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Forage performance and cattle production as a function of the seasonality of a Brazilian tropical region

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ABSTRACT. This study aimed to evaluate forage yield, tiller population density, canopy height, nutritional value as well as cattle performance in alternate stocking from three tropical forage cultivars. The experiment followed a randomized block design, in a 3 x 3 factorial scheme with three replications. Three forage cultivars (Marandu, Massai and Xaraés) distributed in nine hectares were evaluated in three dry season periods (transition wet/dry, dry, and end of dry season), with repeated measures over time. The following variables were evaluated: canopy height, leaf: stem ratio, forage mass, leaf mass, stem mass and dead material mass. Total digestible nutrients, crude protein and *in vitro* dry mass digestibility were evaluated regarding forage nutrition. Animal performance, using 36 eleven-month-old animals (half-blood Nelore), was evaluated by the daily average gain and weight gain by area. During pre-grazing, canopy height presented interaction among forage cultivars and the evaluated periods. The average daily gain showed no interaction among cultivars and period of the year the similarity in animal performance among the cultivars Marandu and Massai show that the Massai grass can be used as an alternative for forage diversification under an alternate management system.

Keywords: pasture diversification; *Megathyrsus maximus*; alternate stocking; *Urochloa brizantha*.

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Introduction

The Brazilian cattle herd has about 215 million head distributed on 162 million hectares of pasture in the country territory (Jank, Barrios, Valle, Simeão, & Alves, 2014; ABIEC, 2019). In Brazil, beef cattle production systems are based mostly on pasture production, which stands out for being the most usual and economic system.

In recent decades, the use of the genus *Urochloa* (syn. - *Brachiaria*) in livestock production has been widespread in several countries of South and Central America (Cuadrado, Torregroza, & Jiménez, 2004). *Urochloa brizantha* cv. Marandu is the most expressive forage in Brazil, with 50 million hectares of cultivated area (Leite et al., 2018). This cultivar presents high forage yield and good adaptation to soils and tropical climatic conditions (Rodrigues, Santos, Silveira Junior, & Santos, 2017). Brazilian pastures are also composed of other species of the genus *Urochloa* (*U. decumbens*, *U. humidicola*, *U. brizantha* cv. Xaraés and others) and species of the genera *Megathyrsus* and *Andropogon* (Guarda & Guarda, 2014).

Currently, several cultivars have emerged to diversify the Brazilian pasture areas. However, there is still a low diversity of forage species in the country (Maciel et al., 2018), which represents a potential problem due to the possible emergence of new pests and diseases as well as the breakdown of resistance to known diseases (Jank, Valle, & Resende, 2011).

The cultivar Xaraés (*Urochloa brizantha*) was released in 2002 in the country as an option for pasture systems due to its higher forage accumulation and faster growth when compared with the cultivar Marandu (Pedreira, Valdson, Bruno, & Sollenberger, 2017). The cultivar Xaraés presents tussock-forming, with high yield, especially of leaves, late flowering, which prolongs the period of grazing in the rainy season, excellent regrowth vigor, high carrying capacity, as well as tolerance to leaf and root fungi (Valle et al., 2004). Despite the good performance of this forage, its use is still not significant in Brazilian pastures, possibly due to the lack of research with the species, especially considering animal performance in the continuous stocking.

The cultivar Massai, which belongs to the genus *Megathyrsus* (syn. - *Panicum*), is a hybrid among *Megathyrsus maximus* and *Megathyrsus infestum*, originally bred in Africa, followed by a selection process in Brazil (Melo, Martins, Silva, Pereira, & Jeromini, 2018). It represents an important forage option, mainly regarding the intensification of pasture production systems (Emerenciano Neto et al., 2016). It presents characteristics similar to other *M. maximus* cultivars, such as high forage production, high carrying capacity and high resistance of dry season in regions with low rainfall (Fernandes et al., 2017). In addition, cultivar Masai, due to its small size and thin stems, has greater flexibility in the rest period than other cultivars of the genus *Megathyrsus* ssp. of larger size. On the other hand, this cultivar demonstrates greater efficiency of forage accumulation than cultivar Marandu (Emerenciano Neto et al., 2013).

During the period of transition waters and dry waters, forages may show a peak in their ecophysiological growth conditions, denoting at most the increase in forage and nutritional values. However, with entry into the dry season, there is a pattern that can be variable in the behavior of forages to nutritional and productive parameters, with a reduction in pasture production until culminating in growth staging (Sales et al., 2011). The genetic characteristics of forages can cause changes in growth behavior, resulting in changes in the resilience patterns of each species.

Given the benefits of introducing new species and diversifying pasture areas, we hypothesized that the cultivars Xaraés and Massai could replace the cultivar Marandu in an alternate stocking system with cattle rearing. Therefore, this study aimed to evaluate forage yield, tiller population density, canopy height, nutritional value as well as cattle performance in alternate stocking from three tropical forage cultivars.

Material and methods

Experimental conditions

The study was conducted under field conditions from March to October 2015, in an experimental area of the Federal University of Tocantins - Araguaína Campus (810751.01; 9213652.69 UTM, with an altitude of 240 m; Figure 1). The climate of the region is classified as "Aw" (Alvarez, Stape, Sentelhas, Goncalves, & Sparovek, 2013), with well-defined dry and rainy seasons. The soil of the experimental area has a sandy texture (Table 1), being classified as Entisol Quartzipsamment (USDA, System classification).

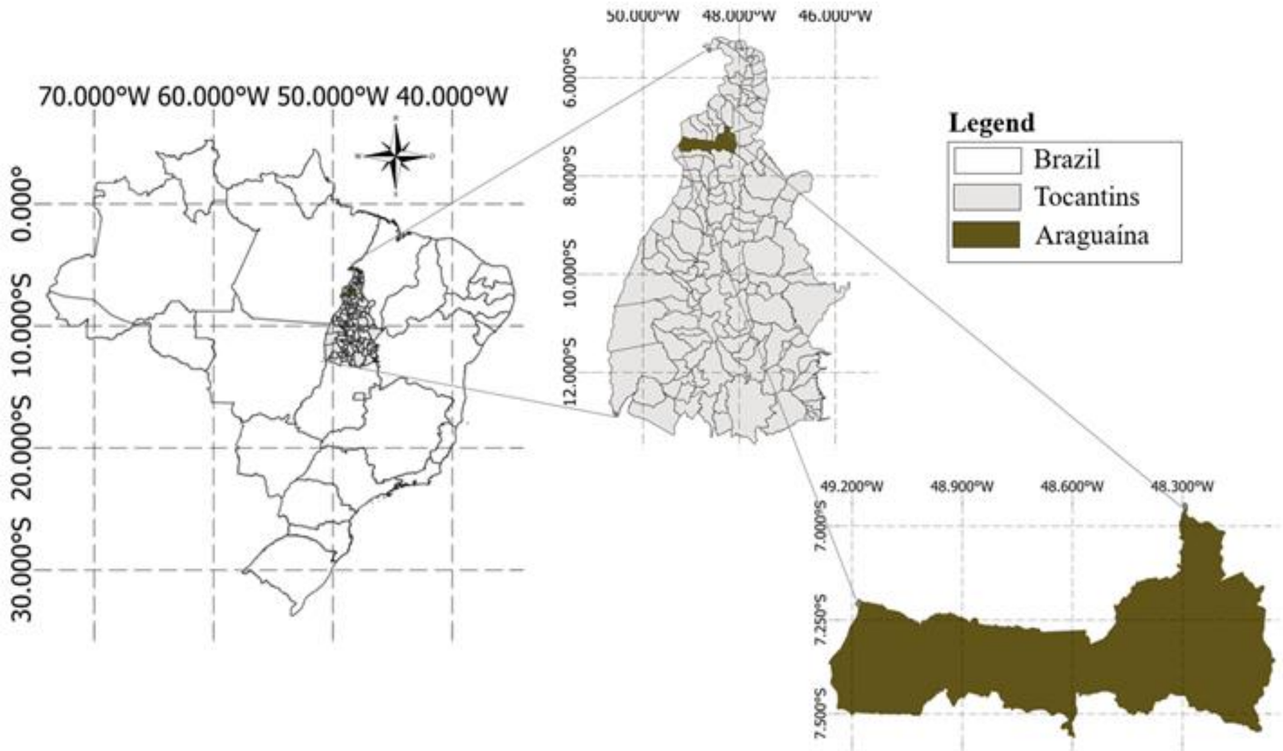

Figure 1. Location of the study area.

Table 1. Chemical and physical characterization of the soil (layer 0-20 cm) of the experimental area.

pH ($CaCl_2$)	4.7	Potential acidity (H+Al) ($cmol_c\ kg^{-1}$)	13.0
Organic matter ($g\ kg^{-1}$)	15.0	Sum of bases (Ca+Mg+K) ($cmol_c\ kg^{-1}$)	10.2
Phosphorus ($mg\ kg^{-1}$)	12.0	Cation exchange capacity ($cmol_c\ kg^{-1}$)	23.2
Potassium ($mg\ kg^{-1}$)	63.0	Base saturation (V%)	44.0
Calcium ($cmol_c\ kg^{-1}$)	10.0	Sand (%)	93.6
Magnesium ($cmol_c\ kg^{-1}$)	5.0	Silt (%)	2.6
Aluminum exchangeable ($cmol_c\ kg^{-1}$)	0.1	Clay (%)	3.8

P and K available: extraction with Mehlich-1; Ca, Mg and Al exchangeable: extraction with KCl; H + Al: calcium acetate extraction.

Fertilization with 45:40:40 kg ha^{-1} $N:P_2O_5:K_2O$ was performed according to the recommendation for the crop (Sousa & Lobato, 2004) at the end of the rains and beginning of the experiment. Nitrogen, phosphorus, and potassium fertilization were performed using urea (45% N), simple superphosphate (18% P_2O_5), and potassium chloride (60% K_2O), respectively.

Experimental design and data collection

The experiment followed a randomized block design, considering three cultivars and three dry season periods as a longitudinal factor. Three different forage cultivars (two *Urochloa brizantha*: Marandu and Xaraés, one *Panicum maximum* Massai) were evaluated in three different dry season periods (transition wet/dry, dry and end of dry season) (Figure 2). The transition wet/dry period corresponded to March 27 to June 20, 2015. As for the beginning of the dry season, it was from June 20 and August 15, and the end of dry season ranged from August 15 to October 10.

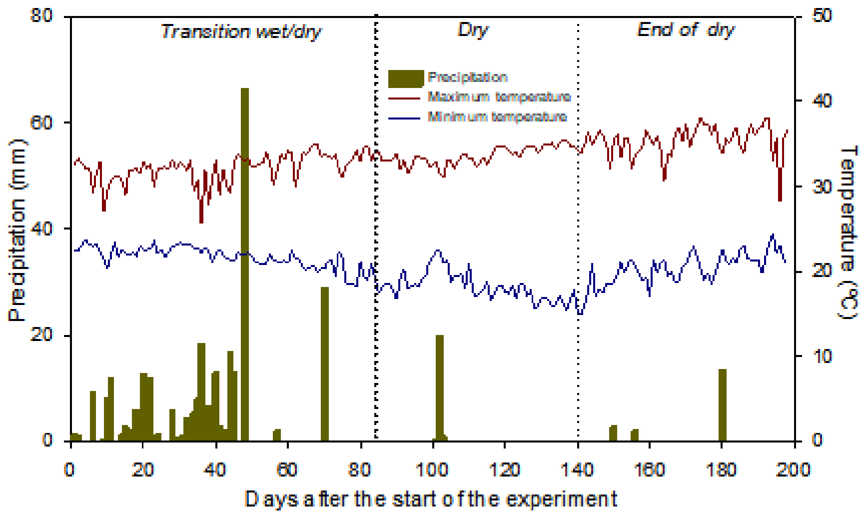

Figure 2. Climatic data during the trial period in the area.

The experimental area consisted of nine hectares of pasture, corresponding to 3 ha for each forage cultivar. The experimental unit consisted of a 1.0-ha module divided into two 0.5-ha paddocks, totalizing six experimental units for treatment. Each paddock of each module had a 28-day occupation, followed by a resting period. In each module, the stocking rate was 2.07 animals units per hectare during the experimental period.

Twelve animals per treatment were used to evaluate performance and weighing was carried out at the end of each 28-day occupation period. The animals were taken early in the morning to the management center, being weighed after fasting for 12 hours (only for the first and last weighing of the experimental each period evaluated climatic). Thirty-six not-castrated bovines (half-blood Nelore) with an initial average weight of 233 kg and 11 months of age were used. At the end of the experiment, weight gain averages were calculated for each treatment and experimental period. All animals received the vaccines provided by the state sanitary defense agency, and drugs to control ecto and endoparasites.

The average daily weight gain (g $animal^{-1}$ day^{-1}) was calculated by the difference in animal weight at the beginning and end of each period, divided by the number of days of the period. Animal weight gain per hectare (kg ha^{-1} of live weight) was obtained by multiplying the average daily animal gain times the number of animals and the number of days of each period.

The height of the forage canopy was taken among the ground distance and the average leaf curvature, obtained by 40 random readings in each system. For tiller counting, a 1.0 x 0.25 m (0.25 m^2) sampling frame was used. A sampling frame of 1.2 x 0.5 m (0.6 m^2) was used to cut the forage, which was placed in previously identified bags and weighed to estimate the forage production and its morphological components.

From the field sample, a 200-g aliquot was taken, from which the components were separated: leaf blade, stem and dead material. The material was oven dried at 55°C for 72 hours to obtain the pre-dry mass of each component. Leaf blade and stem data and the leaf: stem ratio was calculated based on the dry mass. For forage evaluation, data were collected during pre and post grazing.

Simulated grazing was done at the beginning and end of each cycle for each treatment (Vries, 1995). The samples were pre-dried in a forced air oven at 55°C for 72 hours. Subsequently, the dried samples were ground and the crude protein (CP) contents were evaluated, as described by Detmann et al. (2012), *in vitro* digestibility of dry matter (IVDMD) was obtained according to Tilley and Terry (1963), adapted for artificial rumen as described by Holden (1999). Total digestible nutrients (TDN) were estimated according to Cappelle, Valadares Filho, Silva, and Cecon (2001):

$$TDN = 10.43 + (0.8019 * DIVMS)\ (R^2 = 0.89;\ P < 0.01)$$

Statistical analysis

The data obtained were submitted to the normality (Shapiro & Wilk) and homoscedasticity (Levene) tests, followed by repeated measures over time using SAS Proc Mixed software (SAS Institute, 1996). The climatic periods were considered the repeated measure. The means were compared by the PDIFF LSMEANS procedure, with a probability of 0.05.

Results

During pre-grazing canopy height presented interaction among forage cultivars and the evaluated periods. However, regardless of the period, the Xaraés cultivar height was higher than the other studied cultivars (Figure 3A). As expected, in the transition period, canopy height was higher than the periods represented by dry conditions. Nevertheless, only the cultivar Xaraés presented a reduction in canopy height at the end of dry season when compared with the beginning of the dry season.

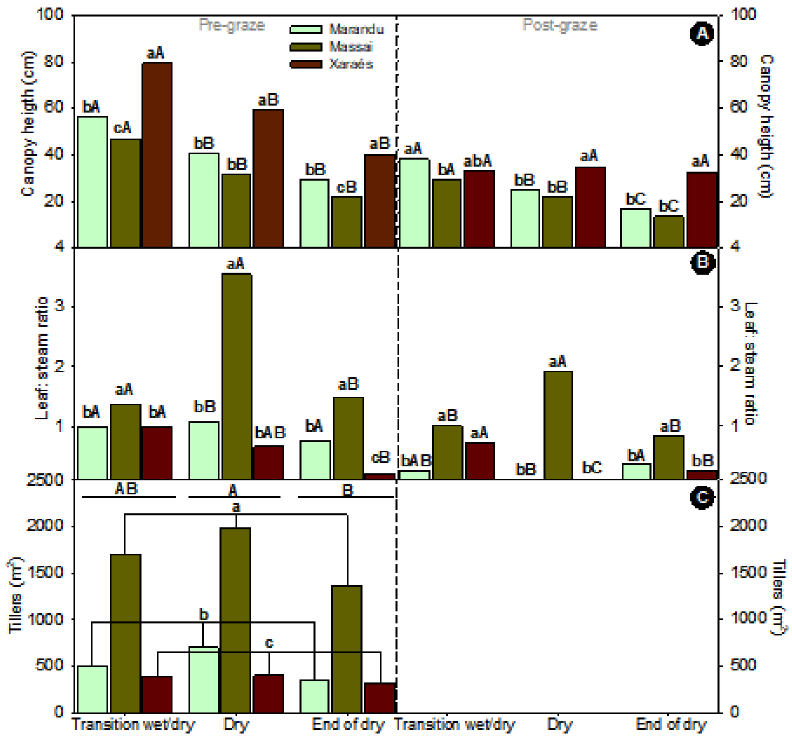

Figure 3. Canopy height (A), leaf: stem ratio (B), and tiller population density (C) of tropical forages at pre and post grazing during the studied periods; Lower case letters in forages and upper-case letters in periods do not differ statistically by the Pdiff test at 5% probability level.

There was interaction among the treatments and the evaluated periods ($p < 0.05$) in the presence of the animals in canopy height. The cultivar Marandu presented better performance in post-grazing canopy height when compared to cultivar Massai. In the two periods represented by dry conditions, Xaraés presented higher post-grazing higher when compared with Marandu and Massai. Regarding the evaluation periods (transition wet/dry, dry and end of dry season), Xaraés did not differ in post-grazing height, regardless of the evaluated period. As for Marandu and Massai, the cultivars presented reduced post-grazing height in the dry periods. Regarding the leaf: stem ratio, there was interaction among cultivars and evaluated periods during pre and post grazing (Figure 3B). During pre-grazing, the cultivar Massai presented leaf: stem ratio 5x higher when compared with the other cultivars. The cultivars Marandu and Xaraés differed in relation to leaf: stem only at the end of dry season, in which Marandu exceeded Xaraés by 2x for leaf: stem ratio.

The cultivar Marandu showed no difference ($p > 0.05$) for leaf: stem ratio in the evaluated periods. As for Massai and Xaraés, the cultivars presented higher leaf: stem ratios during the periods of dry and transition wet/dry, respectively. On the other hand, cultivar Massai was superior to the other cultivars during post grazing in the dry season (beginning and end), demonstrating higher leaf: stem ratio. Nevertheless, it was similar to cultivar Massai in the transition wet/dry.

Regarding the number of tillers, there was no interaction among periods and cultivars (Figure 3C). The cultivar Massai showed a higher number of tillers ($p < 0.05$), 2x and 3x higher, respectively, when compared with Marandu and Xaraés. The plants presented higher number of tillers during the beginning of the dry season.

For dry mass of leaf blades during pre-grazing, there was interaction among forage systems and periods of the year (Figure 4A). In the transition wet/dry, the cultivars Xaraés and Massai presented higher values for forage mass when compared with Marandu. In the beginning of dry season, all cultivars presented similar production ($p > 0.05$). At the end of dry, Massai was superior to the other cultivars.

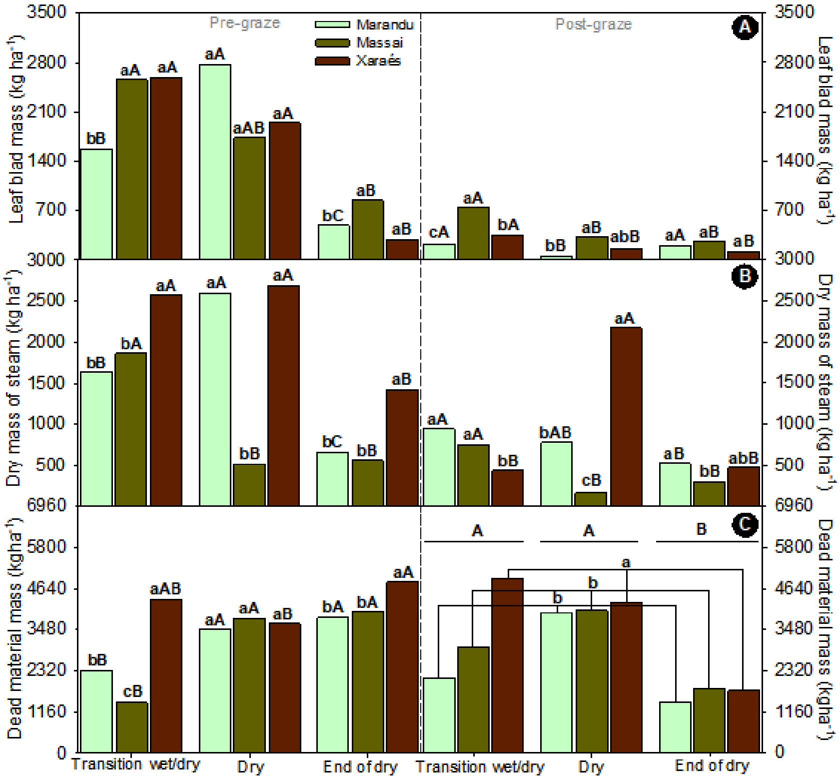

Figure 4. Leaf blade mass (A), dry mass of stem (B), and dead material mass (C) of tropical forages at pre and post grazing during the studied periods; Lower case letters in forages and upper-case letters in periods do not differ statistically by the Pdiff test at 5% probability level.

As for the values of dry mass of leaf blades during post-grazing, there was interaction among the factors (Figure 4A). In the transition wet/dry, the cultivar Massai presented higher forage production, followed by Xaraés. In the following period (dry season), the cultivar Massai remained superior to the others. Nevertheless, the values were similar ($p > 0.05$) at the end of dry.

The values of dry mass of stem for both pre-grazing and post-grazing presented interaction among treatments and the evaluated periods (Figure 4B). For pre-grazing, during the transition wet/dry the cultivar Xaraés presented higher stem production when compared with the other cultivar. As for the dry season, the cultivars Marandu and Xaraés presented higher values for dry mass of stem. At the end of dry, the cultivar Marandu showed a decrease in stem production, and it was similar ($p > 0.05$) to Massai. The cultivar Xaraés maintained the high values for stem production.

The cultivar Xaraés presented high values for the production of stems at post-grazing ($p < 0.05$). Only at the end of the dry season, the cultivar Marandu exceeded the other cultivars regarding stem production. There was interaction among the factors (Figure 4C) considering the mass of dead material during pre-grazing. The cultivar Xaraés presented higher values for dead material mass during the transition wet/dry and end of dry, while in the dry the production of dead material was similar ($p > 0.05$) for the evaluated forage cultivars.

For the mass of dead material during post-grazing condition did not present interaction among cultivars and periods of the year ($p > 0,05$) (Figure 4C). The cultivar Xaraés presented higher values for dead material mass, while Marandu and Massai presented similar production. The highest mass of dead material occurred during the transition wet/dry and dry season.

Forage mass during pre-grazing presented interaction among treatments and periods of the year ($p < 0,05$) (Figure 5). The cultivar Xaraés was superior to the others during the transition wet/dry and the end of dry season. However, at the beginning of the dry, Marandu presented forage mass production similar to Xaraés, and both were superior to Massai. During post-grazing, there was no interaction among cultivars and periods. The cultivar Xaraés was superior to the others regardless of the evaluated period. The plants presented higher values for forage mass during the dry season.

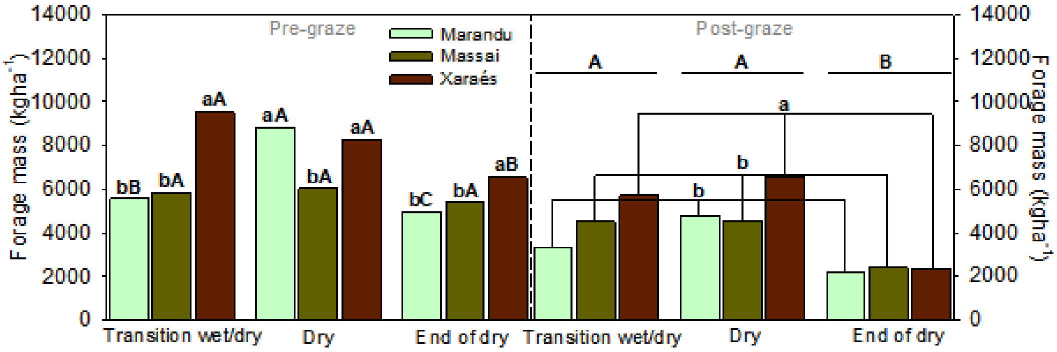

Figure 5. Forage mass of tropical forages at pre and post grazing during the studied periods; Lower case letters in forages and upper-case letters in periods do not differ statistically by the Pdiff test at 5% probability level.

Interactions ($p < 0.05$) among cultivars and periods of the year were observed for total digestible nutrient (TDN), crude protein (CP), and *in vitro* digestibility of dry matter (IVDMD) (Table 2).

Table 2. Total digestible nutrients, crude protein and *in vitro* dry mass digestibility of tropical forages during the studied periods.

Forages	Periods			Average	Standard error
	Transition wet/dry	Dry	End of dry		
	Total digestible nutrients (%)				
Marandu	55.58bA	53.70aA	50.86aB	53.38	
Massai	54.37bA	49.69bB	50.31aB	51.45	0.56
Xaraés	61.47aA	50.82bB	42.49bC	51.60	
Average	57.14	51.40	47.89		
	Crude Protein (%)				
Marandu	7.44bB	9.26aA	6.63aC	7.78	
Massai	10.44aA	6.75bB	4.33cC	7.17	0.11
Xaraés	6.80cA	6.12cB	5.62bB	6.18	
Average	8.22	7.38	5.53		
	in vitro dry mass digestibility (%)				
Marandu	56.06bA	54.41aA	50.41aB	53.63	
Massai	54.85bA	49.25bB	50.57aB	51.56	0.67
Xaraés	63.68aA	50.31bB	40.20bC	51.40	
Average	58.20	51.33	47.06		

Lower case letters in columns and upper-case letters in lines do not differ statistically by the Pdiff test at 5% probability level.

The cultivar Xaraés exhibited a higher TDN value during the transition wet/dry. At the dry season, the cultivar Marandu presented values higher than Xaraés and Massai.

In the transition wet/dry, the cultivar Massai presented higher levels of crude protein and digestibility (Table 2) followed by the cultivar Marandu. In the following periods (dry and end of dry), the cultivar Marandu presented the highest CP contents ($p < 0.05$).

The average daily gain showed no interaction among cultivars and period of the year ($p < 0,05$) (Table 3). Marandu and Massai provided higher average daily gain for the animals when compared to the animals that consumed Xaraés. Regarding the period of the year, the highest gains occurred during the transition wet/dry and dry season, with weight gain by area (WGA) showed interaction among cultivars and evaluated period (Table 3). In the transition wet/dry, WGA was similar ($p > 0.05$) for the three studied cultivars. During the dry season, the cultivar Marandu presented higher values for WGA; it was significantly ($p > 0.05$) similar to Massai and greater than Xaraés. At the end of dry, all cultivars presented negative values for WGA. The smallest losses occurred for the cultivar Massai.

Table 3. Average daily gain and live weight gain per hectare of cattle in alternate stocking of tropical forages during the studied periods.

Cultivar	Periods			Average	Standard error
	Transition wet/dry	Dry	End of dry		
	Average daily gain (kg ha^{-1} day^{-1})				
Marandu	0.418	0.419	-0.235	0.200a	0.1
Massai	0.392	0.312	-0.113	0.197a	
Xaraés	0.273	0.252	-0.169	0.118b	
Average	0.361a	0.327a	-0.172b		
	Live weight gain (kg ha^{-1} of live weight)				
Marandu	140.4aA	93.6aA	-52.5aB	60.6	12.6
Massai	131.7aA	69.6abB	-25.2bC	58.8	
Xaraés	91.5aA	56.4bB	-37.8abB	36.6	
Average	121.2	73.2	-38.5		

Lower case letters in columns and upper-case letters in lines do not differ statistically by the Pdiff test at 5% probability level.

Discussion

Studies of structural characteristics and yield of different forage cultivars are important for the definition of an appropriate pasture management (Pereira et al., 2012). Studying morphogenic and structural characteristics of tropical forage grasses, Rodrigues et al. (2012) concluded that the cultivars Marandu, Massai and Xaraés presented similar growth and development during the rainy season.

The low precipitation during the experimental period (Figure 2) reflected in the low rates of forage production for the evaluated forage cultivars. However, forage stock above 2,000 kg ha^{-1} (Figure 5), which is considered as the minimum limit of forage available on tropical grass pastures so as not to restrict feed intake of forage by the animals, according to Minson (1990).

Canopy heights during pre and post grazing were higher for the cultivar Xaraés throughout the experimental period. According to Flores et al. (2008), the recommended pre-grazing height for Xaraés grass is 40 cm and 25-40 cm for Marandu. According to Barbosa et al. (2013), the cultivar Xaraés can reach up to 45 cm. The height at pre-grazing decreased with the beginning of the dry season. Carvalho et al. (2014) observed similar results in studies with the cultivar Xaraés. The authors related it to favorable environmental conditions for grass development and growth during the rainy (Summer). The main climatic factors that determine forage production are precipitation and temperature (Garay et al., 2017).

Despite the low canopy height for cultivar Massai (Figure 3A), it presented the highest tillering ($p < 0.05$). According to Euclides et al. (2019), the general pattern for plants with high heights is low tiller production. This is due to the competition for light, where low light intensity at the base of the forage is one of the main factors that interfere with the tillering capacity of taller pastures (Sbrissia & Silva, 2008). According to Gomide and Gomide (2000), the productivity of forage grasses derives from the continuous production of leaves and tillers, which is necessary for the restoration of the leaf area after grazing, guaranteeing better forage permanence.

At pre-grazing, the cultivar Massai showed the highest leaf: stem ratio with a ratio greater than 1:1, which is considered critical by Pinto, Gomide, and Maestri (1994), with few stocks of forage. However, this variable did not change with the periods for the Marandu, which might be explained by the grazing system (alternate stocking) offering rest to the plant. The leaf: stem ratio of the cultivars inversely proportional to canopy height, in which higher plants (Marandu and Xaraés) presented lower leaf: stem ratio. Increases in forage height commonly led to a concomitant reduction in the leaf: stem ratio (Sbrissia & Silva, 2008).

The low values of dry mass of leaf blades during pre-grazing found at the end of dry season were determinant for the low animal performance. For post-grazing, cultivar Massai showed higher values of dry mass of leaf blades in the transition wet/dry when compared with the other forages. Thus, Massai presents great potential for regrowth. According to Cutrim, Cândido, Valente, Carneiro, and Carneiro Junior (2011), pasture restoration after defoliation depends on the amount of photosynthetic material remaining in the area, capable of meeting the physiological needs of the plant.

Despite the higher values for pre-grazing forage mass in Xaraés (average of 8,104 kg ha^{-1}) the percentages of dead material (52%) and stems (27%) were also high when compared with the other forages, affected the proportion stem, not recommend it for use in the dry season because of this feature. The percentages of dead material and stem components in Marandu were 25 and 49%, respectively. As for Massai, the average values were 17 and 53% respectively, for stem and dead material. Grazing animal diets commonly contain a high percentage of leaf blades and low stalks and dead material (Hodgson, 1990). The presence of stalks and dead material limits the mass of bit per animal (Prache & Peyraud, 1997), increases the time per bit, reduces the bit rate and increases daily grazing time (Carloto et al., 2011).

Higher forage mass was observed for the cultivar Xaraés in transition wet/dry and end of dry season at pre-grazing. Among the main benefits of using the cultivar Xaraés is the high productivity (Valle et al., 2004). During the dry season, the cultivar Marandu presented values similar to Xaraés. However, the largest forage mass of Xaraés before animal feeding (Figure 5) did not reflect higher average daily gain (Table 3), which is related to higher stem mass and dead material pre-grazing. It shows that only increased forage production without proper management is not a guarantee of increased livestock production. The increased efficiency of forage conversion into animal product is obtained by increasing the stocking rate, without causing damage to productivity (Difante et al., 2010). Successful grazing management depends on finding an efficient balance among forage production, feed intake and animal production for proper maintenance of the production system (Hodgson, 1990).

According to Valle et al. (2004), the cultivar Xaraés has good nutritional value and high carrying capacity, resulting in approximately 20% higher animal productivity per hectare than the cultivar Marandu. However, in this study, there was no superiority in animal gain per area in the severe dry situation (dry and end of dry, Figure 2). Despite the higher forage production (Figure 5), Xaraés did not reflect in lower yield per area due to higher stem mass and dead material in pre-grazing (Figure 4B and C). Considering the great forage potential of tropical grasses, these plants are underused in production systems (Difante et al., 2010).

For the average daily gain of animals, the highest values were found for Marandu and Massai (200 g per day). Compared to Xaraés, the additions were up to 69% in average daily gain. Despite the lower yield of Xaraés when compared with Marandu, it has advantages such as higher forage production, which ensures higher stocking rate and can promote better productivity per area (Euclides, Macedo, Valle, Barbosa, & Gonçalves, 2008; Euclides et al., 2009; Carloto et al., 2011). However, in the present study, it can be observed that the cultivar Massai is able to replace Marandu without losses in animal yield.

The highest heights found for Xaraés at pre grazing were reflected in larger forage mass production. However, the crude protein content of this cultivar was lower than the others, possibly due to the lower leaf: stem ratio (Figure 3B), which impaired the quality of the forage supplied to the animals and reflected in the lower daily weight gain of the animals (Table 3).

Animal gain per area in the transition wet/dry showed no difference ($p > 0.05$) among cultivars. However, at the beginning of dry season, the cultivar Marandu showed 34 and 65% higher animal gain per area when compared with Massai and Xaraés, respectively. AT the end of dry season, both cultivars presented negative values in animal weight gain. Nevertheless, the cultivar Massai showed lower losses ($p < 0.05$) when compared with Marandu and Xaraés.

Conclusion

In terms of leaf production and forage quality, the cultivar Massai was more adequate for the conditions of this study. The similarity in animal performance among Marandu and Massai cultivars shows that the Massai grass can be used as an alternative for forage diversification within rural properties during the transition wet/dry and dry season of the year under alternate management system. Despite the higher forage production of the cultivar Xaraés, it presented higher stem and dead material yield, which reflected in lower weight gain and yield per area.

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