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Establishment of *Brachiaria* cultivars in the soil-climatic conditions of the Brazilian semi-arid region

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ABSTRACT. This study aimed was the establishment of the genus *Brachiaria* in the Brazilian semi-arid region. The experiment was conducted from April to June 2016, as a randomized-block experimental design with five treatments and four replicates. Treatments were represented by five *Brachiaria* cultivars, namely, Marandu, Paiaguás, Piatã, Xaraés and Basilisk. Morphogenetic (leaf appearance rate, leaf elongation rate e stem elongation rate) and structural characteristics (final leaf length, tiller population density e number of leaves per tiller, forage mass, leaf blade mass, stem mass, senescent material mass and leaf:stem ratio) of the forage cultivars were evaluated. Canopy height fitted a linear regression model ($P<0,05$), with estimated daily increases of 0.50, 0.53, 0.53, 0.54 and 0.56 cm for cvs Basilisk, Marandu, Paiaguás, Piatã and Xaraés, respectively. The number of live leaves in cvs Basilisk and Paiaguás increased linearly ($p < 0.05$), by 4.3 and 2.8 leaves per tiller, respectively, during the 60-day period. The recommended height at which the growth of *Brachiaria* cultivars should be interrupted is upon reaching 25 to 35 cm. In the soil-climatic conditions of the Brazilian semi-arid region, the *Brachiaria* cultivars Basilisk, Marandu, Paiaguás, Piatã and Xaraés are established at 75 days after sowing, which is the recommended time for performing the first harvest or lenient grazing to stimulate tillering.

Keywords: herbage; implementation; pasture; Quartzipsamment.

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Introduction

Grasses of the genus *Brachiaria* have advantages over other genera, e.g. adaptation to drought and to low-fertility soils, carbon-sequestration capacity and the ability to increase their nitrogen utilization efficiency by biologically inhibiting nitrification (Euclides et al., 2019). Despite the great benefits shown by those grasses, the adaptation potential of *Brachiaria* species to face water scarcity and long drought periods on Quartzipsamments in the Brazilian semi-arid region remains unknown (Nunes, Cabral, Amorim, Santos, & Albuquerque, 2016).

To optimize production, farmers must properly choose adapted cultivars which exhibit persistence in the production of new tissues in the soil-climatic conditions of the region where they are grown (Cândido, Lopes, Furtado, & Pompeu, 2018). Moreover, efficient soil amendment and fertilization practices and the right choice of the period to implement the pasture are necessary to ensure the germination and growth of forage in quantity and quality.

Understanding the plant dynamics through the study of morphogenetic and structural characteristics that take place the period of establishment makes it possible to ensure pasture longevity, productivity and sustainability over the years (Sousa et al., 2019). The present study was thus undertaken to examine the establishment of five *Brachiaria* cultivars in the soil-climatic conditions of the Brazilian semi-arid region.

Material and methods

Location and experimental period

The experiment was conducted from April to July 2016 in the experimental area of the Group for Forage Studies of the Federal University of Rio Grande do Norte – UFRN, located in Macaíba, Rio Grande do Norte

State, Brazil (5°.53'35.12" S, 35°21'47.03" W, 11 m above sea level). The climate of the region is a dry sub-humid BSh'W type, according to the Köppen classification, with water surplus between May and August (Thornthwaite, 1948).

Average annual precipitation in the region is 1052 mm and the average accumulated annual potential evapotranspiration is 1472 mm. Average monthly temperature ranges between 24.7 and 26.9°C, with an annual mean of 25.5°C. The soil water balance (Figure 1) was calculated by the method described by Thornthwaite e Mather (1955), adopting a water-holding capacity of 25 mm. During the experimental period, an average temperature of 27.1°C (30.5 and 23.5°C, maximum and minimum temperature, respectively) was observed and a total precipitation of 394 mm.

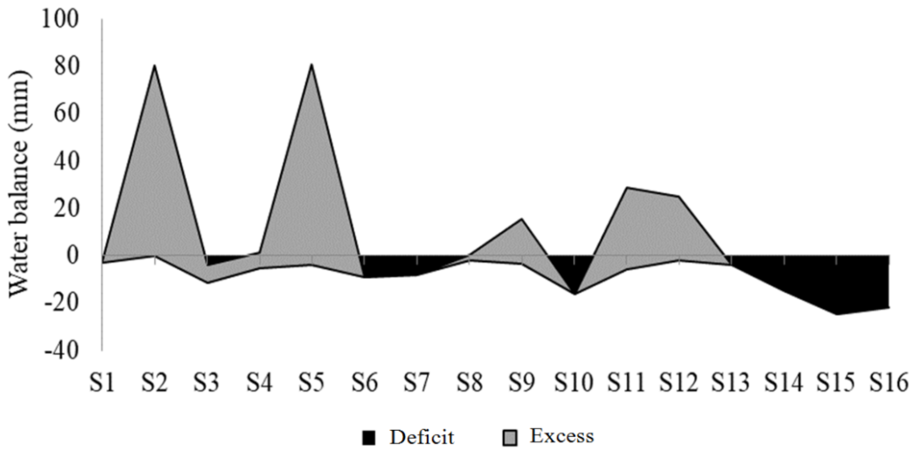

Figure 1. Weekly water balance in the period from April to July 2016.

Soil and fertilization

The soil in the area is classified as a Quartzipsamment of sandy or loamy texture in all horizons up to a minimum layer of 150 cm, with practically no changeable primary minerals (Santos et al., 2018). Soil chemical analyses were performed at the start of the experiment, at the depths of 0-20 and 20-40 cm (Table 1). Based on the results, 500 kg ha^{-1} dolomitic limestone, 105 kg ha^{-1} P_2O_5 and 164 kg ha^{-1} K_20 were applied as fertilizer and correction agents. At 45 days after implementation, 55 kg ha^{-1} N were applied in the form of ammonium sulfate for fertilization.

Table 1. Soil chemical characteristics of the experimental area at 0 to 20 and 20 to 40 cm depths.

Depths (cm)	P	K	Na	pH	Ca	Mg	Al	H+Al	CEC	BS (%)	Granulometry (%)		
	--mg dm^{-3}--				cmol$_c$ dm^{-3}						Sandy	Silt	Clay
0-20	18.0	63.0	20.0	6.6	3.1	0.2	0.0	1.2	4.4	72.7	84.6	4.0	11.4
20-40	8.0	49.0	13.0	5.6	0.9	0.1	0.0	1.1	2.2	50.0	85.2	2.0	12.8

CEC: cation exchange capacity; BS: base saturation

Experiment

The experiment was laid out in a randomized-block design with five treatments and four replicates. Treatments corresponded to five forage cultivars of the genus *Brachiaria*, consisting of four *Brachiaria brizantha* cultivars (Marandu, Paiaguás, Piatã and Xaraés) and one *Brachiaria decumbens* cultivar (Basilisk).

The experimental units were 2.0 × 2.0 m plots, with 1.3 m^2 of usable area. In each plot, 0.70 m of the sides was considered bordering area. Blocks were spaced 2.0 m apart and plots 1.0 m apart. From 50 to 70 pure seeds per m^2 were used. Sowing was performed manually after soil preparation. The sowing depth was one to three cm. A hand compactor was used to improve soil-seed contact. The plot uniformity cut was made at 15 cm above soil level, at 110 days after sowing.

Pasture height

Canopy height was measured at every 15 days, at 10 points representatives of the plot, using a centimeter-graduated ruler. The canopy height at each point corresponded to the average height from soil surface to the average point of curvature of the leaves around the ruler.

Light interception

Light interception by the canopy was determined using a canopy analyzer (PAR – 80, AccuPAR Linear PAR/LAI ceptometer, DECAGON Devices). Eight readings were taken above the forage canopy and eight at soil level per plot, always between 09h00 and 14h00 in sunny weather conditions. The following formula was used to calculate the percentage of light intercepted by the canopy (LI): %LI = 100% – (soil / above × 100).

Chlorophyll content

The chlorophyll content was determined at every seven days by taking eight readings from different plants within the same plot, using a chlorophyll meter (CFL 1030, ClorofiLOG), which provides estimates of the total chlorophyll contents (a+b), expressed in units named Falkner's Chlorophyll Index (FCI). Readings were performed always in the middle third of the first fully expanded leaf (from canopy top to bottom) exposed to solar radiation.

Tiller density

Tiller density (TD, tillers m^{-2}) was measured by counting the tillers within two 0.25 m^2 frames that were placed in each experimental unit. These frames were kept fixed throughout the evaluation period. Tillers were counted at every 28 days.

Morphogenetic evaluations

Morphogenetic evaluations were performed every seven days after emergence, in accordance with the methodology described by Luna et al. (2014).

Masses of herbage and morphological components

The masses of herbage and morphological components were estimated by harvesting all herbage within a 1.0 m^2 area at 15 cm above soil level, in each plot. Two subsamples were collected and weighed. One of them was used to determine fresh weight and then dried in a forced-air oven at 55°C for 72h to determine the dry matter content. The other subsample was used to separate the morphological components of the fractions (leaf blade, stem + sheath, dead material and undesirable plants). The dry weight of the samples was used to estimate the dry matter content. Subsequently, the leaf:stem ratio (L:S) was calculated.

Statistical analyses

Analyses were performed using R software version 3.5.0 (R Development Core Team, 2017). All variables were subjected to analysis of variance according to the following model:

$$Yijk = \mu + Bi + Mj + \alpha ij + Ck + (MC)jk + \beta ijk,$$

where Yijk = observed value in block i, cultivar j, evaluation period k; μ = overall mean effect; Bi = effect of block i; Mj = effect of cultivar j (j = Basilisk, Marandu, Paiaguás, Piatã or Xaraés); αij = effect of random error attributed to the plot; Ck = effect of evaluation period k (k = 1-(4)); (MC)jk = interaction effect between cultivar j and period k; and βijk = effect of random error attributed to the subplot.

For the effect of evaluation days, the data were subjected to variance and regression analyses. The models which best explained the results were chosen based on the 5% significance level and on the coefficient of determination (R^2). The data on the morphogenic and structural characteristics were used to estimate the main components. The software R version 3.5.0 was used for this estimate.

Results and discussion

Establishment of the cultivars

Canopy height fitted a linear regression model ($p < 0.05$), with estimated increments of 0.50, 0.53, 0.53, 0.54 and 0.56 cm for cvs Basilisk, Marandu, Paiaguás, Piatã and Xaraés, respectively (Figure 2). The response shown by those cultivars agrees with the period of establishment. Regardless of the evaluated cultivar, there was an increase in height as influenced by the time of full growth of the forage plant. In general, the recommended height at which the growth of *Brachiaria* should be interrupted is when the plants reach 25 to 35 cm (Silveira et al., 2013; Giacomini et al., 2009; Pedreira, Pedreira, & Silva, 2009). Therefore, based on those recommendations, 75 days after sowing would be the ideal moment to interrupt the growth process during establishment through harvest or lenient grazing.

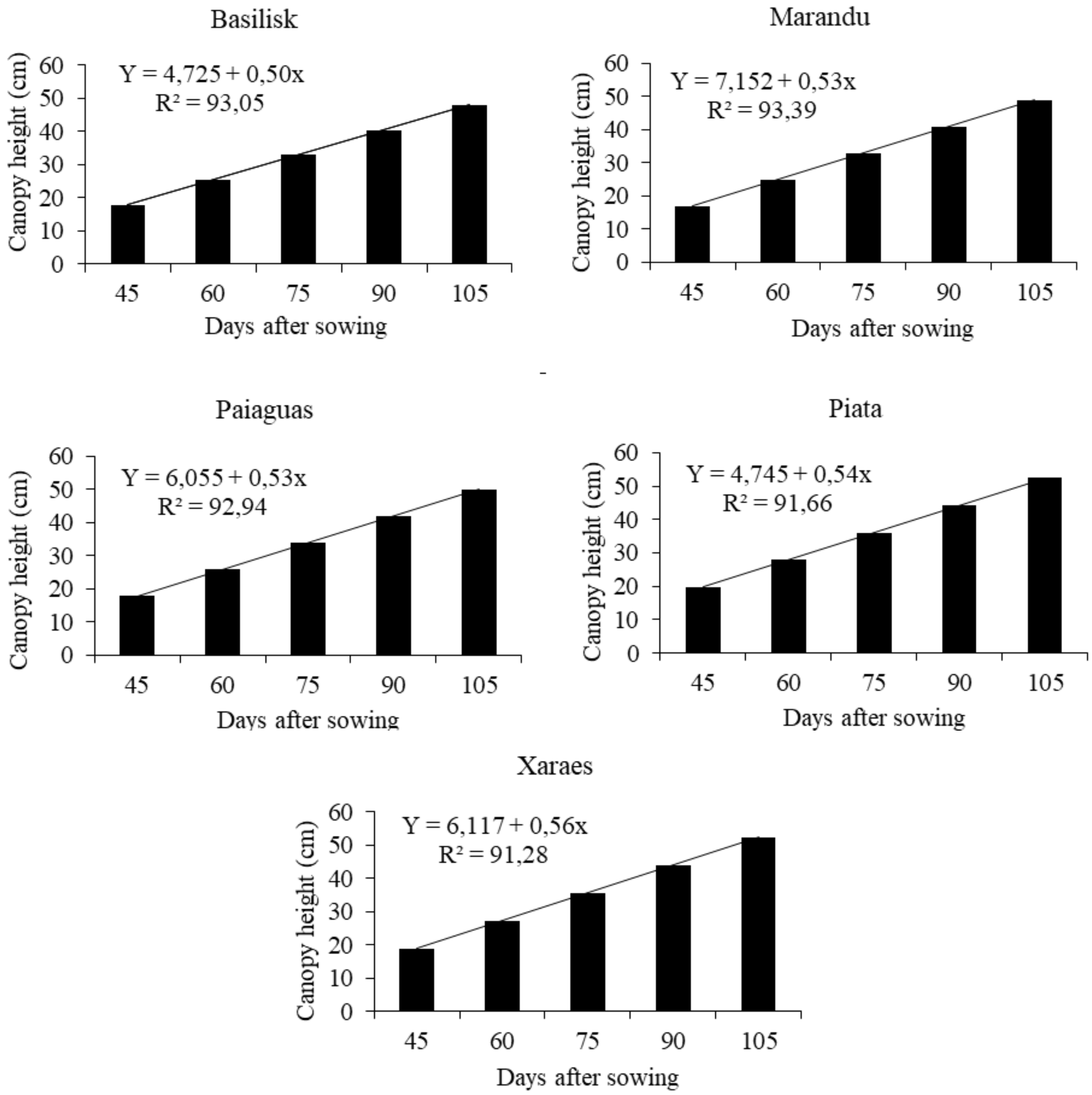

Figure 2. Mean values of pasture heigth on the establishment of *Brachiaria* cultivars in the soil-climatic conditions of the Brazilian semi-arid region.

The number of live leaves in cvs Basilisk and Paiaguás increased linearly ($p < 0.05$), by 4.3 and 2.8 live leaves per tiller, respectively (Figure 3), in the 60-day period. This response indicates that this period was not sufficient for those cultivars to reach the maximum number of live leaves per tiller. The other cultivars maintained a constant number of leaves from the start of the evaluation period due to intrinsic characteristics that provide stability in number of live leaves per tiller in the absence of water and nutrient deficiencies.

Tiller density in cvs Marandu, Paiaguás and Piatã fitted a linear regression model ($p < 0.05$). In each evaluation period, TD increased by 6.0, 9.0 and 6.0 tillers m^{-2} in the respective cultivars (Figure 4). In cvs Basilisk and Xaraés, this parameter was not influenced by the evaluated periods, demonstrating that the tiller population stabilized from the start of the evaluations to 45 days after sowing.

However, even in cvs Basilisk and Xaraés, where no changes were observed for TD, the number of tillers per square meter was much lower than the values found by Luna et al. (2016) for cvs Xaraés (242.3 tiller m^{-2}) and Piatã (414.0 tillers m^{-2}), established at 150 days in the Brazilian semi-arid region. This disparity between results can be attributed to the N dose of 50 kg ha^{-1} used by the authors at the time of sowing. The harvest performed at 65 days after sowing might have also allowed for a rapid change in both quantity and quality of light that reached the base of the plants, which stimulated tillering (Difante et al., 2011).

At 75 days after establishment, the cultivars reached the recommended height for grazing/harvest. This is the ideal moment to interrupt growth through a harvest or lenient grazing to increase tiller density, since despite the increase in canopy height during the evaluation period, the light interception measures did not reach 95%, characterizing a small plant population.

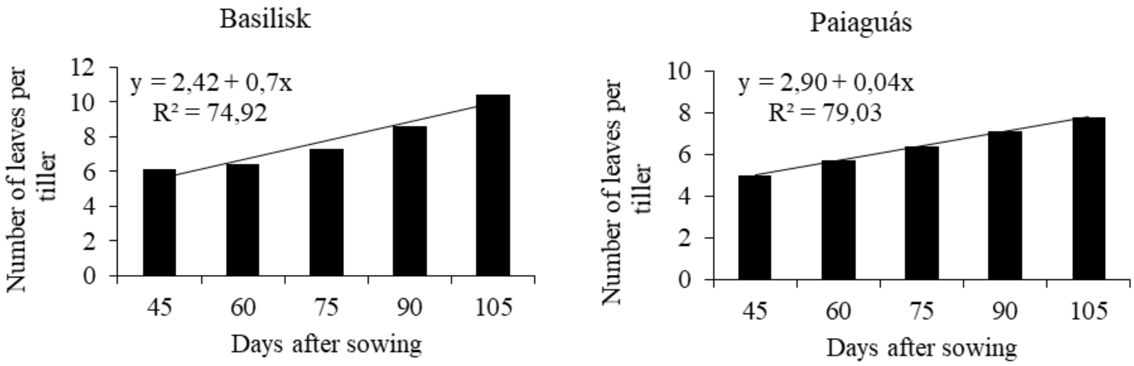

Figure 3. Number of live leaves per tiller on the establishment of *Brachiaria* cultivars in the soil-climatic conditions of the Brazilian semi-arid region.

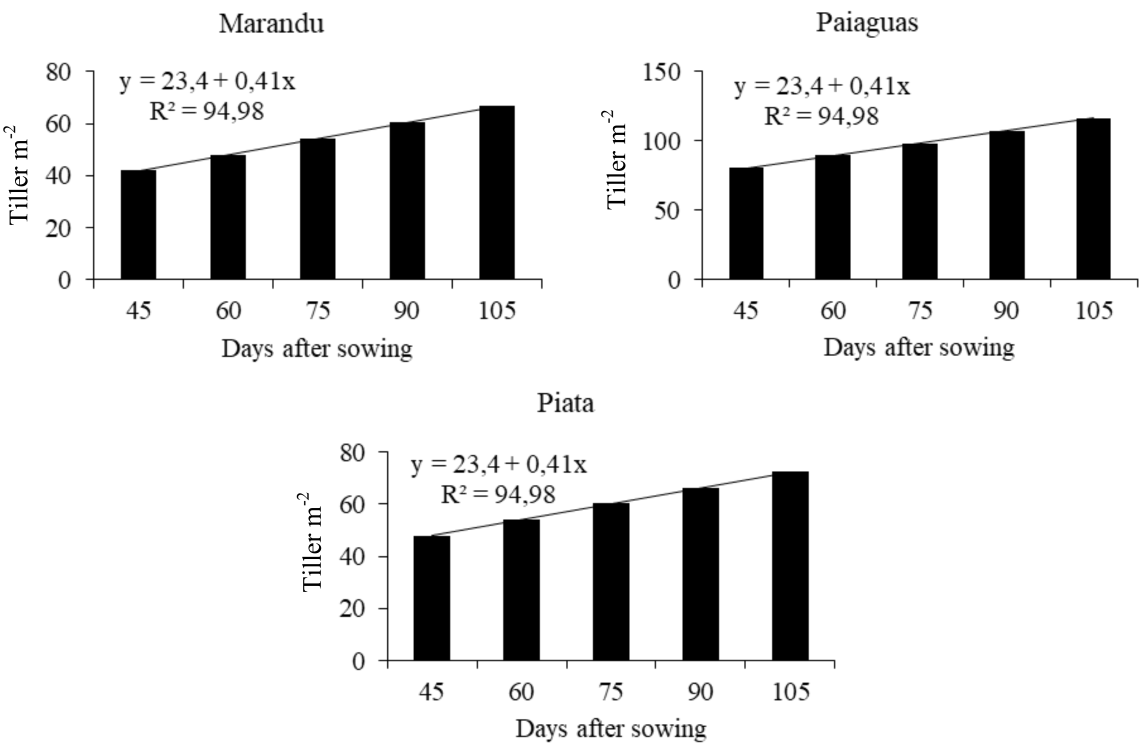

Figure 4. Tiller density on the establishment of *Brachiaria* cultivars in the soil-climatic conditions of the Brazilian semi-arid region.

Morphogenetic and Structural variables

The morphogenetic variables of leaf elongation rate (LER), phyllochron (PHY) and leaf lifespan (LLS) did not differ between the cultivars in the established period (Table 2), which was likely due to the stable climatic conditions of the region.

Leaf appearance rate (LAR) differed between the cultivars. The highest LAR was observed in cultivar Basilisk, as opposed to Paiaguás, and intermediate values were found for the other cultivars (Table 2). Because LAR is an indication of the rate of appearance of axillary buds in the pasture (Santos, Fonseca, & Gomes, 2013), it is very important during establishment, since each bud is capable of generating a new tiller and, thus, increase tiller density in the pasture (Cabral et al., 2012). Pastures with a higher tiller density have a better soil coverage potential with less space between tussocks, in addition to controlling the incidence of undesirable plants that may come to compete with the forage plant for water, light and nutrients (Santos et al., 2011).

Stem elongation rate (SER) was higher in cv. Basilisk when compared to cvs Marandu and Xaraés, and intermediate values were found for cvs Paiaguás and Piatã (Table 2). Stem elongation occurs simultaneously to leaf appearance (Lara & Pedreira, 2011). The higher LAR of cv. Basilisk likely caused each new leaf produced in the upper part of the tiller to induce morphological changes in the plant such as stem elongation.

The highest leaf senescence rate (LSR) was observed in cv. Xaraés, whereas the lowest was found for cv. Basilisk and intermediate values were shown by cvs Marandu, Paiaguás and Piatã (Table 2). The differences in LAR and LSR indicate the tissue flow dynamics and are related to the number of live leaves per tiller (NLL), since a new leaf senesces for every new leaf that emerges (Paulino & Teixeira, 2010). According to Santos et al. (2011), cv. Basilisk has, on average, 10 to 11 live leaves per tiller, while cv. Xaraés has approximately 3 to 4 live leaves per tiller (Galzerano, Malheiros, Raposo, Morgado, & Ruggieri, 2013), and cvs Marandu, Paiaguás and Piatã possess, on average, 4 to 5 leaves per tiller (Casagrande et al., 2010; Orrico Júnior, Centurion, Sunada, & Vargas Júnior 2013; Germano, Vendruscolo, Daniel, & Dalbianco 2018).

Table 2. Mean values of morphogenetic and structural traits on the establishment of *Brachiaria* cultivars in the soil-climatic conditions of the Brazilian semi-arid region.

Variable	Cultivar					SEM	p-value
	Basilisk	Marandu	Paiaguás	Piatã	Xaraés		
LAR	0.08[a]	0.06[ab]	0.05[b]	0.06[ab]	0.06[ab]	0.01	0.001
LER	1.87	2.15	1.81	2.16	2.29	0.07	0.178
SER	0.32[a]	0.15[b]	0.25[ab]	0.21[ab]	0.17[b]	0.03	0.036
LSR	0.78[b]	1.15[ab]	1.16[ab]	1.05[ab]	1.60[a]	0.08	0.001
PHY	13.64	14.79	16.67	16.85	14.65	0.27	0.207
LLS	63.35	59.19	68.93	74.21	53.26	0.58	0.572
FLL	16.81[b]	23.49[a]	20.47[ab]	24.07[a]	24.74[a]	0.10	0.003
NLL	4.75[a]	4.00 b	4.00[b]	4.33[ab]	3.66[b]	0.06	0.001
HM	3378.40	3302.40	3286.81	4267.15	3353.30	19.60	0.800
LM	1196.71	1142.35	993.09	1497.38	1521.76	26.10	0.700
SM	904.30	650.80	806.85	800.08	495.35	32.23	0.700
DMM	328.06	606.20	640.84	402.85	349.27	22.81	0.340
UPM	945.34	1030.15	842.66	1579.87	991.60	34.45	0.790
L:S	1.33[b]	2.10[b]	1.51[b]	2.22[ab]	3.50[a]	0,80	0.008
Height	49,00	49.21	46,31	52.54	54.21	7.14	0.564
Light interception	87.10	84.44	78.73	74.91	79.10	6.80	0.407
Chlorophyll	35.00	30.52	28.20	39.54	34.01	10.11	0.209

Leaf appearance rate (LAR, cm tiller^{-1} day^{-1}), leaf elongation rate (LER, cm tiller^{-1} day^{-1}), stem elongation rate (SER, cm tiller^{-1} day^{-1}), leaf senescence rate (LSR, cm tiller^{-1} day^{-1}), leaf lifespan (LLS, days), final leaf length (FLL, cm), number of live leaves (NLL), herbage mass (HM, kg ha^{-1}), leaf mass (LM, kg ha^{-1}), stem mass (SM, kg ha^{-1}), dead material mass (DMM, kg ha^{-1}), undesirable-plant mass (UPM, kg ha^{-1}), leaf:stem ratio (L:S). Means followed by common lowercase letters in the row do not differ by Tukey's test at the 5% significance level ($p > 0.05$).

Final leaf length (FLL) was higher in cvs Marandu, Piatã and Xaraés than Basilisk, whereas intermediate values were seen in Paiaguás (Table 2). Shorter leaves, such as those found in cv. Basilisk, are directly associated with higher LAR (Luna et al., 2014). Because they have a shorter expansion time, those leaves enter the cell maturation zone earlier and become able to generate meristematic cells, which will form a new leaf, in a shorter interval (Fournier et al., 2005).

There was no cultivar effect for the masses of total herbage, leaf, stem, dead material and undesirable plants. However, cv. Xaraés showed a higher leaf:stem ratio than cvs Basilisk, Marandu and Paiaguás, while Piatã did not differ from the others (Table 2).

The herbage production of a species or cultivar depends mainly on their adaptation to factors such as the medium and the management strategy adopted. Pereira et al. (2011) evaluated *Brachiaria* cultivars on a Quartzipsamment and observed greater productivity in cv. Basilisk as compared to cvs Marandu and Xaraés. According to those authors, this response was due to the low water-holding ability and natural fertility of the soils, which prevent cvs Marandu and Xaraés from expressing their full production potential.

The number of undesirable plants did not differ in the establishment period. Natural control occurred due to intraspecific competition caused by the soil coverage from the cultivated species, which resulted in shading and reduced space for the development of undesirable plants.

The higher L:S ratio found in cv. Xaraés is explained by the results found for LER and SER (Table 2). The lower contribution of the stem is a desirable characteristic in grasses, given is lower nutritional value and digestibility when compared to leaf blades (Emerenciano Neto et al., 2018; Difante et al., 2011). By contrast, in addition to higher nutritional value (Emerenciano Neto et al., 2014), a higher percentage of leaves provides greater photosynthetic capacity to the canopy (Atkinson et al., 2016).

No difference was detected between the cultivars during the establishment period for canopy height, light interception and chlorophyll content (Table 2). The correlation between chlorophyll content and nitrogen concentration in the plant (Silva et al., 2012) likely did not differ because the nitrogen fertilizer applied 30 days after sowing provided uniform growth and chlorophyll contents between the cultivars.

Pasture height and light interception can be used as management tools in tropical forages (Euclides, Euclides Filho, Montagner, Figueiredo, & Lopes, 2014; Difante et al., 2010), as they allow the herbage to be harvested in the same physiological condition according to variations in accumulation rate (Lima et al., 2013). However, during the establishment phase (90 days), none of the cultivars reached 95% light interception at the heights described in the literature: 25 cm for cvs Marandu and Piatã (Trindade et al., 2007; Gobbi, Lugão, Bett, Abrahão, & Tacaiama, 2018), 30 cm for cv. Xaraés (Sousa et al., 2011) and 35 cm for cv. Paiaguás (Gobbi et al., 2018).

Principal component analysis

A more accurate approach to estimate associations between correlated variables, as is the case of pasture structural and morphogenetic variables (Santos et al., 2012), is via multivariate analyses (Silva & Sbrissia, 2010). This statistical tool can be successfully used to support decision-making when choosing variables that effectively contribute to elucidating the target trait.

Therefore, five principal components (PC) were generated in the analysis of variables. The results revealed that 81% of the variation in the dataset were explained by only two PC (Figure 5). When the first two PC explain more than 60% of the data variation, it is recommended to discard the other generated components (Silva & Sbrissia, 2010).

Additionally, no similarity was observed between the cultivars due to their equidistribution in the positive and negative quadrants (Figure 5). The primary use of PC analysis is to reduce the dimensionality of the dataset, retaining as much information as possible in the lowest number of principal components. Thus, although few differences were observed between the cultivars, according to univariate statistic techniques, PC analysis can indicate differences based on combinations of variables that explain the total variation of data (Silva & Sbrissia, 2010). It is also important to remark that PC analysis does not take the separate effect of blocks, treatments or time into account.

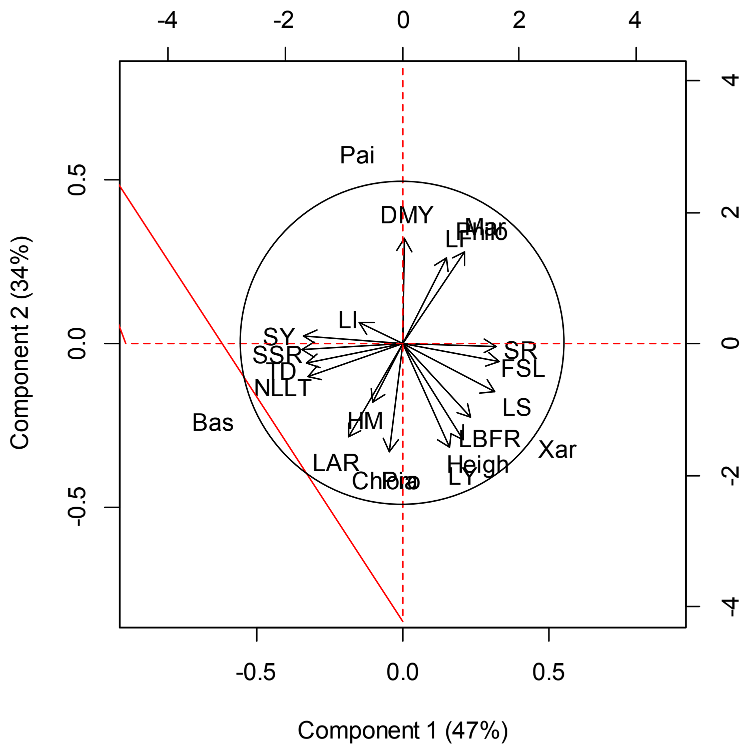

Figure 5. Principal component analysis: proportion of variance explained by two components.

The first PC explained 47% of the total data variation and shows that, of the analyzed variables, FLL, LER and leaf blade percentage were positively correlated with each other and highly associated with cv. Xaraés (Figure 5). This indicates that higher LER were observed in cv. Xaraés because it is considered a taller cultivar, with longer leaves, among the *Brachiaria* cultivars (Silveira et al., 2010).

Leaf lifespan and phyllochron were correlated with each other. As the time for the emission of two consecutive leaves is increased, so is leaf lifespan. Those variables were highly associated with cv. Marandu, due to its high phenotypic plasticity, which allowed for a higher NLL to be maintained under unfavorable soil-climatic conditions. Dead material mass and LSR were similar across the cultivars, as those are the variables most influenced by management and environment.

Conclusion

In the soil-climatic conditions of the Brazilian semi-arid region, the *Brachiaria* cultivars Basilisk, Marandu, Paiaguás, Piatã and Xaraés are established at 75 days after sowing. At that time, harvesting or lenient grazing are recommended to increase tiller density.

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