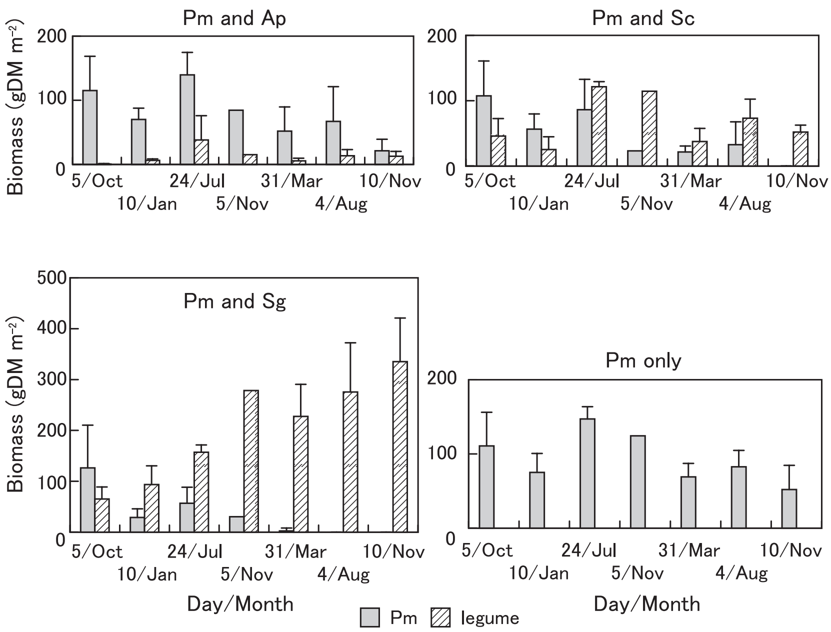

Fig. 5. Grass and legume biomass for Pm-L

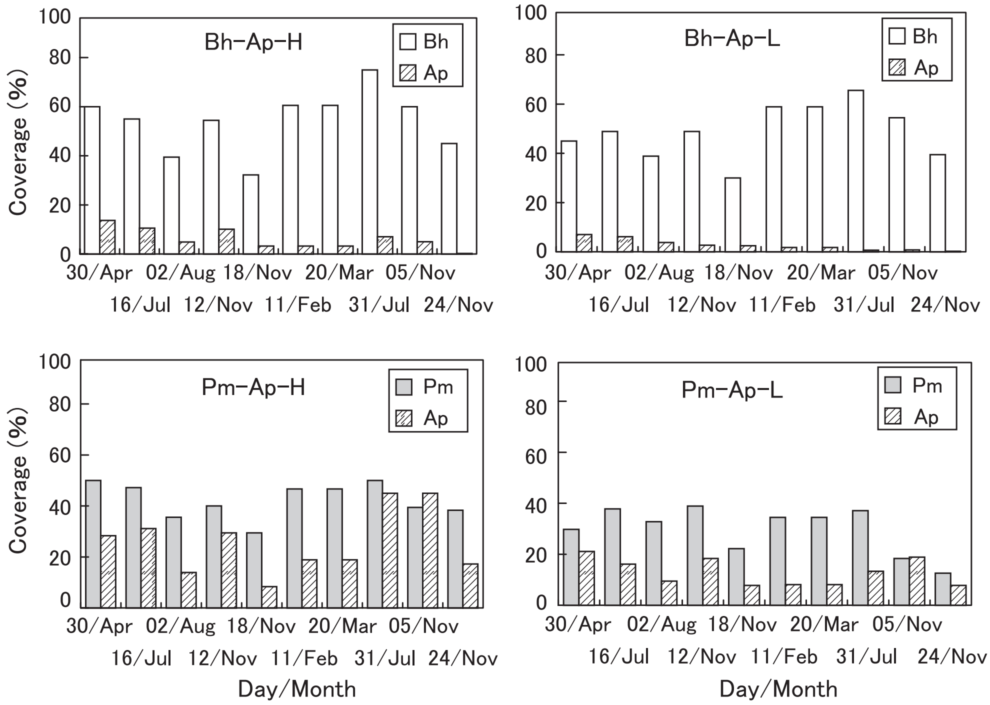

Fig. 6. Changes in ground coverage of Ap and grasses

well with Pm, particularly under the high fertility condition.

3. Preference of forage by cattle

Table 1 shows the differences in plant biomass before and after grazing which corresponds to the forage consumption by cattle. In 1996, the intake volume of grasses was in the range of 20–40 gDM m^{-2}, while in 1997 it was about 30–120 gDM m^{-2}. This difference might be due to the biomass of grasses before grazing and the stocking rate. The intake volume of legumes varied widely too, and the order of intake volume changed from

Table 1. Difference in biomass before and after grazing

Combination	High fertilizer levels (gDM m^{-2})				Low fertilizer levels (gDM m^{-2})			
	July 1996		Nov. 1997		July 1996		Nov. 1997	
	Grass	Legume	Grass	Legume	Grass	Legume	Grass	Legume
Bh-Ap	0.9	6.8	65.8	12.4	33.5	2.3	56.8	0.3
Bh-Sc	33.6	43.3	115.9	25.6	33.8	27.3	51.4	13.3
Bh-Sg	32.8	–25.4	120.9	123.0	44.2	11.8	74.7	101.0
Bh-No	19.9		180.2		34.9		85.3	
Mean-Bh	21.8		120.7		36.6		67.1	
Pm-Ap	31.8	28.3	73.7	14.7	38.3	17.6	14.2	11.0
Pm-Sc	24.9	27.0	59.7	41.4	29.3	26.6	0.0	37.4
Pm-Sg	40.7	9.4	104.6	155.2	22.8	–20.6	0.0	84.2
Pm-No	13.7		97.0		39.8		43.1	
Mean-Pm	27.8		83.8		32.6		28.7	
Mean-Ap		17.6		13.6		10.0		5.7
Mean-Sc		35.2		33.5		27.0		25.4
Mean-Sg		(9.4)		139.1		(11.8)		92.6

Table 2. The degree of defoliation of each plant

Combination	Volume grazed / Biomass before grazing (%)								
	July 1996		Nov. 1997			July 1996		Nov. 1997	
	Grass	Legume	Grass	Legume		Grass	Legume	Grass	Legume
Bh-Ap-H	(1.6)	84.7	50.9	91.6	Bh-Sg-H	55.4	(–37.5)	68.3	63.9
Bh-Ap-L	59.0	94.5	59.6	100.0	Bh-Sg-L	69.4	14.5	73.0	53.6
Pm-Ap-H	46.5	98.0	86.2	91.9	Pm-Sg-H	65.8	14.1	59.0	74.9
Pm-Ap-L	54.8	92.3	66.7	86.9	Pm-Sg-L	80.5	(–26.2)		25.1
Mean-Ap		92.4		92.6	Mean-Sg		14.3		54.4
Bh-Sc-H	61.5	81.6	71.8	94.8	Bh-No-H	29.5		75.7	
Bh-Sc-L	51.9	77.8	56.6	89.5	Bh-No-L	49.3		60.3	
Pm-Sc-H	34.9	42.0	52.2	79.6	Pm-No-H	20.1		85.4	
Pm-Sc-L	67.8	43.9		72.0	Pm-No-L	54.1		82.7	
Mean-Sc		61.3		84.0					
Mean-Bh	57.5		59.7			50.9		69.3	
Mean-Pm	51.0		68.4			55.1		75.7	

Sc>Ap>Sg in 1996 to Sg>Sc>Ap in 1997. This result shows Sg was less preferred by cattle (in 1996), but was eaten well when the dry matter content of other legumes was less available in relative volume (in 1997, Fig. 3).

To examine the preference (or the palatability) by cattle, the degree of defoliation (the volume grazed/ volume of biomass before grazing) was calculated and shown in Table 2. The degree of defoliation of the legumes was in the order of Ap>Sc>Sg in both years. Whereas that of Ap was greater than 90% in both years, that of Sg was low (14%) in 1996, but high (54%) in 1997, due to the previously described biomass conditions. The two grass species had similar values for the degree of defoliation (51–76%) in both years. Ap seems to be the most palatable of the three legume species.

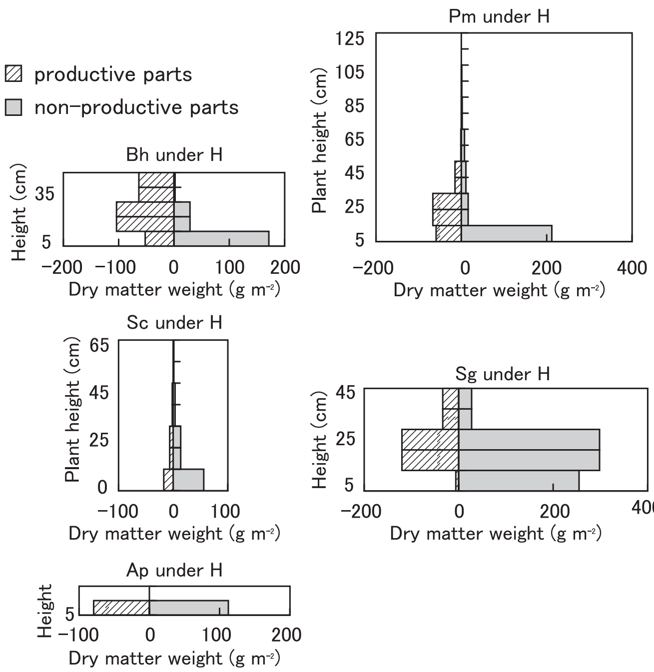

Fig. 7. Production structure of each species (6 Nov. 1997, 125 weeks after sowing)
Vertical axes are plant height (cm).

4. Discussion

Based on the results mentioned above, it is suggested that the two grasses and three legumes tested here have particular features in growth pattern and palatability to cattle. To establish a sustainable grassland that produces plant biomass under severe conditions, a mixture of Sg and Bh appears to be the best combination. On the other hand, the growth of Ap is slow, but its palatability is the best of the three legumes. Also a mixture of Ap and Pm showed relatively good compatibility under the higher fertilizer condition. This mixture requires chemical fertilizer and an extended period to establish a pasture but this combination can support more production of cattle.

It is considered that differences in growth patterns in grass-legume mixtures of the two grasses and the three legumes are related to plant growth, plant type and response to grazing. Fig. 7 shows the production structure of each species, which indicate a distribution for productive (leaf) and non-productive parts (stem and flower) at various heights. While Pm-H plant height was high (130 cm), Bh-H height was shorter, with more leaf mass at a height of 0 to 50 cm. Mature Pm plants are characterized as "erect and cespitose", while Bh is characterized as "prostrate and stoloniferous"[5]. Fig. 7 does not show the difference clearly, but it was observed that the Bh plant type was prostrate and grew aggressively. With Sg-H, the mass of non-productive parts was significantly greater than productive parts, due to the hard stems of this species. The growth type of both Sg and Sc are "erect or prostrate herbaceous" plants[5] but in this study the observation was that the stem of Sg was harder than Sc. For that reason Sg would be less preferred by cattle and grow vigorously. Ap-H is a stoloniferous species and would not coexist with the aggressive growth of Bh, but is compatible with the erect Pm, especially under the high fertility condition.

References

1. Alarcón, E. (1978) Regional pasture trials in acid infertile soils of Colombia. *In* Pasture production in acid soils of the tropics, eds. Sánchez, P. A. & Tergas, L. E., CIAT, Cali, Colombia, 431–447.
2. Evans, T. R. (1978) Interpretation of research results in the management of tropical pastures. *In* Pasture production in acid soils of the tropics, eds. Sánchez, P. A. & Tergas, L. E., CIAT, Cali, Colombia, 271–287.
3. Paladines, O. & Leal, J. A. (1978) Pasture management and productivity in the Llanos Orientales of Colombia. *In* Pasture production in acid soils of the tropics, eds. Sánchez, P. A. & Tergas, L. E., CIAT, Cali, Colombia, 311–325.
4. Sánchez, P. A. (1978) Tropical pasture research in acid, infertile soils of Latin America: present status and needs for the future. *In* Pasture production in acid soils of the tropics, eds. Sánchez, P. A. & Tergas, L. E., CIAT, Cali, Colombia, 471–476.
5. Torres, G. A. M. et al. (1993) Inventory of tropical forage species maintained at CIAT. Working Document No. 125. CIAT, Cali, Colombia, pp.36.