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Yield, chemical composition, and efficiency of utilization of applied nitrogen from BRS Kurumi pastures

Joyce Pereira Alves[1] Sanayra Silva Mendes[1] Edgar Salvador Jara Galeano[1] Marco Antonio Previdelli Orrico Junior[1*] Tatiane Fernandes[2] Marciana Retore[3] Ana Carolina Amorim Orrico[1] Lucas Silva Lopes[1]

[1]Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados (UFGD), 79804-970, Dourados, MS, Brasil. E-mail: marcojunior@ufgd.edu.br.
[*]Corresponding author.
[2]Faculdade de Veterinária, Universidade de Lisboa (ULisboa), Lisboa, Portugal.
[3]Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Agropecuária Oeste, Dourados, MS, Brasil.

ABSTRACT: *The objective was to evaluate the effect of nitrogen fertilization levels on productivity, and nutritional value of BRS Kurumi managed at different residue heights during rainy and dry periods of the year. The pasture was managed in three residue heights (20, 35, and 50 cm) and three nitrogen fertilization levels (0, 100, and 200 kg N/ha/year) during the rainy and dry seasons. When the height of the grass of each plot reached 80 cm, the Kurumi was cut manually at the pre-established residue heights. Around 89% of the dry matter (DM) production was observed during the rainy season. The residue height of 35 cm together with doses of 100 or 200 kg N/ha/year, and the residue height of 20 cm, with a dose of 100 kg N/ha/year were the treatments that had the highest DM production during the rainy period. No differences in DM production were observed between tested treatments during the dry period. The Kurumi cultivated during the dry period had the highest content of neutral detergent fiber and lowest digestibility. The Kurumi managed with residue heights of 20 and 35 cm and fertilized with 100 kg N/ha had the highest values of efficiency of utilization applied nitrogen. The use of 20 or 35 cm of residue height and 100 kg of N/ha/year is recommended to obtain greater biomass production and nutrients, nutritional quality, and nitrogen use efficiency.*
Key words: *dwarf elephant grass, nitrogen fertilization, pasture structure, residue height, season.*

Produção, composição química e eficiência da utilização de nitogênio aplicado de pastagens de BRS Kurumi

RESUMO: *O objetivo foi avaliar o efeito dos níveis de fertilização nitrogenada na produtividade e no valor nutritivo do BRS Kurumi quando manejado em diferentes alturas de resíduos durante os períodos seco e chuvoso do ano. O capim foi manejado em três alturas de resíduos (20, 35 e 50 cm) em associação com três níveis de fertilização com nitrogênio (0, 100 e 200 kg N/ha/ ano), durante o período seco e chuvoso do ano. Quando a altura do capim de cada parcela atingiu 80 cm, o Kurumi foi cortado nas alturas de resíduos pré-estabelecidas. Cerca de 89% da produção de MS foi observada durante o período chuvoso. A altura do resíduo de 35 cm juntamente com doses de 100 ou 200 kg N/ ha/ ano, e a altura do resíduo de 20 cm, com dose de 100 kg N/ha/ ano foram os tratamentos que apresentaram maior produção de MS durante o período chuvoso. Não foram observadas diferenças na produção de MS entre os tratamentos testados durante o período da seca. O Kurumi cultivado no período da seca apresentou maior teor de fibra em detergente neutro e menor digestibilidade. O Kurumi manejado com alturas de resíduo de 20 e 35 cm e fertilizado com 100 kg N/ha apresentou os maiores valores de eficiência de utilização do nitrogênio aplicado. Recomenda-se a utilização de 20 ou 35 cm de altura do resíduo e 100 kg de N/ha/ ano para obter maior produção de biomassa e nutrientes, qualidade nutricional e eficiência no uso do nitrogênio.*
Palavras-chave: *capim elefante anão, adubação nitrogenada, estrutura do dossel, altura do resíduo, estação do ano.*

INTRODUCTION

The efficient use of pasture represents one of the most effective ways to improve animal productivity and reduce feed costs. In 2012, Embrapa released BRS Kurumi, a dwarf cultivar of *Pennisetum purpureum*, which is recommended for grazing and has a small size (compared to other species of elephant grass) and a high proportion of leaves and great nutritional value (PEREIRA et al. 2017). However, studies evaluating the most appropriate defoliation and fertilization strategies for this cultivar are limited.

According to GOMIDE et al. (2015), the residue height is one of the main factors for grazing

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management because when this is too low, there is a reduction in the regrowth vigor, resulting in a longer time for the reestablishment of the pasture. However, high residue height can lead to a reduced growth rate of grasses and a decrease in the daily forage accumulation (GOMIDE et al. 2015).

CHAVES et al. (2013), analyzing BRS Kurumi under two heights of post-grazing residue (30 and 50 cm), did not observe differences for most of the parameters evaluated. According to these authors, only a slight superiority in forage accumulation rate was observed for the post-grazing residue height of 30 cm. Thus, there is little scientific evidence to recommend a specific residue height for the management of BRS Kurumi pasture.

Nitrogen fertilization can significantly alter residue height recommendations because the availability of nitrogen influences plant growth and development (LOBO et al. 2014). According to SALES et al. (2014) plants fertilized with higher N doses can have their height of post-grazing residue reduced without affecting their regrowth rate.

Because it is a cultivar used exclusively for grazing, the studies published so far on BRS Kurumi have focused on the evaluation of the grass during the rainy season (CHAVES et al. 2013; FERNANDES et al. 2016; PEREIRA et al. 2017), leaving open the possible variations that might occur in the management of this plant when subjected to conditions of limited rainfall, temperature, and light, which are characteristic of autumn-winter in tropical regions. In an experiment carried out in southern Brazil (Santa Rosa do Sul-RS) with several elephant grass cultivars and adopting residue heights of 50 cm, ARBOITTE et al. (2019) observed that BRS Kurumi was the cultivar that accumulated the least dry matter (DM) (683 kg DM/ha) between May and August. This low forage production may indicate that BRS Kurumi experiences strong interference from the seasons on its productive performance.

The present study was to verified the effect of residue heights (20, 35, and 50 cm) and nitrogen fertilization levels (0, 100, and 200 kg N/ha/year) on productivity, nutritional value, and efficiency of nitrogen use of BRS Kurum, during rainy and dry periods. The present study tested the following hypotheses: i) When the BRS Kurumi is managed with higher amounts of nitrogen its residue height can be decreased without affecting the productivity of the plant; ii) residue height of 50 cm results in a lower total production of biomass and nutrients than residue heights of 20 and 35 cm; and iii) BRS Kurumi productivity is strongly influenced by the climatic conditions throughout the year.

MATERIALS AND METHODS

The research was conducted at experimental area of Embrapa Agropecuária Oeste, in the municipality of Dourados, MS, Brazil (22° 11′ S, 54° 56′ W, and 452 m above sea level). The climate of the region is humid mesothermal (Cwa), with hot summers and dry winters (FIETZ & FISCH, 2008). The meteorological data observed during the experiment are presented in figure 1.

The soil of the experimental area is classified as dark red distroferric Latosol of very clayey texture (SANTOS et al. 2018). The soil had the following characteristics: sand, 87.7g/kg; silt, 183.3g/kg; clay, 728.9g/kg; pH in $CaCl_2$, 5.1; P, 29.3 mg/dm^3; K, 0.5 cmolc/dm^3; Ca^{+2}, 3.3 cmolc/dm^3; Mg^{+2}, 0.7 cmolc/dm^3; $H^+ + Al^{+3}$, 3.2 cmolc/dm^3; base sum, 4.6 cmolc/dm^3; cation exchange capacity, 7.8 cmolc/dm^3; MO, 16.7 g/kg; and base saturation, 58.8%.

For planting, BRS Kurumi seedlings were used at 60 days of age with two to three internodes. Planting of the BRS Kurumi grass was performed on April 12, 2017, in pits 10 cm deep and with 0.5 m distance between the pits. Two elephant grass seedlings were used in each pit that were covered with soil and slightly compacted to favor the emission of tillers. The area was divided into 36 experimental plots, measuring 3 × 3 m each, with 1 m between the experimental plots.

The experiment was conducted in a randomized block design in a factorial scheme with subdivided plots. The effects of three residue heights (20, 35, and 50 cm) and three nitrogen fertilizer levels (0, 100, and 200 kg N/ha/year) were evaluated in the plots and the two seasonal periods of the year (rainy and dry) were analyzed in the subplots. Four plots were analyzed per treatment (k), totaling 36 experimental units. The rainy period was from September 15, 2017 to March 15, 2018 and the dry period was from March 16, 2018 to September 14, 2018. The nitrogen fertilizers were distributed on the soil surface without incorporation. The doses applied followed the recommended treatments and were divided into three periods: October 2017, January 2018, and March 2018, using protected urea (FH Nitro Mais ™ Heringer) as the N source.

On August 21, 2017, the grass was uniformly cut 5 cm from the ground, initiating the evaluation period. When the height of the grass of each plot reached 80 cm (the height at which BRS Kurumi presents its best mass accumulation; (GOMIDE et al. 2015)), the grass was cut at the pre-established residue heights (20, 35, or 50 cm). Monitoring of the plot heights was undertaken weekly

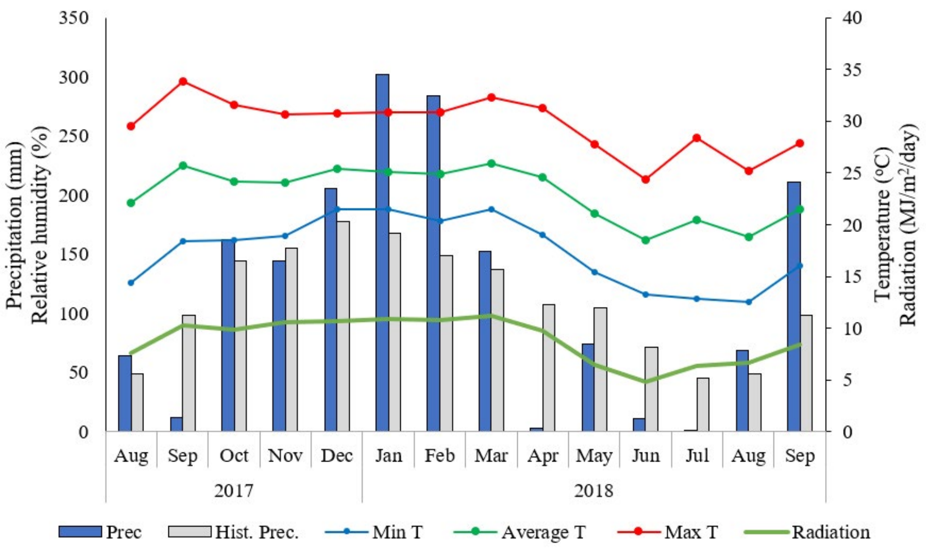

Figure 1 - Average (average T), maximum (Max T), and minimum (Min T) air temperature, precipitation (Prec.), historical precipitation (Hist. Prec. 1979-2021), and radiation verified during the experimental period.

using a graduated ruler, with three readings within the useful area of each plot. At the time of cutting, the plants were collected within a 0.25 m^2 metal square, and three samples were collected within each plot. The collected material was sent to the laboratory to determine the biomass of fresh forage.

A sample of approximately 300 g of fresh forage from each plot was sent for pre-drying in a forced circulation oven at 55 °C for 72 h. The pre-dried samples were ground in a Willey mill with a 1mm sieve. The dry matter (DM) and organic matter (OM; method 942.05) contents were determined according to AOAC (2005). Crude protein (CP; method 990.03) was determined by the Dumas combustion method using an automatic elemental analyzer (Elementar® model Vario MACRO Cube) according to the AOAC (2005) methodology. The neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents were analyzed according to the protocols suggested by (MERTENS, 2002). *In vitro* dry matter digestibility (IVDMD) was determined according to the methodology described by (TILLEY & TERRY, 1963).

The calculation of yield/ha/year (of each DM fraction) was undertaken by multiplying the total DM yields by the respective nutrient contents in the forage. The efficiency of utilization of applied nitrogen (EUAN; kg/kg N) was calculated for DM production, OM production, CP production, and digestible DM production using the following formula:

$$EUAN = \frac{(P - Pc)}{Napp}$$

Where: P = production of DM or DM fraction in the treatment that received fertilization (kg); Pc = production of DM or nutrients in the treatment that did not receive fertilization (kg); Napp. = nitrogen dose applied in the area (kg).

The effects of residue heights, nitrogen fertilization, cutting periods, and the interaction of these factors on the response variables were evaluated by analysis of variance (F test). When the interaction of factors was significant ($\alpha \leq 0.05$), the combinations of factors were read separately for the analysis. For non-significant interactions, the factors were analyzed using main factor analysis.

Data were analyzed using the statistical program RStudio, version 3.6.0. The means were compared by the Scott Knott test, with a significance level of 5%.

The data of productive and nutritional aspects of BRS Kurumi, in the different seasons, were analyzed according to the following model:

$$Yijkl = \mu + \gamma k + \alpha i + \delta i + (\alpha\delta)_{ij} + \varepsilon ijk + \beta l + (\alpha\beta)_{il} + (\delta\beta)_{jl} + (\alpha\delta\beta)_{ijl} + \varepsilon ijk$$

Where, Yijkl = the dependent variable, μ = the overall mean; γk = the block effect (random effect; k = 1, 2, 3, and 4); αi = the effect of the residue height (fixed effect; i = 20, 35, and 50); δi = the effect of nitrogen fertilization (fixed effect; j = 0, 100, and 200 kg N/ha/year); $(\alpha\delta)_{ij =}$ the interaction effect of the residue height and nitrogen fertilization; εijk = the random error of block, residue height, and nitrogen fertilization; βl = the effect period of the year, in the subplot (fixed effect; l = rainy and dry); $(\alpha\beta)_{il}$ = the interaction effect of residue height and period of year; $(\delta\beta)_{i}$ = the interaction effect of nitrogen fertilization and period of year; $(\alpha\delta\beta)_{ijl =}$ the interaction effect of the residue height, nitrogen fertilization, and period of year; and εijkl = the random error, including subplot, with mean zero, variance X, independent, and with normal distribution.

The annual data of productive, nutritional, and EUAN aspects of BRS Kurumi were analyzed according to the following model:

$$Yijk = \mu + \gamma k + \alpha i + \delta i + (\alpha\delta)_{ij\,+}\ \varepsilon ijk,$$

Where, Yijk = the dependent variable, μ = the overall mean; γk = the block effect (random effect; k = 1, 2, 3, and 4); αi = the effect of residue height (fixed effect; i = 20, 35, and 50); δik = the effect of nitrogen fertilization (fixed effect; j = 0, 100, and 200 kg N/ha/year); $(\alpha\delta)_{ij}$ = the effect of the interaction of residue height and nitrogen fertilization; and εijk = the random error, with mean zero, variance X, independent, and with normal distribution.

RESULTS AND DISCUSSION

The seasonal periods of the year interfered in the productive responses of BRS Kurumi regarding the doses of nitrogen and heights of residue tested (Figure 2 and Table 1). Tropical grasses show low productive performance during the dry period (autumn and winter), and this productive seasonality is more evident in the south-central region of Brazil (ARAUJO et al. 2018; ORRICO JUNIOR et al. 2012; ORRICO JUNIOR et al. 2013). The decrease in biomass production during the dry period is due to the low air temperature and rainfall, and shorter photoperiod, which are characteristics of the dry period (Figure 1).

Only 11% of all biomass production of BRS Kurumi was produced during the dry season, no being observed influence of the tested treatments on the biomass production in this period. These results showed that the BRS Kurumi is strongly influenced by the seasons compared to other elephant grass cultivars. Different results were reported by VITOR et al. (2009) and FERNANDES et al. (2016), who observed biomass productions greater than 20% of annual production during the dry period for Napier and CNPGL 00-1-3 elephant grass, respectively. MONÇÃO et al. (2020) observed for *Pennisetum purpureum* BRS Capiaçu yields greater than 30% of the annual biomass production during the dry period. These data demonstrated that BRS Kurumi should be grazed with caution during the dry period because an overload of animals during this period could lead to greater degradation of the pasture.

The number of cuts performed for grasses managed with residue heights of 20, 35, and 50 cm

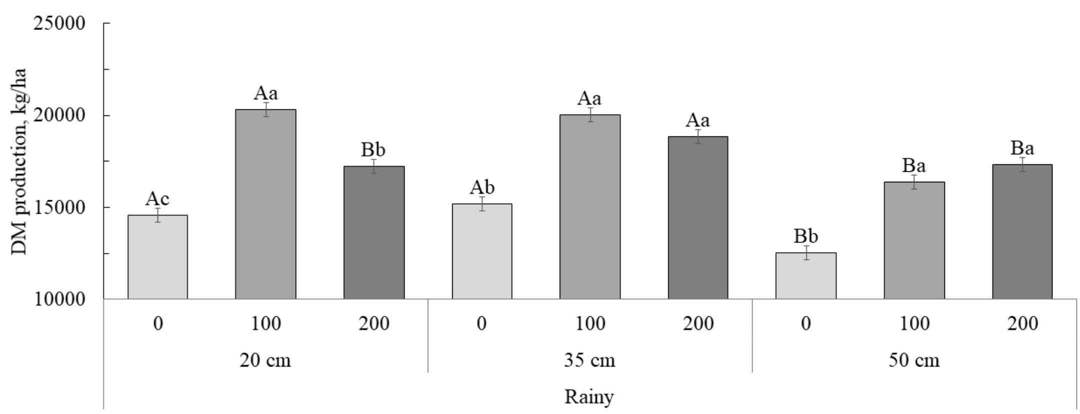

Figure 2 - Biomass production (DM, kg/ha) of BRS Kurumi managed with different residue heights and nitrogen fertilizers (kg/ha/year) during the rainy season. There was no significance in dry period (Mean=2058 kg/ha). Averages followed by different uppercase letters differed for residue heights, by lowercase letters differed for nitrogen fertilizers, according to Scott Knott test at 5% probability.

Table 1 - Dry matter productivity, chemical composition, and *in vitro* dry matter digestibility of BRS Kurumi managed with different residue heights (cm) and nitrogen fertilization (kg/ha/year) during the rainy and dry periods.

Parameter		Production	DM	OM	CP	NDF	ADF	IVDMD
		kg DM/ha	% NM					
Period	Rainy	16,940	11.91	85.48	16.04	58.85	22.51	80.7
	Dry	2,058	14.52	87.04	12.06	61.35	22.97	78.99
Height	20	9,908	12.74b	85.64b	13.64	59.73	22.66	79.9
	35	10,034	13.21a	86.32a	14.22	60.18	23.08	79.63
	50	8,554	13.70a	86.82a	14.29	60.38	22.48	80
Dose	0	7,813	12.93	86.31A	14.06	60.29	23.48A	79.93
	100	10,624	13.11	85.83B	14.36	59.72	22.29B	80
	200	10,059	13.61	86.64A	13.73	60.28	22.45B	79.6
SEM		19	0.263	0.234	0.285	0.387	0.239	0.469
P value	L	**	**	**	**	**	ns	**
	H	**	*	**	ns	ns	ns	ns
	D	**	ns	ns	ns	ns	**	ns
	L*H	**	ns	ns	ns	ns	ns	ns
	L*D	**	ns	ns	ns	ns	ns	ns
	H*D	ns	ns	ns	*	ns	**	ns
	L*H*D	**	ns	ns	ns	ns	ns	ns

Averages followed by different letters differ by the Scott Knott test at 5% probability. Capital letters represent differences between nitrogen doses and lowercase letters represent differences between cutting heights. SEM = standard error of mean; DM = dry matter; NM = natural matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; IVDMD = *in vitro* dry matter digestibility; L = period; H = height; D = nitrogen fertilizer dose; ns = non-significant; * significant at 5% probability; ** = significant at 1% probability.

were: 7, 8, 8 for grasses fertilized with a dose of 0 kg N/ha/year, 11, 12, 12 for grasses fertilized with the dose 100 kg N/ha/year and 14, 15, 15 for grasses fertilized with the dose 200 kg N/ha/year, respectively. The incorporation of macronutrients, especially nitrogen, allowed the increase of vegetative growth, by stimulating the growth of young leaves, with a higher number of leaves, the amount of chlorophyll absorbed by the leaves is also high so that can increase the growth speed. The same number of cuts for the residue heights of 35 and 50 cm is due to the re-growth capacity of elephant grasses, which is more dependent on the organic reserves than the residual leaf area (SILVA et al., 2021). Also, because BRS Kurumi has higher dry matter production of leaves, as well as more axillary and basal tillers (PEREIRA et al., 2017).

The treatments with a residue height of 35 cm that received doses of 100 or 200 kg N/ha/year, and the treatment with a residue height of 20 cm that received a dose of 100 kg N/ha/year had the highest biomass production. Probably, these results could be linked with the higher incidence of light in the basal portion of the canopy, which stimulates tillering when the grass is cut at lower residue heights (LOBO et al., 2014). These results corroborated the research of PACIULLO et al. (2015), who observed a lower rate of stem elongation and a high volumetric density of leaf blades when BRS Kurumi was managed at lower residue heights.

Although, lower than the other treatments tested, the average biomass production observed for the 0 kgN/ha/ano dose can be considered high (15,626 kg DM/ha/year) even more because it did not has received nitrogen fertilization and was planted in a soil with low OM content (16.74 g/kg). This result might be explained by the ability of some cultivars of elephant grass to perform biological fixation of atmospheric nitrogen (BNF) (OLIVEIRA et al. 2014). According to MORAIS et al. (2012), the BNF dependence of elephant grass might vary depending on the type of soil and genotype and can reach up to 50% of the N requirements of this grass. According to these authors, the presence of N_2-fixing bacteria of the genus *Herbaspirillum spp*. reinforces the possibility that BNF is an important process for the survival and productivity of elephant grass. BNF occurrence may explain the smaller nitrogen need (kg DM grass/kg N applied) of elephant grass cultivars in comparison to other forage grass species (OLIVEIRA et al. 2014).

The lowest CP content and one of the highest fiber levels (Figure 3) observed for the residue height of 20 cm can be explained by the greater participation of stems in the lower portion of the canopy because the closer to the ground the cut is made, the greater the participation of stems in the portion of the forage collected. This behavior was more evident in the treatments without nitrogen fertilization because the lack of stimulus to leaf development contributed to a reduction in the CP levels. The mean CP values observed in this study were high and consistent with the literature data for BRS Kurumi (PEREIRA et al. 2017)

The higher fiber levels were reported during the rainy period in comparison to the dry period of the year (Table 1). Probably, this had occurred due to increased grass lignification process caused by the higher speed of grass growing during this period (ADESOGAN et al. 2019). Similar results were observed by ANDRADE et al. (2003) when they evaluated the effect of rainy and dry periods on the chemical composition of the Napier cultivar.

No interaction was observed between residue heights and nitrogen fertilizer doses on the annual production of DM, OM, CP, fibers fractions, and DMD (Table 2). The residue heights of 20 and 35 cm showed the highest annual biomass production, which were, on average, 16.56% higher than the biomass production for plants managed at 50 cm residue height. Similar results were obtained in this study for the OM production and the other nutrients evaluated. In addition, the management with residue heights of 20 and 35 cm associated with fertilization of 100 and 200 kg N/ha was essential for producing higher yields of nutrients/ha/year (Table 2).

An interaction was observed between the nitrogen fertilizer doses and tested residue heights on the EUAN values (Figure 4). The dose of 100 kg N/ha/year associated with residue heights of 20 and 35 cm were the treatments that had the best EUAN results, which were the most appropriate options when seeking a balance between nitrogen dose and nutrient production per area. Similar results were obtained by BUENO et al. (2020), where the dose of 100 kg/ha/year showed greater utilization efficiency of the applied N compared to doses of 150 and 200 kg/ha/year.

These results may be another indication that BNF, which occurs in some cultivars of elephant grass (MORAIS et al. 2012), may have occurred in this current study. This might help to explain why the dose of 200 kg N/ha/year did not promote significant improvement in the pasture performance. Another justification for the greater EUAN at the dose of 100 kg N/ha/year may be linked to the Mitscherlich law (decreasing increments), which stated that increases in crop production decrease as the dose of a given nutrient increases, i.e., there are not proportional increases between plant production and the doses of nutrients applied (PILBEAM, 2018).

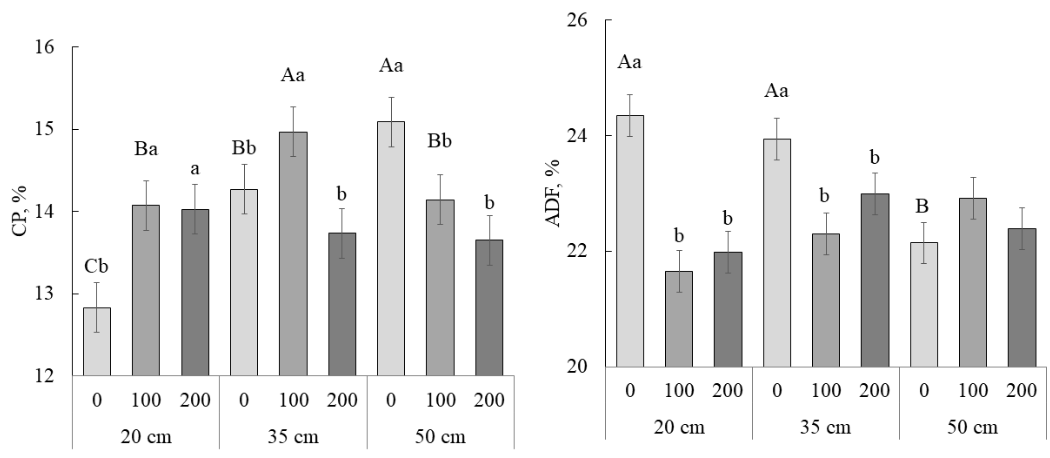

Figure 3 - Effect of the interaction between residue height and nitrogen fertilization (kg/ha/year) on the crude protein (CP) and acid detergent fiber (ADF) content of BRS Kurumi. Averages followed by different uppercase letters differed for residue heights, by lowercase letters differed for nitrogen fertilizers, according to Scott Knott test at 5% probability.

Table 2 - Annual production of dry matter and nutrients (kg/ha) of BRS Kurumi managed with different residue heights (cm) and nitrogen fertilization (kg/ha/year).

Parameter		DM	OM	CP	NDF	ADF	DMD
		---kg/ha---					
Height	20	19,816a	16,855a	2,989a	11,640a	4,406a	15,974a
	35	20,069a	17,193a	3,174a	11,827a	4,550a	16,214a
	50	17,108b	14,752b	2,753b	10,200b	3,871b	13,713b
Dose	0	15,626B	13,384C	2,335B	9,272B	3,606B	12,605C
	100	21,249A	18,140A	3,428A	12,470A	4,669A	17,230A
	200	20,118A	17,266B	3,154A	11,925A	4,552A	16,066B
SEM		379.8	308.1	86.2	232.8	84.1	322.5
P value	H	**	**	**	**	**	**
	D	**	**	**	**	**	**
	A*D	ns	ns	ns	ns	ns	ns

Averages followed by different letters differ by Scott Knott test at 5% probability. Capital letters represent differences between nitrogen doses and lowercase letters represent differences between cutting heights. SEM = standard error of mean; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; DMD = dry matter digestible; H = height; D = nitrogen fertilizer dose; ns = non-significant; ** = significant at 1% probability.

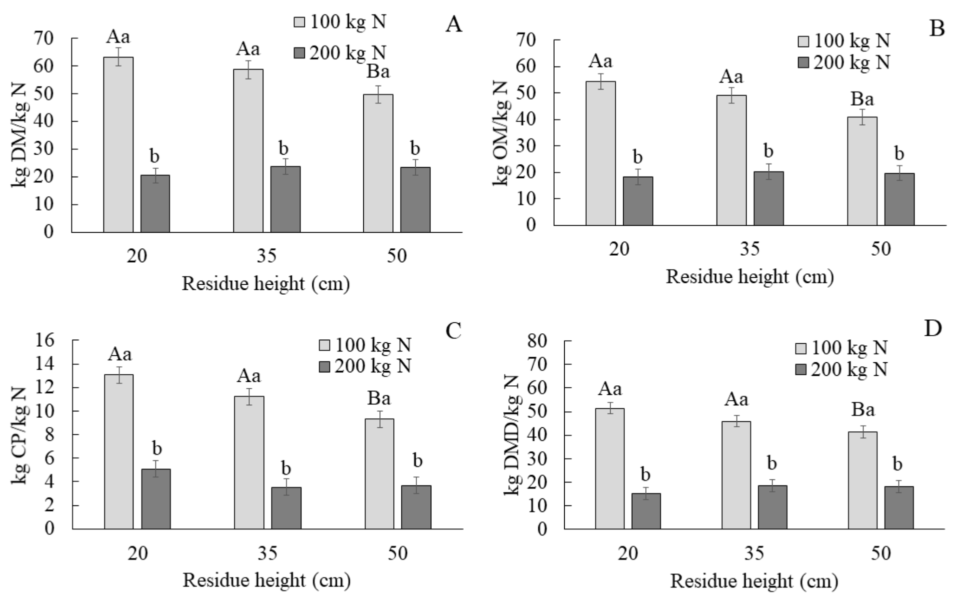

Figure 4 - Utilization efficiency of applied nitrogen (kg/kg N) for dry matter production (A), organic matter production (B), crude protein production (C), and digestible dry matter production (D) of BRS Kurumi managed with different residue heights and nitrogen fertilization (kg/ha/year). Averages followed by different uppercase letters differed for residue heights, by lowercase letters differed for nitrogen fertilizers, according to Scott Knott test at 5% probability.

CONCLUSION

Fertilization with 200 kg N/ha/year do not result in improved production performance of BRS Kurumi, even when managed at the lowest residue height. During the rainy season, the use of 20 or 35 cm of residue height associated with 100 kg of N/ha/year is recommended for obtaining higher biomass and nutrients production, nutritional quality, and efficiency of nitrogen use.

During the dry period, the height of residue and nitrogen fertilization do not interfere with the productive performance of BRS Kurumi, which shows a strong influence of the seasons on this grass cultivar.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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