Australian Journal of Crop Science
AJCS
Aust J Crop Sci. 18(12):866-870 (2024) | https://doi.org/10.21475/ajcs.24.18.12.p163
ISSN:1835-2707

Productivity and chemical composition of *Pennisetum purpureum* cv. BRS Capiaçu at different harvest ages

Emerson Silva Miranda[1], Fagton de Mattos Negrão[2*], Lucien Bissi da Freiria[2], Raphael dos Santos Gomes[2], Alan Andrade Mesquita[2], Rafael Henrique Pereira dos Reis[2], Junio Cesar Martinez[3], Eduardo Mitke Brandao Reis[4], Fabiana Alves Demeu[5], Maria Helena Ferrari[6], João Carlos Arruda de Oliveira[1], Daniele de Jesus Ferreira[7], Anderson de Moura Zanine[7], Luciano da Silva Cabral[1]

[1]Federal University of Mato Grosso, Cuiabá, MT, Brazil
[2]Federal Institute of Rondônia, Colorado do Oeste, RO, Brazil
[3]State University of Mato Grosso, Pontes e Lacerda, MT, Brazil
[4]Federal University of Acre, Rio Branco, AC, Brazil
[5]Federal Institute of Rondônia, Ariquemes, RO, Brazil
[6]Federal Institute of Rondônia, Vilhena, RO, Brazil
[7]Federal University of Maranhão, Chapadinha, MA, Brazil

***Corresponding author: Fagton de Mattos Negrão**
ORCID iD: https://orcid.org/0000-0002-2134-0974

Received: 04/04/2024
Revised: 03/07/2024
Accepted: 02/09/2024

Abstract: Livestock farming in the tropics faces several challenges, especially the scarcity of forage during the year's dry season. In this context, it is crucial to generate information about forages that can be used for roughage supplementation. Therefore, the objective was to evaluate the productivity and chemical composition of *Pennisetum purpureum* cv. BRS Capiaçu was subjected to different harvest ages after the standardization cut the North region. The experiment was conducted in a randomized block design with four treatments and five replicates (blocks), with harvest intervals of 60, 90, 120, and 150 days after the standardization cut. The increase in the age of BRS Capiaçu grass promoted a higher production of dry matter per unit area, with the production of 84.49 Mg ha^{-1} after 150 days. The crude protein content was linearly reduced ($P < 0.01$) from 14.37% at 60 days to 3.51% at 150 days. The best indication of quality in the levels of neutral detergent insoluble fiber (74.59%) and acid detergent insoluble fiber (43.93%) was observed at 90 days. Therefore, a harvest interval between 90 and 120 days of the standardization cut is recommended because it holds a balance between yield and fiber quality. Ages more significant than 120 days significantly impair the chemical composition of the forage.

Keywords: agronomic assessment; chemical composition; forage; maturity; seasonality.
Abbreviations: ADF_acid detergent fiber; Al_aluminum; ANOVA_analysis of variance; Ca_calcium; CD_stem diameter; CP_crude protein; CTC_cation exchange capacity; DM_dry matter; DMP_dry matter production; HEM_hemicelulose; IL_internode length; K_potassium; Mg_magnesium; NDF_neutral detergent fiber; P_phosphor; PH_plant height; pH H_2O_hydrogen potential in water; SL_leaf length; SW_leaf width; V%_base saturation.

Introduction

Brazil, with its tropical climate, provides favorable climatic conditions for plant production, especially forage grasses, which are widely used in livestock production systems as feed for the herd (Fagundes et al., 2007; Delevatti et al., 2019), mainly due to low maintenance costs and the extensive available land suitable for cultivation.

However, forages are strongly influenced by seasons, as they undergo a seasonal production period characterized by high production of green matter during the rainy season and scarcity during the dry season (Euclides, 2000; Koscheck et al., 2011). Thus, this seasonal production directly affects the productive performance of the herd, as the low supply and quality of forages reduce nutritional intake and, consequently, meat and milk production.

Therefore, an alternative to solve or at least alleviate this forage shortage during the dry season is the use of elephant grass plantations for extensive supplementation, either through chopped green forage in feed troughs or silage. Currently, elephant grasses belonging to the *Pennisetum* genus have been widely cultivated for this purpose (Leal et al., 2020) in various tropical and subtropical regions around the world (Carvalho et al., 1997), mainly due to their high production of dry matter per unit area (Rosa et al., 2019). In this context, the BRS Capiaçu cultivar, released by Embrapa in 2016, has dominated among other cultivars, mainly due to its late flowering, erect and dense clumps, resistance to lodging, tolerance to water stress, and high production capacity, capable of yielding approximately 50 Mg ha^{-1}year^{-1} of dry matter (Pereira et al., 2016).

However, being relatively new, the cultivar still lacks studies, as existing work is mainly focused on the management of the harvest and chemical composition of the cultivar (Pereira et al., 2016; Monção et al., 2019; Alves et al., 2022), with a significant portion of these studies conducted in the Southeast and Midwest regions of Brazil, and under fermentative profiles of silage mass (Amaral et al., 2020; Monção et al., 2020; Ribas et al., 2021). Furthermore, the BRS Capiaçu cultivar is widely distributed in the Northern region. Therefore, more studies are needed in the northern region, considering its specific soil and climate characteristics, to provide information for small and medium

producers to increase beef and milk production under effective and efficient management practices.
These additional pieces of information would be crucial to a deeper understanding of the productivity, quality, and longevity of grass at different ages. As Rosa et al. (2019) mentioned, this would expand the possibilities of offering higher-quality forage to animals throughout the agricultural year.
According to Santos et al. (2001), the most desirable nutrients in forage tend to decrease as the harvest age advances. This characteristic is quite evident in elephant grass despite its high dry matter production (Queiroz Filho et al., 2000). It shows a rapid decline in chemical composition as the age progresses, as highlighted in studies by Monção et al. (2019), Martins et al. (2020), and Alves et al. (2022).
Therefore, it was hypothesized that with the advancement of the age of the cv. BRS Capiaçu, the maturation stage of the forage, would progress, leading to significant increases in the morphological components, the content of dry matter, and the productivity of the cultivar, accompanied by reductions in chemical values.
Therefore, the objective was to evaluate the productivity and chemical composition of *Pennisetum purpureum* cv. BRS Capiaçu was subjected to different harvest ages after the standardization cut in the northern region.

Results and Discussion

Productivity and dry matter production

As the age increased from 60 to 150 days, there was a linear increase ($P < 0.01$) in plant height (PH), leaf length (SL), and dry matter production (DMP) (Table 2). When comparing the observed height at 60 days of 3.39 meters with the final height at 150 days of 4.61 meters of BRS Capiaçu, there was an increase of 1.22 meters (0.0126 m day^{-1}). This substantial height of the forage is characteristic of the species *Pennisetum purpureum*. Furthermore, Santos et al., (2017) reported that the plant can employ stem elongation if the leaf blade is not exposed to sunlight radiation to enhance exposure of the photosynthetically active part.
Forage height is of great importance in estimating productivity. Oliveira et al., (2007) evaluated different estimates of forage availability under grazing in 16 genotypes of the genus *Pennisetum* sp., with intervals of 42 days in the rainy season. The authors obtained the highest coefficient of determination (R^2 = 0.78) when using the height variable to determine the availability of forage.
With the increase in plant height and leaf length throughout the days, there was a higher dry matter production (DMP), with daily increments of 0.420 Mg ha^{-1} until the plant reached 60 days. The DMP at 60 days was equivalent to 29.86% of the production measured at 150 days, which can be explained by the genetic factors inherent to BRS Capiaçu (Pereira et al., 2016), as well as the soil in which the crop was managed (V% of 86.76%). These factors ensured the nutritional needs of the plant. After the grass was established in the area, the vigor became more evident due to the higher number of tillers per unit area and rooting of the crop, in addition to the soil and climatic conditions of the North region, which met the crop's requirements. Elephant grass thrives in hot and humid regions with annual precipitation above 1000 mm and an ideal average temperature of 24 ° C. During the evaluation months, the accumulated precipitation was 1,470 mm, well distributed throughout the months, these data being above the annual requirement of elephant grass.
Monção et al. (2019), when evaluating different ages of the BRS Capiaçu grass (30, 60, 90, 120, and 150 days), observed a Dry Matter Production (DMP) of 49.86 Mg ha^{-1} at 150 days, representing an increase of 90.97% compared to the first age. However, these values are lower than those obtained in the present study, which may be partially attributed to notable differences in soil and climatic conditions between research locations. Although the precipitation accumulated during the evaluation period of the present study totalled 1,470 mm, surpassing the 876 mm of average annual precipitation accumulated in the authors' research region, the soil fertility in our study area was also higher, which may have contributed to the results obtained. Alves et al. (2022), working with the BRS Capiaçu cultivar with three harvest ages (60, 90, and 120 days) and three levels of nitrogen fertilization (0, 100, and 200 kg N $ha^{-1}year^{-1}$), observed a DMP of 67.52 Mg ha^{-1} at 120 days of age, with these data being lower than those obtained at 120 days in the present investigation.
No significant differences ($P \geq 0.09$) were found for the leaf width, internode length, and stem diameter variables, with averages of 5.28 cm, 0.175 m, and 17.98 mm, respectively. These results, represented by averages, align with those observed by Pereira et al., (2016).

Chemical composition

Advancing the age of forage influenced the concentrations of nutrients evaluated (Table 3). A linear increase ($P < 0.01$) was observed for the content of dry matter (DM), neutral detergent fiber (NDF), and insoluble acid detergent fiber (ADF) with increasing age.
There was an increase in DM content with increasing age, obtaining the lowest content (17.37%) at 60 days of age and the highest content (28.89%) at 150 days, with an increase of 11.5 percentage points in the content of DM (0.1326% day^{-1}). The increase in DM content is a natural process in grasses as they age and reach physiological maturation, characterized by the loss of water in plant cells.
As the grass ages, the concentrations of NDF and ADF increase, from 70.75 and 39.23% to 77.12 and 45.85% for grass cut at 60 and 150 days, respectively. There was an increase in NDF of 6.37 percentage points (0.0666% day^{-1}). It is worth noting that the high values found were due to the analyses using only tillers that reached maturity in 150 days, as the grass fell and stimulated growth with the clump's basal tillers.
Leal et al. (2020), when investigating the correlations between cv's productive and nutritional characteristics. BRS Capiaçu identified highly positive correlations between PH and NDF and ADF and lignin content, with R^2 of 0.76, 0.80, and 0.73, respectively. This loss of chemical quality may be associated with a lower leaf/stalk ratio, as, according to Queiroz Filho et al. (2000), a higher leaf/stalk ratio is associated with a better chemical quality, including a high protein content and lower NDF concentrations in the forage. Therefore, high DMP cultivars generally have a lower leaf/stalk ratio. Thus, it can be inferred that the drop in the chemical composition of cv. BRS Capiaçu obtained after 150 days is related to this parameter. This relationship between the harvest age of elephant grass and the reduction in the leaf/stalk ratio was corroborated by Queiroz Filho et al. (2000), Martins-Costa et al. (2008), and Ferreira (2015).
The NDF and ADF fractions represent the main components of the plant cell wall, and the increase in their concentrations in forage with advancing age can be explained by the increase in the thickness of the plant cell wall at the expense of the reduction in cell content (Van Soest et al., 1991).
Silva et al. (2007), evaluating elephant grass at different harvest ages, observed that as the plant's age increased, NDF concentrations increased, accompanied by increases in the indigestible fraction and reductions in degradation rates. This trend occurs because the fractions solubilized in neutral detergent systems, as defined by Van Soest et al. (1991), are those with a high digestion potential. However, this decreases proportionally to the increase in NDF content.
Therefore, the NDF fraction is the most appropriate food component to predict dry matter intake by ruminants (Allen, 2000), with this variable determining the amount of nutrients available for animal production (NRC, 2001). Van Soest (1994) reported that NDF is inversely related to the diet's energy content and directly affects rumen filling.
Martins et al. (2020), evaluating nutritional components of elephant grass (*Pennisetum purpureum* Schum) at three harvest ages (56, 84, and 112 days), observed NDF and ADF contents of 66.76 and 37.19%; 71.62 and 44.77%; 74.05 and 44.53%, respectively, these values being close to those obtained in the

Table 1. Chemical and granulometric characteristics of the soil.

Soil attributes	Depth (m)
	0.00-0.20
pH H_2O (1)	6.40
Ca (2)	8.00
Mg (2)	1.46
Al (2)	0.00
Organic matter (3)	18.34
P (5)	3.17
K (5)	0.37
CTC (6)	11.33
V% (7)	86.76
Clay (8)	241.60
Silt (8)	128.00
Sandy (8)	630.40

(1)by potentiometry; (2)in potassium chloride, by titration ($cmol_c$ dm^{-3}); (3)dry way, on a weight basis, in muffle (g kg^{-1}); (5)in double acid (hydrochloric acid and sulfuric acid), by colorimetry (mg dm^{-3}); (6)obtained through the sum of bases (Mg, Ca, K, Al and H) at pH 7 ($cmol_c$ dm^{-3}); (7)obtained by the ratio between the sum of the bases Mg, Ca, K and the CTC at pH 7, multiplied by 100 (%); (8)granulometry by the pipette method (g kg^{-1}).

Table 2. Average values of plant height (PH), leaf length (SL), leaf width (SW), internode length (IL), stem diameter (CD) and dry matter production (DMP) of BRS Capiaçu grass in different ages.

Variables	Age (days)				SEM	P-value		
	60	90	120	150		Treatment	Linear	Quadratic
PH (m)[1]	3.39	4.43	4.55	4.61	0.038	<0.01	<0.01	<0.01
SL (m)[2]	1.38	1.49	1.50	1.53	0.014	<0.01	<0.01	0.02
SW (cm)[3]	4.94	5.33	5.36	5.49	0.133	0.10	0.03	0.37
IL (m)[4]	0.17	0.17	0.18	0.18	0.327	0.09	0.02	0.47
CD (mm)[5]	17.09	18.15	18.30	18.41	0.392	0.17	0.06	0.27
DMP (Mg ha^{-1})[6]	25.23	38.09	73.19	84.49	8.040	<0.01	<0.01	0.93

[1] $\hat{Y} = 2.9220+0.0126X$ (R^2 = 0.73); [2] $\hat{Y} = 1.3130+0.0015X$ (R^2 = 0.82); [3] $\hat{Y} = 5.28$; [4] $\hat{Y} = 0.1748$; [5] $\hat{Y} = 17.98$; [6] $\hat{Y} = -19258.9900+709.6418X$ (R^2 = 0.96).

Table 3. Average contents of dry matter (DM), crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), and hemicellulose (HEM) of elephant grass cv. BRS Capiaçu at different ages.

Variables (%)	Age (days)				SEM	P-value		
	60	90	120	150		Treatment	Linear	Quadratic
DM[1]	17.39	20.9	26.17	28.89	1.051	<0.01	<0.01	0.72
CP[2]	14.37	7.84	6.91	3.51	0.781	<0.01	<0.01	0.09
Ash[3]	12.12	9.38	8.79	7.92	0.544	0.01	<0.01	0.14
NDF[4]	70.75	74.59	75.44	77.13	0.455	<0.01	<0.01	0.06
ADF[5]	39.23	43.93	45.26	45.85	0.566	<0.01	<0.01	0.01
HEM[6]	31.52	30.66	30.18	31.27	0.445	0.24	0.56	0.07

[1] $\hat{Y} = 9.4157+0.1326X$ (R^2 = 0.98); [2] $\hat{Y} = 19.8970-0.1117X$ (R^2 = 0.91); [3] $\hat{Y} = 14.1713-0.0439X$ (R^2 = 0.88); [4] $\hat{Y} = 67.486+0.0666X$ (R^2 = 0.91); [5] $\hat{Y} = 36.151+0.0706X$ (R^2=0.88); [6] $\hat{Y} = 30.91$.

present study. The advancement of the harvest interval is accompanied by more significant proportions of the plant cell wall in the forage biomass due to its crucial role in supporting the tillers to prevent tipping over. This increase was also corroborated by Queiroz Filho et al. (2000) working with elephant grass (*Pennisetum purpureum* Schum) cv. Purple at different harvest ages reported NDF contents of 65.7 to 77.0% for grass ranging from 40 to 100 days of age, respectively.

However, increasing the age did not influence the hemicellulose content (P = 0.24). According to Chensson and Forsberg (1997), as the forage matures, the most significant changes are related to the composition of hemicellulose carbohydrates rather than their concentration in the forage.

The levels of crude protein (CP) were linearly reduced (P < 0.01) with increasing age intervals. There was a sudden reduction of 6.53 percentage points in the CP content of the forage between the harvest interval of 60 to 90 days. At 60 days, the plant had a CP content of 14.37% and dropped to 3.51% at 150 days of age, resulting in a daily reduction of 0.1117% of CP. This is a natural behavior in forage plants, as over time, the plant cell tends to increase the thickness of the cell wall to support the tillers, and at the same time, there is a reduction in cellular content and, consequently, a reduction or dilution of CP due to the fact that a large part of the nitrogen compounds is allocated in the cellular content. This fact is more accentuated due to the reduction in the leaf/stem ratio with advancing age (Queiroz Filho et al., 2000), whose leaf component has a higher PC content in relation to the stemun.

Elephant grass loses its nutritional quality in a relatively short period. Machado et al. (2008) observed CP values ranging from 14.10 to 5.18% for cv. Cameroon with an age between 33 and 93 days, respectively. Concomitantly, there are reductions in the soluble fraction and potential degradation of CP (Monção et al., 2019) due to the complexation of CP with components of NDF with increasing age. Kozloski et al. (2007) state that the low consumption and digestibility of tropical forages at a high level of maturity are associated with a low nitrogen concentration, resulting in a low ammonia supply for cellulitis bacteria in the rumen. According to Sniffen et al. (1993) and Minson (1990), CP levels below 7% limit ruminal fermentation. Thus, cv. The BRS Capiaçu cut up to 116 days meets the minimum CP levels for ruminal fermentation, and later ages require protein supplementation to achieve adequate levels of ruminal fermentation.

For ash, a linear reduction (P = 0.01) was observed with increasing forage age. The highest ash value for cv. BRS Capiaçu was offered at the lowest ages. Increasing the harvest age leads to a more significant deposition of organic matter with a concomitant reduction in the ash fraction.

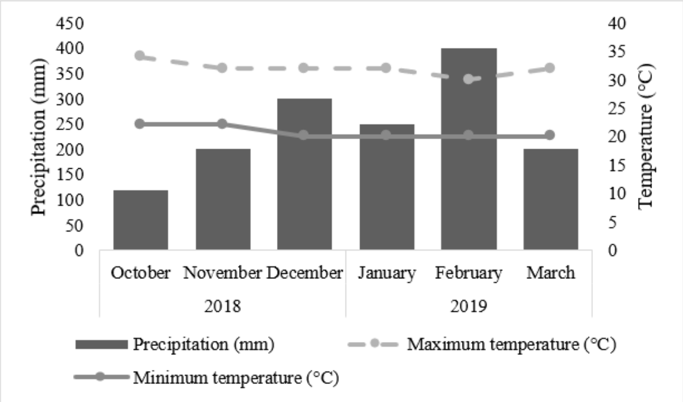

Fig 1. Cumulative precipitation and maximum and minimum air temperatures during the months of the experimental period from October 2018 to March 2019. Source: National Institute of Meteorology, INMET (2023).

Materials and Methods

Experiment location

The research was carried out at the Rondônia Federal Institute of Education, Science, and Technology in the municipality of Colorado do Oeste, RO, Brazil (11° 43' S, 49° 15' W, and altitude of 460m).

In the region, the prevailing climate is hot and subhumid tropical, with a four-month dry season and eight months of rain, according to Köppen & Geiger (1928) and Alvares et al. (2014). The soil characterization was carried out as described by Teixeira et al. (2018) (Table 1). The climatic data observed during the experimental period, a crucial aspect of the study, are presented in Figure 1.

The cultivar used was *Pennisetum purpureum* cv. BRS Capiaçu was established using stem segments containing three to four buds planted in furrows at a depth of 0.25 m using the "inverted position of the seedling ends" method.

Experimental design and conduction of study

The experimental design used was a completely randomized block design, with treatments consisting of four harvest ages after the standardization cut (60, 90, 120, and 150 days) and five replications (blocks). The treatments were allocated in plots with a total area of 12 m², comprising four rows of 3 m in length, with a spacing of 1 m between rows. Each plot was considered an experimental unit.

To start the experiment (day zero), a uniform cut was performed at ground level. After the cultivar reached a height of 0.50 m, fertilization was applied using an NPK fertilizer formulated as 20-05-20 at a rate of 1.2 Mg $ha^{-1}year^{-1}$, as recommended by Pereira et al. (2016). The fertilizer was incorporated into the soil through a furrow built near the plants.

At each age, the grass was cut close to the ground, eliminating the borders (the lateral rows and 1 meter from each side of the central row of the plots). Regarding the useful area (2 linear meters), samples from each experimental unit were weighed on a mechanical balance, with an analytical precision of 0.1 kg, ensuring the accuracy of the biomass weight measurements.

To determine green matter productivity (kg ha^{-1} of GM), samples of 2 linear meters were collected manually, approximately 5 cm from the soil, and weighed, with the values being extrapolated to the hectare. For the determination of the dry matter productivity (kg ha^{-1} of DM), the weight of the grass in 2 linear meters was multiplied by the dry matter content. Then, the values were extrapolated to the hectare.

The sampled forage was taken to the laboratory to measure morphological components, including plant height, leaf length and diameter, internode length, and stem diameter. These measurements were carried out using a graduated tape measure in meters and a graduated digital caliper in millimeters. Subsequently, the forage was pre-dried in a forced air oven at 65 ° C for 72 hours and then ground in a Wiley mill with a 1 mm sieve for chemical analysis.

The pre-dried samples were then subjected to a comprehensive chemical analysis, including dry matter (DM), ash, and crude protein (CP) content, according to Detmann et al., (2012). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined in sequential analyses, while hemicellulose (HEM) was calculated as the difference between NDF and ADF, as determined by Van Soest et al., (1991).

Statistical analysis

The data obtained were subjected to statistical analysis using the SAEG program (1999; version 8.1). Analysis of variance (ANOVA) was performed to assess differences between treatments, followed by regression analysis to evaluate linear, quadratic, and cubic effects of the age (in days) on the variables studied. All analyses were performed at a significance level of 5%. In the generated equations, the variable Y represents the estimation of the dependent variable, while X corresponds to the age. The selection of the model that best fits the data was based on the significance values (P) and the coefficient of determination (R^2).

Conclusions

The cv. BRS Capiaçu demonstrated high biomass production under the edaphoclimatic conditions of the North region. However, as the age advances, the forage presents a rapid drop in chemical composition. Therefore, a harvest interval between 90 and 120 days is recommended. Ages more significant than 120 days significantly impair the chemical composition of the forage.

Acknowledgments

The authors thank the Department of Research, Innovation, and Postgraduate Studies at the Federal Institute of Rondônia, Colorado do Oeste campus.

Statement of contributions

ESM and FMN planned the experiment, ESM conducted the experiment and statistical analyzes, ESM, LBF, RSG, and FMN wrote the first draft. All authors reviewed and approved the latest version of the manuscript.

Compliance with Ethical Standards

The authors declare that they have no conflict of interest.

References

Allen MS (2000) Effects of diet on short-term regulation of feed intake by lactating dairy cattle. J Dairy Sci. 88(7): 1598-1624.

Alves JP, Mendes SS, Galeano ES, Orrico Júnior MAP, Fernandes T, Retore M, Orrico ACA (2022) Forage production and quality of BRS Capiaçu as a response of cutting age and nitrogen application. Trop Ani Sci J. 45 (2): 179-186.

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek G (2014) Köppen's climate classification map for Brazil. Meteorologische Zeitschrift. 22(6): 711-728.

Amaral RC, Carvalho BF, Costa DM, Morenz MJF, Schwan RF, Ávila CLS (2020) Novel lactic acid bacteria strains enhance the conservation of elephant grass silage cv. BRS Capiaçu. Anim Feed Sci Tech. 264: 114472.

Carvalho MM, Alvim MJ, Xavier DF, Carvalho ELA (1997) Elephant grass: production and use. 2° ed. Revised. Brasília: Embrapa, Juiz de Fora.

Chesson A, Forsberg CW (1997) Polysaccharide degradation by rumen microorganisms. In: HOBSON PN, STEWART CS. The rumen microbial ecosystem. Londres: Brackie Academic & Professional, Cap. 8, 329-381.

Delevatti LM, Cardoso AS, Barbero RP, Leite RG, Romanzini EP, Ruggieri AC, Reis RA (2019) Effect of nitrogen application rate on yield, forage quality, and animal performance in a tropical pasture. Sci Rep-Uk. 9: 7596.

Detmann E, Souza MA, Valadares Filho SC, Queiroz AC, Berchielli TT, Saliba EOS, Cabral LS (2012) Methods for Food Analysis. 1.ed. Visconde do Rio Branco: Suprema.

Euclides VPB (2000) Alternatives for beef intensification on pastures. Campo Grande: Embrapa Gado de Corte.

Fagundes JL, Fonseca DM, Mistura C, Salgado LT, Queiroz DS, Morais RV, Vitor CMT, Moreira LM (2007) Nitrogen and potassium fertilization in elephant grass cv. Napier under rotational grazing. B Ind Ani. 64(2): 149-158.

Ferreira DF (2011) Sisvar: a computer statistical analysis system. Cienc Agrotec (UFLA). 35(6): 1039-1042.

INMET - INSTITUTO NACIONAL DE METEOROLOGIA (2023) Registered conditions. Brasília, On-line. Available in: <https://tempo.inmet.gov.br/CondicoesRegistradas>. Accessed on: 22 Jan 2024.

Köppen W, Geiger R (1928) Klimate der Erde. Gotha: Verlag Justus Perthes.

Koscheck JFW, Zevoudakis JT, Carvalho DMG, Cabral LS, Amorim KP, Silva RGF, Silva RP (2011) Supplementation of beef cattle in a grazing system. Unicências. 15(1): 377-412.

Kozloski GV, Reffatti MV, Bonnecarrere SLM, Lima LD, Cadorin Júnior RL, Härter CJ, Fiorentini G (2007) Intake and digestion by lambs fed a low-quality grass hay supplemented or not with urea, casein or cassava meal. Anim Feed Sci Tech. 136: 191-202.

Leal DB, Monção FP, Rocha Júnior VR, Carvalho CCS, Alencar MAS, Moura MMA (2020) Correlations between the productive and nutritional characteristics of BRS capiaçu grass managed in the semiarid region. Braz J Develop. 6(4): 18951-18960.

Machado PAS, Valadares Filho SC, Valadares RFD, Detmann E, Paixão ML, Pina DS (2008) Nutritional evaluation of elephant grass (Cameroon) at different regrowth ages. Rev Bras Zootecn. 37(6): 1121-1128.

Martins LF, Prado DMB, Gomes GR, Teixeira AM, Oliveira LN, Gonçalves LC, Oliveira FS (2020) Nutritional value of green elephant grass harvested at different regrowth ages. Arq Bras Med Vet Zoo. 72(5): 1881-1890.

Martins-Costa RHA, Cabral LS, Bhering M, Abreu JG, Zervoudakis JT, Rodrigues RC, Oliveira IS (2008) Nutritional value of elephant grass obtained at different cutting ages. Rev Bras Saud Prod Ani. 9(3): 397-406.

Minson DJ (1990) Forage in ruminant nutrition. Academic Press: San Diego.

Monção FP, Rocha Júnior VR, Silva JT, Jesus NG, Marques OFC, Rigueira JPS, Sales ECJ, Silva Júnior AAG, Alves, DD, Carvalho CCC, Gomes VM, Leal DB (2020) Nutritional value of BRS Capiaçu grass (*Pennisetum purpureum*) silage associated with Cactus Pear. Iran J Appl Ani Sci. 10 (1): 25-29.

Monção, FP, Costa MAMS, Rigueira JPS, Moura MMA, Rocha Júnior VR, Gomes VM, Leal DB, Maranhão CMA, Albuquerque CJB, Chamone JMA (2019) Yield and nutritional value of BRS Capiaçu grass at different regrowth ages. Semin-Cienc Agrar. 40(5): 2045-2056.

NRC - National Research Council (2001) Nutrient requirements of dairy cattle. The National Academic Press: Washington.

Oliveira, TN, Santos MVF, Lira MA, Mello ACL, Ferreira RLC, Júnior JCBD (2007) Methods for assessing forage availability in *Pennisetum* sp. clones under grazing. Rev Bras de Cienc Agrar. 2(2): 168-173.

Pereira, AV, Ledo FJS, Morenz MJF, Liete JLB, Santos AMB, Martins CE, Machado JC (2016) BRS Capiaçu: high-yielding elephant grass cultivar for silage production. Comunicado técnico 79. Embrapa Gado de Leite: Juíz de Fora.

Pereira AV, Ledo FJ, Machado JC (2017) BRS Kurumi and BRS Capiaçu - new elephant grass cultivars for grazing and cut-and-carry system. Crop Breed Appl Biot. 17: 59-62.

Queiroz Filho, JL, Silva DS, Nascimento IS (2000) Dry matter production and quality of elephant grass (*Pennisetum Purpureum* Schum.) purple cultivar at different cutting ages. Rev Bras Zootecn. 29(1): 69-74.

Ribas WFG, Monção FP, Rocha Júnior VR, Maranhão CMA, Ferreira HC, Santos AS, Gomes VM, Rigueira JPS (2021) Effect of wilting time and enzymatic-bacterial inoculant on the fermentative profile, aerobic stability, and nutritional value of BRS capiaçu grass silage. Rev Bras Zootecn. 50:e20200207.

Rosa PP, Silva PM, Chesini RG, Oliveira APT, Sedrez PA, Faria MR, Lopes AA (2019) Characteristics of elephant grass *Pennisetum purpureum* (schumach) and its new cultivars BRS Kurumi and BRS Capiaçu. Pesqui Agropecu Gaúcha. 25(1/2): 70-84.

Santos EA, Silva DS, Queiroz Filho JL (2001) Chemical composition of elephant grass cv. Roxo cut at different heights. Rev Bras Zootecn. 30(1): 18-23.

Santos MER, Sousa BML, Rocha GO, Freitas CAS, Silveira MCT, Sousa DOC (2017) Canopy structure and tiller characteristics in Piatã grass pastures managed with variable nitrogen rates and deferral periods. Cienc Ani Bras. 18: 1-13.

Silva PA, Valadares Filho SC, Valadares RFD, Cecon PR, Detmann E, Paixão ML (2007) Energy value of elephant grass at different regrowth ages and estimation of *in vivo* digestibility of neutral detergent fiber. Rev Bras Med Vet Zoo. 59(3): 711-718.

Sniffen CJ, Beverly RW, Mooney CS, Roe MB, Skidmore AL, Black JR (1993) Nutrient requirements versus supply in the dairy cow: strategies to account for variability. J Dairy Sci. 76: 3160-3178.

Teixeira PC, Donagemma GK, Fontana A, Teixeira WG (2017) Manual of soil analysis methods. Brasília: Embrapa Solos.

Van Soest PJ, Roberton JB, Lewis BA (1991) Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci. 74(10): 3583-3597.

Van Soest PJ (1994) Nutritional ecology of the ruminant. 2. ed. Cornell University Press: Ithaca.