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Effect of different fertilization protocols and cutting intensity on marandu grass

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Abstract. The present study aimed to investigate the effects of different cutting intensities, combined with different fertilizations, on the productive characteristics, carbohydrate concentration and photosynthetic pigments of *Urochloa brizantha* cv. Marandu. It was carried out in a completely randomized design in which five fertilization treatments were evaluated: a control treatment without fertilizers and four fertilizer combinations (PK; NP; NK; NPK). The cutting intensities tested were 10 and 20 cm in height. There were four replicates per treatment. Plastic pots of 12 liters were used as experimental units, which were filled with 10 dm^3 of soil with a clayey-sandy loam texture. Seeds of *Urochloa brizantha* cv. Marandu, with 80% of cultural value, were used. There was a significant difference for fertilization with NP and NPK, which resulted in higher production of shoot dry mass (PMSPA), residue dry mass (PMSRE) and root dry mass (PMSRA) in addition to higher concentrations of total soluble sugars in the shoot, residue and root. At a cutting intensity of 20 cm, NK and NPK fertilizations provided the highest levels of chlorophyll a. On the other hand, when analysing chlorophyll b and total chlorophyll at an intensity of 10 cm, NK fertilization presented the highest levels. However, at an intensity of 20 cm, NPK fertilization presented the highest levels of chlorophyll b, carotenoids and total chlorophyll. Regarding starch content, the PK and NPK treatments presented lower values at an intensity of 10 cm, while, at an intensity of 20 cm, NK fertilization resulted in the lowest starch content. Given the results presented, it is concluded that the use of NP fertilization at an intensity of 20 cm is recommended because it provides better indices on photosynthetic pigments, productive characteristics and total soluble sugar contents of *Urochloa brizantha* cv. Marandu.

Key words: chemical fertilization, cutting intensity, grasses.

INTRODUCTION

Agribusiness is one of the fastest growing sectors in Brazil, accounting for more than 20% of the country's GDP growth, in which livestock farming plays a major role in job creation (BCA, 2025). Cultivated pastures represent the basis of livestock feed, and the search for more efficient production systems with less environmental impact is crucial to meet the growing demand for meat and other animal products (Horn et al., 2023). Among the various forage species used in Brazil, *Urochloa brizantha* cv. Marandu stands out for its wide adaptation, productivity and nutritional value, being widely cultivated in several regions of the country (Seixas et al., 2023).

Several studies demonstrate the importance of nitrogen (N), phosphorus (P) and potassium (K) fertilization for the growth and development of forage grasses, including *Urochloa brizantha.* However, the dependence on chemical sources of NPK has generated discussions, especially regarding environmental impacts and the sustainability of production systems (Hungria et al., 2016).

Nitrogen emerges as the most limiting macronutrient. This occurs not only due to its low natural availability in the soil and the difficulty of absorption by plants, but also due to its high extraction rate by the crop and its fundamental role in crucial metabolic pathways, such as protein synthesis and the formation of structural organs. Phosphorus and potassium, in turn, are essential for root development, energy metabolism and resistance to stress (Hungria et al., 2016; Cruz et al., 2023; Motta et al., 2024).

Cutting management also has a significant influence on forage production and quality. More frequent cutting intensities can stimulate tillering and vegetative growth, while less severe cutting can result in greater biomass accumulation, but with lower nutritional value (Rodrigues et al., 2019). The interaction between fertilization and cutting management has been the subject of study, seeking to optimize pasture production and persistence (Abreu et al., 2020).

Optimizing forage quality, achieved through proper management and balanced fertilization, directly influences animal performance. For ruminants such as cattle, forage that provides adequate transport of proteins, energy and minerals with greater biomass production is essential. It ensures that animals receive the necessary substrates for essential physiological processes, such as weight gain, milk production and reproduction. In this way, the production of quality forage not only optimizes feed conversion, but also contributes to the health and well-being of animals, reducing the need for external supplementation and making a specific production more efficient and sustainable (Capstaff & Miller 2018).

In view of the above, the present study has the general objective of evaluating the influence of different combinations of N, P and K fertilizers and two cutting intensities of 10 and 20 cm on the production and development of *Urochloa brizantha* cv. Marandu. To achieve this objective, the following specific objectives will be carried out: to measure the impact of different fertilizer combinations (N, P, K) and two intensities on the growth and biomass accumulation of the aerial part of cv. Marandu; to determine the chlorophyll contents; concentration of soluble carbohydrates in the plant tissues; and the amount of starch in the reserve tissues.

MATERIALS AND METHODS

Experimental design

The experiment was carried out at the Universidade Estadual do Sudoeste da Bahia (UESB), Juvino Oliveira Campus, located in the municipality of Itapetinga, Bahia, Brazil. Itapetinga - Bahia has a Köppen-Geiger bioclimatic classification of Aw. Tropical with dry season. The experimental period occurred between April and June 2019, recording maximum temperatures of 41.4 °C and minimum temperatures of 20.8 °C. The research was conducted in a completely randomized design in a 5×2 factorial design, five fertilization protocols (Control: no fertilizers; PK fertilizer combination;

NP fertilizer combination; NK fertilizer combination; NPK fertilizer combination), and two cutting intensities (10 and 20 cm), with four replicates per treatment.

Each experimental unit consisted of a 12-liter plastic pot containing 10 dm^3 of soil with a clayey-sandy loam texture. The soil was collected from a layer of 0 to 20 cm in depth, and its chemical properties are presented in Table 1.

Table 1. Soil chemical analysis

pH	mg kg^{-1}	--------------------------Cmol$_c$ dm^{-3} de soi--------------------------								%	
(H_2O)	P_2O_5	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	S.B	t	T	V	m
4.7	2.29	0.1	0.7	0.6	1.4	5.8	1.4	2.8	8.6	16	50

S.B: Sum of bases; t: effective cation exchange capacity; T: pH cation exchange capacity; V: base saturation; m: Aluminum saturation.

Following the recommendations for the medium technological level of Alvarez & Ribeiro (1999), there was a need for liming, which was carried out 30 days before planting with the application of 17.7 g of calcitic limestone with PRNT 82% per pot.

$$NC\ (t\ ha^{-1}) = Y \cdot [Al^3 + (mt \cdot t/100)] + [X - (Ca^2 + Mg^2)] \cdot 100/PRNT \quad (1)$$

where NC = limestone requirement; Y = factor that varies according to soil texture; mt = maximum tolerated aluminum saturation; t = effective cation exchange; X = calcium and magnesium requirement; PRNT = relative total neutralizing power of the limestone to be applied.

At the time of planting, chemical fertilization was performed, applying triple superphosphate (110 kg ha^{-1} of P_2O_5) and potassium chloride (60 kg ha^{-1} of K_2O) as sources of P and K, respectively. The N source was in the form of urea (150 kg ha^{-1} of N) and was applied in two moments, the first part being carried out after the uniformity cut and the second application after the second cut (0.84 g pot^{-1} in each application).
Seeds of *Urochloa brizantha* cv. Marandu, with a cultural value of 80%, were planted. After 20 days of emergence (DAE), plants that presented low stamina or uneven development were eliminated, in which four plants were maintained per experimental unit (replicates). After emergence (DAE) at 40 days, leveling was performed at a height of 10 and 20 cm in relation to the soil, followed by the initial application of nitrogen fertilization. At 68 DAE, the second cut was performed, accompanied by the second application of nitrogen. After the application of the fertilization protocols, monitoring and analysis of the plants were started over two growth cycles, each lasting 28 days, in which Marandu reached a height of 30 cm.

To assess the water retention capacity of the soil, three plastic pots with dry soil were weighed and subjected to saturation with water for three days. After the excess water drained naturally by gravity, the containers were weighed again, and the difference between the moist soil and the soil showed the maximum water retention capacity, which corresponded to 80%. This value was determined as a parameter to maintain the water levels of the experimental units close to the retention capacity, with the buckets being weighed daily and water replenished whenever necessary.

Plant analysis

The vegetative parts of the plant were collected and dried in an oven with forced circulation at 55 °C for 72 hours. They were then weighed to determine the values of dry matter production of the aerial part (PMSPA). The residue corresponding to the 0–10 cm extract of the soil was also weighed to calculate the values of dry matter production of the residue (PMSRE). The pots were disassembled to determine the root volume (RV). A graduated test tube with a previously known volume of water was used, in which the roots were immersed, and the RV was calculated by the difference in volume. The roots were then dried in an oven with forced circulation at 55 °C for 72 hours, in order to determine the dry matter production of the roots (PMSR).

At the end of each growth period in all experimental units, two fully expanded leaves were collected, packed in aluminum foil envelopes and promptly stored on ice. They were then sent for analysis of chlorophyll a, chlorophyll b, carotenoids and total chlorophyll contents. For this purpose, 0.03 g of the fresh mass (FM) of the leaves were placed in glass vials with 5 mL of dimethyl sulfoxide and surrounded by aluminum foil for 72 hours. Subsequently, the reading was taken on the spectrophotometer to determine the concentration of photosynthetic pigments, according to the method described by Wellburn (1994), with the results presented in mg g^{-1} of fresh matter (FM).

To quantify total soluble sugars (TSS) in tissues (leaves, residue and root), 0.3 g of samples previously ground in a ball mill were weighed. The samples were subjected to extraction with distilled water, involving maceration followed by centrifugation for 20 min at 9,000 g. The procedure was performed twice, and the resulting extract was used to determine total soluble sugars by the Antrona method (Dische, 1962). The insoluble residue, obtained from the residue and root fractions, was resuspended in 5 mL of 200 mM potassium acetate buffer (pH 4.8) and incubated in a water bath at 100 °C for 5 min, under constant stirring. After cooling the mixture to approximately 50 °C, the enzyme solution with 0.08 mL of amyloglucosidase was added. The mixture was kept in a water bath at 50 °C for two hours, under constant stirring. After the incubation period, the mixture was centrifuged at 9,000 g for 20 minutes. The supernatant was collected and the volume adjusted to 5 mL with the same buffer, and the starch content (AMD) was subsequently determined by the Antrona method (Dische, 1962).

Statistical analysis

Data were analyzed by two-way analysis of variance using the Statistical Analysis System (SAS) OnDemand for Academics software (SAS Institute Inc., Cary, NC). Fertilization protocols (F), height (H), and the interaction between fertilization and height (F × H) were considered as sources of variation in the statistical model. In case of significant interactions, they were unfolded, and the means were compared by Tukey's test at 5% probability.

RESULTS AND DISCUSSION

There was a significant interaction ($P < 0.05$) between cutting intensity and fertilization for the production of dry matter of the aerial part (PMSPA) of *Urochola brizantha* cv. Marandu (Table 2).

At an intensity of 10 cm, the NP and NPK treatments showed greater production of dry matter of the aerial part compared to the depth of 20 cm. For cuts performed closer to the ground, a greater production of forage dry matter is expected in the short term compared to cuts at higher heights, due to the greater removal of the stem fraction and harvesting efficiency (Martuscello et al., 2015).

Table 2. Effect of different fertilizations and cutting intensities on the production of aerial part dry mass (PMSPA) of *Urochloa brizantha* cv. Marandu

Intensity (cm)	Chemical fertilization protocols				
	Witho	PK[1]	NP[2]	NK[3]	NPK[4]
	PMSPA (kg/ MS)				
10	118.8Ab	284.6Ab	492.3Aa	284.6Ab	559.6Aa
20	120.6Ac	295.1Ab	437.0Ba	254.1Abc	449.2Ba

Averages followed by the same lowercase letter in the row and uppercase letters in the column do not differ from each other according to the *Tukey test* ($P > 0.05$). [1]Phosphorus + potassium; [2]Nitrogen + phosphorus; [3]Nitrogen + potassium; [4]Nitrogen + phosphorus + potassium. Witho = without the use of fertilizers.

The results in Table 2 demonstrate that the application of nitrogen-containing fertilizers NP, NK and NPK promoted a significant increase in the dry biomass production of the aerial part (PMSPA) of *Urochloa brizantha* cv. Marandu. This result is in line with the literature, which widely recognizes nitrogen as the most limiting macronutrient and with the greatest impact on the accumulation of dry matter in forage grasses (Martuscello et al., 2011). N plays a central role in the constitution of proteins, enzymes and chlorophyll, essential elements for photosynthesis and plant growth and development processes. The increase in nitrogen availability, therefore, optimizes the metabolic pathways that culminate in greater biomass production, as observed in our study.

The interaction between cutting intensity and fertilization was not significant ($P > 0.05$) for the production of dry mass of residue (PMSRE) and production of dry mass of root (PMSRA). However, a significant difference ($P < 0.05$) was observed for cutting intensity for PMSRE, while for fertilization there was a significant difference ($P < 0.05$) for both variables analyzed, PMSRE and PMSRA (Table 3).

Table 3. Effect of different fertilizations and cutting intensities on the production of dry mass of residue (PMSRE) and dry mass of root (PMSRA) of *Urochloa brizantha* cv. Marandu

Variable ($kg\ ha^{-1}$)	Intensity (cm)		Chemical fertilization protocols					*P*-value			
	10	20	Witho	PK[3]	NP[4]	NK[5]	NPK[6]	Int[1]	F[2]	I*F	CV[1]
PMSRE	276.6B	422.8A	229.8b	302.8b	471.2a	260.3b	484.5a	0.000	0.000	0.116	19.7
PMSRA	558.9A	588.9A	366.7c	505.4bc	880.6a	419.0c	700.1ab	0.000	0.000	0.343	33.2

[1]Coefficient of variation in percentage. Int = Intensity; F = fertilization; IxF = interaction between factors. Means followed by the same uppercase letter for the cutting intensity factor and lowercase letter for the fertilization factor do not differ from each other by the *Tukey test* ($P > 0.05$). [1]Phosphorus + potassium; [2]Nitrogen + phosphorus; [3]Nitrogen + potassium; [4]Nitrogen + phosphorus + potassium. Witho = without the use of fertilizers. Degrees of freedom: Chemical fertilization protocols (GL = 4) and cutting intensities (GL = 1), and their interaction (GL = 4), The experimental error was evaluated with (GL = 30).

The cutting intensity of 20 cm resulted in a higher PMSRE, whereas at this height the cut is carried out higher, leaving a greater quantity of leaves and, consequently, a greater production of dry material from the residue.

NP and NPK fertilizations resulted in higher PMSRE, being equivalent to each other and superior to the other fertilizations. These same fertilizations also promoted greater aerial part production, indicating that they provided greater production of plant mass. Therefore, this is a relevant characteristic for the choice of fertilization, since the greater the production of plant mass, the greater the availability of food for animal production.

It was observed that PMSRA followed the same behavior pattern as PMSRE and PMSPA, with NP and NPK fertilizations resulting in higher production. Thus, it can be concluded that, to achieve higher production of PMSRE and PMSRA, it was also necessary to obtain higher production of PMSRA, since the greater the production of roots, the greater the capacity of the plant to absorb nutrients from the soil for its development and production.

The interaction between cutting intensity and fertilization was significant ($P < 0.05$), influencing the concentration of chlorophyll a, chlorophyll b, carotenoids and total chlorophyll of *Urochola brizantha* cv. Marandu (Table 4).

Table 4. Effect of different fertilizations and cutting intensities on the content of chlorophyll a, chlorophyll b, carotenoids and total chlorophyll *Urochloa brizantha* cv. Marandu

Intensity	Chemical fertilization protocols				
(cm)	Witho	PK[1]	NP[2]	NK[3]	NPK[4]
	Chlorophyll *a* (mg g^{-1} MF)				
10	1.4Aa	1.2Aa	1.7Aa	1.3Ba	1.5Ba
20	1.4Aab	1.1Ab	1.4Aab	1.7Aa	1.8Aa
	Chlorophyll *b* (mg g^{-1} MF)				
10	0.53Ab	0.38Ab	0.75Aab	0.97Aa	0.54Bb
20	0.59Abc	0.52Ac	0.58Abc	0.99Aab	1.21Aa
	Carotenoids (mg g^{-1} MF)				
10	0.29Aa	0.27Aa	0.29Aa	0.27Aa	0.2Bc
20	0.31Aab	0.23Ab	0.25Ab	0.32Aab	0.3Aa
	Total chlorophyll (mg g^{-1} MF)				
10	1.9Aab	1.6Ab	2.4Aa	2.3Ba	2.0Bab
20	2.0Ab	1.7Ab	2.0Bb	2.7Aa	3.1Aa

Averages followed by the same lowercase letter in the row and uppercase letters in the column do not differ from each other according to the *Tukey test* ($P > 0.05$). [1]Phosphorus + potassium; [2]Nitrogen + phosphorus; [3]Nitrogen + potassium; [4]Nitrogen + phosphorus + potassium. Witho = without the use of fertilizers.

Regarding the levels of chlorophyll a, chlorophyll b, carotenoids and total chlorophyll, there was no significant difference due to the cutting intensity. However, when analyzing chlorophyll a as a function of fertilizers at a cutting intensity of 10 cm, no difference was observed between fertilizations. For the 20 cm cut, on the other hand, it was observed that NK and NPK fertilizers resulted in the highest levels of chlorophyll a.

This increase is favorable because it is essential for the photophosphorylation process. Such efficiency in capturing light by chloroplasts, in turn, drives ATP synthesis, as well described by Taiz & Zeiger (2016).

The joint application of nitrogen and potassium doses plays a fundamental role in plant nutrition, since nitrogen is a component of proteins and directly interferes with the photosynthetic process, participating in the chlorophyll molecule. Potassium, the most abundant cation in plants, performs important physiological and metabolic functions, such as enzyme activation, photosynthesis, assimilated translocation, nitrogen absorption and protein synthesis (Wasselai et al., 2020).

When evaluating chlorophyll b in the 10 cm cut, the NK treatment provided the highest chlorophyll content. At an intensity of 20 cm, the fertilization that presented the highest content was NPK. Regarding the carotenoid content, at an intensity of 10 cm, no difference was observed between the fertilizations. At an intensity of 20 cm, the highest content was recorded in the NPK treatment. In the 10 cm cut, total chlorophyll was higher in the fertilizations with NP and NK, while at an intensity of 20 cm, the highest contents were observed in the treatments with NK and NPK.

Accessory pigments, such as chlorophyll b and carotenoids, play a crucial role in assisting chlorophyll in capturing light and efficiently transferring energy to the centers of occurrence. In this process, the light energy absorbed by the molecular structure of chlorophyll b is released to the chlorophyll a molecule, where it is converted into chemical energy during photosynthesis. At the same time, carotenoids act as essential antioxidants, protecting leaves against photooxidation damage, which can be caused by high levels of radiation (Kluge et al., 2015). In this context, the results related to photosynthetic pigments show a direct relationship between chlorophyll levels in plants and the type of fertilizer provided, providing the influence of nutritional management on photosynthetic efficiency.

The interaction between cutting intensity and fertilization was not significant ($P > 0.05$) for the total soluble sugar (AST) contents in the leaves, residues and roots of *Urochloa brizantha* cv. Marandu (Table 5). However, a significant difference ($P < 0.05$) was observed in all AST analyses for the intensity, in which high cutting provides a greater number of leaves in the tiller, which allows the plant to perform photosynthesis telling, resulting in greater carbohydrate production.

Table 5. Effects of different fertilizations and cutting intensities on total soluble sugar (AST) levels in the leaves, residues and roots of *Urochloa brizantha* cv. Marandu

Variable (mg g^{-1} MS)	Intensity (cm)		Chemical fertilization protocols					*P*-value			
	10	20	Witho	PK[3]	NP[4]	NK[5]	NPK[6]	Int[1]	F[2]	I*F	CV[1]
AST Sheet	11.9B	12.5A	10.7b	10.6b	15.6a	9.1b	15.0a	0.001	0.001	0.001	15.6
AST Resíd	13.7B	15.7A	14.4a	16.3a	17.6a	9.8b	17.3a	0.001	0.001	0.001	20.6
AST Root	35.2B	36.1A	27.7bc	28.2bc	35.8b	21.5c	54.2a	0.001	0.001	0.381	24.8

[1]Coefficient of variation in percentage. Int = Intensity; F = fertilization; IxF = interaction between factors. Means followed by the same letter saved for the cutting intensity factor and lowercase for the fertilization factor, not significantly between them by the *Tukey test* ($P > 0.05$). [1]Phosphorus + potassium; [2]Nitrogen + phosphorus; [3]Nitrogen + potassium; [4]Nitrogen + phosphorus + potassium. Witho = without the use of fertilizers. Degrees of freedom: Chemical fertilization protocols (GL = 4) and cutting intensities (GL = 1), and their interaction (GL = 4), The experimental error was evaluated with (GL = 30).

Fertilization showed a significant difference ($P < 0.05$) for AST, with the NP and NPK treatments providing the forage with more balanced nutrition, which resulted in greater production and storage of total soluble sugars in the aerial part, residue and root.

There was interaction between fertilizers and cutting intensity was significant ($P < 0.05$), which influenced the amount of starch in the residue and root of *Urochloa brizantha* cv. Marandu (Table 6).

The analysis of starch content in the residue (Table 6) shows that the PK and NK treatments accumulated less starch in the residue at the 10 cm cut compared to the 20 cm cut. This difference can be attributed to the higher intensity of the 10 cm cut, which probably presented a greater mobilization of carbohydrate reserves, including starch, to sustain the regrowth and initial growth of *Urochloa brizantha*. These results are in agreement with the literature, which points to a high concentration of reserve carbohydrates during defoliation and subsequent regrowth, with this reduction being directly proportional to the intensity and frequency of defoliation (Rodrigues et al., 2006). The residues of the treatments with NP and NPK fertilizers at both cutting intensities presented lower starch contents.

Table 6. Effect of different fertilizations and cutting intensities on starch content in the residue and root of *Urochloa brizantha* cv. Marandu

Intensity	Chemical fertilization protocols				
	Witho	PK[1]	NP[2]	NK[3]	NPK[4]
	Starch residue (mg g^{-1} MS)				
10	27.1Aa	24.0Bab	20.5Abc	17.3Bc	29.0Aa
20	27.6Aab	31.6Aa	16.8Ac	22.1Abc	30.1Aa
	Root starch (mg g^{-1} MS)				
10	34.6Aa	25.4Bb	33.6Aa	27.4Aab	31.7Bab
20	36.6Ab	32.2Abc	16.5Bd	25.3Ac	44.8Aa

Averages followed by the same lowercase letter in the row and uppercase letters in the column do not differ from each other according to the *Tukey test* ($P > 0.05$). [1]Phosphorus + potassium; [2]Nitrogen + phosphorus; [3]Nitrogen + potassium; [4]Nitrogen + phosphorus + potassium. Witho = without the use of fertilizers.

In the analysis of starch in the roots, it was observed that the treatments with PK and NPK fertilizers indicate a lower fraction of starch in the root at the cut at 10 cm, while NK fertilization presented the lowest starch content in the root at the intensity of 20 cm.

CONCLUSIONS

Marandu grass showed variations with the interaction between fertilization protocols and cutting intensities in dry mass production, carbohydrate accumulation and photosynthetic pigment concentration. The combination of NP stood out, especially when associated with cutting at 10 cm for dry mass production of the aerial part and cutting at 20 cm for photosynthetic pigments, dry mass production of residue and root, and total soluble sugar contents.

Although NPK fertilization has also shown satisfactory results, NP fertilization has proven to be an efficient and possibly more economical alternative. Therefore, the use of NP fertilization is recommended, adjusting the cutting intensity according to the objective at 10 cm for dry mass production or 20 cm for the other parameters.

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