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Research Article

Cultivation of Marandu grass with doses of lime associated with nitrogen fertilization

Cultivo de capim Marandu com doses de calcário associadas a adubação nitrogenada

Paulo Henrique Aparecido Pinto *[1](ORCID 0009-0007-9258-9260), **Adauton Vilela de Rezende** [1](ORCID 0000-0001-8515-484X), **Fabrício Vilela Andrade Fiorini** [2](ORCID 0000-0001-7458-0149), **Hudson Carvalho Bianchini** [1](ORCID 0000-0002-3531-8233), **Tayla Évellin de Oliveira** [1](ORCID 0000-0001-5184-6549)

[1]Universidade Professor Edson Antônio Velano - UNIFENAS, Alfenas, MG, Brazil. *Author for correspondence: paulo.aparecido@aluno.unifenas.br
[2]Centro Superior de Ensino e Pesquisa de Machado - CESEP, Machado, MG, Brazil.

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ABSTRACT

The objective was to evaluate increasing doses of lime associated with nitrogen fertilization on the agronomic and bromatological characteristics of Marandu grass. The experimental design was a randomized block design (DBC) in a 5x2 factorial scheme, with five levels of dolomitic limestone (0; 2; 4; 6 and 8 t ha-¹) in the presence and absence of nitrogen fertilizer (controlled release urea). under cover (250 kg ha-¹), with four repetitions. Agronomic characteristics (plant height, number of tillers and productivity), bromatological parameters (crude protein (CP), neutral (NDF) and acid detergent fiber (ADF), lignin, cellulose and hemicellulose) and macronutrient contents (N, P, K, Ca, Mg, and S) and micronutrients (B, Cu, Mn, Zn, and Fe) of plants. There were significant changes in production, nutrient content and bromatological parameters of the crop. Lime doses of 2 to 4 t ha-1 associated with nitrogen fertilization increased productivity, the number of tillers, CP (%) and the contents of nutrients N, P, K, Ca, Mg and S and reduced the NDF (%), ADF (%) and Fe and Mn contents in forage. Nutrient extraction decreased in the following order: K > N > Ca > Mg > P > S. The use of higher dosages of limestone negatively affected the analyzed variables.

KEYWORDS: Brachiaria. Bromatology. Dry matter productivity. Liming.

RESUMO

Objetivou-se avaliar doses crescentes de calcário associadas à adubação nitrogenada nas características agronômicas e bromatológicas do capim Marandu. O delineamento experimental foi o de blocos casualizados (DBC) em esquema fatorial 5x2, sendo cinco níveis de calcário (0; 2; 4; 6 e 8 t ha^{-1}) na presença e ausência de adubação nitrogenada (ureia de liberação controlada) em cobertura (250 kg ha^{-1}), com quatro repetições. Avaliou-se as características agronômicas (altura de plantas, número de perfilho e a produtividade), parâmetros bromatológicos (proteína bruta (PB), fibra em detergente neutro (FDN) e ácido (FDA), lignina, celulose e hemicelulose) e os teores de macronutrientes (N, P, K, Ca, Mg e S) e micronutrientes (B, Cu, Mn, Zn e Fe) das plantas. Houve alterações significativas na produção, nos teores de nutrientes e nos parâmetros bromatológicos da cultura. As doses de calcário entre 2 e 4 t ha^{-1} associadas à adubação nitrogenada, aumentaram a produtividade, o número de perfilhos, a PB (%) e os teores dos nutrientes N, P, K, Ca, Mg e S e reduziram a FDN (%), FDA (%) e os teores de Fe e de Mn na forrageira. A extração de nutrientes foi decrescente na seguinte ordem: K > N > Ca> Mg > P > S. O uso de dosagens maiores do calcário afetou negativamente as variáveis analisadas.

PALAVRAS-CHAVE: Brachiária. Bromatologia. Calagem. Produtividade de matéria seca.

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INTRODUCTION

Grass forages are the main source of nutrients for cattle in Brazil and, when properly managed, provide food in an appropriate quality and quantity for animal development. The competitiveness of Brazilian livestock farming is recognized worldwide, which is only possible due to lower production costs in grazing systems that mainly use *Brachiaria* as a feed source (ALMEIDA FILHO et al. 2022). However, these pastures are mostly managed without adequate replenishment of nutrients to the soil, resulting in losses to their yield.

In the Brazilian Cerrado, more than 50% of cultivated pastures are undergoing some state of degradation, mainly because of the lack of soil correction and insufficient fertilization during implementation and maintenance, especially when it comes to nitrogen fertilization, which, in most cases, is deficient. These factors resulted in many areas with low productivity after just a few years of use, affecting the efficiency and sustainability of the system's production (TERRA et al. 2019).

In this sense, it is important to highlight that pastures must be managed like any other agricultural crop, with soil corrections and fertilization being carried out regularly. In Brazil, there are several forage species available for cultivation in pastures. However, the main genus used is *Urochloa* (syn. *Brachiaria*), with *Urochloa brizantha* standing out, with the Marandu cultivar being the most used, constituting approximately 70% of the country's pastures (DUSI et al. 2023).

This forage occupies large areas of pastures because of its multiple benefits, such as good dry matter production, adequate crude protein content, and its responsiveness to fertilization, especially nitrogen (N) (HUNGRIA et al. 2021), since it significantly contributes to increased productivity, nutritional value, number of tillers and leaves and, therefore, promotes plant development. In addition, N is the main nutrient that maintains the productivity of forage grasses because it participates in photosynthesis (ALMEIDA et al. 2023).

Besides adequate fertilization, liming is also a fundamental process, as it increases soil pH and, consequently, promotes greater efficiency in the absorption of water and nutrients by plants, mainly due the presence of Ca^{2+} that stabilizes the soil structure, promoting better distribution of pores with different sizes and functions. Correcting acidity improves the root environment, stimulating nutrient absorption and reducing toxicity caused by Al^{3+} and Mn^{2+}, generally present in high quantities in Brazilian soils (BOURAY et al. 2022).

Furthermore, second RAMÍREZ et al. (2021) as limestone increases the soil's CEC (cation exchange capacity), there is greater retention of calcium (Ca^{2+}) and potassium (K^{+}). This is achieved by neutralizing the positive charge sites of Fe and Al^{3+} oxides and hydroxides, a crucial process that minimizes the adsorption of phosphates and significantly improves the conditions for the root system's development, increasing the efficiency of fertilization.

In search of better answers about the use of high doses of limestone associated with nitrogen in *Urochloa brizantha* cv. Marandu, this research aimed to evaluate different doses of the dolomitic lime with and without nitrogen fertilization regarding its agronomic and bromatological characteristics.

MATERIALS AND METHODS

The experiment happened at Professor Edson Antônio Velano University (UNIFENAS), Alfenas/MG campus, at an altitude of 880 m and geographic coordinates of 21º25' S and 45º56' W (GOOGLE EARTH 2023). The classification of the soil used was Clayey Dystrophic Red Latosol (EMBRAPA, 2013) and had the following chemical characteristics: pH in CaCl2 = 4.7; phosphorus (P) = 1 mg/dm³; potassium (K) = 0.1 $cmol_c/dm^3$; calcium (Ca^{2+}) = 0.6 $cmol_c/dm^3$; magnesium (Mg^{2+}) = 0.4 $cmol_c/dm^3$; Al^{3+} = 1.3 $cmol_c/dm^3$; H+ = 5.9 cmolc/dm³; sum of bases = 1.1 $cmol_c/dm^3$; effective cation exchange capacity (CEC) = 2.4 cmolc /dm³; CEC at pH 7.0 = 8.3 $cmol_c/dm^3$; base saturation (V) = 13% and MO = 1.8 dag kg^{-1}. The sand, silt and clay contents of soil were 310, 100 and 450 g/kg, respectively.

Agronomic management and treatments

The experiment was designed in randomized blocks, in a 5 x 2 factorial arrangement, with four replicates. The treatments consisted of increasing doses of limestone at five levels of 0, 2, 4, 6 and 8 t ha-1 (MOREIRA et al. 2024), in the presence and absence of nitrogen fertilization in topdressing, using the dose of 250 kg ha-1 of N (protected urea 46%) as per (RIBEIRO et al. 1999), totaling 10 treatments and 40 experimental plots arranged in pots of 29 x 24.5 cm and volume of 10 liters.

In August 2021 limestone (10% MgO, 40% CaO, and 85% total neutralizing power -TNP) was incorporated into the soil, the dose corresponding to each treatment was applied to the pots which were irrigated for 60 days to promote the limestone-soil reaction. The forage was sown in trays in a grow house, and after 15 days of germination, they were transplanted as more vigorous and active seedlings, totaling four plants per pot. Planting fertilization consisted of 110 kg ha-1 of P_2O_5 in the form of triple superphosphate and 60 kg ha-1 of K_2O in the form of potassium chloride (RIBEIRO et al. 1999).

Nitrogen fertilization was applied after each cutting and divided into three applications, and three times a week, the pots were irrigated. The forage was cut 10 cm from the soil surface when the leaf area index (LAI) was 95%. Four cuts were made during the experiment, and the evaluations were carried out from November 4, 2021, to June 30, 2022. It is worth mentioning that the average values of the cuts were considered for the statistical analysis.

Agronomic assessments

The plants' height (ALT, cm) was measured before each cut using a graduated ruler to evaluate the crop's agronomic performance. After the cuts, each pot's number of tillers (PERF/pot number) was counted. After being cut, the leaves and stems were weighed, placed in paper bags, and taken to the greenhouse at 55 ºC for 72 hours, thus obtaining the pre-dry matter. We considered the pot area of 0.07065 m² to calculate the dry matter productivity (PMSA in kg ha^{-1}).

The nutritional characteristics were evaluated at the Bromatology Laboratory of UNIFENAS, where the pre-dried samples were ground in a Willey mill, and the material used for the determinations of total dry matter (AOAC, 1995), crude protein (AOAC, 1990), acid detergent fiber (ADF) and neutral detergent fiber (NDF) (VAN SOEST et al. 1994). We used the methodology of GOERING & VAN SOEST, 1970 to determine the cellulose, hemicellulose, and lignin in H_2SO_4.

For nutrient extraction, samples of the ground material were sent to the Foliar Chemistry Laboratory of the Federal University of Lavras (UFLA), quantifying the macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), in g/kg and the micronutrients, boron (B), copper (Cu), manganese (Mn), zinc (Zn) and iron (Fe) in mg/kg of plant DM, using the methodology proposed by (MALAVOLTA et al. 1989).

Data analysis

For data analysis, R software version 3.2.4 (R Core Team 2016) was used, considering the Shapiro-Wilk test to assess the normality of the residuals, the F test in the analysis of variance (ANOVA) to compare the means at $p < 0.05$, and the quadratic regression analysis of the evaluated quantitative characteristics. Thus, with the data submitted to regression analysis, it was possible to estimate the maximum technical efficiency dose of limestone for each variable. The quadratic equation (1) was used, where x is the amount of limestone applied and y is the studied variable.

$$Y = ax^2 + bx + c \quad (1)$$

Where y = dependent variable, x = independent variable, a, b, and c are regression coefficients and parameters to be estimated using least squares methods. Thus, maximum technical efficiency was obtained by the derivative of the homogeneous quadratic function (2) (DA ROSA et al. 2021). Where, x represents the limestone dose that implies the highest value of y (variable analyzed).

$$x_{max} = -(b/2a) \quad (2)$$

RESULTS

For the agronomic performance of Marandu grass, there was a positive influence by the limestone x nitrogen interaction (Figure 1; $P<0.05$) in the variables number of tillers (PERF) and dry matter productivity of the aerial part (PMSA kg ha-¹). Plant height did not significantly affect any of the factors evaluated ($P>0.05$).

According to (Figure 1A), dry matter productivity was higher with the dose of 2.9 t ha-1 of limestone, with approximately 4,095 kg ha-1. On the other hand, the doses of 6 to 8 t ha-1 of the corrective reduced productivity, resulting in values of 2,586.81 and 1,599.00 kg ha-1, respectively. In (Figure 1B), we can note that there was an increase in the number of tillers in the managed plants, and with the doses of 2.8 t ha-1 of limestone, there was the highest value of 64 tillers per pot.

Of the crop's bromatological characteristics, CP (%), NDF (%), and ADF (%) were altered by the limestone x nitrogen interaction (Figure 2; $P<0.05$). Figure 2A shows that the management association increased the CP (%) content in the plants, with the highest value found for a dose of 2.7 t ha-¹ of the corrective, with 12.04% protein.

For NDF (Figure 2B), the dose of 3.1 t ha-¹ of the corrective reduced its content in the plants, with 51% in the average of the four cuts. Similar to NDF, ADF (Figure 2C) had its lowest value in the managed plants, and considering the dose of 3.2 t ha-¹ of the corrective its content was 21.12%. Total dry matter, lignin, cellulose, and hemicellulose were insignificant for any factors evaluated ($P>0.05$).

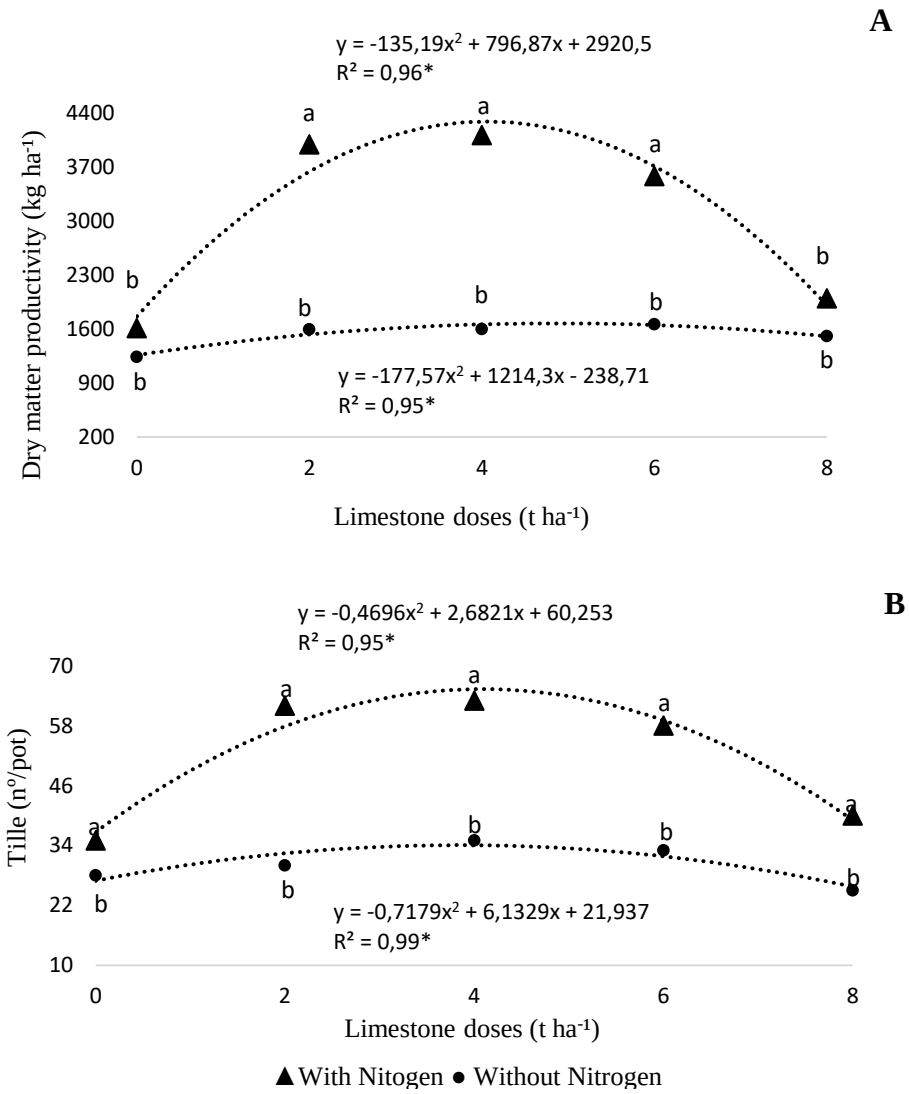


Figure 1. Interaction of liming and nitrogen fertilization on dry matter productivity (A) and number of tillers (B) of Marandu grass. Average of 4 cuts. Lowercase letters do not differ from each other at a significant level of 5% probability. Alfenas/MG, 2023.

Regarding the leaf analysis, with liming associated with nitrogen fertilization, N, P, K, Ca, Mg, and S had their highest levels in the plants, and Mn and Fe > P > S were reduced, with the data fitting the regression model (Figures 3 and 4; $P < 0.05$). Nutrient absorption followed a decreasing order for the macronutrients K > N > Ca > Mg.

Figure 3A shows that the highest nitrogen content (19.13 g/kg) occurred with a dose of 3.9 t ha-¹ of the corrective. The concentration of phosphorus (Figure 3B) was higher for the dose of 3.5 t ha-¹ of limestone when nitrogen fertilizer was applied as a top dressing, being the fifth most accumulated nutrient, presenting 2.03 g/kg in the DM of the plants. For K (figure 3C), the highest content of this nutrient, 25 g/kg, was observed with the estimated dose of 4.2 t ha-1. In treatments without nitrogen, the average potassium content was 17.85 g/kg.

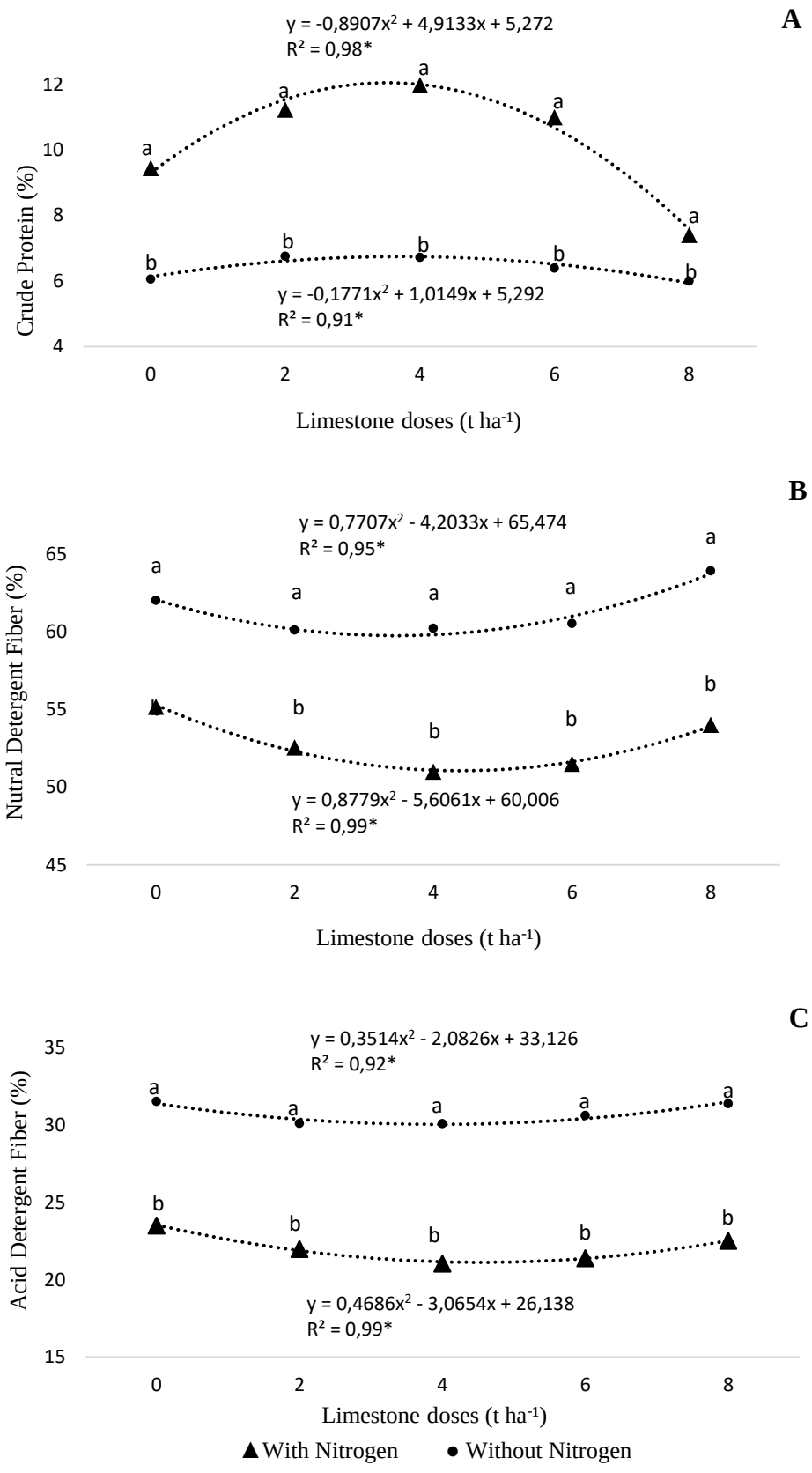


Figure 2. Interaction between liming and nitrogen fertilization on the crude protein (CP) (a), neutral detergent fiber (NDF) (b) and acid detergent fiber (ADF) (c) content of Marandu grass. Average of 4 cuts. Lowercase letters do not differ from each other at a significant level of 5% probability. Alfenas/MG, 2023.

Concerning the macronutrients, S (Figure 3F) had the highest content in plants, 1.85 g/kg, for an estimated dose of 3.5 t ha-1 of limestone, and the interaction between the factors promoted an increase of 58.11%. For Ca (Figure 3D) and Mg (Figure 3E), the nutrients presented higher contents, 3.67 and 2.63 g/kg for doses of 3.5 t ha-1 of the corrective. These values were higher than those found in treatments with exclusive application of limestone, which presented average contents of 2.6 and 1.9 g/kg for Ca and Mg, respectively.

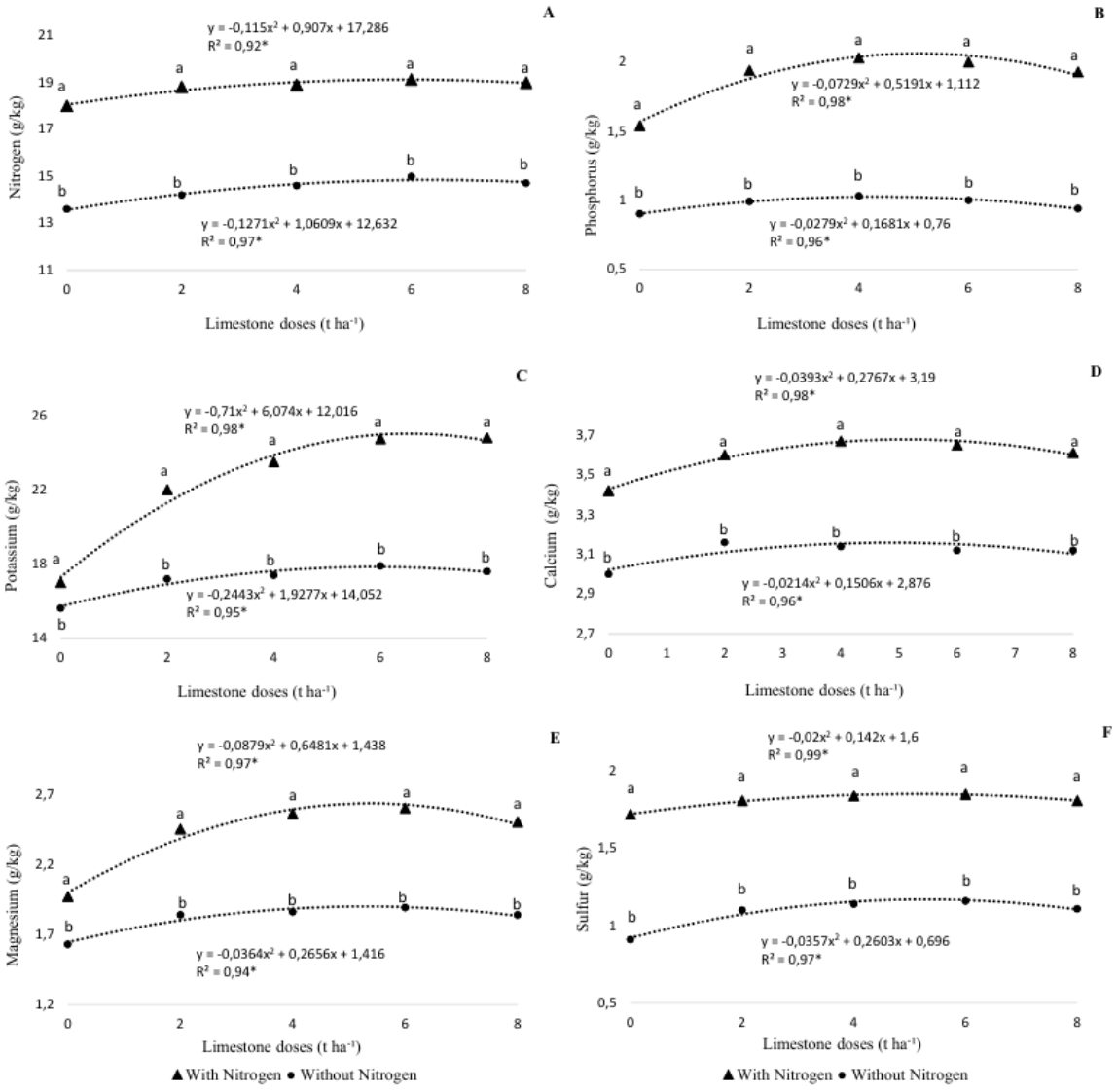


Figure 2. Interaction between liming and nitrogen fertilization on the levels of macronutrients nitrogen (A), phosphorus (B), potassium (C), calcium (D), magnesium (E), and sulfur (F) in Marandu grass. Average of 4 cuts. Lowercase letters do not differ from each other at a significant level of 5% probability. Alfenas/MG, 2023

Figures 4A and 4B show that unlike the macronutrients, the association of liming and nitrogen fertilization management reduced the Mn and Fe contents of the forage, and the lowest values found were 191.31 mg/kg and 207.37 mg/kg for Mn and Fe, respectively, considering the estimated doses of 3.7 tons ha-1 of limestone. On the other hand, the highest contents of these nutrients occurred in the control treatment, with 220.99 mg/kg for Mn and 247.74 mg/kg for iron.

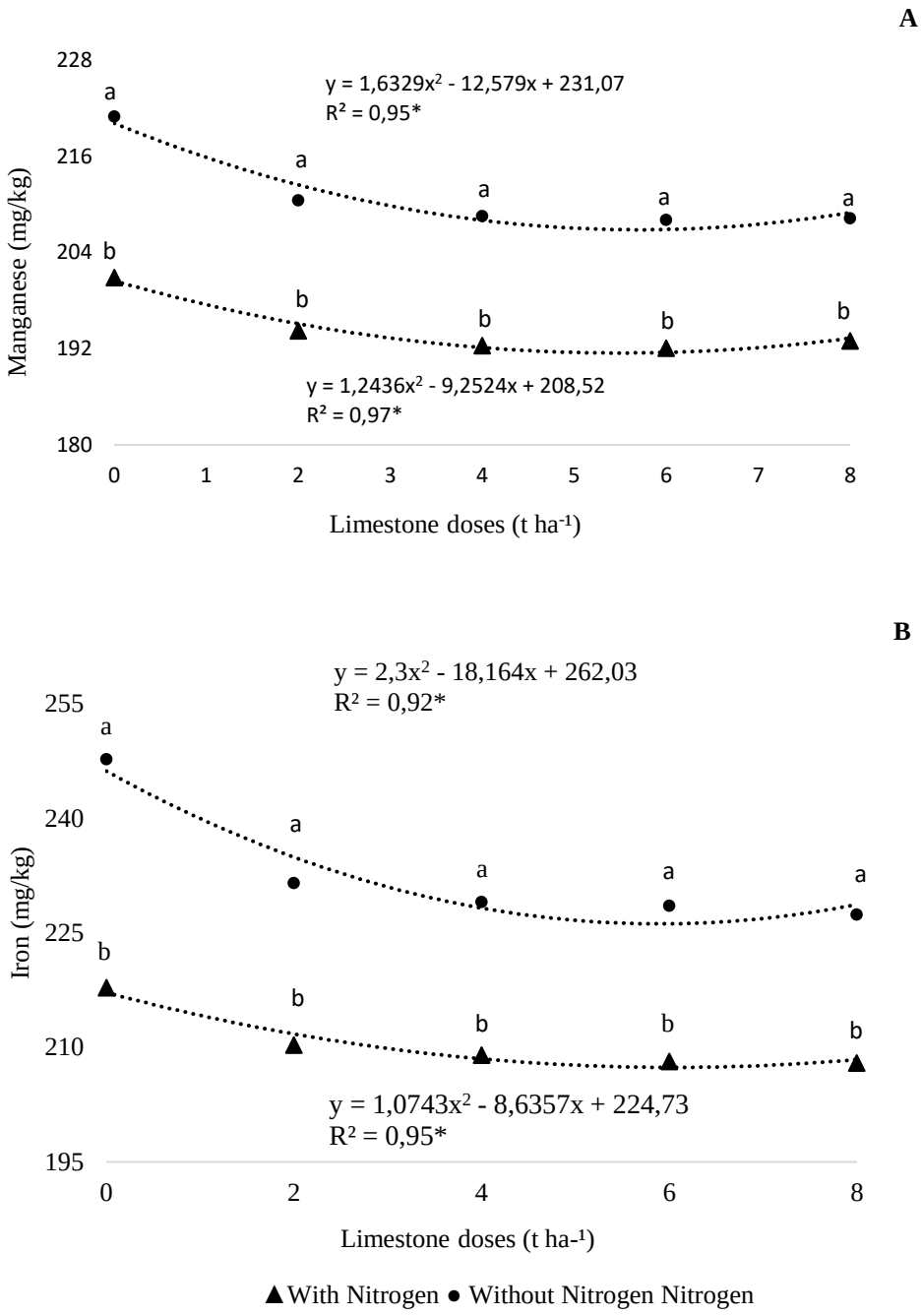


Figure 3. Interaction between liming and nitrogen fertilization on the levels of the micronutrients manganese (A) and iron (B) in Marandu grass. Average of 4 cuts. Lowercase letters do not differ from each other at a significant level of 5%. Alfenas/MG, 2023.

DISCUSSION

Considering the dry matter productivity obtained in the treatments with liming associated with nitrogen fertilization, the average annual forage production would be 16,000 kg ha^{-1} $year^{-1}$, resulting in an average increase of 62.09%. This value is probably due to liming, which, as already observed, enhances the chemical conditions of the soil and the absorption of N, a fundamental nutrient for plant development, consequently increasing crop productivity. Corroborating, GALINDO et al. (2018) indicate that when managed with soil correction and in a favorable climate, Marandu

grass responds well to nitrogen fertilization, producing between 20 and 36 t ha^{-1} year of DM.

There were also gains in tillering with liming management and plant nitrogen application. According to DE OLIVEIRA et al. (2020), nitrogen fertilization in forage grass promotes several benefits to the production system, the main one being the increase in the mass of forage produced through the greater rate of expansion of the leaf area and number of tillers in the plants.

CP (%), NDF (%), and ADF (%) had a positive influence on the interaction between liming and nitrogen fertilization, which can be attributed mainly to the use of nitrogen fertilizer since nitrogen promotes leaves and stems growth, providing a greater leaf-to-stem ratio in plants and reducing their fibrous proportions. Comparing the higher protein content obtained with liming associated with N, with the average of control treatment of 6.39%, the increase for the variable was 87.48% in the managed plants.

According to MARTINS et al. (2022), nitrogen plays a crucial role in plant growth and development. Increasing nitrogen supply leads to an increase in photosynthetic activity, which in turn stimulates the mobilization of carbon and nitrogen reserves for the production of new leaves and tillers. Consequently, nitrogen increases forage production and CP (%) content and, in some cases, decreases NDF (%) and ADF (%). MEDEIROS et al. (2011), studying *Brachiaria brizantha* cv Vitoria, noted decreasing linear effects on NDF (%) concerning the increase of nitrogen doses. Similarly, COSTA (2004) concluded that, as the concentration of N in plants increased, there was a decrease in ADF (%) contents of forage.

The main benefits of using liming and nitrogen fertilization in this study are because of these practices on the soil-plant system. Limestone is essential for plant nutrition, as it regulates soil pH, reducing its acidity, Al^{3+}, and toxic Fe and Mn^{2+}, which generally exist in high quantities in Brazilian soils. As liming favors the increase in soil CEC, it also enhances the retention of Ca^{2+}, Mg^{2+}, and K^{+}, in addition to improving the availability of P for plants, enhancing the soil's nutrient reservoir and reducing its exchangeable acidity (RAMÍREZ et al. 2021).

Nitrogen fertilization, by providing greater development of the aerial part of plants, also increases their demand for nutrients. Nitrogen is an important component of proteins and is the main nutrient for maintaining the quality and productivity of grass forages (MARTINS et al. 2022). Thus, in addition to improving the productivity and bromatological parameters of the crop, the levels of macronutrients in the plants increased with the association of liming and nitrogen fertilization management. This result is probably because of the greater volume of soil explored by the forage and the increase in the mineralization of organic matter due to the greater activity of soil microorganisms.

Therefore, these higher levels of nutrients such as N for plants, agreed with those found by OLIVEIRA et al. (2007). Compared to the control treatment, there was a 44.22% increase in N content, highlighting the importance of limestone and nitrogen fertilization for this forage. CARDOSO et al. (2016) observed that liming and nitrogen fertilization also increased the concentration of N, Mg and Ca (g/kg) in the leaf blades

of Massai grass and concluded that the crop responded positively to this type of management.

Due to its well-developed and well-distributed roots, Marandu grass can easily absorb nutrients, such as P and K, by diffusion or mass flow. Phosphorus absorption can also be favored through its greater availability in soils managed with lime since, in acidic soils, P tends to form insoluble compounds, which reduces its availability.

The phosphorus levels observed in this study agree with the values found by OLIVEIRA et al. (2007), which were 0.8 to 3.0 g of P/kg, which meets the requirements for cattle (NRC, 1996). Comparing the higher content of the nutrient obtained with liming and nitrogen fertilization to the control treatment, there was an increase of 100.99% in the P content in the managed forage.

The association of liming with nitrogen fertilization is reflected in the levels of several nutrients in the forage, as they favor the increase in leaf area and forage mass, therefore accelerating the plant's metabolism, transpiration, and the extraction of nutrients from the soil, which, in turn, raises the absorption of elements such as K+. PRIMAVESI et al. (2006) also observed high K extractions related to greater biomass production by the plants. The interaction of liming with nitrogen in this research increased 40.05% of the soil's K levels, the nutrient most extracted by Marandu grass.

Liming improves biological activity in the soil and provides Ca and Mg to plants. As expected, Ca extraction was greater than Mg due to using CaCO3 (13% MgO and 40% CaO). The nutrient increases in the treatments with liming and nitrogen fertilization represented values of 22.33% and 61.34% for Ca and Mg, respectively. Brazilian pastures generally have adequate levels of Ca and Mg to meet the requirements of beef cattle, according to the National Research Council (NRC 1996).

The levels of the micronutrients Fe and Mn were higher in the control treatment, which had an acidic pH (4.7), low levels of Ca^{2+} and Mg^{2+} (0.6 and 0.4 mol/dm-³, respectively), and high Al^{3+} saturation (74%). The availability of these nutrients is greatly affected by soil pH due to their increased solubility in acidic soils. As soil pH decreases, the solubility of Fe and Mn increases, as does that of other cationic micronutrients, such as Zn and Cu.

By increasing soil pH, using liming reduced the availability of Fe and Mn2+ and, consequently, the nutrients' absorption by plants. The values found agree with those described by PRIMAVESI et al. (2006), and the forage produced would be capable of meeting the nutritional needs of animals in pastures, according to NRC (1996).

The presented study showed that higher doses of limestone negatively affected most of the variables analyzed, which may be justified by the excessive liming, which can alter soil pH to alkaline levels, reducing the availability of nutrients such as P and, mainly, reducing the availability of cationic micronutrients, which are poorly extracted by brachiarias (PRIMAVESI et al. 2004).

CONCLUSION

In relation to this research, we concluded that according to the adopted management, the use of limestone at doses of 2 to 4 t ha-1 with nitrogen topdressing increased the productivity and nutritional quality of the plants, allowing higher levels of macronutrients absorbed by *Urochloa brizantha* cv. Marandu.

NOTES

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Adauton Vilela de Rezende, Paulo Henrique Aparecido Pinto and Hudson Carvalho Bianchini; software and validation, Fabrício Vilela Andrade Fiorini, Tayla Évellin de Oliveira and Adauton Vilela de Rezende; investigation, Paulo Henrique Aparecido Pinto and Tayla Évellin de Oliveira; resources and data curation, Fabrício Vilela Andrade Fiorini, Adauton Vilela de Rezende and Paulo Henrique Aparecido Pinto; writing-original draft preparation, Paulo Henrique Aparecido Pinto, Tayla Évellin de Oliveira and Hudson Carvalho Bianchini; writing-review and editing, Adauton Vilela de Rezende, Hudson Carvalho Bianchini and Paulo Henrique Aparecido Pinto; visualization, Fabrício Vilela Andrade Fiorini, Adauton Vilela de Rezende and Hudson Carvalho Bianchini; supervision, Adauton Vilela de Rezende, Hudson Carvalho Bianchini and Tayla Évellin de Oliveira; project administration, Paulo Henrique Aparecido Pinto and Adauton Vilela de Rezende; funding acquisition, Adauton Vilela de Rezende. All authors have read and agreed to the published version of the manuscript.

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INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable for studies not involving humans or animals.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available under request.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest

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