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# Liming and application of micronutrients in the establishment of Tifton pasture

## Calagem e aplicação de micronutrientes na implantação de pastagem de Tifton

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**Abstract**

Tifton pastures (*Cynodon* spp.) are widely used in tropical regions of Brazil, but are relatively recent in sub-tropical soils of southern Brazil. The objective of this work was to evaluate the Tifton response to liming and fertilization with copper (Cu), zinc (Zn) and boron (B) in the pasture establishment in the state of Santa Catarina. The experiment was installed in a Rhodic Ferralsol, in a randomized block design with subdivided plots. The treatments consisted of limestone doses in the main plots and application or non-application of Cu, Zn and B in the subplots. The doses tested were 4.25 t $ha^{-1}$ limestone (half the recommended dose to raise the pH ($H_2O$) to 5.5); 8.5 t $ha^{-1}$ (dose to raise the pH ($H_2O$) to 5.5); 11.9 t $ha^{-1}$ (dose to raise the pH ($H_2O$) to 6.0) and 15.7 t $ha^{-1}$ (dose to raise the pH ($H_2O$) to 6.5), in addition to a treatment without limestone application (control). Micronutrients Cu ($CuSO_4$), Zn ($ZnSO_4$) and B (borax) were applied, respectively, at the doses of 2.0, 2.0 and 1.0 kg $ha^{-1}$. In the Tifton establishment, limestone application decreased the values of Al and Cu and increased the values of Ca, Mg, pH and soil base saturation. The limestone application in the soil increased the dry matter production of Tifton up to the dose of 8.5 t $ha^{-1}$, regardless of the application of micronutrients.

**Additional keywords:** acidity correction; boron; copper; perennial pasture; zinc.

**Resumo**

As pastagens de Tifton (*Cynodon* spp) são amplamente utilizadas nas regiões tropicais do Brasil, porém são relativamente recentes nos solos subtropicais sul-brasileiros. O objetivo deste trabalho foi avaliar a resposta do Tifton à calagem e fertilização com cobre (Cu), zinco (Zn) e boro (B), na implantação da pastagem no Estado de Santa Catarina. O experimento foi instalado em um Latossolo Vermelho, em delineamento de blocos casualizados, com parcelas subdivididas. Os tratamentos constaram de doses de calcário nas parcelas principais e aplicação ou não de Cu, Zn e B nas subparcelas. As doses testadas foram de 4,25 t $ha^{-1}$ de calcário (metade da dose recomendada para elevar o pH-$H_2O$ até 5,5); 8,5 t $ha^{-1}$ (dose para elevar o pH-$H_2O$ até 5,5); 11,9 t $ha^{-1}$ (dose para elevar o pH-$H_2O$ até 6,0) e 15,7 t $ha^{-1}$ (dose para elevar o pH-$H_2O$ até 6,5), além de um tratamento sem aplicação de calcário (testemunha). Os micronutrientes Cu ($CuSO_4$), Zn ($ZnSO_4$) e B (Bórax) foram aplicados nas doses de 2,0, 2,0 e 1,0 kg $ha^{-1}$. A aplicação de calcário na implantação de Tifton diminuiu os valores de Al e Cu, e aumentou dos Ca, Mg, pH e saturação por bases do solo. A aplicação de calcário no solo aumentou a produção de massa seca de Tifton até à dose de 8,5 t $ha^{-1}$, independentemente da aplicação de micronutrientes.

**Palavras-chave adicionais:** boro; cobre; correção da acidez; pastagem perene; zinco.

## Introduction

The state of Santa Catarina is the fifth largest dairy producer in Brazil, with a production of 2,700 thousand liters, with the main dairy basin located in the west region, accounting for 74% of the state production (EPAGRI, 2013). In this region, cattle feeding is based on pasture, which represents an economic form of production, since it shows adequate climatic conditions, without presence of dry season and very rigorous winter, allowing pasture production at all times of the year. In addition to favorable climatic conditions, satisfactory pasture performance requires an adequate nutrient content in the soil and absence of toxic elements such as aluminum (Al) and excess manganese (Mn) in the soil solution.

The soils of the western region of Santa

Catarina present high clay content, with medium to high organic matter content and acid pH (Ernani & Almeida, 1986). Therefore, for acidity-sensitive crops, it is essential to apply soil correctives which neutralize soil acidity, thus neutralizing $Al^{3+}$ and increasing the availability of calcium (Ca) and magnesium (Mg) to plants (Ernani et al., 2002; Kaminski et al., 2005; Volpe et al., 2008). In some cases, the increase of pH by liming may increase the availability of macronutrients essential for plants, such as phosphorus (P) (Ernani et al., 2001) and nitrogen (N) (Silva & Vale, 2000), in addition to reducing the availability of some micronutrients (Nascimento et al., 2007). Although some forage species are rustic and adapted to tropical acid soils (Bandinelli et al., 2005), pastures generally do not reach the maximum yield potential due to absence of agronomic techniques such as liming and fertilization.

Micronutrients copper (Cu), zinc (Zn) and boron (B) are adsorbed to soil components (organic matter, oxides, clay minerals) and only a small amount is available to the plants (Nascimento et al., 2007; Garcia et al., 2008; Brunetto et al., 2014). Normally, soils with high clay and organic matter content at their natural pH present reasonable reserves of these micronutrients that are in equilibrium with the soil solution. However, fertilizer companies have pressured the market for the application of micronutrients, both via soil and foliar, without the use of technical criteria.

The proposed increase in the soil pH to be reached by the practice of liming is conditioned, among others, to the need of the plant, with plants more or less responsive to liming (Tiecher et al., 2013), and to the buffer power (Gatiboni et al., 2000; CQFS-RS/SC, 2004). However, few studies address the response of pastures with micronutrients (Volpe et al., 2008) and the interaction of these with liming, since in some situations micronutrient deficiency may occur in plants (Impa & Johnson - Beebout, 2012). Nonetheless, due to the high dry matter production, the export of nutrients, among them micronutrients, is significant (Matos et al., 2010).

The hypotheses of the study are: (I) Liming will increase the pH, Ca and Mg values and, consequently, the dry matter production of Tifton (*Cynodon* spp); (II) The application of micronutrients will increase the availability of micronutrients and the production of Tifton. The objective of the study was to evaluate the influence of liming and copper, zinc and boron application on the production of Tifton (*Cynodon* spp.) forage in a Rhodic Ferralsol in southern Brazil.

## Material and methods

The experiment was conducted at the Agricultural School Demétrio Baldissarelli, in the municipality of Chapecó-SC, located at 27°12'40" South latitude and 52°37'36" West longitude, with an average altitude of 668 m. The climate of the region is Cfa, mesothermal humid subtropical, according to the Köppen classification. Precipitation and temperature data are presented in Figure 1. The soil of the experimental area is classified as Rhodic Ferralsol (FAO, 1998) and presented the following characteristics for the 0-20 cm layer before the experiment: pH (water) = = 4.9; SMP index = 4.8; $Ca^{2+}$ = 3.8 $cmol_c\ dm^{-3}$; $Mg^{2+}$ = = 1.2 $cmol_c\ dm^{-3}$; $Al^{3+}$ = 3.1 $cmol_c\ dm^{-3}$; P (Mehlich-1) = = 7.7 mg $dm^{-3}$; K = 45.6 mg $dm^{-3}$; Cu = 1.8 mg $dm^{-3}$; Zn = 0.2 mg $dm^{-3}$; B = 0.2 mg $dm^{-3}$; Organic Matter = = 75.3 g $kg^{-1}$; Clay = 600 g $kg^{-1}$.

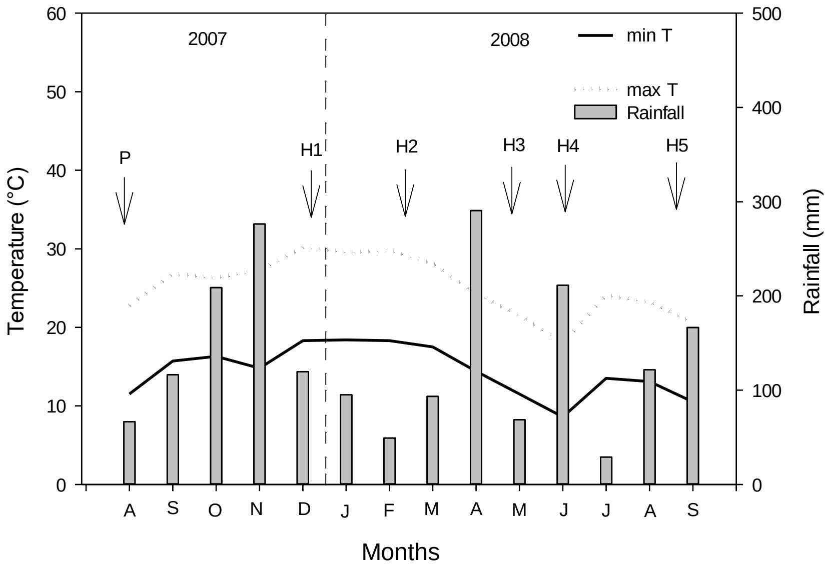


**Figure 1** - Rainfall (mm) and maximum average temperature (T max) and minimum average temperature (T min) from August 2007 to September 2008 in Chapecó - SC. P - planting; H1 - harvest 1; H2 - harvest 2; H3 - harvest 3; H4 - harvest 4; H5 - harvest 5.

The experiment was carried out in an area where there was Bermuda grass, which was extinguished with two applications of glyphosate-based herbicide at the dose of 3.0 L $ha^{-1}$, performed at 45 and 30 days before planting the seedlings. Subsequently, the soil was plowed with disk plows and leveled with a leveling harrow.

The treatments were set up in a randomized complete block design, under a split-plot arrangement, with four replications. Doses of limestone was allocated to the main plots (24 m²) and application or non--application of micronutrients (Cu, Zn and B) to the subplots. The limestone doses tested were 4.25 t $ha^{-1}$ limestone (half the dose to raise the pH ($H_2O$) to 5.5); 8.5 t $ha^{-1}$ (dose to raise the pH ($H_2O$) to 5.5, being the recommendation for the crop (CQFS-RS/SC, 2004)); 11.9 t $ha^{-1}$ (dose to raise the pH ($H_2O$) to 6.0) and 15.7 t $ha^{-1}$ (dose to raise the pH ($H_2O$) to 6.5), in addition to a treatment without limestone application (control). Micronutrients Cu, Zn and B were manually applied to the soil (total area) and incorporated, after 30 days of limestone application, at the doses of 2.0, 2.0 and 1.0 kg $ha^{-1}$, respectively (Lopes, 1999), having $CuSO_4$, $ZnSO_4$ and borax as sources. Dolomitic limestone was used, with 82% based on an acid-neutralizing capacity, with half of the dose being applied to the soil surface and incorporated with disk plow, followed by application of the other half of the dose and plowing and harrowing up to 20 cm depth, 30 days before planting, transversely to the block.

NPK fertilization was carried out in all plots based on the official recommendation (CQFS - RS/SC, 2004), applying 100 kg $ha^{-1}$ $P_2O_5$, 100 kg $ha^{-1}$ $K_2O$ at the time of planting, and 400 kg $ha^{-1}$ N, in the form of triple superphosphate, potassium chloride, and urea, respectively. P and K were applied on the surface at the moment of planting of the seedlings and incorporated, while the nitrogen was applied in split plots, immediately after the second, third, fourth and fifth pasture harvests (100 kg $ha^{-1}$ N in each time).

Tifton 85 seedlings were planted manually on 08/19/2007 in a spacing of 0.5 x 0.5 m. As a result of lack of rainfall after planting the seedlings, the seedling survival and soil cover rate were very low and, therefore, seedlings were replanted 32 days after the first planting. The dry matter yield of the forage was evaluated for 12 months, being analyzed each time the first experimental units reached the average height of 30 cm, which occurred on the following dates: Harvest 1 = 12-27-2007, Harvest 2 = 02-21-2008, Harvest 3 = = 04-12-2008, Harvest 4 = 05-31-2008 and Harvest 5= = 08-30-2008. Forage production was determined by cutting at 5 cm height of three subsamples of 0.25 $m^2$ per plot. After each harvest, the experimental area was immediately mowed and the forage removed from the plots.

The plant material was dried in an air circulation oven at 60 °C for determination of dry matter production and absorbed amounts of nutrients. The average daily growth (ADG) was calculated by dividing the amount of material harvested per hectare by the number of days of growth until cutting. Soil samples were sampled in the 0-20 cm layer, after the fifth harvest of the forage, using a Dutch auger. The contents of available Ca, Mg and exchangeable Al, Cu, Zn and B were analyzed, in addition to the pH ($CaCl_2$), according to the methodologies described by Tedesco et al. (1995).

The results were submitted to analysis of variance and, when significant, Tukey's mean comparison test ($p<0.05$) and adjustments of polynomial regression equations were performed. For the choice of the best regression model, we opted for the significant model with the highest degree. For quantitative data, the linear-plateau regression model was used, using SAS software when significant (SAS, 2003).

## Results and discussion

Liming affected growth rate and forage production in the first four harvests, but no effect of micronutrient application or interaction between liming and micronutrient was observed with respect to forage production (Table 1). In the first harvest, the pasture presented a slow growth, since it included the period of pasture establishment, presenting an average daily growth (ADG) of 19.2 kg $ha^{-1}$ $day^{-1}$ forage DM (Table 1). Cutting periods 2 and 3, occurring in the summer, had the highest ADG values, of 76.5 and 62.4 kg $ha^{-1}$ $day^{-1}$ DM, respectively. On the other hand, harvests 4 and 5, in the autumn and winter, presented ADG values of 30.4 and 42.9 kg $ha^{-1}$ $day^{-1}$ forage DM, respectively (Table 1). In the last harvest, the pasture showed no response to liming.

For the first four harvests evaluated separately and for the total dry matter production, the response of plants was quadratic to the limestone application in the soil (Figure 2), the maximum yield being obtained with the dose of 9.8 t $ha^{-1}$, i.e., 15% above the dose of 8.5 t $ha^{-1}$, which is the limestone recommendation to raise the pH ($H_2O$) to 5.5. At the dose of 8.5 t $ha^{-1}$, the yield was 99% of the estimated maximum yield and, at the dose of 4.25 t $ha^{-1}$, the yield was 96% of the estimated maximum yield, indicating that this dose can be recommended. The increase in the dry matter yield by liming may be due to the increase in the levels of $Ca^{2+}$, $Mg^{2+}$, and, consequently, in the values of base saturation (Table 2, Figure 3A) and pH ($CaCl_2$) (Figure 3B), in addition to the decrease of $Al^{3+}$ in the soil (Figure 3b) (Almeida et al., 1999). These improvements in soil chemical quality probably led to an increase in the number of root hairs (Barber, 1984), increasing plant tillering and number of leaves; consequently, the plants absorbed more solar energy, reflecting higher biomass (Prado & Barion, 2009).

**Table 1**.- Variance analysis for Tifton grass dry mass, Tifton dry mass and average daily growth (in parentheses, kg $ha^{-1}$ $day^{-1}$) over 5 harvests in an Ferralsol with application of lime and micronutrient.

| Causes of variation | Dry mass (kg $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Harvests | | | | |
| | 1 | 2 | 3 | 4 | 5 |
| Lime (L) (t $ha^{-1}$) | | | | | |
| 0.00 | 2,455 (18.9) | 3,877 (69.2) | 2,544 (50.9) | 1,213 (25.3) | 3,980 (46.3) |
| 4.25 | 2,267 (17.4) | 4,230 (75.5) | 3,080 (61.6) | 1,568 (32.7) | 3,311 (38.5) |
| 8.50 | 2,837 (21.8) | 4,504 (80.5) | 3,523 (70.5) | 1,613 (33.6) | 3,964 (46.1) |
| 11.90 | 2,963 (22.8) | 4,603 (82.2) | 3,189 (63.8) | 1,565 (32.6) | 3,530 (41.0) |
| 15.70 | 2,352 (18.1) | 4,208 (75.1) | 3,251 (65.0) | 1,337 (27.8) | 3,677 (42.8) |
| F test | 4.39* | 8.70** | 8.95** | 3.58* | 0.90ns |
| CV (%) | 16.1 | 6.4 | 10.9 | 17.9 | 23.1 |
| Micronutrient (M) (kg $ha^{-1}$) | | | | | |
| With | 2,609 (20.1) | 4,228 (75.5) | 3,141 (62.8) | 1,482 (30.9) | 3,603 (41.9) |
| Without | 2,541 (19.5) | 4,343 (77.5) | 3,093 (61.9) | 1,436 (29.9) | 3,784 (44.0) |
| F test | 0.28ns | 1.62ns | 0.19ns | 0.43ns | 0.94ns |
| L x M | 1.08ns | 1.62ns | 0.89ns | 0.63ns | 0.52ns |
| CV (%) | 15.9 | 6.7 | 11.3 | 15.1 | 15.7 |

CV – Coefficient of variation; *Significant at 5% of probability F test; ** Significant at 1% of probability; ns - not significant.

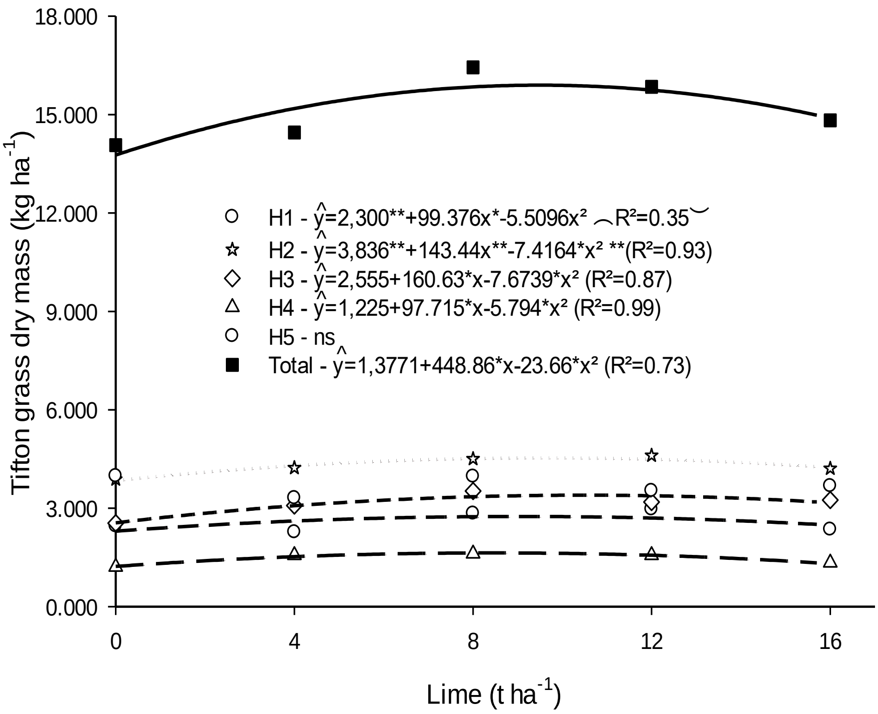


**Figure 2** - Tifton grass dry mass in response to application of lime in the soil. H1 - harvest 1; H2 - harvest 2; H3 - harvest 3; H4 - harvest 4; H5 - harvest 5; Total - total dry matter.
*Significant at 5% of probability F test; ** Significant at 1% of probability; ns - not significant.

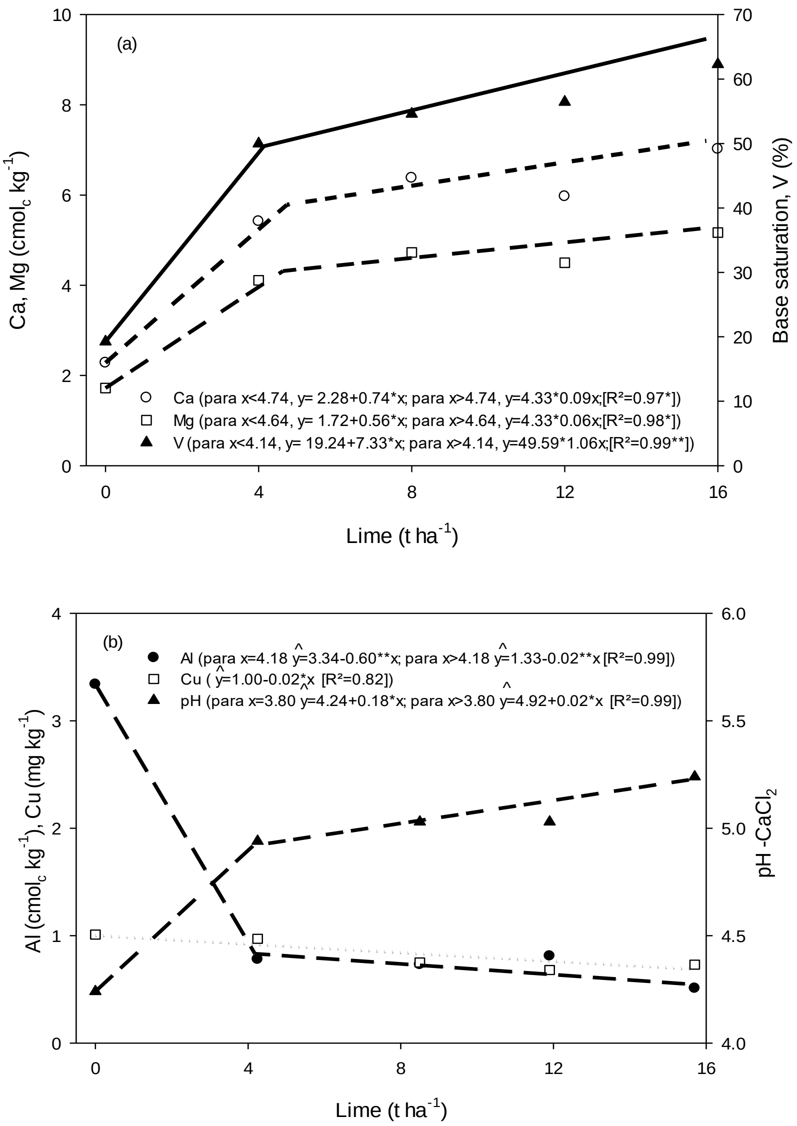


**Figure 3 -** Calcium and magnesium exchangeable, base saturation (a), pH in $CaCl_2$, exchangeable aluminum (Al) and available copper (Cu) (b) of Ferralsol in response to application of lime in the soil cultivated with Tifton. *Significant at 5% of probability F test; ** Significant at 1% of probability; ns - not significant.

The application of micronutrients in the soil increased the available contents for all micronutrients (Table 2), but did not affect dry matter production and daily growth (Table 1). The lack of effect of the application of micronutrients Cu, Zn and B on forage production is probably due to the high micronutrient content available in the soil (CQFS-RS/SC, 2004) and the high organic matter content in the 0-20 cm soil layer (75 g $kg^{-1}$). Hence, with levels above the critical level, the plants did not respond to micronutrient applications (CQFS-RS/SC, 2004). Therefore, even in the case of a plant with a high growth rate and nutrient uptake, micronutrient applications in the soil should only be performed if there is deficiency of availability according to soil analysis following technical criteria (CQFS-RS/SC, 2004).

Except for available Cu, whose decrease in availability was linear with the increase in pH (Figure 3b), for the other micronutrients, there was no decrease in availability with increasing liming. This shows that although the increase of soil pH provided by liming decreases the bioavailable fractions and increases the adsorption (Nascimento et al., 2007) by redistributing these elements into more stable fractions with higher binding energy (Brunetto et al. 2014), the methods used in routine laboratories to evaluate the availability of these micronutrients are not always able to detect these changes (Fonseca et al., 2010). On the other hand, liming causes greater mineralization of organic matter by improving the soil chemical condition for microorganisms (Ernani et al., 2002), which can provide part of the micronutrients that were present in the soil organic matter.

**Table 2 -** pH, calcium, magnesium, aluminum, copper, zinc and boron in an Ferralsol with application of lime and micronutrient cultivated with grazing Tifton.

| Causes of variation | pH | V | Ca | Mg | Al | Cu | Zn | B |
|---|---|---|---|---|---|---|---|---|
| | ($CaCl_2$) | (%) | ------- ($cmol_c$ $kg^{-1}$) -------- | | | -------- (mg $kg^{-1}$) -------- | | |
| Lime (L) (t $ha^{-1}$) | | | | | | | | |
| 0.00 | 4.2 | 19.24 | 2.28 | 1.72 | 3.34 | 1.01 | 7.69 | 0.42 |
| 4.25 | 4.9 | 49.98 | 5.42 | 4.11 | 0.78 | 0.97 | 6.88 | 0.29 |
| 8.50 | 5.0 | 54.58 | 6.38 | 4.73 | 0.73 | 0.75 | 6.35 | 0.39 |
| 11.90 | 5.0 | 56.44 | 5.97 | 4.50 | 0.81 | 0.68 | 6.45 | 0.36 |
| 15.70 | 5.2 | 62.28 | 7.02 | 5.17 | 0.51 | 0.73 | 6.29 | 0.31 |
| F test | $9.48^{**}$ | $13.91^{**}$ | $17.94^{**}$ | $22.20^{**}$ | $46.74^{**}$ | $3.99^{*}$ | $1.02^{ns}$ | $1.23^{ns}$ |
| CV (%) | 7.2 | 26.49 | 22.8 | 20.1 | 39.7 | 26.0 | 24.1 | 40.3 |
| Micronutrient (M) (kg $ha^{-1}$) | | | | | | | | |
| With | 4.9 | 47.83 | 5.25 | 4.05 | 1.30 | 0.95a | 7.50a | 0.40a |
| Without | 4.9 | 49.17 | 5.58 | 4.04 | 1.17 | 0.70b | 5.97b | 0.30b |
| F test | $0.02^{ns}$ | $0.23^{ns}$ | $1.14^{ns}$ | $0.00^{ns}$ | $1.26^{ns}$ | $17.97^{**}$ | $22.18^{**}$ | $12.75^{**}$ |
| L x M | $0.44^{ns}$ | $0.78^{ns}$ | $0.62^{ns}$ | $0.66^{ns}$ | $1.29^{ns}$ | $1.11^{ns}$ | $1.49^{ns}$ | $1.78^{ns}$ |
| CV (%) | 4.4 | 18.23 | 18.0 | 18.2 | 29.1 | 23.0 | 15.2 | 25.7 |

CV – Coefficient of variation; *Significant at 5% of probability F test; ** Significant at 1% of probability; ns - not significant.

For the other soil parameters, two stages of response to liming were observed. In a first moment, the application of limestone at the dose of 4.25 t $ha^{-1}$ produced a rapid increase of $Ca^{2+}$, $Mg^{2+}$, V and pH ($CaCl_2$) and a decrease in exchangeable Al. At doses greater than 4.25 t $ha^{-1}$, the acidity correction reaction was slower, producing gentle increases in Ca, Mg, V and pH ($CaCl_2$). This is due to the coarser granulometry of the limestone used (82% RTNP), causing the dissolution to be gradual and enhanced by the existence of high acidity. In addition, acidity correction depends on a chemical equilibrium reaction between the products ($Ca^{2+}$ and $OH^-$) that cause the limestone dissolution rate to decrease. Thus, at lower doses, the existence of higher acidity stimulates limestone dissolution. At higher doses, however, the reaction is slower, increasing the residual effect of liming (Kaminski et al., 2005).

In general, forage grasses are more adapted to soil acidity than legumes or even grain-producing grasses (CQFS-RS/SC, 2004). The results of this work show a significant effect of liming up to the recommended dose (8.50 t $ha^{-1}$) to achieve a pH (water) of 5.5 after 5 harvests. Notwithstanding, the choice of the limestone dose to be applied should consider the soil and crop conditions, the residual effect and the financial condition of the producer. Under conditions of low available capital, half the dose (4.25 t $ha^{-1}$) could be applied to reach a pH of 5.5, since this dose already presents adequate conditions such as base saturation around 60% and low $Al^{3+}$. It should be noted that the use of half the dose would reduce the residual effect of liming and, because it is a perennial plant, future applications may be applied on the surface.

## Conclusions

In the Tifton establishment, limestone application at half and full dose to achieve a pH (water) of 5.5 increased pasture productivity.

The use of limestone increased the values of pH ($CaCl_2$), base saturation, exchangeable calcium and magnesium, and decreased the levels of exchangeable aluminum and copper available in the soil.

The application of copper, zinc and boron provided greater availability of micronutrients in the soil, but did not influence the dry matter production of Tifton.

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