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Forage Production and Quality of BRS Capiaçu as a Response of Cutting Age and Nitrogen Application

J. P. Alves, S. S. Mendes, E. S. Galeano, M. A. P. Orrico Junior*, T. Fernandes, M. Retore, A. C. A. Orrico, & L. da S. Lopes
Faculty of Agricultural Science, Federal University of Grande Dourados,
Dourados, MS, 79804-970, Brazil
*Corresponding author: marcojunior@ufgd.edu.br
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ABSTRACT

Capiaçu is a cultivar of elephant grass (*Pennisetum purpureum* Schum.), which is a promising species for use in ruminant feed and presents a high potential for biomass production. However, as this grass became subjected to different management strategies, fluctuations in biomass production were observed, reflecting on its nutritive value. The objective was to verify the effect of cutting age and nitrogen (N) application on the productivity and nutritional value of BRS Capiaçu. A randomized block design was used in a 3 × 3 factorial scheme: three cutting ages (60, 90, and 120 days) and three levels of nitrogen fertilization (0, 100, and 200 kg N/ha/year). The variables evaluated were: productivity and chemical composition of the leaf, stem, and whole plant fractions, besides the production of nutrients and efficiency of utilization of applied nitrogen (EUAN). There were interaction effects between cutting ages and N application on dry matter (DM), crude protein (CP), cellulose, hemicellulose, and lignin production. Plants cut every 120 days and fertilized with 100 or 200 kg N/ha had the highest annual DM production. Nitrogen fertilization was efficient in increasing the percentage of leaves and the production of CP and DM digestibility of the grass. The highest CP production (in kg/ha/year) was observed for the 60- and 90-days old grass fertilized with 200 kg of N/ha/year. Grasses that were cut every 90 days and that received nitrogen fertilization of 100 kg N/ha/year were the ones that presented the highest EUAN. The cutting at 90 days of age, associated with N fertilization of 100 kg N/ha/year, is the best strategy for BRS Capiaçu.

Keywords: chemical composition; elephant grass; maturity stage; Pennisetum purpureum

INTRODUCTION

The growing demand for food, associated with the need to conserve natural resources, has forced farmers to adopt more efficient animal production systems. In this context, the use of elephant grass cultivars (*Pennisetum purpureum* Schum.) to ensure the supply of feed during the drier season of the year is an alternative that has been used in several countries with tropical climates (Tessema *et al.*, 2010).

Elephant grass is a forage species that presents high biomass production, good tolerance to prolonged drought, is adapted to various soil types, and is suitable for mechanized cutting (Tessema *et al.*, 2010; Monção *et al.*, 2019; Silva *et al.*, 2020). Due to its productivity, elephant grass needs frequent fertilization because high nutrient extraction can lead to a decline in soil fertility in a short period (Siri-Prieto *et al.*, 2020).

In general, nitrogen is the highest nutrient demanded in the development of forage grasses (Orrico Junior *et al.*, 2012; Orrico *et al.*, 2013; Silveira *et al.*, 2018). However, in the relevant literature, there is still a wide variation in the data regarding the effect of nitrogen fertilization on the biomass productivity of elephant grass cultivars. It is common to find data such as those of Flores *et al.* (2012), in which there was no increase in biomass production of elephant grass with the use of N fertilizer, as well as results similar to Bueno *et al.* (2020), who found the highest efficiency of N use for a median dose application (100 kg N/ha/year).

The elephant grass cultivar BRS Capiaçu is between the accessions Guaco-BAGCE 60 and Roxo-BAGCE 57. This cultivar is characterized by late-flowering; tall size; upright clumps, leaves with wide, long, and green blades; yellowish-green leaf sheath; and stem with a thick diameter and yellowish internodes (Pereira *et al.*, 2017). It was released in 2016 by EMBRAPA, and the initial scientific reports on this cultivar were described by Pereira *et al.* (2017). In this research, the authors observed a biomass production of 49 tons dry matter (DM)/ha/year, which placed it as the most productive among the other elephant grass cultivars used in Brazil. However, as this cultivar began to be grown in the other regions and was subjected to different management strategies, biomass production was much higher than those obtained by Pereira *et al.* (2017). An example of this was that in the study conducted by Monção *et al.* (2020), the authors observed biomass production of 72 ton DM/ha/year, with the use of fertilization of 50 kg/ha of the formula 20-0-20 (N-P-K) after each cut, at 120 days of regrowth.

Besides fertilization, the cutting frequency also affects the growth characteristics, yield of DM, and nutritive value of elephant grass. According to Tessema *et al.* (2010), when the interval between cuts is short, the plant's productivity is compromised because, at each defoliation, the grass needs to mobilize its energy reserves for the emergence of new leaves. On the other hand, when the interval between cuts is too long, elephant grass losses its nutritional quality besides having its growth compromised by excessive shading, thus making its use unfeasible (Rodolfo *et al.*, 2015; Monção *et al.*, 2019). Therefore, the balance between biomass production and the nutritional quality of the grass is essential for cultivar management.

As it is a cultivar of elephant grass recently launched and which presents DM productions higher than the other elephant grass cultivars, studies are needed to determine the best N dose and the best interval between cuts to maximize the production of nutrients per hectare and promote efficient use of applied N. Thus, the objective of this study was to evaluate the effect of cutting age (60, 90, and 120 days) and N application (0, 100, and 200 kg N/ha/year) on biomass production and nutritive value of BRS Capiaçu.

MATERIALS AND METHODS

The study was conducted at Embrapa Agropecuária Oeste, in the municipality of Dourados, MS, Brazil (22° 11′ S, 54° 56″ W and 452 m above sea level) from August 2017 to September 2018. The climate of the region is humid mesothermal (Cwa), with hot summers and dry winters. The meteorological data observed during the experiment are presented in Figure 1.

The soil of the experimental area was classified as dark red distroferric Latosol with a very clayey texture (Santos *et al.*, 2018). The soil had the following characteristics: sand, 88.71 g/kg; silt, 182.32 g/kg; clay, 728.97 g/kg; pH in $CaCl_2$, 5.22; P (Mehlich), 28.23 mg/dm^3; K, 0.51 cmolc/dm^3; Ca^{+2}, 3.39 cmolc/dm^3; Mg^{+2}, 0.75 cmolc/dm^3; $H^+ + Al^{+3}$, 3.39 cmolc/dm^3; cation exchange capacity: 8.04 cmolc/dm^3, base sum: 4.65 cmolc/dm^3; organic matter, 16.74 g/kg and base saturation, 57.83%. Fertilization based on P and K was not necessary, as the concentrations of these nutrients in the soil were adequate for elephant grass cultivation (Pereira *et al.*, 2016).

The BRS Capiaçu grass seedlings were composed only of the plant's stems (approximately 120 days old), cut into pieces containing three to four internodes. The planting of BRS Capiaçu grass was undertaken on April 12, 2017, in furrows with 15 cm depth and 1 m distance between furrows. The seedlings were placed at the bottom of the furrow, covered with soil, which was lightly compacted to favor the emission of tillers. The area (1000 m^2) was divided into 36 experimental plots, measuring 5 × 3 m each.

The experiment was conducted in a factorial randomized block design, with three cutting ages (60, 90, and 120 days) and three levels of N application (0, 100, and 200 kg N/ha/year), and four repetitions per treatment (one repetition per block). During one year of evaluation, six, four, and three cuts were performed for the managed grass, with intervals between cuts of 60, 90, and 120 days, respectively.

On August 21, 2017, the grass was uniformly cut at the height of 5 cm from the ground, initiating the experimental period. Nitrogen fertilizers were applied manually on the soil surface, using protected urea as a source of nitrogen. The nitrogen fertilization doses were divided according to the number of cuts, i.e., the doses of 100 and 200 kg/ha/year were divided into six, four, and three applications (after each cut) in the plots managed with intervals between cuts of 60, 90, and 120 days, respectively.

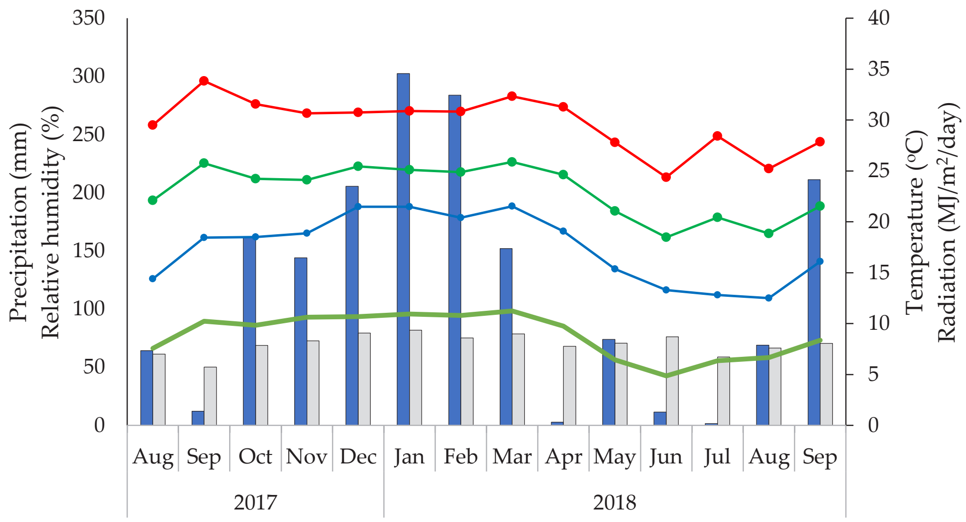

Figure 1. The meteorological data observed during the experimental period. Average T (—●—)= Average, Max T (—●—)= maximum, Min T (—●—)= minimum, RH (▭)= relative humidity, Prec (▬)= precipitation, and radiation (▬).

As soon as the plants reached the ages established for cutting, height and biomass production were measured per plot. The data of plants height were obtained by measuring three random points within each plot (from the ground up to the insertion of the last leaf blade). The plants contained within 2 m of each of the three central rows of the plots were collected to quantify the fresh forage production. Subsequently, the material was cut and removed from the rest of the plot to standardize the regrowth of the plots.

The sampled plants were taken to the laboratory for morphological separation (leaf + sheath and stem) and determination of the DM content of each plant fraction. The samples were pre-dried in an oven with forced air circulation at 55 °C for 72 hours. The dry samples were ground in a Willey mill, with a 1 mm mesh sieve, to determine the contents of DM, organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, hemicellulose, lignin, and *in vitro* digestibility of dry matter (IVDMD), through the near-infrared spectroscopy technique. The curves were calibrated in a FOSS NIR Systems Model 5,000, using ISI WINISI II Project Manager V1.02 software (Shenk *et al.*, 1979). Based on the fresh weight and the DM contents, the DM production of the whole plant, leaf, and stem per hectare (ha) was calculated, as well as the leaf: stem ratio. The calculation of production/ha/year (of each nutrient) was undertaken by multiplying the total production of DM by the respective nutrient contents contained in the whole plant. With these values, it was possible to calculate the efficiency of utilization of applied nitrogen (EUAN), which was calculated using the formula:

$$EUAN= (P - Pc)/Napp$$

where P was the production of DM or nutrients in the treatment that received fertilization (kg), Pc was the production of DM or nutrients in the treatment that did not receive fertilization (kg), and Napp. was nitrogen dose applied in the area (kg).

The effects of cutting ages and N application and the interaction of these factors on the response variables were evaluated by an analysis of variance (F test). When the interaction of factors was significant ($\alpha \leq 0.05$), the factors were considered separately for analysis. In the case of non-significant interaction, the factors were analyzed by principal component.

The data were analyzed using the statistical program SAS (version 9.0, Statistical Analysis System). The means were compared using the Tukey test at a 5% significance level.

RESULTS

An interaction effect ($p<0.05$) between cutting ages and N application on the biomass production of the grass was observed (Figure 2). At 120 days of age and fertilized with 100 or 200 kg N/ha/year, plants had the highest biomass production (average of 77,350 kg of DM/ha/year). The lowest annual production was observed for grass managed with intervals between cuts of 90 and 60 days and without nitrogen fertilization.

Leaf and stem biomass yields were influenced by cutting age and the amount of N applied (Table 1). Plants obtained the highest stem yields at 120 days of age. In contrast, leaf production was higher for plants managed at 90 days intervals between cuts, and there was no difference in leaf production between plants aged 60 and 120 days. Nitrogen fertilization favored leaf and stem biomass production, with the highest values being obtained in the treatments that received the highest dose of nitrogen. The highest leaf proportion was observed for plants managed at 90 days of age between cuts, while the lowest leaf proportion was observed for plants aged 120 days. The opposite trend was observed for the proportion of stem. Nitrogen fertilization did not influence the leaf and stem proportions of the plants but influenced the production of these constituents. The age of the grass influenced the height of the plants, with the highest values for plants aged 120 days, followed by plants aged 90 days and lower values for plants aged 60 days. No influence of nitrogen fertilization on plant height was observed.

Nitrogen fertilization (200 kg/ha/year) increased the OM content of both the leaf and the stem (Table 2). The other parameters were not influenced by nitrogen fertilization. On the other hand, the age of the grass influenced the concentrations of the nutrients evaluated. The contents of CP in the leaf, stem, and whole plant decreased by 30.48%, 57.77%, and 49.66%, respectively, with an increase in plant age from 60 to 120 days.

The fibrous fractions of the leaf, stem, and whole plant followed an inverse behavior to the CP contents. The lowest mean values of NDF, ADF, cellulose, hemicellulose, and lignin were observed for the 60 days old grass and the highest for the 120 days old grass. In comparison between the 60- and 120-days old grass, there was an increase of 79.85% in the lignin content of the whole plant.

The IVDMD coefficient decreased by 11.98%, 25.83%, and 19.26% for leaf, stem, and whole plant, respectively, comparing 60- and 120-days old grass. The stem was the plant fraction that showed the most significant changes in chemical composition (in percentage terms) as a function of advancing plant age.

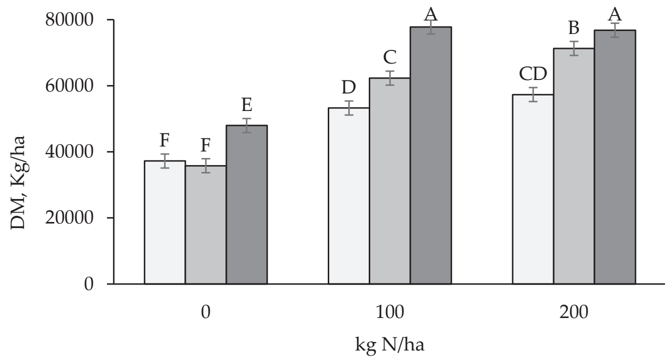

Figure 2. Annual production of dry matter (DM) of BRS Capiaçu at different cutting ages (60, 90, and 120 days, □60 □90 ■120) and different levels of N applied (0, 100, and 200 kg N/ha). Bars indicated by different letters differ by the Tukey test at 5% probability.

Table 1. Biomass production (whole plant, leaf, and stem), leaf and stem proportions, and height of BRS Capiaçu at different cutting ages (60, 90, and 120 days) and different levels of N applied (0, 100, and 200 kg N/ha)

Variables	Age (days)			Dose (kg N/ha)			SEM	P value		
	60	90	120	0	100	200		A	D	A*D
Leaf, kg DM/ha/year	22,641[b]	29,511[a]	21,068[b]	16,687[C]	27,599[B]	28,934[A]	252.7	**	*	ns
Stem, kg DM/ha/year	24,733[c]	26,954[b]	46,449[a]	23,163[C]	36,167[B]	38,806[A]	336.5	**	**	ns
Leaf, %	45.90[b]	52.20[a]	31.13[c]	42.59	43.85	42.79	0.587	**	ns	ns
Stem, %	50.25[b]	47.80[c]	68.87[a]	56.13	54.87	55.92	0.55	**	ns	ns
Leaf:Stem ratio, %	0.91[b]	1.09[a]	0.45[c]	0.76	0.8	0.76	0.08	**	ns	ns
Height, m	1.73[c]	2.22[b]	3.15[a]	2.36	2.31	2.42	0.037	**	ns	ns

Note: Means in the same row with different superscripts differ significantly (p<0.05). Averages followed by different letters indicate significant differences by the Tukey test at 5% probability. Capital letters represent differences between nitrogen doses and lowercase letters represent differences between cutting ages. SEM= standard error of mean; DM= dry matter; A= age; D= nitrogen fertilizer dose; ns= non-significant; * = (p<0.05); ** = (p<0.01).

Table 2. Chemical composition and *in vitro* dry matter digestibility of leaf and stem (%) of BRS Capiaçu at different cutting ages (60, 90, and 120 days) and different levels of N applied (0, 100, and 200 kg N/ha)

Variables	Age (days)			Dose (kg N /ha)			SEM	P value		
	60	90	120	0	100	200		A	D	A*D
Leaf										
DM, % forage	22.54[b]	23.94[ab]	24.57[a]	23.45	22.54	23.87	0.037	**	ns	ns
Organic matter, % DM	90.13[c]	90.78[b]	91.39[a]	90.52[B]	90.71[AB]	91.06[A]	0.107	**	*	ns
CP, % DM	12.30[a]	9.89[b]	8.55[c]	10.06	10.26	10.42	0.166	**	ns	ns
NDF, % DM	68.23[c]	70.35[b]	72.41[a]	70.43	70.19	70.37	0.119	**	ns	ns
ADF, % DM	37.37[c]	39.01[b]	39.90[a]	38.85	38.62	38.82	0.106	**	ns	ns
Cellulose, % DM	34.19[b]	35.25[a]	35.61[a]	35.22	34.89	34.95	0.096	**	ns	ns
Hemicellulose, % DM	30.85[b]	31.34[b]	32.51[a]	31.58	31.57	31.55	0.15	**	ns	ns
Lignin, % DM	3.18[c]	3.76[b]	4.29[a]	3.63	3.73	3.87	0.069	**	ns	ns
IVDMD, % DM	64.48[a]	59.80[b]	56.75[c]	60.4	60.41	60.22	0.254	**	ns	ns
Stem										
DM, % forage	23.87[b]	24.87[ab]	25.27[a]	23.85	24.12	23.19	0.057	**	ns	ns
Organic matter, % DM	89.90[c]	91.53[b]	93.40[a]	91.30[B]	91.47[AB]	92.05[A]	0.170	**	*	ns
CP, % DM	6.46[a]	4.34[b]	2.73[c]	4.39	4.44	4.69	0.131	**	ns	ns
NDF, % DM	71.74[c]	74.71[b]	79.18[a]	75.17	75.1	75.36	0.164	**	ns	ns
ADF, % DM	43.49[c]	47.48[b]	52.99[a]	47.86	47.89	48.21	0.230	**	ns	ns
Cellulose, % DM	38.11[c]	40.39[b]	43.92[a]	40.78	40.72	40.91	0.162	**	ns	ns
Hemicellulose, % DM	28.25[a]	27.23[b]	26.19[c]	27.3	27.21	27.15	0.222	**	ns	ns
Lignin, % DM	5.39[c]	7.10[b]	9.07[a]	7.08	7.17	7.30	0.089	**	ns	ns
IVDMD, % DM	59.60[a]	52.52[b]	44.20[c]	52.17	52.3	51.85	0.305	**	ns	ns

Note: Means in the same row with different superscripts differ significantly (p<0.05). Averages followed by different letters indicate significant differences by the Tukey test at 5% probability. Capital letters represent differences between nitrogen doses and lowercase letters represent differences between cutting ages. SEM= standard error of mean; DM= dry matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; IVDMD= *in vitro* dry matter digestibility; A= age; D= dose. ns= non-significant; * = (p<0.05); ** = (p<0.01).

The evaluation of the effect of cutting age and N application on the total nutrient production and the interactions (p<0.05) of both factors, were observed on the production of CP, cellulose, hemicellulose, and lignin (Figure 3). The highest CP yields (in kg/ha/year) were observed for the 60- and 90-days old grass fertilized with 200 kg N/ha/year, followed by the 60- and 90-days old grass with 100 kg N/ha/year. The least CP production was observed for the grass aged 120 days and without nitrogen fertilization. In comparing the least effective and best treatments, an average increase in annual CP production of 3,160 kg/ha/year was observed, i.e., an increase of 146.5% in CP production.

The production of lignin and hemicellulose was higher in plants aged 120 days and fertilized with 100 or 200 kg of N/ha/year. The lowest production of lignin and hemicellulose was in the 60 days old grass that did not receive nitrogen fertilization. A contrasting behavior was observed for cellulose production, which was similar for 90- and 120-days old grasses, regardless of the type of nitrogen fertilization adopted.

Plants managed with intervals between cuts of 120 days provided the highest yields of NDF and ADF per hectare/year. The yields of NDF and ADF were on average 56.3% and 71.1% higher in plants aged 120 days compared to plants aged 60 days, respectively, with intermediate productions for plants aged 90 days. For digestible dry matter (DMD) production, no difference was observed between the 90- and 120-days old grass, with the 60 days old grass presenting the lowest values

Table 3. Chemical composition and *in vitro* digestibility of dry matter (%, whole plant) and annual nutrient production (kg/ha) of BRS Capiaçu at different cutting ages (60, 90, and 120 days) and different levels of N applied (0, 100, and 200 kg N/ha)

Variables	Age (days)			Dose (kg N /ha)			SEM	P value		
	60	90	120	0	100	200		A	D	A*D
%, DM										
DM, % forage	19.50^{a}	22.80^{b}	26.44^{c}	22.07	23.36	23.31	0.343	**	ns	ns
Organic matter, % DM	90.34^{c}	91.46^{b}	92.75^{a}	91.22^{B}	91.44^{AB}	91.89^{A}	0.136	**	*	ns
CP, % DM	8.98^{a}	7.27^{b}	4.52^{c}	6.73	6.93	7.1	0.124	**	ns	ns
NDF, % DM	67.33^{c}	72.80^{b}	77.05^{a}	72.43	72.25	72.49	0.131	**	ns	ns
ADF, % DM	39.35^{c}	43.45^{b}	49.13^{a}	44.02	43.78	44.13	0.173	**	ns	ns
Cellulose, % DM	35.08^{c}	37.95^{b}	41.46^{a}	38.27	38.02	38.2	0.113	**	ns	ns
Hemicellulose, % DM	27.98^{b}	29.35^{a}	27.92^{b}	28.42	28.46	28.37	0.179	**	ns	ns
Lignin, % DM	4.27^{c}	5.50^{b}	7.68^{a}	5.75	5.77	5.93	0.078	**	ns	ns
IVDMD, % DM	59.43^{a}	55.72^{b}	47.98^{c}	54.37	54.55	54.22	0.226	**	ns	ns
kg/ha										
Organic matter	44,525^{c}	51,679^{b}	62,671^{a}	36,825^{B}	59,047^{A}	63,002^{A}	1,959.2	*	**	ns
NDF	33,156^{c}	41,112^{b}	52,045^{a}	29,366^{C}	46,967^{B}	49,979^{A}	877.9	**	*	ns
ADF	19,376^{c}	24,555^{b}	33,164^{a}	17,943^{B}	28,602^{A}	30,551^{A}	738.3	**	*	ns
DMD	29,290^{b}	31,464^{a}	32,382^{a}	21,699^{C}	34,674^{B}	36,763^{A}	523.1	*	*	ns

Note: Means in the same row with different superscripts differ significantly (p<0.05). Averages followed by different letters indicate significant differences by the Tukey test at 5% probability. Capital letters represent differences between doses of nitrogen and lowercase letters represent differences between cutting ages, SEM= standard error of mean; DM= dry matter; N= natural matter; CP= crude protein; NDF= neutral detergent fibre; ADF= acid detergent fibre; IVDMD= *in vitro* dry matter digestibility; DMD= digestible dry matter; A= age; D= dose. ns= non-significant; * = (p<0.05); ** = (p<0.01).

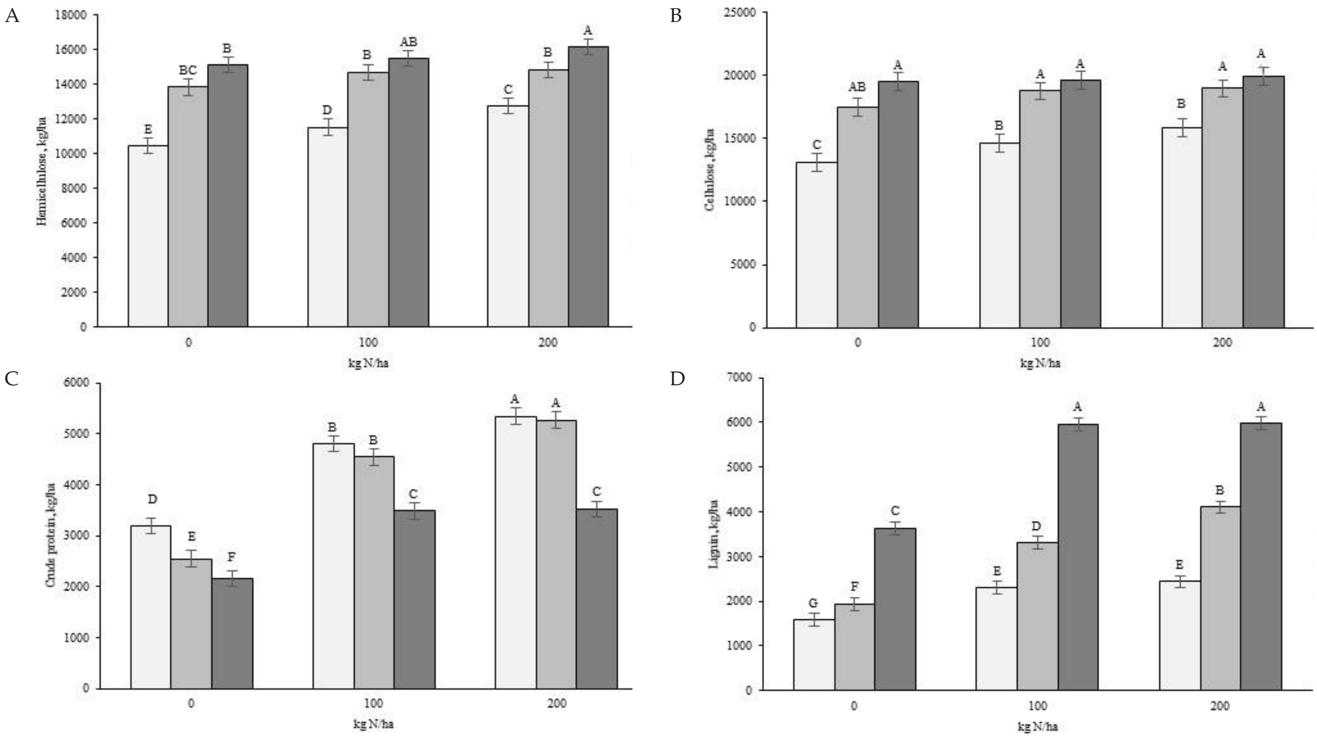

Figure 3. Annual production (kg/ha) of cellulose (A), hemicellulose (B), crude protein (C), and lignin (D) of BRS Capiaçu at different cutting ages (60, 90, and 120 days, □60 ■90 ■120) and different levels of N applied (0, 100, and 200 kg N/ha). Bars indicated by different letters indicate significant differences by the Tukey test at 5% probability.

for this parameter. The fertilization favored the increase in NDF, ADF, and DMD production, especially in the treatment that received the highest doses of nitrogen. The production of DMD of plants that received 200 kg of N/ha, was 5.86 and 69.20% higher than that of plants that received 100 N/ha and no fertilization, respectively.

There were interaction effects (p<0.05) between cutting age and N application on EUAN (Figure 4). Although fertilization with 200 kg N/ha showed, in general, the highest yields of plants and nutrients per hectare, this treatment showed lower efficiency of N use applied, regardless of plant age (Figure 4). Based on a

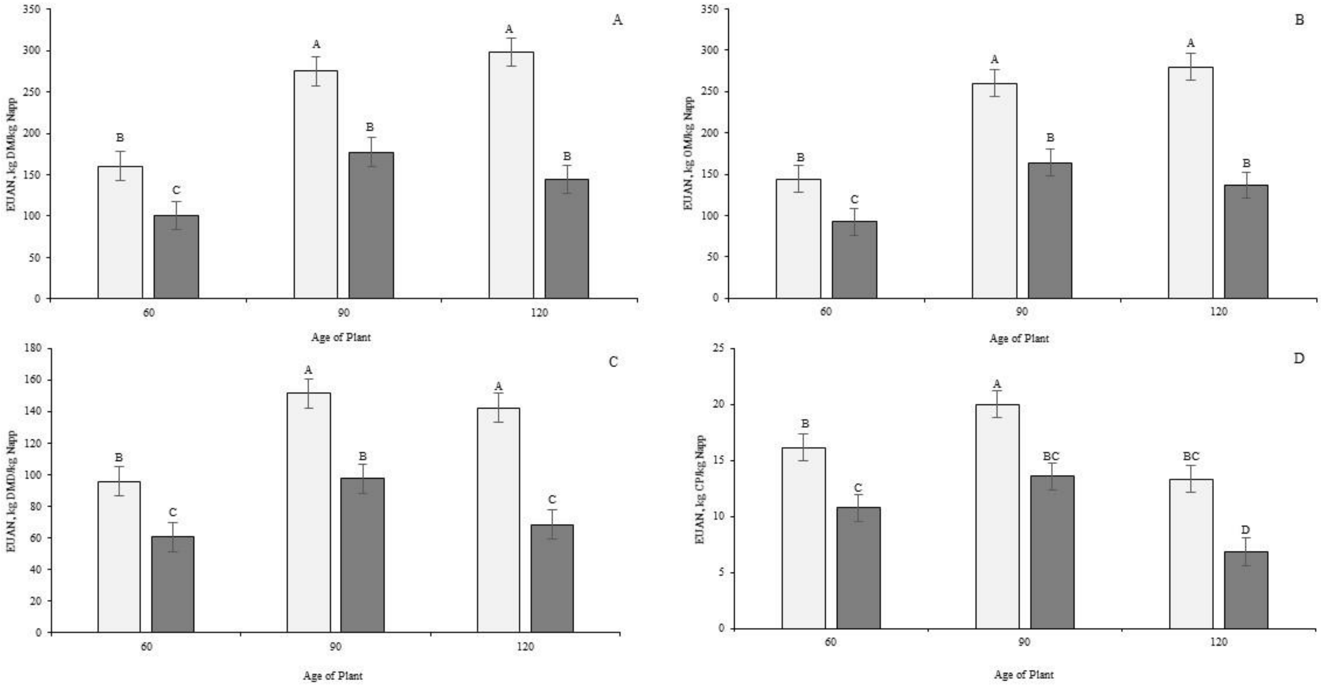

Figure 3. Utilization efficiency of applied nitrogen (EUAN) for yields of dry matter (A: p<0.01 and SEM = 17.19), organic matter (B: p<0.01 and SEM = 15.89), digestible dry matter (C: p<0.01 and SEM = 9.23), and crude protein (D: p<0.01 and SEM = 1.21) of BRS Capiaçu at different cutting ages (60, 90, and 120 days) and different levels of N applied (0, 100, and 200 kg N/ha). Bars indicated by different letters indicate significant differences by the Tukey test at 5% probability. ▭= 100 kg N; ■= 200 kg N.

comparison of the efficiency of utilization of applied nitrogen, it can be seen that the grass at 90 days of age and that received the application of 100 kg of N/ha was the one that had the highest values of EUAN for production of DM, SW, CP, and DMD (in kg/ha/year). Regardless of the plant age, the utilization of nitrogen applied for the production of DM, CP, and DMD (in kg/ha/year) was on average 71.37%, 72.26%, and 58.63% higher for the dose of 100 kg N/ha/year when compared to the dose of 200 kg N/ha/year.

DISCUSSION

The BRS Capiaçu is an elephant grass cultivar with high biomass production per hectare. This study showed that the use of nitrogen fertilizer and adequate soil conditions could increase the production of this cultivar. Initial studies with this cultivar showed an average biomass production of 49.75 tons DM/ha/year (Pereira *et al.*, 2017), approximately 64% of the product obtained in this study.

Corroborating the present study, Monção *et al.* (2020) obtained an average of 72 tons DM/ha/year when applying a dose of 30 kg N/ha/year (50 kg/ha/cut of the formula 20-00-20 of N-P-K), showing that nitrogen fertilization favors the growth of BRS Capiaçu. It is likely that BRS Capiaçu can be more demanding in nutrients than the cultivars used in its development because Flores *et al.* (2012) observed no effect of nitrogen fertilization on the productivity of the elephant grass cultivars Paraíso and Roxo (Roxo cultivar involved in the crossbreeding that gave rise to BRS Capiaçu).

The variation in results observed in the literature between biomass production and nitrogen doses can be explained by the capacity of some elephant grass cultivars to fix atmospheric nitrogen (BNF). According to Morais *et al.* (2012), the BNF dependence of elephant grass varies with the type of soil and genotype and may reach up to 50% of the N needs of elephant grass. According to these authors, the presence of N_2-fixing bacteria of the genus *Herbaspirillum* spp. reinforces the possibility that biological nitrogen fixation is an important process for the survival and productivity of this forage species. The occurrence of BNF may explain the low need for nitrogen fertilizer in terms of efficiency of N use (kg DM grass/kg N applied) of elephant grass cultivars compared to other forage grass species (Oliveira *et al.*, 2014).

Although N directly participates in synthesizing the primary organic compounds necessary for plant growth and development (Orrico Junior *et al.*, 2012; Vasconcelos *et al.*, 2020), no increase in canopy height was observed with the use of N fertilizer. Likely, the greater availability of N in the soil in treatments with 100 and 200 kg N/ha provided a greater number of plants/m^2 (more intense tillering) or greater weight of DM/plant. This would explain the increase in biomass production without any increase in plant height in the canopy. Bueno *et al.* (2020), when evaluating increasing doses of nitrogen (0, 50, 100, 150, and 200 kg/ha/year) in fertilization of elephant grass, also observed no changes in plant height in the second year of evaluation. However, the plants showed higher values of individual weight and a greater number of tillers per area.

The results of biomass production by morphological component showed that BRS Capiaçu had a peak in the production and proportion of leaves at 90 days of plant age, after which there was a significant decrease in the production. The decrease in leaf production observed may be linked to the natural process of leaf senescence, in which the oldest leaves initiate the process of cell death, directing part of their nutrients to other parts of the plant (the drainage organs) that are in the development phase (Avila-Ospina *et al.,* 2014).

In this case, the stem was the plant fraction that had the greatest development as the plant age increased. According to Pereira *et al.* (2017), BRS Capiaçu can reach 4.2 m in height and a stem diameter of 1.6 cm, requiring a large deposition of fibrous (lignified) support tissues to maintain the plant structure. This explains the high production of stems observed in this experiment for 120-days old grass and with the use of nitrogen fertilizer.

The high leaf to stem ratio is generally used as an indicator of the nutritional value of grass because leaves have high proportions of mesophyll cells, which are more digestible than lignified stems, rich in parenchyma cells, and mainly of chlorophyll compounds (Taiz *et al.,* 2017; Adesogan *et al.,* 2019). In addition, the digestibility of the plant is also dependent on its stage of development. At the early developmental stage, the primary cell wall of plants is composed of cellulose, arabinoxylans, xyloglucans, mixed-linked glucans, pectin, proteins, and ferulic p-coumaric acids in grasses and lignin deposition is very limited during this early stage (Taiz *et al.,* 2017). The secondary phase of cell wall development begins after the mature plant cell reaches its final size and the secondary cell walls are deposited (Taiz *et al.,* 2017). During this phase, lignin deposition intensifies in the primary wall region of the middle lamella, which is the least digestible portion (Taiz *et al.,* 2017). Both in this study and Monção *et al.* (2020), increases in lignin levels led to a significant reduction in the digestibility of DM, leading to more intense drops in the quality of BRS Capiaçu, especially after 90 days of plant age.

The lower OM contents in the younger grasses may be related to the low cutting height of the grass (5 cm from the ground). According to Diehl *et al.* (2014), with a lower height of forest canopy, the proportion of soil particles that can be adhered to the plants and that end up being quantified as mineral matter can be higher. Thus, due to the dilution effect, there is an increase in the OM content when biomass production increases (effect of age and fertilization). Another explanation for this would be a greater synthesis of organic tissues due to the maturity of the plants and/or the availability of nutrients (nitrogen fertilization), leading to a reduction in the proportion of mineral matter in the final composition of the plant (Ullah *et al.,* 2010).

The decrease in the nutritional value of the plants after 90 days of age was reflected in the total production of CP/ha. The plants that were 120 days old had the lowest CP/ha, regardless of fertilization. The low levels of CP observed in the 120-day-old plants (4.52% CP) require greater participation of protein concentrates in the formulation of animal diets, which results in high feed costs (Adesogan *et al.,* 2004).

The balance between the production of DM and the nutritional quality of the grass is certainly the most interesting option for efficient plant management. In the case of this experiment, the production of nutrients/ha was superior for most of the parameters evaluated for fertilization with 200 kg N/ha/year. However, when comparing the efficiency of utilization of applied nitrogen, the dose of 100 kg N/ha/year associated with 90 days old grass was the treatment that presented the best results. This is the most appropriate option when seeking greater efficiency of the system.

Similar results were obtained by Bueno *et al.* (2020), who also reported that the dose of 100 kg/ha/year showed greater efficiency of utilization of applied N when compared to doses of 150 and 200 kg/ha/year. These results may indicate that the biological fixation of nitrogen common in some cultivars of elephant grass (Morais *et al.,* 2012) may also have played a role in this experiment, thus reducing the need for large amounts of nitrogen via mineral fertilization. Another justification for the greater efficiency of N use applied at a dose of 100 kg N/ha/year may be linked to the theory of Mitscherlich's law, or the theory of decreasing increments. The theory states that increases in crop production tend to reduce as the dose of a particular nutrient increases, i.e., there are no proportional increases between plant production and the amount of N applied (Pilbeam, 2011).

CONCLUSION

The cutting of BRS Capiaçu at 90 days of age with an N application of 100 kg/ha/year proved to be the best treatment tested because it was the one that showed the best balance between biomass production, nutritional quality, nutrient production in kg/ha, and efficiency of N applied.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

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