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Agronomic response of forage mixtures in a silvopastoral system in the Colombian dry tropics

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Abstract
Mixtures of forage grasses and legumes were established on 9.7 ha, using the following treatments: *Brachiaria hybrida* cv. Cayman, *Brachiaria hybrida* cv. Toledo, *Panicum maximum* cv. Mombaza, *Brachiaria hybrida* cv. Cayman + *C. brasiliensis*, *Brachiaria hybrida* cv. Toledo + *C. brasiliensis*, *Panicum maximum* cv. Mombaza + *C. brasiliensis*. The following variables were evaluated: vigor, height of the plant, coverage, incidence of pests and diseases at the four-week mark and production of forage and dry matter were recorded at the six-week mark. Statistical differences were found for plant height, which evidenced which of the treatments behaved best in terms of growth. Non-combined treatments were found to perform best for the production of dry matter variable. *C. brasiliensis* contributes to the growth of the combined grasses during the first four weeks of establishment, but after this time the legume begins to compete for space and light, affecting the development of the other forage species.

Keywords: legume; grass; *Canavalia brasiliensis*; interspecific competition.

Respuesta agronómica de mezclas forrajeras en un sistema silvopastoril de trópico seco colombiano

Resumen
Se establecieron 9,7 ha, en asociación de gramíneas y leguminosas forrajeras utilizando los siguientes tratamientos: *Brachiaria hibrido cv* Cayman, *Brachiaria hibrido cv* Toledo, *Panicum maximum* cv. Mombaza, *Brachiaria hibrido cv* Cayman + *C. brasiliensis*, *Brachiaria hibrido cv* Toledo + *C. brasiliensis*, *Panicum maximum* cv Mombaza + *C. brasiliensis,* evaluándose las variables de vigor, altura de la planta, cobertura, incidencia de plagas y enfermedades a la cuarta semana y en la sexta semana se registraron valores de producción de forraje y materia seca de las asociaciones. Se encontraron diferencias estadísticas para altura, evidenciado mejor comportamiento en los tratamientos asociados; mientras que la variable de producción de materia los tratamientos sin asociación presentaron altos valores. *C. brasiliensis* contribuye al crecimiento de las gramíneas asociadas durante las cuatro primeras semanas de establecimiento, después de este tiempo la leguminosa inicia proceso de competencia por espacio, afectando el desarrollo de la otra especie forrajera.

Palabras clave: leguminosa, gramínea, *Canavalia brasiliensis*, competencia interespecífica.

1. Introduction

In Colombia, cattle production is one of the main contributors to GDP, and has developed in regions with a warm, dry climate. These regions tend to have extreme environmental conditions, which, together with climate change, limit the food supply and the profitability of the sector. In 2017, the department of Cauca recorded a growth in GDP where agricultural sector activities contributed the most to this growth (8.3%).

In this context, livestock activity in Cauca is mainly developed in the Patía valley, a region characteristic of the tropical dry forest ecosystem [1], where livestock production is extensive [2] and managed traditionally, which tends to be inefficient and have a low load capacity of 0.75 UGG / ha.

In the prairies, species like Angleton (*Dichanthium aristatum*), *Braquiaria spp*., *Paspalum sp*., and Pointer

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(*Hyparrhenia rufa*) predominate. Although they survive in times of drought, their yield and nutritional content decreases, affecting the sustainability of the productive sector [3].

Some researchers propose that the strata should be diversified for the production of forage (silvopastoral systems), which improves the supply conditions, since the use of shrubs and trees in grasslands allows for water and nutrient extraction processes from soil horizons inaccessible to grass roots. Similarly, these species contribute organic matter to the soil in the form of leaves, flowers, fruits, branches and dead roots [4,5].

However, the long periods of drought in the Patía valley generate a deficit in the food supply. In these circumstances, the inclusion of legumes can be a source of economical and good quality protein, which, due to their root system, can endure environmental changes and provide a wide range of essential amino acids that contribute to adequate livestock nutrition [6-8].

Given the above, and with the purpose of contributing to the improvement of the livestock systems of the Patía valley, this study looked at the agronomic behavior of *Canavalia brasiliensis* when planted alongside different grasses, and evaluated its productive potential for silvopastoral systems in the dry tropics.

2. Materials and methods

2.1. Location

The research was carried out in the Patía valley in the south of the department of Cauca-Colombia, a region with dry tropical climatic conditions, at an altitude of 550 m.s.m. with an average temperature of 28 ° C and rainfall of 1200 mm per year. This zone has deep, fertile soils of alluvial origin that are acidic to neutral pH (5.8). The relief is flat with slopes of between 1 and 3%, the soil is moderately deep to very shallow, from very poorly to well drained, with a fine to moderately thick texture, and a pH that is strongly acid to moderately alkaline. The soils undergo moderate erosion and are moderately to highly fertile, and are composed of Fluventic Haplustolls (40%), Entic Haplustolls (30%) and Udic Haplustolls (30%) [9].

2.2. Trial establishment

Forage mixtures (grasses and legumes) were established in a silvopastoral system where *Guazuma ulmifolia* (Guacimo), *Crescentia cujete* (Totumo), and *Mangifera indica* (Mango) were growing, with live fences of *Swinglea glutinosa*. The area where the trial took place had low tree coverage and density; the trees were irregularly placed and scattered across the pastures, with most of the trees having been eliminated during the establishment of the pasture as a monoculture. However, the diameters of the trees observed show an advanced ecological succession (Silvopastoral System - Scattered Trees in El Potrero) [10].

The forage species used in the mixture were selected taking into account different results from research carried out by the Agricultural Nutrition Research group (NUTRIFACA) of Universidad de Cauca and the Tropical Forages program of the International Center for Tropical Agriculture. The sowing was carried out in line with technical recommendations, using 8 kilos of grass seed and 2.5 kilos of legume per hectare, conserving a respective proportion of 70:30 over the pasture.

2.3. Experimental design

The experiment used a completely randomized block design, where the block factor was influenced by the slope of the terrain, and the treatment factor was determined by the different combinations of *Canavalia brasiliensis* with the following grasses:

T1: *Brachiaria hibrido* cv. Cayman
T2: *Brachiaria brizantha* cv. Toledo
T3: *Panicum maximum* cv. Mombaza
T4: *Brachiaria hibrido* cv. Cayman + *C. brasiliensis*
T5: *Brachiaria brizantha* cv. Toledo + *C. brasiliensis*
T6: *Panicum maximum* cv. Mombaza + *C. brasiliensis.*

Each treatment was evaluated for agronomic behavior using the methodology of type B regional tests of the International Network of Evaluation of Tropical Pastures (RIEPT) [11].

2.4. Variables to be evaluated

The following production evaluations were carried out from the 12th week after sowing:

- Vigor. The state of the plant, color, growth and health is evaluated on a scale of 1 to 5, with 1 being the worst and 5 the best, with the entire trial acting as a standard of comparison.
- Height and coverage of the plant. Measured in centimeters (cm) as the distance from the ground to the highest part of each plant in its natural state (last formed leaf), excluding inflorescences. Coverage was estimated by considering the colonization percentage of plants (grasses) in one square meter [12].
- Incidence of pests. Rated as 1 = Presence of the insect with damage of less than 1%, 2 = Mild damage of 1-10%, 3 = Moderate damage of 11-20%, 4 = Serious damage of more than 30%.
- Incidence of diseases. For each evaluation, the damage caused by diseases was taken into account, where the effect on the plant is measured as: 1 = Presence of the disease: 5%. 2 = Mild damage: 5-20%. 3 = Moderate damage: 20-40%. 4 = Severe or severe damage: more than 50%.
- Green forage production: three surveys were carried out in each experimental unit, following the recommendations of Toledo [11], by weighing the forage produced by the grass and legumes [13].
- Dry matter: The samples were baked in an oven with a temperature of 60 ° C for 72 hours, after this time the

weight of the dry matter was found by subtracting the final weight from the start weight [12].

2.5. Statistical analysis

An analysis of variance (ANOVA) was used to determine statistical differences in the blocks, evaluations and established treatments. The Duncan multiple range test was applied for the variables that presented divergences. In the case of categorical ordinals (vigor, incidence of pests and diseases), these were analyzed using correlations, frequency tables and chi-square, using the statistical program SPSS V 25.0.

3. Results and discussion

The analysis of variance found statistical differences (P <0.05) for height, production of green forage from the grass and production of dry matter from the grass.

3.1. Height

The Duncan averages test shows three groups. The first group consists of treatments T6, T3 and T5; the second T3, T5 and T2; and the third T5, T2, T4 and T1. The test showed that the mixed treatments are taller than the grasses by themselves (Table 1).

These results can be attributed to the benefits that the legume can provide to the grass in terms of nitrogen available in the soil [14,15].

Li et al. [16] assert that the incorporation of legumes in pastures contributes to the improvement of soil fertility since they supply the soil with nitrogen through the symbiotic fixation of this element. This is reflected in the improved growth of the plant species, compared to those not planted in combination with legumes. Conrad et al. also state that the use of these plants enriches the soil with nutrients and improves its physical and chemical characteristics, contributing to changes in the architectural aspects of the pasture, that is, the height of the plants [17]. This observation was reflected in the results obtained in the present study, where the presence of *Canavalia brasiliensis* improved the growth of the grasses.

Specifically, it was observed that, in terms of height, of the treatments studied, *Panicum maximum* cv. Mombasa showed the most growth, with an average height of 167.3 cm, while *Bracharia hybrid* cv. Cayman showed the least (93.4 cm), probably due to the size characteristics of each species [18], since this type of forage species has a maximum height of 60 to 90 cm [19].

Table 1.
Behavior of height in the establishment of grasses mixed with *Canavalia brasiliensis* in a silvopastoral system in the dry tropics.

Treatment	height of the plant (cm)
Brachiaria hibrido cv. Cayman	93.4 (c)
Brachiaria hibrido cv. Cayman + *Canavalia brasiliensis*	99.5 (c)
Brachiaria hibrido cv. Toledo	122.8 (b) (c)
Brachiaria hibrido cv. Toledo + *Canavalia brasiliensis*	133.4 (a) (b) (c)
Panicum maximum cv. Mombaza	156.2 (a) (b)
Panicum maximum cv. Mombaza + *Canavalia brasiliensis*	167.3(a)

Source: The Authors.

Table 2.
Behavior of the variables of green forage and dry matter production from grasses mixed with *Canavalia brasiliensis* in a silvopastoral system in the dry tropics.

Treatment	Green fodder grass (gr)	Dry matter grass (gr)
P. maximum cv. Mombasa + *C. brasiliensis*	900.3 (c)	213.5 (b)
B. hibrido cv. Cayman + *C. brasiliensis*	975.0 (b) (c)	178.8 (b)
B. hibrido cv. Toledo + *C. brasiliensis*	1163.3 (a) (b) (c)	249.2 (b)
B. hibrido cv. Cayman	1702.7 (a) (b) (c)	350.2 (a) (b)
B. hibrido cv. Toledo	2450.7 (a) (b)	661.9 (a)
P. maximum cv. Mombasa	2652.0 (a)	633.8 (a)

Source: The Authors.

3.2. Green forage production

In relation to the production of green forage (GF), the best contender was T3 *Panicum maximum* cv. Mombasa and the worst was T6 *Panicum maximum* cv. Mombasa + *C. brasiliesis*. The hybrid T2 *Bracharia brizabtha* cv. Toledo produced the most dry matter (DM) and T4 *Bracharia hybrid* cv. Cayman + *C. brasiliensis* produced the least (Table 2).

The results obtained show that the grass performs better on its own than when it is mixed with the legume. This can be explained by the way that the legume grows, as it is a climbing plant with strong, thin vines that seek support on other substrates or species [20] and can start to crowd the light of neighboring plants.

Two weeks after the forage species were established on the prairie, *Canavalia brasiliensis* showed greater growth and therefore started to compete with the grasses [19] for space and solar rays which made their photosynthetic process inefficient. This, in the end, was reflected in the production of biomass [21] as the progressive change in the quantity and quality of the light manifests in alterations in the growth and development of forage plants, reducing the yield of dry matter [22].

However, the decrease in productivity of the mixed grasses is compensated by the productive contribution of the legumes planted alongside them [23], since these contribute to the improvement of the animals' diet, upping the protein content and digestibility of the dry matter as feed [24]. Studies carried out at the International Center for Tropical Agriculture (CIAT - Colombia), show that including species such as *Canavalia brasiliensis* improves protein content by 3% and increases gross energy, as well as decreasing the indigestible neutral detergent fiber and lignin [25]. This is important, as the quality of the forage affects passage rates, the level of consumption and the production of methane, which in turn affect animal productivity [26].

Added to the above, drought tolerance in livestock systems in the dry tropics allows for system stability throughout the year, supplementing the cattle's diet during periods of drought [27]. Finally, the legume in the pasture contributes organic matter to the soil which improves fertility and nutrient cycling [28].

4. Conclusions

The mixture of legumes and grasses in meadows improves the growth and development of forage in the grasslands within four weeks of establishment; this is evidenced by the height of the plants.

After six weeks of establishment, a field with mixed planting of *Canavalia brasiliensis* alongside the grasses began to evidence processes of interspecific competition between the two, therefore it is advisable that in the fifth week of establishment, management and control processes (grazing or cutting) are implemented to curb the legume.

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