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EFFECTS OF FERTILIZATION PROTOCOLS ON THE MORPHOLOGICAL AND PRODUCTIVE CHARACTERISTICS OF *Brachiaria Brizantha* CV. MARANDU

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ABSTRACT

The objective of this study was to evaluate the morphogenic and productive characteristics and water use efficiency of *Brachiaria brizantha* cv. Marandu in the presence and absence

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of liming, under different fertilization protocols. The experiment was carried out in a greenhouse, at the State University of Southwest Bahia, Campus "Juvino Oliveira", in Itapetinga, BA, between March and June 2023, and was organized in a completely randomized design, with four replications, in a 2 x 5 factorial scheme, composed of the presence or absence of liming and different dosages of NPK (0, 50, 100, 150 and 200%, on the 100% recommendation of the Fifth Approximation - Recommendations for the use of correctives and fertilizers in Minas Gerais), evaluated during two periods of 28 days. Fertilization boosted the development of morphogenic and productive characteristics of the plants. The leaf appearance rate and the phyllochron showed quadratic behavior, with optimal points at 173.6% and 153.8% of the dose, respectively. The leaf elongation rate, the SPAD index, the number of tillers, and the biomass production showed increasing linear responses to fertilization, with increases proportional to the doses applied. Total dry mass and root dry mass also showed a linear increase, while root volume and water use efficiency showed quadratic behaviors, with optimal points in 222.2% and 181.3% of fertilization, respectively. Thus, doses higher than 150% of NPK favor plant development, even without liming, optimizing productivity and water efficiency.

Keywords: Water use efficiency. Fertilization. Morphogenesis. Pasture. Productivity.

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INTRODUCTION

In animal feed, pasture is the most economical way to use concentrates because it has nutrients available abundantly in extensive system breeding. In addition, well-managed forages promote environmental sustainability by helping to conserve soil, combating erosion and weeds, facilitating nutrient cycling, capturing carbon, and combating climate change (MARINS et al., 2025).

The degradation of pastures is a challenge faced worldwide, mainly due to the inefficient use of the soil for the implementation of crops and inadequate adjustment of stocking by area, also resulting in losses in animal productivity. This scenario compromises the development of grasses due to the deficit of minerals and increases the degradation of pastures (DIAS FILHO, 2017).

Therefore, it is essential to replace nutrients based on the requirements to maintain soil cover and adequate development of the aerial part, as well as promote the full development of the root system (BECKER, 2025). In addition, the growing demand for animal products and the importance of environmental impacts on production make fertilization an efficient strategy in the management of soils with nutritional deficit, as it stimulates sustainable development and helps maintain pastures to increase productivity (LEITE & ARAÚJO, 2025).

Therefore, fertilization is an indispensable practice to boost plant growth, as it reacts quickly in the soil, supplying the necessary nutrients to stimulate growth efficiently (FLORENTINO et al., 2022).

Nitrogen is essential to aid growth, as it increases leaf development, being essential in plant metabolism by promoting the synthesis of proteins and chlorophylls (ALMEIDA et al., 2023).

Alexandrino et al.. (2010) evaluated pastures of *Brachiaria brizantha* cv. Marandu verified that the nitrogen fertilization applied since the establishment acted as a differential for the increase in the number of tillers and leaves.

After nitrogen, phosphorus increases the expansion of the shoot and roots, as well as energy metabolism and cellular respiration, improving water and nutrient absorption (COSTA et al., 2023; OLIVEIRA et al., 2022).

Potassium, on the other hand, regulates osmosis performed in plant cells, acting as the main cation in turgor, maintaining electroneutrality in cells and activating enzymes responsible for respiration and photosynthesis (TAIZ & ZEIGER et al., 2013).

According to Touhami et al. (2022), the combination of nitrogen, phosphorus, and potassium (NPK) increases the reuse of calcium and phosphorus in the soil, acting on the evolution of roots and the activity of microorganisms.

In addition, fertilization efficiency is directly related to irrigation due to the water supply providing nutrient retention such as nitrogen, amplification of enzymatic activity in the soil, increased absorption, transport of nutrients, and their use by plants (HAN et al., 2025).

The objective of this study was to evaluate the morphogenic and productive characteristics and water use efficiency of *Brachiaria brizantha* cv. Marandu under increasing levels of fertilization, with or without liming application, seeking to maximize productivity and improve the quality of this grass.

METHODOLOGY

LOCATION AND SETUP OF THE EXPERIMENT

The experiment was conducted in a greenhouse at the State University of Southwest Bahia in Itapetinga-BA between March and June 2023.

The assay was carried out in a 2x5 factorial scheme, without or with liming, with increasing doses of NPK, being 0, 50, 100, 150 and 200% over the recommendation of 100% from the 5th approximation, to evaluate the potential response of the plant below and above the recommended levels of fertilization, which corresponded to 341 kg of urea/ha, 611 kg of super simple/ha and 103 kg of potassium chloride/ha (CANTARUTTI et al., 1999). The experiment was organized in a completely randomized design, with four replications, totaling 40 experimental units.

The soil was collected at the Bela Vista farm, municipality of Encruzilhada-BA, with a depth of 0 to 20 cm, and the plot was classified as a dark red latosol with a Sandy Clay Franc texture.

According to the chemical and physical analysis of the soil, carried out by the Soil Laboratory of the Department of Agricultural Engineering and Soils of UESB-Vitória da Conquista (Tables 1 and 2), the recommendations of the "5th approximation", developed by the Soil Fertility Commission of the State of Minas Gerais (ALVAREZ and RIBEIRO et al., 1999), were made.

Table 1. Physical analysis of the soil.

Particle size composition (g/kg)

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Sand	Silt	Clay	Textural Class
515	30	340	Franco Argilo Arenosa

Source: UESB-Vitória da Conquista Soil Laboratory

Table 2. Chemical analysis of the soil.

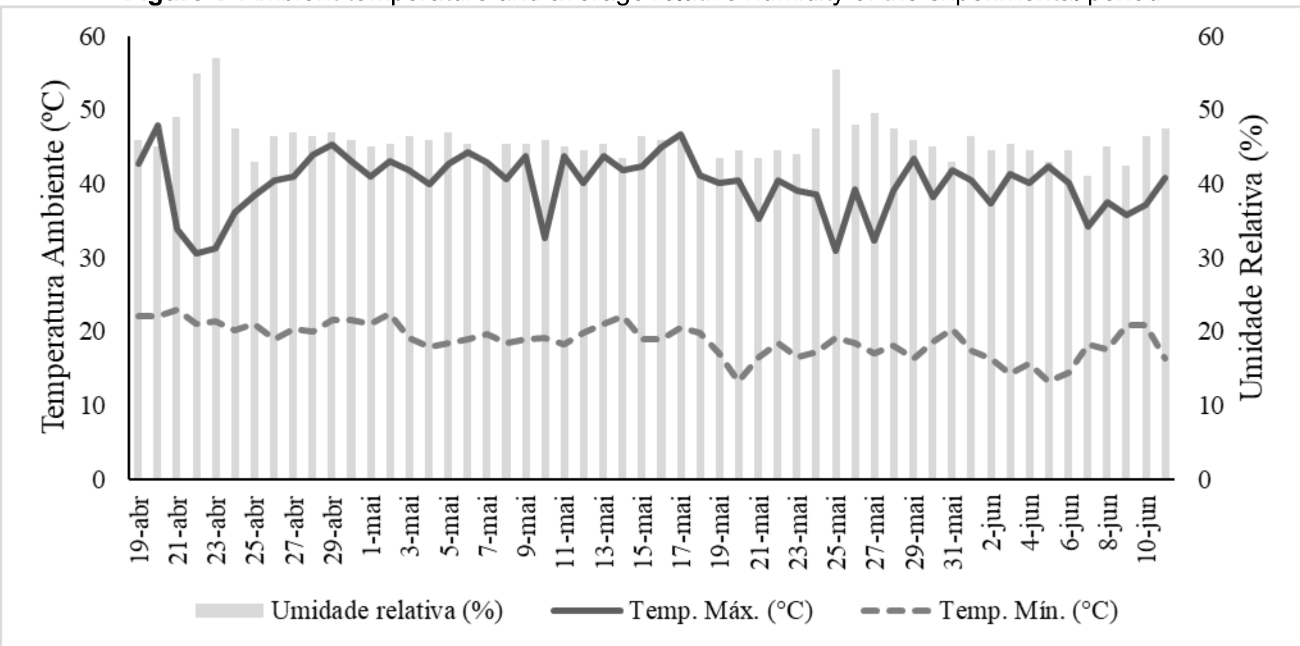
ph	*mg/dm³		............*cmolc/dm³ of soil...........								%	
(H20)	P	K+	Ca2+	Mg+	Al3+	H+	Na+	SB1	T2	T3	V4	m5
4,5	5	0,13	0,6	0,4	1,1	3,6	-	1,1	2,2	5,8	19	49

1Base sum; 2CTC effective; 3CTC pH 7; 4Base saturation; 5Saturation by Al3+. Source: UESB-Vitória da Conquista soil laboratory.

Liming was incorporated 30 days before planting, in pots with a capacity of 12 liters, each occupied with 10 kg of dry soil and 10.05 g of dolomitic limestone/pot (corresponding to 1675 kg/ha) and with PRNT of 90% was added.

Daily weighings were made, always keeping the soils moist, recording the weights of the pots during the experimental period, as well as the humidity and temperatures in the greenhouse, obtained by means of a Digital Thermo-hygrometer (Figures 1).

Figure 1. Ambient temperature and average relative humidity of the experimental period.



Source: Survey data.

Sowing was carried out in a 1 m x 0.80 cm sand bed, with the planting of seeds of *Brachiaria brizantha* cv. Marandu. Subsequently, at 20 days, transplanting was performed, with the selection of uniform and vigorous seedlings, keeping 4 plants per pot.

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One day after transplanting, fertilization was carried out with urea (source of N), simple superphosphate (source of P), and potassium chloride (source of K) for each specific treatment, diluted in irrigation water (Chart 1).

Table 1. Description of the experimental treatments

Liming	Dose NPK (%)	*Urea		Simple superphosphate		Potassium chloride	
		(kg/ha)	(g/pot)	(kg/ha)	(g/pot)	(kg/ha)	(g/pot)
Absence/presence	0	---	---	---	---	---	---
	50	170,5	0,85	305,50	1,53	51,50	0,26
	100	341,0	1,71	611,0	3,05	103,0	0,52
	150	511,50	2,57	916,50	4,58	154,50	0,78
	200	682,0	3,41	1222,0	6,10	206,0	1,04

*Fractional fertilization in two applications (transplant and first cut). Source: Survey data.

After 48 days of transplanting, the uniformization cut was carried out, with a residue of 15 cm from the soil. This procedure was carried out in the first and second cuts. In the study, there were two periods of 28 days each, totaling 56 days of evaluation.

ANALYSIS

Morphogenic characteristics

Two tillers were chosen in each pot, homogeneous with each other and marked with tapes, and measurements were taken on the length of the leaves every three days and on the stem at the end of each experimental period.

As part of the evaluations, the appearance of the leaf apex, stem length, and number of leaves, according to the instructions of Marcelino et al. (2006), were calculated:

- Leaf appearance rate **-** TApF (leaves/day/tiller): division of the number of leaves that emerged in the tillers by the regrowth period.
- Phylochronus = Inverse of TApF (day/leaf): 1/ TApF
- Leaf elongation rate - TAlF (cm/day.tiller): division of the variation in leaf length by the evaluation period.
- Stem elongation rate - TAlC (cm/tiller.day): difference between the final and initial stem lengths divided by the measurement interval.
- Leaf life span (DVF (days): Time between the appearance of the leaf apex and the first sign of blade senescence.
- Number of tillers (NP) = count of the number of tillers per pot at the end of each period.

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SPAD Index

The determination of chlorophyll concentration was carried out indirectly, using the chlorophyll meter SPAD-502 (Soil Plant Analysis Development) device (MINOLTA, 1989). The values were recorded the day before each cut, starting at 10 am. To perform the procedure, three completely expanded leaves per vase were randomly chosen and three readings were taken per leaf, including one point at each end and one in the center of the leaf blade, always with the device sensor in the portion of one third in the middle of the slide, avoiding the central vein.

Production of fresh and dry pasta

After each experimental period, the samples were separated and identified in paper bags. Then, they were weighed on an analytical scale to obtain fresh mass. In all periods, the production of the aerial part (leaf and stem) was analyzed.

In the second period, the production of residue and root was also evaluated. After weighing, the samples were dried in a forced ventilation oven at 55°C for 72 hours. After drying, a new weighing was carried out to determine the dry mass. With the data obtained in each period, the average dry mass production of the shoot (considering the two periods) was calculated, as well as the dry mass production of the residue and the root in the second period.

Root Volume

This procedure was performed only in the second cut, using a 1000 mL beaker (known volume) to introduce the roots, and with the difference found, the volume was obtained.

Water use and efficiency

All pots were weighed to maintain soil moisture, and the amount of water replenished was recorded, and at the end of each period, the amount of water used was calculated.

With the dry matter produced and the amount of water replenished during the study, calculations were made to determine the amount of water needed to produce 1 g of dry matter with 1 L of water (gDM/L). This relationship was expressed in terms of water use efficiency.

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STATISTICAL ANALYSIS

The data obtained were grouped and analyzed as the mean of the two evaluative cutoffs and then submitted to analysis of variance (ANOVA), considering as sources of variation the fertilization and liming protocols and their interaction, tested at 5% probability. The interaction was unfolded, or not, according to significance, and the effect of the fertilization protocols was evaluated by regression analysis while the liming effect was compared by the F test, using the statistical program SAEG System for Statistical Analysis (2007).

RESULTS AND DISCUSSION

No interaction between liming and fertilization was found (P>0.05). Likewise, the variables were not influenced by liming (P>0.05), and this practice did not contribute as expected to increase plant productivity, which may have been a result of the controlled environment, the liming action time was insufficient, as well as the recommendation was not efficient to neutralize soil acidity due to its sandy texture.

However, there was an effect of fertilization (P<0.05) on leaf appearance rate (TApF), phyllochron, leaf elongation rate (TAlF), number of live leaves (NFV) and SPAD index (Table 3).

Table 2. Morphogenic characteristics and SPAD index of the *Brachiaria brizantha* without or with liming under different percentages of the NPK fertilization recommendation.

Variable	Liming		Fertilization (% of recommendation)[1]					EPM	P2 Value		
	Without	With	0	50	100	150	200		Lime	Adu	Cal*Adu
TApF (payroll/day)	0,17	0,18	0,16	0,17	0,18	0,18	0,18	0,0006	0,8245	0,0014	0,6745
Philochronus (days/sheet)	5,9	6,0	6,8	5,9	5,9	5,6	5,7	0,22	0,6173	0,0005	0,9018
TAIF (cm/day)	5,5	5,6	4,9	5,2	5,3	5,7	6,1	0,28	0,8998	0,0013	0,1916
TAIC (cm/day)	0,19	0,18	0,15	0,18	0,18	0,18	0,24	0,03	0,7613	0,0715	0,1816
DVF (days)	23,0	22,9	22,7	23,0	23,0	23,0	23,0	0,16	0,32553	0,4229	0,4229
NFV (leaves/tiller)	4,0	4,0	3,6	4,0	4,1	4,2	4,2	0,12	0,8998	0,00015	0,7751
SPAD	41,0	40,5	39,9	40,0	40,5	41,3	42,1	0,59	0,1751	0,0282	0,5551

1Fertilization corresponding to the percentage of the recommendation of the 5th approximation. EPM=Standard error of the mean; Lime = liming; Adu = fertilizer; CalxAdu = interaction between the factors.

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For TAfF, there was a quadratic behavior (P<0.05) with a maximum point of 173.6% of the recommended dose, which corresponded to 0.18 leaves/day (Figure 2a). This variable drives the emergence and increase of the photosynthetic rate to assist in the recovery of pasture. In addition, the higher the TApF about the phyllochron, the appearance of leaves occurs in shorter time intervals.

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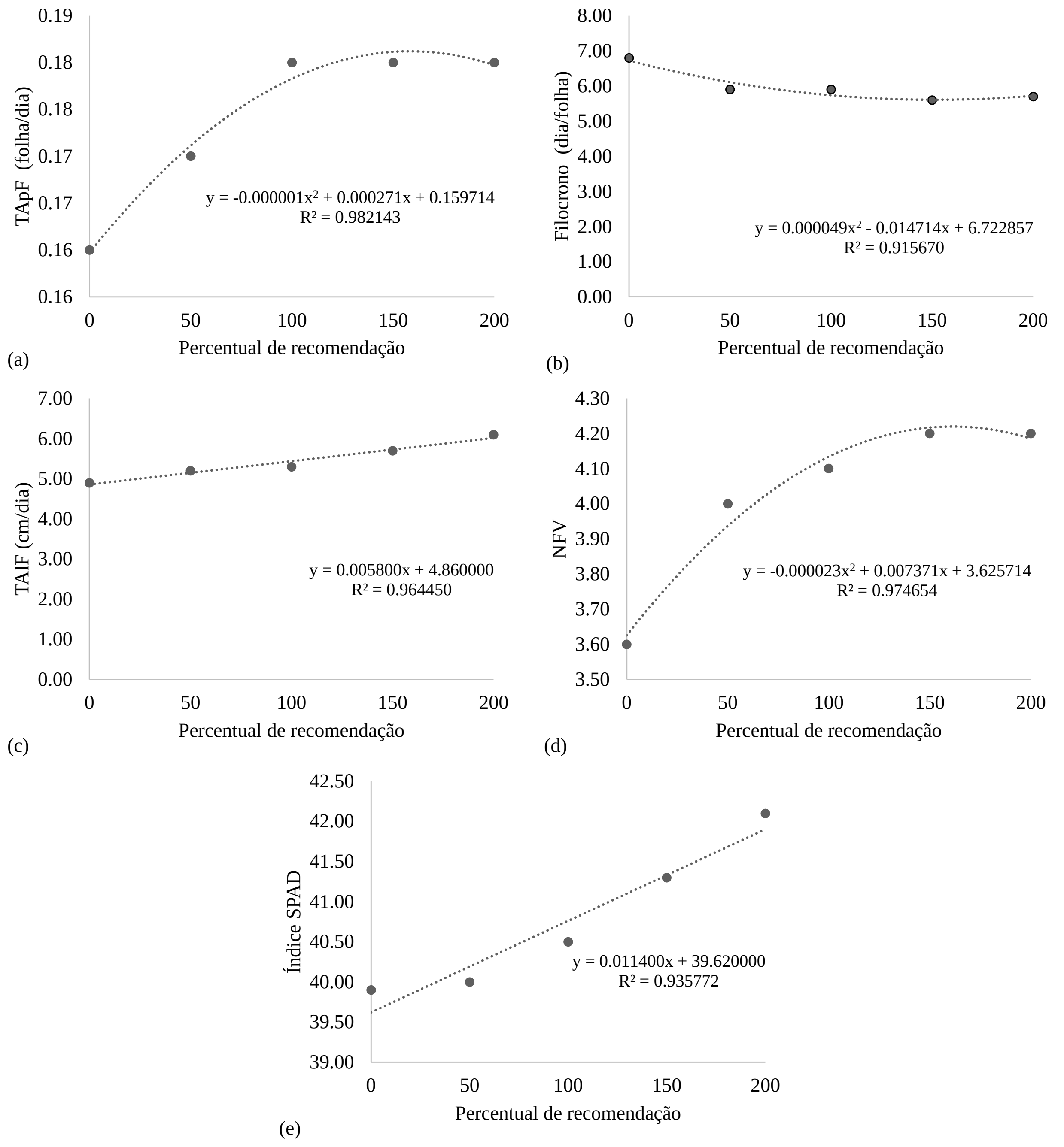
Figure 2. Leaf appearance rate, phyllochron, leaf elongation rate, number of live leaves and SPAD index of *Brachiaria brizantha* under different percentages of the NPK fertilization recommendation.



Source: Survey data.

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Martuscello et al. (2005) when evaluating *Brachiaria brizantha* cv. Xaraés fertilized with 0, 40, 80 and 120 mg/dm^3 of N, adopting defoliation of three, four and five expanded leaves, the TApF showed an increasing linear behavior about the N rates, with 0.096 leaves/day without nitrogen fertilization and 0.121 leaves/day with 120 mg/dm^3 of N, which showed an increase of 25% about the absence of nitrogen. Silva et al. (2015) evaluated *Brachiaria brizantha* cv. Marandu at doses of 0, 250, 500, 750, and 1,000 kg/ha/year of N and observed an increase in TApF, which resulted in division and elongation of the meristematic cells of the tiller.

The phyllochron showed quadratic behavior with a minimum point for the fertilization percentage of 153.8% of fertilization, which corresponded to 5.6 days in each leaf formed (Figure 2b). For this variable, as the values decrease, there is an increase in leaf production in shorter intervals of time.

In a study developed by Martuscello et al. (2015) of the morphogenic and structural characteristics and biomass production of *Panicum maximum* cv. Massai in the field, under doses of 0, 80, 160, and 240 kg/ha/year of N and found phyllochron values with 9.08 at the maximum dosage.

For TAlF, there was an increasing linear behavior, with an increase of 0.0059 cm/day for each percentage unit, corresponding to 6.1 mm/day (Figure 2c). For this variable, the higher the rate, the faster the emergence of tillers, increasing leaf production with the use of NPK, which is also related to TapF.

Lopes et al. (2013) state that TAlF contributes to biomass flow, driving the highest proportion of leaves and contributing to the increase in photosynthesis. In addition, nitrogen increases the TAlF, number and size of cells synthesized in cell division, and this phenomenon is common in cespitosa grasses due to the competition for assimilates between leaves and stolons (PEREIRA et al., 2011). According to Martuscello et al. (2015), fertilization provides a linear increase in TAlF and TAfF, reducing phyllochron values.

The NFV showed a quadratic behavior for the fertilization percentage of 168.5%, which corresponded to 4.24 live leaves/tiller to reach the maximum point (Figure 2d). This variable is related to the APR because as the levels of fertilization increased, there was an increase in these variables, which occurred due to the availability of nutrients promoted by fertilization, irrigation, and the favorable conditions of temperature and luminosity of the greenhouse. In addition, this variable usually also expresses a relationship with FVD, which was not observed in this study.

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According to Costa et al. (2019), the number of live leaves/tillers is directly related to genetics, but they may be interfered with by the environment and the management adopted. In a study by Silva et al. (2016) in a greenhouse to evaluate *Brachiaria decumbens* cv. Basilisk, *brizantha* cv. Marandu, Xaraés *and Panicum* cv. Mombasa and CV. Tanzania, the cultivar Basilisk presented the best number of live leaves per tiller (3.49 number of live leaves/tiller) among the *Brachiarias.*

According to Costa et al. (2019), the number of live leaves/tillers is determined by genetics, however, they may be interfered with by environmental factors and management used. A study developed by Bezerra et al. (2020) evaluated the influence of Cambisol and Ultisol soils on *Brachiaria* Piatã and Marandu and their interactions on productive, morphogenic, and structural characteristics. being found for Marandu 4.31 n^{of} live leaves/tiller was found.

For the SPAD Index, there was an increasing linear behavior, with an increase of 0.0115227 for each percentage unit, which corresponded to 41.9 SPAD units (Figure 2e). To evaluate the intensity of the green of the leaves, this index is used for its correlation between the intensity of the green and the chlorophyll content of the leaf (MARTUSCELLO et al., 2009).

Zanine et al. (2020) analyzed *Brachiaria brizantha* cv. Piatã in the before and after grazing with the use of nitrogen fertilization during the seasons of the year, with doses of 0, 150, 300 and 450 kg/ha of N and found 41.22 for the SPAD Index at the maximum dose, being found with increasing linear effect ($P<0.05$) in the pre-grazing and SPAD index value of 41.46 in the spring. These results showed that nitrogen fertilization increased photosynthetic production, with greater development of the aerial part.

For the number of tillers/pot, number of tillers/plant, fresh mass (g/pot), leaf dry mass (g/pot), stem dry mass (g/pot), root dry mass (g), total dry mass (g/pot), root volume (mL) and water use efficiency, differences were observed only ($P<0.05$) for fertilization (Table 4).

Table 4. Growth and accumulation of biomass of *Brachiaria brizantha* with and without liming, under percentages of the NPK fertilization recommendation.

Variable	Liming		Fertilization (% of recommendation)[1]						P-value		
	Without	With	0	50	100	150	200	EPM	Lime	Adu	Cal*Adu
Number of tillers/pot	40,9	43,7	14,9	37,1	44,6	53,1	61,8	3,58	0,2394	<0.0001	0,1972

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Number of tillers per plant/plant	10,2	10,9	3,7	9,3	11,1	13,3	15,4	0,89	0,2405	<0.0001	0,1960
Fresh pasta (g MV/vessel)	207,8	210,1	86,2	158,6	213,8	266,9	319,1	7,74	0,6432	<0.0001	0,3048
Dry pasta Leaf (g/pot)	14,7	14,7	6,7	11,8	15,5	18,3	21,3	0,50	0,8779	<0.0001	0,1105
Dry stem dough (g /vase)	5,3	5,6	1,42	4,0	5,7	7,0	9,1	0,44	0,3237	<0.0001	0,1595
Dry pasta Total (g/pot)	20,1	20,3	8,1	15,9	21,2	25,3	30,4	0,75	0,6299	<0.0001	0,0734

1Fertilization corresponding to the percentage of the recommendation of the 5th approximation. EPM= Standard error of the mean; Lime = liming; Adu = fertilizer; CalxAdu = interaction between the factors.

For the number of tillers/pot, there was a quadratic behavior for the fertilization percentage of 246.9%, which corresponded to 62.2 tillers per pot to reach the maximum point (Figure 3a). However, this dosage exceeds the maximum recommendation tested in this study. The increase in the number of tillers promotes better pasture development, as well as uniformity, controlling the appearance of weeds, pests and soil erosion, resulting in pasture vigor, rapid renewal, persistence and higher productivity.

In addition, the emergence of new tillers is directly related to APf, demonstrating that the nutrients were efficiently compensated by fertilization, contributing to the development of the plant, which also correlates with the increase in fresh mass production. On the other hand, the nutrient deficiency caused by the absence of fertilization reduces tiller production and increases the number of dormant buds in pastures.

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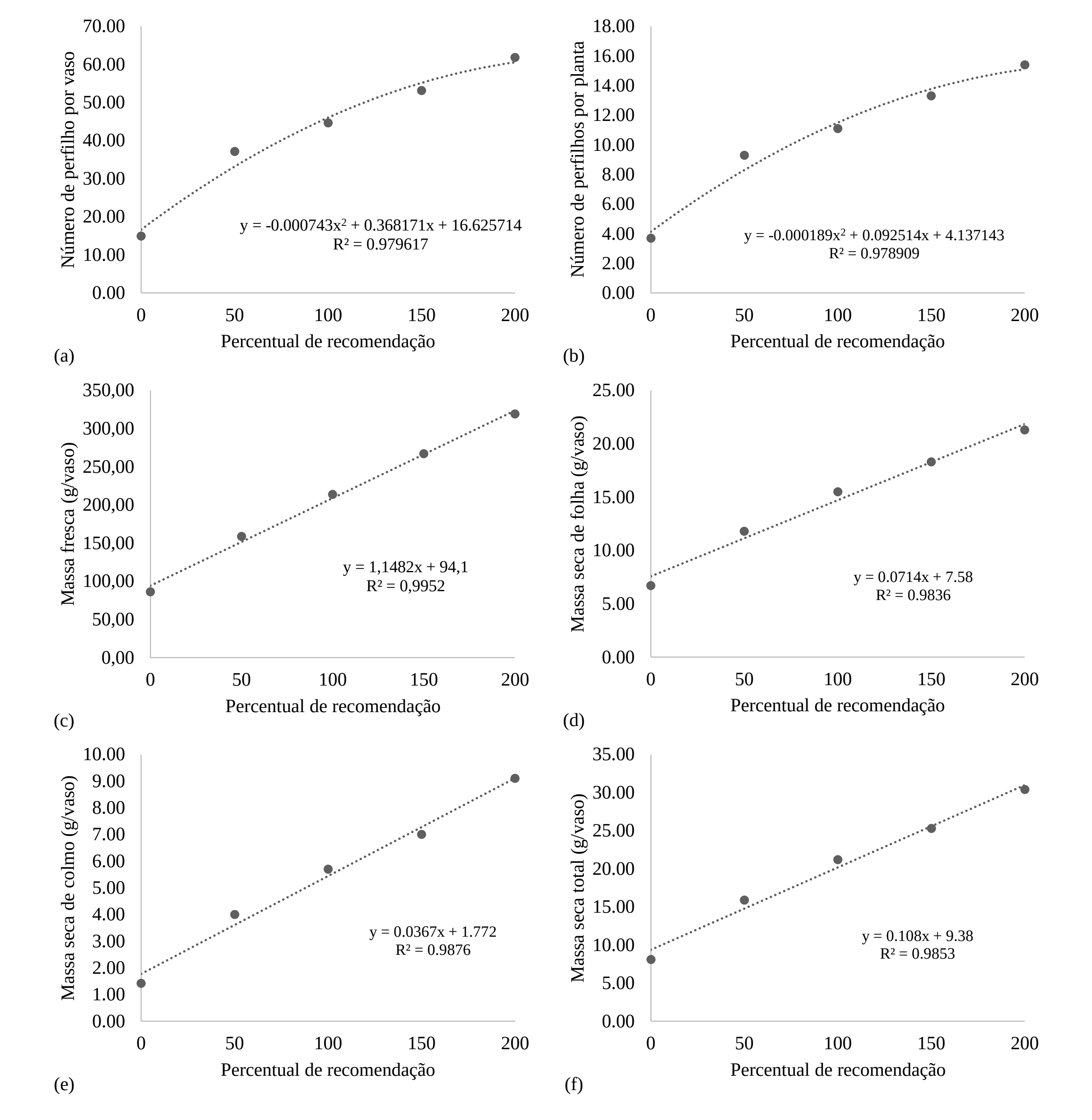
Figure 3. Growth and accumulation of biomass of *Brachiaria brizantha* under percentages of the recommendation of fertilization with NPK.



Source: Survey data.

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According to Nunes et al. (2023), increasing doses of phosphorus increase the emergence of new tillers, boost photosynthetic capacity, growth, and favor regrowth.

The number of tillers/plant showed quadratic behavior with a maximum point for the fertilization percentage of 246.7%, which corresponded to 15.5 tillers per plant (Figure 3b). However, this dosage exceeds the maximum recommendation tested in this study. The increase in plant production with fertilization increased production, helped in recovery and increased the production potential of grasses.

In a study developed by Silva et al. (2016) in *Brachiaria decumbens* cv. Basilisk, *Brizantha* cv. Marandu, Xaraés and *Panicum* cv. Mombasa and cv. Tanzania in a greenhouse, found that Basilisk and Mombaça had the highest number of tillers per plant (10.16 and 9.33), as well as Marandu reached 4.58, demonstrating the high tillering capacity, in which fertilization was essential, even varying the tiller production according to the cultivars.

The production of fresh mass (g/pot) showed an increasing linear behavior, with an increase of 1.14833 g for each percentage unit, which corresponded to 323.8 g (Figure 3c). In pastures, the higher production of fresh mass provides ample supply of forage for animal consumption and the use of fertilization increases forage growth, increasing leaf production.

Fertilization promotes the complete development of the plant, and the application of nitrogen, phosphorus and potassium together contribute to the formation of the aerial part, occurring as expected the influence of this practice. Among the most important nutrients for absorption in plants, nitrogen acts directly on photosynthesis, increasing leaf production daily and stimulating structural development.

Teixeira et al. (2018) evaluated a pasture of *Brachiaria brizantha* cv. Marandu with 0, 100, 200 and 300 kg/ha of nitrogen and found that there was an increasing linear increase in fresh mass with an increase in phosphorus and nitrogen doses. In addition, phosphorus in the initial phase contributes to the growth of the root system and tillering, promoting an increase in production in fertilized plants.

Thus, nitrogen fertilization stimulates productivity depending on the level adopted and the species, making it possible to increase the grazing carrying capacity, accelerating the formation and growth of the aerial part (SILVA et al., 2012).

For Camargo et al. (2022), factors such as temperature, irrigation, and nutrients directly interfere with the leaf area index of the aerial part, influencing its production.

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Therefore, fertilization with nitrogen increases nutritional value, carrying capacity and acts on the functioning of plant cells.

For the dry mass of the leaf (g/pot) there was an increasing linear behavior, with an increase of 0.0712854 for each percentage unit, which corresponded to 21.8 g/pot (Figure 3d).

The increase in the number of tillers and the TAIF provide greater production of dry matter, increasing the potential for photosynthesis, and as this occurs the expansion of leaves in less time, leading to an increase in the production of dry mass by the plant.

In a study developed by Costa et al. (2009) to evaluate *Brachiaria brizantha* cultivars Marandu, Xaraés and MG-4, with 0, 50, 100 and 150 mg/dm^3 of nitrogen in the greenhouse, there was a linear increase in dry mass for all cultivars with elevation of this nutrient, obtaining average values of 35.43, 36.80 and 39.98 g/pot, with 26; 28 and 31% higher than without fertilization. Based on these results, the authors found that nitrogen fertilization increases the volumetric density of forage and the number of leaves in the canopy, contributing to the growth and elongation of the shoot and greater production of dry mass.

Rodrigues et al. (2008) evaluated *Brachiaria brizantha* cv. Xaraés with application of 0, 75, 150 and 225 mg/dm^3 of nitrogen and 0, 50 and 100 mg/dm3 of potassium and noticed that leaf mass presented quadratic behavior for nitrogen and potassium, with maximum points at the doses of 177, 176 and 168 mg/dm^3 for nitrogen for all cuts and potassium with 61 mg/dm^3, demonstrating that these nutrients are essential for the growth of *Brachiaria brizantha* and affect dry matter production and tiller number.

The dry mass of stem (g/pot) showed an increasing linear behavior, with an increase of 0.0368863 g/pot for each percentage unit, which corresponded to 9.2 g/pot (Figure 3e).

Martuscello et al. (2009) evaluated the dry mass production of *Brachiaria brizantha* cv. Xaraés and *Panicum maximum* cv. Massai at doses of 0, 40, 80 and 120 mg/dm^3 of nitrogen cultivated in a greenhouse and verified that the stem mass showed a positive linear behavior ($P<0.05$) for the N rates for both forages, which was already expected because nitrogen contributes to the accumulation of dry mass in the plant and promotes growth with increasing doses of fertilization.

For total dry mass (g/pot), there was an increasing linear behavior, with an increase of 0.108172 g for each percentage unit, which corresponded to 31 g/pot (Figure 3f). The

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association of nutrients, especially nitrogen, accelerated the production of dry matter of the plants, resulting in higher productivity compared to the absence of fertilization.

Alexandrino et al.. (2003), when evaluating *Brachiaria brizantha* cv. Marandu in a greenhouse, using doses of 0, 45, 90, 180 and 360 mg/dm^3 of nitrogen at cutting frequencies between 14 and 28 days showed that from the first cut there was a linear response of the total dry matter production at the doses of 45, 90, 180 and 360 mg/dm3, with an increase of 41.96, 73.21, 166.79, and 274.64% compared to plants that did not receive fertilization.

Differences (P<0.05) were identified for root dry mass (g, g, water/g DM), root volume (mL), and water use efficiency (g water/g DM) were identified only with the use of fertilization (Table 5).

Table 5. Root dry mass (g), root volume (mL) and water use efficiency (g water/g DM) of *Brachiaria brizantha* with and without liming, under percentages of the NPK fertilization recommendation.

Variable	Liming		Fertilization (% of recommendation)[1]						P-value		
	Without	With	0	50	100	150	200	EPM	Lime	Adu	Cal*Adu
Dry pasta Root (g)	43,3	37,4	13,2	32,1	43,2	52,3	60,4	6,20	0,1451	<0.0001	0,6456
Root Volume (mL)	219,0	207,0	92,5	177,5	225,0	280,0	290,0	21,60	0,3869	<0.0001	0,7623
Water use efficiency (g water/g DM)	97,2	95,1	141,1	102,5	87,0	78,5	71,6	4,52	0,5081	<0.0001	0,6731

1. 1Fertilization corresponding to the percentage of the recommendation of the 5th approximation. EPM Standard error of the mean; Lime = liming; Adu = fertilizer; CalxAdu = interaction between the factors.

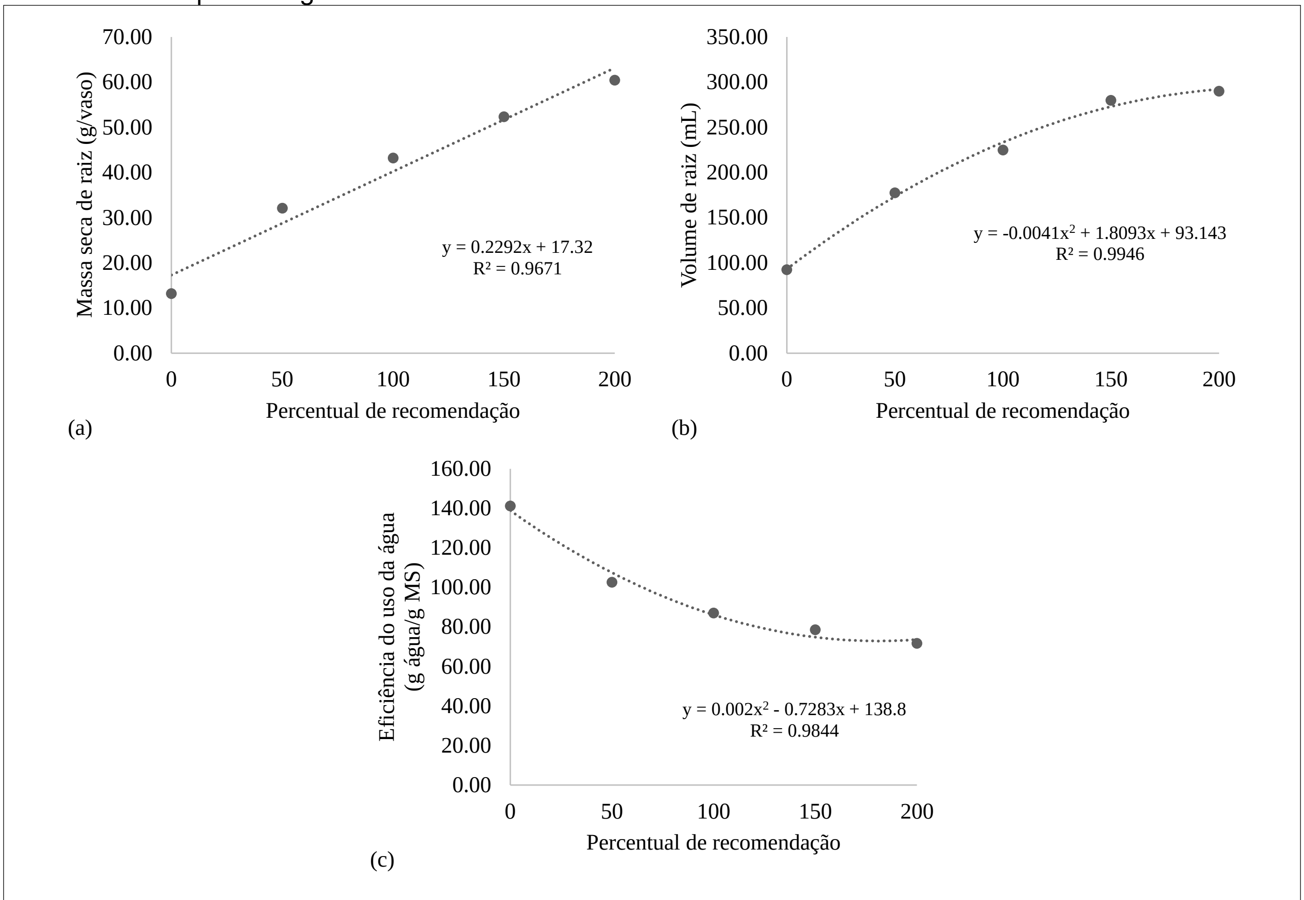
For root dry mass (g/pot), there was an increasing linear behavior, with an increase of 0.230153 g/pot for each percentage unit, which corresponded to 63.4 g/pot (Figure 4a).

The production of this component showed favorable development with fertilization, as the presence of NPK boosted the development of the root system with increasing doses of fertilization, promoting accelerated growth in the plant.

In a study developed by Fernandes et al. (2019) on *Brachiaria brizantha* cv. Marandu and Massai (*Panicum maximum* x *P.infestum*) in a greenhouse, using a nutrient solution with 0%, 25%, 50%, 75% and 100% of the phosphorus concentration in a solution equivalent to 0 mg/dm3, 36.9 mg/dm3, 73.8 mg/dm3, 110.8 mg/dm3 and 147.6 mg/dm3 between 0 and 60 days after emergence, found that *Brachiaria* By extracting and accumulating phosphorus after 60 days of emergence, there was better development and enhanced the maximum development of the root system, as this nutrient favored the absorption of water and nutrients.

The root volume showed a quadratic behavior, reaching the maximum point for the fertilization percentage of 222.2%, which corresponded to 294.2 cm3 (Figure 4b). However, this dosage exceeds the maximum recommendation in this study. The greater root volume promotes a developed and deep root system, increases the absorption of water and phosphorus, which stimulate growth, while potassium helps in the formation of secondary roots and nitrogen, improves carbon fixation, stimulating the development of roots.

Figure 4. Root dry mass (g/pot), root volume (mL) and water use efficiency (g water/gDM) of *Brachiaria brizantha* under percentages of the NPK fertilization recommendation.



Source: Survey data.

The higher root volume contributed to higher root dry matter production, promoting better plant development, which could increase soil exploration by the root system in search of maximizing water absorption, especially nitrogen and phosphorus under field

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conditions. In addition, controlled conditions favored the absorption of nutrients, due to the daily replacement of water, which also favored the action of potassium.

According to Fernandes et al. (2019), when the phosphorus need is met by the plant, there is an accelerated emergence in the roots, increasing efficiency in photosynthesis and developing the root system.

According to Silva et al. (2020), the greater root volume is related to the physical properties and amount of organic matter present in the soil, which facilitates root penetration, greater moisture retention, and nutrient absorption, especially nitrogen and phosphorus.

The water use efficiency (water/gDM) showed a quadratic behavior for the fertilization percentage of 181.3%, which corresponded to 72.9 g/L to reach the minimum point (Figure 4c).

Efficiency in the use of water promotes a reduction in irrigation costs, combating the scarcity of this resource, especially in places with irregular rainfall. The reduction in the use of this resource was demonstrated by the increasing levels of fertilization, which provided an increase in dry mass and root volume.

In addition, fertilization with NPK helps in more efficient water absorption and also provides the necessary nutrients to the soil.

Silva et al. (2007) evaluated the recovery of *Brachiaria decumbens* in a greenhouse, using doses of 0, 100, 200, 300 and 400 mg/dm3 nitrogen and 0, 10, 20, 30 and 40 mg/dm3 of sulfur and observed that from the second cut nitrogen played a crucial role in the efficiency of water use, mainly at 317 and 305 mg/dm3. This greater water efficiency allowed accelerated growth, recovery of the roots and directing more energy to the development of the aerial part. Thus, the combination of high doses of nitrogen with daily water replacement promoted a significant increase in the production of total dry matter, since soil moisture favored the action of nitrogen in plant growth.

CONCLUSION

Fertilization is a favorable practice, as it has been shown to improve morphogenic and productive characteristics, as well as reduce the use of water, a resource that must be optimized in production, aiming at the sustainability of the entire ecosystem. In addition, the use of NPK in doses from 150% favors plant development, even without liming application.

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