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Artícle

Production of forage leguminous species at different cutting times in Tolima, Colombia

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Abstract

Different studies have shown that leguminous forage species have a high impact and value in silvopastoral systems in terms of the contribution they represent for livestock feeding, based on the increase in both the potential of soils and the production of meat for livestock. The objective was to determine the productive potential in terms of dry matter in two contrasting seasons, dry and wet, for the leguminous species *Albizia guachapele* (Kunth) Dugand, *Albizia niopoides* (Benth.) Burkart, *Albizia saman* (Jacq.) Merr., and *Leucaena leucocephala* (Lam.) de Wit. This study was conducted at the Nataima Research Center of the Colombian Agricultural Research Corporation, located in the municipality of Espinal-Tolima, Colombia, between March and August 2018. A design of repeated measures over time and arrangement of randomized complete blocks, four treatments, and two evaluation periods were used, and eight interactions between the species and rainy season factors were worked on. The species *A. guachapele* presented the best productive potential compared to the others; there were statistical differences for cutting times in the species evaluated, and a high variability effect was observed due to the time factor. *A. saman* was the least productive species, while production stabilization was demonstrated for all those evaluated over time. There was no significant bidirectional interaction for the season factor, and the best performance corresponded to those carried out in the dry season. This allowed a greater expression of the productive potential as a food alternative for low rainfall areas.

Keywords:

adaptation, interaction, potential, stabilization.

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Introduction

Implementing silvopastoral systems is very useful and favors the conservation of the environment; they involve tree and shrub species with high aptitude in biomass production suitable for bovine feeding and for other uses, such as shade (Uribe *et al*., 2011). One way to identify their capacity in the systems is to look at the productive capacity and the preferences of cattle for each of these in the grazing systems (Balehegn and Berhe, 2016).

There are species with good behavior and adaptation to different management techniques and adverse conditions present in the systems; this is reflected in the adequate productivity and supply of biomass per unit area, as is the case for *Leucaena leucocephala* (Francisco *et al*., 1998). Different studies attribute an important role in animal feeding to woody forage species (trees and shrubs).

The following species stand out: *Albizia guachapele* (Kunth) Dugand, *Albizia niopoides* (Benth.) Burkart, *Albizia saman* (Jacq.) Merr, and *Leucaena leucocephala* (Lam.) de Wit (Garcia *et al*., 2008; Uribe *et al*., 2011). Therefore, it is necessary to recognize their productive potential in terms of dry matter and incorporate their functional knowledge; in addition to providing biomass, they contribute to soil conservation, design efficiency, and maintenance or management of production systems that depend on the forage resource (Román-Miranda *et al*., 2017).

Additionally, it is of great importance to mention that many of these species with forage potential have excellent nutritional content, with high and low dry matter (DM) productions (Lombo, 2012). Some forage species of tree legumes have the ability to increase the level of nitrogen in the soil due to their ability to fix it from the atmosphere through the association that they have in the roots with nitrifying bacteria.

At the same time, they provide other ecosystem services due to nutrient cycling processes (Botero and Russo, 2002). This work aimed to determine the productive potential in terms of dry matter (DM) in two contrasting seasons for the leguminous species Iguá *Albizia guachapele*, Bayo *Albizia niopoides*, Saman *Albizia saman*, and Leucaena *Leucaena leucocephala*.

Materials and methods

Study site

Since 2013, production evaluations have been carried out for 22 tree and shrub species at the Nataima Research Center of the Colombian Agricultural Research Corporation (Agrosavia), located in the municipality of Espinal-Tolima, Colombia, Coordinates 4° 10’ 34” - 4° 11’ 26” north latitude and 74° 58’ 02” - 74° 50’ 44” west longitude at 391 masl, average temperature of 28 °C, average relative humidity of 65%, and annual rainfall of 1 400 m. This zone corresponds to Colombia’s tropical dry forest (TDF) (Serrano and Calderón, 2016).

Of the 22 species, the following were selected: *Albizia guachapele*, *Albizia niopoides*, *Albizia saman*, and *Leucaena leucocephala*, due to their excellent characteristics of adaptation to the area and high nutritional contribution. They were managed as shrubs of 1.8 to 2.0 m. They were used for the present research, carried out between March and August 2017.

A cutting or harvesting height of 80 cm was used, where a systematic random sampling (SRS) was carried out; it consisted of making daily homogenizations to groups of six plants (sampling unit), with systematic cuts and a daily cutting frequency until reaching forty days. All degraded leaves and branches less than 8 mm in diameter were considered. Each species had a population of 240 individuals of the same age planted in 1 x 1 m rows.

For the determination of dry matter (DM), 300 g of fresh fodder (FF) was taken from each species and packed in craft paper bags to facilitate the elimination of moisture; subsequently, by the traditional method, they were subjected to drying in an oven at temperatures between 60 and 65 °C for 24 to 72 h. Samples were weighed every 12 h until the time when the dry weight stabilized was determined. This process was carried out in the laboratories of Agrosavia, Espinal, Tolima.

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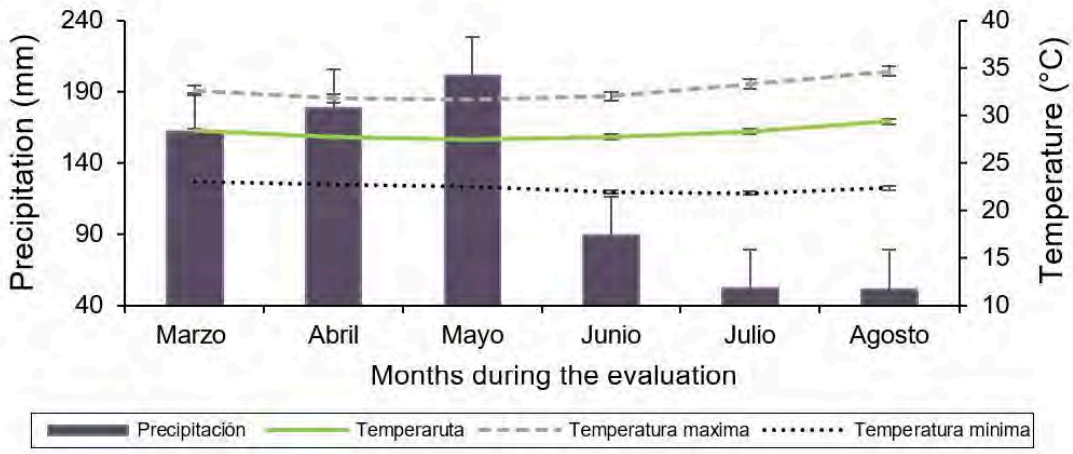
The response variable was expressed in terms of dry matter (%) DM of forage, measured in grams (g), over 5.3 months in four production cycles of 40 days each (production times or replications).

Experimental design

The experiment used a design of repeated measures over time, with an arrangement of randomized complete blocks, four treatments (species) by two seasons, dry and wet, which resulted in eight interactions between the species and rainy season factors, 40 repetitions in 4 periods, giving 160 experimental units of six plants each.

During the species evaluation period from March to August for the year 2018, there were two well-defined and contrasting seasons in relation to the rainfall and temperatures recorded (Figure 1).

Figure 1. Accumulated precipitation and temperature from March to August 2018, Vintage station pro-2. Nataima Research Center, Colombian Agricultural Research Corporation (Agrosavia). Espinal-Tolima, Colombia.



Statistical analysis

The information obtained was analyzed through the R V.4.1.3 software (R Core Team, 2020) using the tidyverse (Wickham *et al*., 2019), ggpubr (Kassambara, 2020) and rstatix (Kassambara, 2021) packages. Assumptions were verified by identifying the presence of extreme outliers, normal distribution of the data with the Shapiro-Wilk statistic ($p> 0.05$), normal QQ plots for each time point, and the assumption of sphericity using the Mauchly statistic.

The effects of the treatments on the forage yield variable expressed in grams (g) of dry matter (DM) were analyzed through a unidirectional and bidirectional repeated measures analysis of variance and were considered significant at $p< 0.05$. In the presence of test significance, multiple paired t-tests were performed for the difference between treatments.

Results and discussion

For the species *A. guachapele* (Figure 2a), the data show that the dry matter production variable was statistically significant at the different times [F (1; 44; 56, 289) = 33.02; $p= 0.0001$, generalized eta squared= 0.46], which represents the high variability presented due to each of the cutting cycles over time. On the other hand, post hoc analyses with a Bonferroni adjustment revealed statistically significant differences for the DM variables between the pairwise comparisons for treatments (t), with $p< 0.0001$, between t1 and t2, t1 and t3, t1 and t4, t2 and t3, and t2 and t4, and highly significant between t3 and t4.

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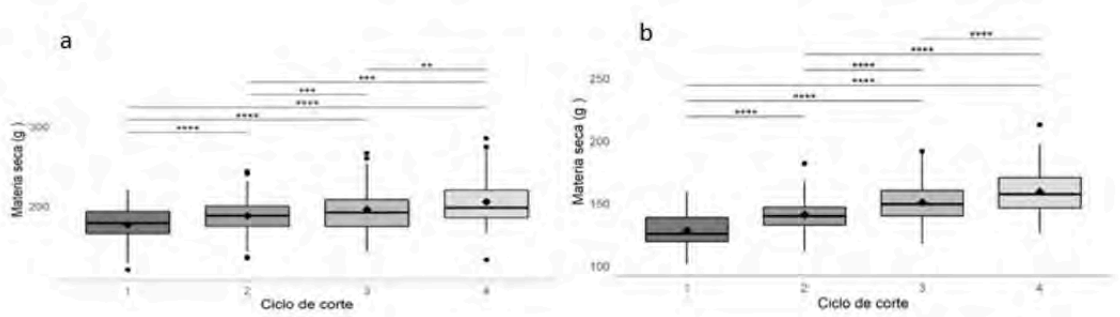
Figure 2. Effect of time on dry matter production (g) in *A. guachapele* (a); and *A. niopoides* (b), at the Nataima Research Center, Colombian Agricultural Research Corporation (Agrosavia). Espinal-Tolima, Colombia, 2018. The asterisks report the boundary of the significance value for which it is greater than the *p*-value. **= probabilities less than 1%; ♦= it represents the arithmetic mean; ***= probability less than or equal to 1%; **= probability below 5%.**



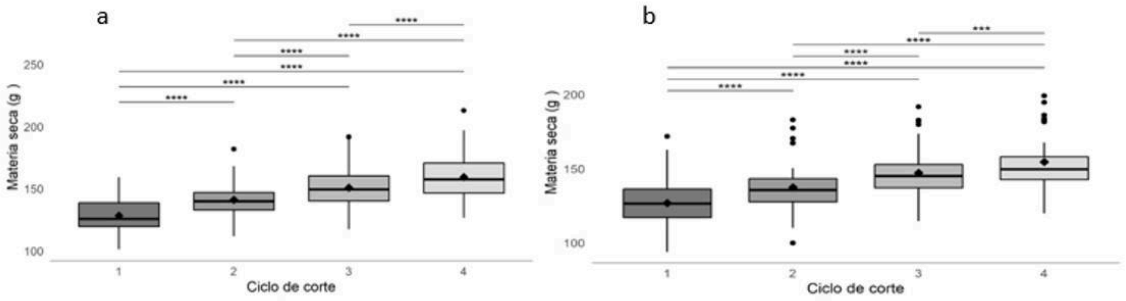
The fourth cut had the highest yields, averaging 205 g DM per plant. Treatments 1 and 2 presented yields of less than 200 g DM per plant, but with statistical differences between them due to the variability between cuts made for the four cycles.

For the species *A. niopoides* (Figure 2b), dry matter production was lower and exhibited statistically significant differences for the four times [F (1.64; 64.05) = 106.8, *p*= 0.0001 and a generalized eta squared= 0.73]. There was a variability effect due to cutting cycles. Time showed the highest value for eta in the four species evaluated, producing greater variability for species *A. niopoides*.

On the other hand, post hoc analyses with a Bonferroni adjustment revealed statistically significant differences in DM (g) between the comparisons, as those between t1 and t2, t1 and t3, t1 and t4, t2 and t3, t2 and t4, t2 and t4, and t3 and t4 had a *p*< 0.0001, where the fourth cut exhibited the highest yields and a mean of 160 g DM per plant, due to the variability that this species shows in relation to its growth.

For the species *A. saman* (Figure 3a), dry matter production was statistically significant at the different evaluation times [F (1.48; 57.63)= 42.34; *p*= 0.0001; generalized eta squared= 0.52]. There was high variability in the experiment due to the time factor (t) for the four moments evaluated.

Figure 3. Effect of time on dry matter production (g) in *A. saman* (a) and *L. leucocephala* (b) in the Nataima Research Center, Colombian Agricultural Research Corporation (Agrosavia). Espinal-Tolima, Colombia, 2018. **= probabilities less than 1%; ♦= it represents the arithmetic mean; ***= probability less than or equal to 1%; **= probability below 5%.**



Post hoc analyses with a Bonferroni adjustment revealed statistically significant differences in dry matter (g) between pairwise comparisons, *p*< 0.0001, between t1 and t2, t1 and t3, t1 and t4, t2

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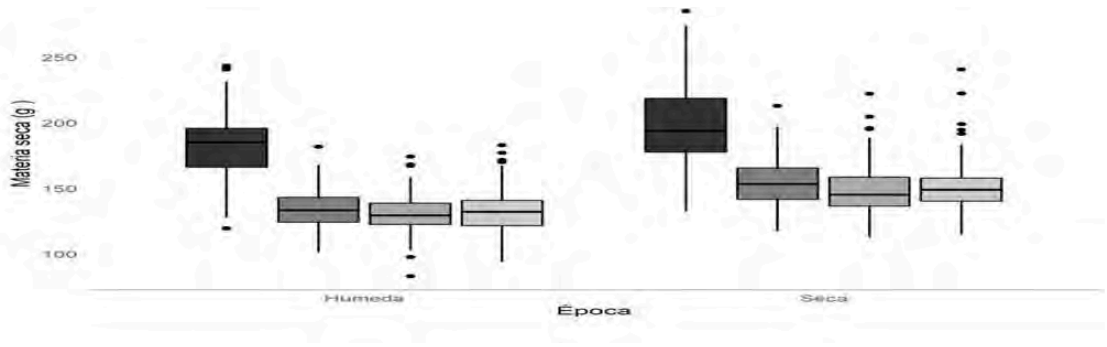
and t3, t2 and 4, and t3 and t4, where the first cut was below 150 g, and the fourth exhibited the highest yields with an average of 155 g DM per plant.

For the species *L. leucocephala* (Figure 3b), DM production was statistically significant at different evaluation times [F (1.66; 64.87)= 73.58; *p*= 0.0001 with generalized eta squared= 0.65], which indicated that there is a variability effect due to the t-factor. Post hoc analyses with a Bonferroni adjustment revealed statistically significant differences in DM (g) between pairwise comparisons, *p*< 0.0001, between t1 and t2, t1 and t3, t1 and t4, t2 and t3, t2 and t4, and t3 and t4, where the fourth cut showed the highest yields, with a mean of 158 g DM per plant.

All the species evaluated underwent a stabilization process over time. The availability of water resources and nutrients, among other production factors, was considered, which means that with longer recovery times, the species increases the production of DM (g). This is related to their physiology, morphology, and ability to adapt to the evaluated environmental conditions, represented by greater rooting and nutrient extraction (Cerón, 2013).

It was observed that there was no significant bidirectional interaction, which indicates that the impact that the species factor has on the dry matter variable does not depend on the levels for this (season) (Figure 4). Then, the main effects of each of the two factors (species and time) were interpreted.

Figure 4. Effect of the rainy season on dry matter (g) production in the legume species evaluated. Nataima Research Center, Colombian Agricultural Research Corporation (Agrosavia). Espinal-Tolima, Colombia, 2018.



The results of the analysis of variance were considered, and there were statistically significant main effects of the species factor [F (2.4; 189; 25)= 200.779, *p*= 0.0001], season factor [F (1.79)= 229.910, *p*< 0.0001] in the DM (g) variable. The cuts made for the dry season corresponded to those with the highest productivity recorded through the four evaluation moments.

Concerning the DM variable (g), the factors separately exhibited significant differences, where it was shown that for the species factor, *A. guachapele* had the highest yields in both the dry and wet seasons, and productions of 191.26 and 164.39 g, respectively, and statistically significant differences *p*< 0.0001 compared to the other treatments. These were not evident in the comparison made for the other treatments species *A. niopoides*, *L. Leucocephala*, and *A. saman*, and productions of 144.95, 142.67, and 140.39 g, respectively. The highest yields observed corresponded to the dry season, 164.39 g, and they were statistically different from the wet season, with 145.25 g harvested on average (Table 1).

Table 1. Evaluation of dry matter yield in forage leguminous species for the independent factors, species and season.

		Dry matter (g)
Species (legumes)	*A. guachapele*	191.26[a]
	A. niopoides	144.95 [b]
	L. leucocephala	142.67 [b]

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		Dry matter (g)
	A. saman	140.39 [b]
Season (time)	Dry	164.39 [a]
	Wet	145.25 [b]

[a , b, c]= means with different letters in columns differ from each other according to Tukey's test ($p< 0.05$)/ [a, b, c]. Nataima Research Center of the Colombian Agricultural Research Corporation (Agrosavia). Espinal-Tolima, Colombia. 2018.

Different trials have shown that soil and climatic conditions have an important effect on the survival and development of different plant species used in animal feeding (Lombo, 2012; Bueno *et al*., 2019). However, it is unclear how soil conditions, different rainfall, and the length of the dry period affect the individual behavior of each species (van Breugel *et al*., 2011).

In this sense, the species *A. guachapele* presented the highest DM yields for the four legume species evaluated; according to Lombo *et al*. (2012), this is due to the fact that this species, a pioneer in reforestation processes due to its rapid growth with great abundance in the secondary dry forest, showed a great capacity for adaptation and resistance to adverse climatic conditions, which makes it one of the main species to be used under conditions of water deficit and low fertility (Lombo, 2012; Guarachi, 2020).

It was shown that species development varies with edaphic conditions but that there are specific and differential responses to soil variables (Haggar *et al*., 1998). Therefore, species specialization to edaphic conditions not only shows adaptations to soil conditions but also the interaction of soil conditions with other covariates, such as pest pressure and phytosanitary disturbances (Fine *et al*., 2004).

There is evidence that sensitivity to drought varies greatly between species (Engelbrecht and Kursar, 2003; Poorter and Markesteijn, 2008); this was observed in the results obtained in this study developed in a dry environment, showing that the species presented similar survival but not the same production (DM) performance.

It is suggested that the history of the field regarding tillage practices affects the physicochemical properties of the soil by making these types of variables a more limiting factor than the variability in the distribution of precipitation itself (van Hughes *et al*., 2002; van-Breugel *et al*., 2011) All species showed a positive effect, with an increase in DM content through the two cutting moments, similar to what was found in other studies, where three cutting heights were evaluated for the species *L. leucocephala*, where there was an increase in its biomass as a function of the cutting height (Francisco *et al*., 1998).

The same study also showed that the higher the cutting height for the species, the higher its recovery rate; so, the cutting height of this evaluation, 40 cm, corresponded to half of the height to which the species were subjected in the present study (Francisco *et al*., 1998). This allowed these species to show greater and faster recovery and therefore, a progressive increase in DM content over time.

The biomass recorded for the wet season in this study was lower than that of the research carried out by (Francisco *et al*., 1998), where most of the yields for this trait occurred in the wet period; the above is due to the fact that the frequent and excessive rainfall of this period caused the cessation of metabolic and development processes, decreasing the production of biomass for these. Therefore, these species showed greater adaptation due to the fact that their origin presents extreme conditions for their adaptation (Pérez *et al*., 2015).

The lowest production corresponds to *A. saman* and *L. leucocephala* in the two periods evaluated, more for the wet season; it agrees with Olivarez *et al*. (2005) findings, where it is stated that the species *L. leucocephala* shows a reduced growth rate compared to other species, due to the fact that it has metabolisms that make it inefficient for the conversion of CO_2 to carbohydrates, which are necessary for the formation of new tissues, limiting their development (Francisco, 1998).

At the same time, these species require well-drained soils without excess rainfall and good effective depth for their development, which leads to little development and potential for these species in the area (Botero and Russo, 2002). In contrast, lower yields have shown in the dry season (Latt *et*

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al., 2000). This is because there is less accumulation of carbohydrate reserves for these species for this dry season.

The species *A. guachapele* presented an excellent performance, especially for the dry season, with a DM weight of more than 200 g for the same period evaluated. This is due to its abundant growth, similar to Samán, and this agrees with what was reported by Pérez *et al*. (2015), where 19 species were evaluated, among which *A. guachapele* presented high productivity as well as survival with cutting periods of 30 days and 80 cm in height, it also showed the best adaptability behaviors to the conditions of Espinal-Tolima in Colombia.

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