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Forage production in tropical legumes, in the dry Colombian Caribbean region

Esteban Burbano-Erazo, José Edwin Mojica-Rodríguez, Guillermo Alberto Brochero-Aldana, Juan Leonardo Cardona-Iglesias and Edwin Castro-Rincón

Corporación Colombiana de Investigación Agropecuaria AGROSAVIA
Corresponding author. E-mail ecastro@agrosavia.co
ORCID: https://orcid.org/0000-0001-5056-9893

Abstract

The objective of this study was to evaluate the forage production in accessions of *Canavalia brasiliensis* Mart. ex Benth., *Canavalia ensiformis* (L.) DC. and *Vigna unguiculata* (L.) Walp. with different regrowth ages, under conditions of the dry Colombian Caribbean. A split-plot design was used, where the accession was the main plot and the regrowth age, the subplot. The height range of the plants was 29,8-69,8 cm; 31,7-54,9 cm; and 34,2-48,3 cm in *C. brasiliensis, C. ensiformis* and *V. unguiculata*, respectively. The accessions 20095 and 17009 of *C. brasiliensis* had the highest dry forage productions ($p < 0,05$), with values between 1 412,7 and 2 553,4 kg DM/ha. In *V. unguiculata* a range was observed between 9 800 and 14 275 kg DM/h; while for *C. ensiformis* the production varied between 5 498 and 8 071 kg DM/ha. In all the genotypes, as the regrowth age advanced, the forage production increased ($p < 0,05$). The *C. brasiliensis, C. ensiformis* and *V. unguiculata* accessions showed good adaptation to the soil and climate conditions of the dry Colombian Caribbean.

Keywords: feeding, Bovinae, regrowth, yield

Introduction

The world population has experienced an exponential growth in the last decades, for which the demand for animal protein has increased. In this sense, cattle husbandry is one of the sectors with higher contribution to the protein supply, from its base products: beef, milk and their derivatives (Tilman *et al*., 2011). It has promoted the intensification of this productive system, but has also forced the searching for options that allow to increase feed efficiency in cattle, from the implementation of better technologies, but with lower negative impact on the environment (Garcia *et al*., 2018).

One of the alternatives to improve nutrition in ruminants is the inclusion of legumes as protein source, which increases feed availability, mainly in regions where drought negatively affects the offer in grazing, as occurs in the dry Colombian tropic (Castro-Rincón *et al*., 2017).

Diverse studies have proven that legumes provide important contributions to the ecosystem. For example: the forage and grain serve as feeding sources with high protein content, for the animals; they are used as plant cover for the soil in different crops, and as green manure; they are atmospheric nitrogen fixing species; and reduce greenhouse gas emissions (Castro-Rincón *et al*., 2016; Prudhomme *et al*., 2017).

In addition, legumes represent a supplement of interest in animal husbandry, during prolonged periods. Under these conditions grazing is based on the use of native grasses, which generally have low nutritional value (Muchadeyi, 1998); this could affect not only nutrient contribution, but also the physiological processes in the animal (Frøslie, 2017; McLean *et al*., 2018). Nevertheless, in spite of the nutritional benefits identified in these species, their use is not yet habitual in animal husbandry systems (Junior *et al*., 2017); this could be possibly due to the lack of forage legumes and to the little transference of technologies validated for these species.

In the search for feed source with high protein content, the legumes *Canavalia brasiliensis* (Mart. ex Benth.), *Canavalia ensiformis* (L.) and *Vigna unguiculata* (L:) Walp have turned out to be promising for animal husbandry systems (Garcia *et al*., 2018). However, it is necessary to determine the optimum conditions of agronomic management and to continue researching this type of alternative (Peters *et al.,* 2011). *Canavalia* sp. has been catalogued as a genetic material of high interest for animal feeding (Douxchamps, 2010a), mainly because of its adaptive capacity to water deficit conditions and its biomass production. On the other hand, the studies with *Vigna* spp. proved the potential of this species as nutritional supplement (forage and grain) in monogastric animal feeding (Picot *et al*., 2015).

Intense drought periods and climate variability are threats that decrease the forage availability of grasses under grazing and meat and/or milk productivity of cattle husbandry systems of the Colombian dry Caribbean. In addition, the offer of legumes released for cattle farmers in the region is low (Castro *et al*., 2018).

For such reason, the objective of this study was to evaluate the forage production of *C. brasiliensis*, *C. ensiformis* and *V. unguiculata* accessions with different regrowth ages, under conditions of the Colombian dry Caribbean region.

Experimental methodology

The trial was conducted at the Motilonia Research Center, of the Colombian Corporation of Agricultural Research (AGROSAVIA), located at 10º 0′ 7′′ North latitude and 73º 14′ 51′′ West longitude in the Codazzi municipality, in the Valley of Cesar micro-region of the Cesar Department. The zone shows an annual average temperature of 28,7 ºC, relative humidity of 70 % and mean annual rainfall of 1 600 mm, with bimodal distribution in May-June and from September to December. The soil is limey-sandy, with pH 7,5. The study was conducted in September, October and November, corresponding to the second rainy season of 2016 (fig. 1).

Genotypes, accessions and regrowth age. Three legumes were used, with different number of accessions, which were requested to the germplasm bank of the International Tropical Agriculture Center (CIAT, for its initials in Spanish) –Colombia–. In *C. brasiliensis* eight accessions were used (17009, 20090, 17973, 18501, 20095, 20096, 20098 and 20304), in *C. ensiformis*, five accessions (2168, 7753, 9108, 715 and 3214), and in *V. unguiculata*, four genetic materials: 2442, 3413, 2430 and 2404. The regrowth age was evaluated at 4, 6 and 8 weeks.

The herbaceous legumes (*C. brasiliensis* and *V. unguiculata*) were planted in rows separated by 0,5 m with 0,5 m between plants, and the shrub legume (*C. ensiformis*) was sown in rows separated by 0,7 m with 0,5 m between plants.

Response variables. For the case of *V. unguiculata*, after plant emergence the evaluation period started; while for *C. brasiliensis* and *C. ensiformis* a homogenization cutting was performed (10 cm from the soil level) after an establishment period of four months. In the regrowth ages indicated above the following variables were evaluated:

- Plant height: it was measured from the soil to the petiole of the tallest leaf.
- Green forage production: the green forage (GF) production was measured in 0,25 m^2, and it was expressed as kg GF/ha.
- GF samples were taken which were dried in oven during 48 h, at a temperature of 60 ºC to determine the dry matter content and the dry forage (DF) production per hectare.

Design and experimental area. A randomized block design was used with split-plot arrangement

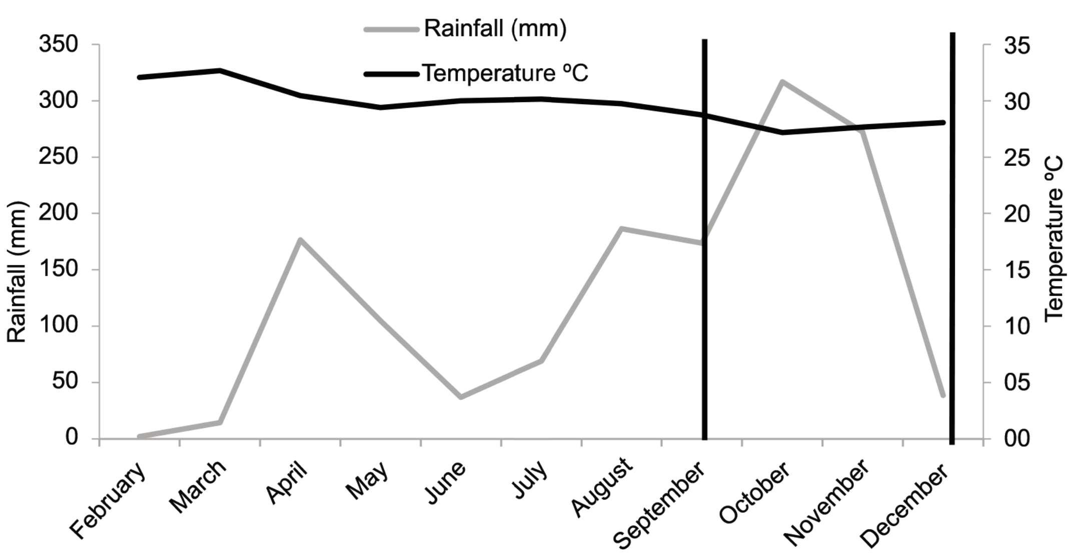


Figure 1. Performance of temperature and rainfall in the evaluation season .

(Steel and Torrie, 1999), in which the main plot corresponded to the legume accessions and the subplot, to the regrowth age within each species. The total area for the trial was 3 500 m^2. The dimensions of the main plot were 2,5 m long x 2,0 m wide. Three replicas of all the accessions were made.

Variance analysis (Proc Anava) and mean comparison according to Duncan's test, with a significance level of 5 %, were carried out. For such purpose, the statistical program SAS® version 9.4 was used. In the case in which the interaction was significant ($p < 0,05$) between the accession and regrowth age, orthogonal contrasts were carried out for mean comparison in the variable dry forage production per hectare.

Results and Discussion

As the regrowth age in *C. brasiliensis* advanced, the height in the genotypes was higher (table 1); the same occurred between the regrowth age and the biomass production ($p < 0,05$). This coincides with the report in the productive evaluation of other forage species (Castro *et al*., 2018).

Interaction was observed between the accession and the regrowth age ($p < 0,05$) on the dry forage production of *C. brasiliensis* (fig. 2). The dry forage production increased as the regrowth age advanced in all the accessions. However, in the accession 17009 the highest forage production occurred at 56 days of regrowth ($p < 0,05$). The increase in dry matter production was 101, 140 and 164 % in the accessions 20090, 17009 and 18501, respectively, between 28 and 42 days. The accession 17009 showed the highest increase in dry matter production (138 %) between 45 and 56 days (fig. 2).

When making the analysis of orthogonal contrasts, in which all the regrowth ages were taken into consideration, the accessions 17009 and 20095 showed the highest dry forage productions ($p < 0,05$) compared with the others; while the accession 17973 showed the lowest dry forage production ($p < 0,05$) with regards to the rest (table 2).

In other works with *C. brasiliensis* (Douxchamps *et al*., 2011), similar values to the production range observed in this study (2 448-5 357 kg DM/ha) were found. This indicates the promising performance of this species, with higher biomass productions than 2 000 kg DM/ha under the conditions of the dry Colombian Caribbean (Castro *et al*., 2018), and is in accordance with the report by Douxchamps (2010) in some agroecosystems of the Pacific and central region of Nicaragua (2 117 kg DM/ha). Nevertheless, in other studies higher yields have been reported in sowing carried out at the end of the rainy season, in which the effect of the water resource was positive regarding the species yield or due to the soil conditions of the Cauca Valley in Colombia (Salamanca *et al.,* 2004).

The response variables quantified in this species showed significant linear correlations ($p > 0,001$), which indicated that with higher plant height and regrowth age, higher forage production was generated (table 3).

In addition, as it is a legume, *C. brasiliensis* has good nutritional composition and contributes high protein contents (Albrecht and Beauchemin, 2003); for which it can be an important supplement for the elaboration of preserved forages and/or mixture of grasses with lower nutritional quality (Heinritz *et al*., 2012), mainly in regions with low-rainfall periods where the forage availability for grazing decreases (Solano *et al*., 2014).

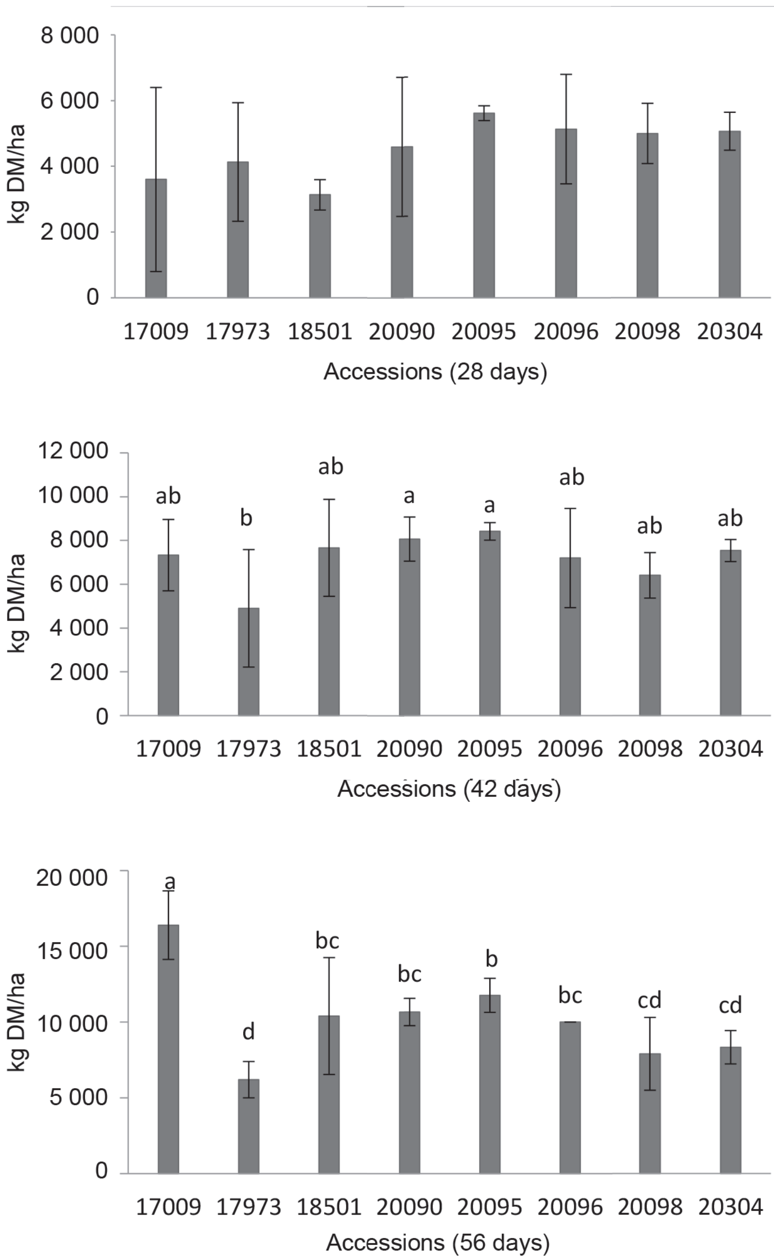
In the dry Caribbean a crude protein content of 17,1 % has been reported, for which this species is considered of high interest for animal husbandry (Schmidt *et al*., 2005), because of the capacity to grow in the dry season in animal husbandry regions, preserving its cover for animal consumption (Douxchamps, 2010).

Regarding *V. unguiculata*, no effect of the interaction between regrowth age and accession on

Table 1. Effect of regrowth age on plant height and dry matter production in *C. brasiliensis* accessions.

Regrowth age (days)	Dry mater production, kg/ha	Plant height, cm
28	1 188,5^c	29,79^c
42	2 087,9^b	47,41^b
56	3 150,3^a	69,75^a

Different letters in the same column indicate significant differences, according to Duncan's test ($p < 0,05$)



Different letters indicate significant differences ($p < 0,05$).

Figure 2. Dry forage production of *C. brasiliensis* accessions at different regrowth ages.

the plant height was observed. As the regrowth age advanced height increased ($p < 0,05$). The tallest accessions were 2442 and 3413.

At the highest regrowth age (eight weeks), the average height of all the accessions was 66,1 cm and the forage production 5 295 kg DM/ha; while at the lowest regrowth age the height was 27,9 cm. The production of DM/ha was similar to the one reported by Diaz *et al.* (2004), who argue that the utilization of *Vigna* varieties could be an alternative to increase the quantity of forage and to use it in animal feeding.

Apáez-Barrios *et al.* (2016) stated that the V. *unguiculata* yield could be maximized depending

Table 2. Orthogonal contrasts among *C. brasiliensis* accessions with higher and lower dry forage productions per hectare, compared with the average of the other accessions.

Contrasts			Dry forage production,kg/ha		P - Value
Factor 1	Vs	Factor 2	F1	F2	
17009	Vs	Remaining accessions	2 304,70	2 088,74	0,0017
17973	Vs	Remaining accessions	1 412,70	2 207,60	<,0001
18501	Vs	Remaining accessions	2 253,86	2 123,35	0,4694
20090	Vs	Remaining accessions	2 284,99	2 088,09	0,3078
20095	Vs	Remaining accessions	2 553,40	2 047,10	0,0037
20096	Vs	Remaining accessions	2 132,97	2 111,99	0,9393
20098	Vs	Remaining accessions	2 062,62	2 122,01	0,5107
20304	Vs	Remaining accessions	2 055,33	2 123,13	0,4762

Table 3. Pearson's linear correlations between response variables and the age factor, in *C. brasiliensis* accessions.

	DM production	Plant height	Regrowth age
DM production	1	0,62***	0,78***
Plant height		1	0,84***
Regrowth age (days)			1

*** $p < 0,001$

on the planting distance and the use of organic fertilizers on the soil.

There was no effect of the interaction or the accession on the dry forage production; yet, the regrowth age positively affected this indicator. In turn, at higher age an increase was observed in forage yield per hectare (table 4).

The dry matter yield was of interest, due to the capacity of these species to produce under the adverse conditions of the region where the study

Table 4. Height and forage production in *V. unguiculata* accessions.

Accession	Height, cm	Dry forage production, kg/ha
2442	48,3[a]	10 231
3413	48,1[a]	9 800
2430	39,3[ab]	11 600
2404	34,2[b]	14 275
Regrowth age (weeks)		
4	27,9[c]	1 663,5[c]
6	41,4[b]	3 331,1[b]
8	66,1[a]	5 295,8[a]
Variation source	P-value	
Accession	0,0309	0,6895
Regrowth age	< 0,0001	0,0025
Accession x age	0,5926	0,5131

Different letters in the same column indicate significant differences, according to Duncan's test ($p < 0.05$).

was conducted (Solano *et al*., 2014), because the dry season and the soil characteristics were two of the main limitations. According to Castro *et al.* (2016) *C. brasiliensis* and *V. unguiculata*, for being legumes, allow to improve soil fertility, mainly due to their capacity of fixing nitrogen and because of its cover in the Cesar department. These authors mention that such species have been used as green manure with favorable results in the dry Caribbean region.

All the compared variables showed a direct linear and statistically significant correlation (table 5). Thus, the biomass production (kg DM/ha) was observed to increase as the height and regrowth age increased.

In *C. ensiformis* the interaction between age and accession was not significant, just as it occurred in the response variable dry matter production (kg/ha). However, the values were of interest regarding biomass production in all the accessions and 715 stood out numerically with 8 071 kg DM/ha. In plant height there was statistical difference ($p < 0,05$); the accession 3214 had the highest value and 2168 was the smallest one.

In the case of the variation source age, the plants with lower establishment time in field had more height (table 6). The same was observed for the effect of age on dry matter production, because the highest production was found with the highest regrowth age.

The response of the quantified indicators was also analyzed through Pearson's linear correlations. Direct and statistically significant correlation ($p < 0,05$) was found among plant height, cutting height and dry matter production, which indicates that as these indicators increase so does biomass production (table 7).

Table 5. Pearson's linear correlations between response variables and the age factor in *C. brasiliensis* accessions.

Variable	Dry matter production	Plant height	Regrowth age
Dry matter production	1	0,46**	0,65***
Plant height		1	0,83***
Regrowth age			1

*** $p < 0,001$, **$p < 0,01$

Table 6. Height (cm) and forage production (kg DM/ha) in *C. ensiformis* accessions.

Accession	Height, cm	Dry forage production, kg/ha
2168	31,7[b]	7 137
7753	43,0[ab]	5 498
9108	47,3[ab]	6 214
715	49,5[ab]	8 071
3214	54,9[a]	6 634
Regrowth age (weeks)		
4	33,0[c]	3 638[c]
6	42,2[b]	7 259[b]
8	64,9[a]	10 224[a]
Variation source	P - Value	
Accession	0,1812	0,7312
Regrowth age	< 0,0001	0,0004
Accession x age	0,3217	0,4743

Different letters in the same column indicate significant differences, according to Duncan's test ($p < 0,05$).

Table 7. Pearson's linear correlations between response variables and the factor age in *C. ensiformis* accessions.

	Dry matter production	Plant height	Regrowth age
Dry matter production	1	0,61***	0,61***
Plant height		1	0,67***
Regrowth age			1

The dry forage production of the *C. ensiformis* accessions varied between 5 498 and 8 071 kg DM/ha, similar values to the ones reported by Cook *et al.* (2005). Nevertheless, the maximum forage production (8 071 kg DM/ha) was similar to that reported by Martín *et al.* (2007) in Havana (Cuba): 9 380 and 9 760 kg DM/ha, respectively. In turn, it was higher than the one reported by Díaz *et al.* (2003) in Cuba, in the dry season, and also than the values informed by García *et al.* (2017): 4 000 kg DM/ha in the dry season and 5 330 kg DM/ha in the rainy season. According to Crespo (2009) and Hernández *et al.* (2012), *C. ensiformis* is a rustic species, with optimum biomass yield, for which it is ideal for becoming established in animal husbandry systems where the soil fertility and climate conditions are adverse for the establishment of pastures.

The results indicate that these accessions could be considered promising genetic materials, due to their excellent forage production for animal production under conditions of the Colombian dry Caribbean region.

In general, the species showed good-performance accessions regarding dry forage production. The difference in productive potential, according to the projected dry forage yield, was marked among the legumes. Their use in animal feeding constitutes a promising alternative against the low feed availability generated by climate variability (Lüscher *et al*., 2014). Thus, the use of species such as *C. brasiliensis*, *C. ensiformis* and *V. unguiculata* has been considered, due to their adaptive and resilient capacity in the face of little favorable abiotic conditions, such as drought (Castro *et al*., 2018; Garcia *et al*., 2018); which turns them into a feed source to be used in cattle husbandry systems (Kebede *et al*., 2016). For such reason, it is considered important to continue the studies focused on identifying new forage offers, which allow to mitigate the feed deficit in regions with periods of scarce rainfall, such as the Colombian dry Caribbean.

Conclusions

- The *C. brasiliensis, C. ensiformis* and *V. unguiculata* accessions showed good adaptation to the soil and climate conditions of the Colombian dry Caribbean region.
- The accessions 20095 and 17009, of *C. brasiliensis*, showed superiority regarding productivity compared with the other accessions of this species.
- All the *C. ensiformis* and *V. unguiculata* accessions had high productive potential. For such reason, they could be used as forage crops and, later, as feed source for cattle, especially in the forage shortage seasons.

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