International Journal of Plant & Soil Science
7(3): 160-171, 2015; Article no.IJPSS.2015.141
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

Changes in the Chemical Properties of Soil Cultivated with *Brachiaria ruziziensis* Regarding Nitrogen Fertilization

Karina Batista[1*], Alessandra Aparecida Giacomini[1], Waldssimiler Teixeira de Mattos[1], Luciana Gerdes[1] and Ivani Pozar Otsuk[1]

[1]Scientific researcher at the Instituto de Zootecnia, Centro de Pesquisa e Desenvolvimento em Nutrição Animal e Pastagem, Rua Heitor Penteado, 56, Centro, CEP: 13460-00 Nova Odessa-SP, Brasil.

Authors' contributions

This research was carried out in collaboration between authors. The idea was designated by author KB. Authors KB, AAG, WTM and LG conducted the research in greenhouse. Author IPO performed the statistical analysis. All authors contributed to manuscript writing and formatting. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2015/17601
Editor(s):
(1) Junhong Bai, School of Environment, Beijing Normal University, Beijing, China.
Reviewers:
(1) Anonymous, Ibn Khaldoun University, Algeria.
(2) Anonymous, Kibet Sitienei 1Tea Research Foundation of Kenya, Kericho, Kenya.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1095&id=24&aid=9201

Original Research Article

Received 19th March 2015
Accepted 20th April 2015
Published 8th May 2015

ABSTRACT

The present study aimed to determine the effects of nitrogen fertilization on the chemical properties of Oxissol (Red Latosol), in an area cultivated with *Brachiaria ruziziensis* cv. Common where crop succession system was used ("safrinha" corn (second growing season) planted in succession to soybean) in no-tillage system, regarding the combinations of nitrogen doses. The experimental treatments consisted of two doses of nitrogen applied in the planting of *Brachiaria ruziziensis* and four doses of nitrogen applied after the first grass cut. The treatments were arranged in 2x4 factorial design, as follows: 0.0; 0.15; 0.30; 0.45; 15.0; 15.15; 15.30 and 15.45 mg dm^{-3}. The experimental design used was completely randomized blocks with four repetitions The soil chemical properties assessed were: pH; cation exchange capacity; base saturation; potential acidity; soil contents of organic matter, phosphorus, sulfate, potassium, calcium, magnesium, boron, copper, iron, manganese and zinc. F test was used in the comparisons between nitrogen

*Corresponding author: E-mail: batistakarin@gmail.com;

means during planting, and regression analyzes were used for the nitrogen treatments after the first grass cut. The nitrogen fertilization does not interfere in the values of pH, organic matter, phosphorus, boron, iron, manganese and zinc of the soil cultivated with *Brachiaria ruziziensis*. It is necessary to monitor the contents of K, Ca, Mg and B in the soil when nitrogen is applied to *Brachiaria ruziziensis*. The minimum sulfate content in soil cultivated with *Brachiaria ruziziensis* is 4.94 mg dm^{-3} for the dose of 36.3 mg dm^{-3} of nitrogen. The non-application of nitrogen at planting associated to the application of 28.5 mg dm^{-3} of nitrogen after the first grass cut results in higher copper content in soil (4.14 mg dm^{-3}). The application of 15 mg dm^{-3} of nitrogen at planting associated to the increase in nitrogen doses after the first grass cut led to increase in copper content.

Keywords: Brachiaria ruziziensis; fertility of the soil; micronutrients in the soil; organic matter; potential acidity.

1. INTRODUCTION

The development of systems that reduce the establishment of cover crops and the subsequent establishment of the grain crop shall increase the quality of soil and water in tropical regions [1]. In order to increase grain production and with the possibility of production of ground cover and forage in times of water shortage, the use of "safrinha" corn - second growing season - in consortium with *Brachiaria ruziziensis* cv. Common in no-tillage system has been expanding in recent years. The consortium system favors the development of corn, the main crop. Thus, doubts regarding the mineral nutrition of the grass, particularly when it is subsequently grazed by beef cattle, are frequent.

A proper management of plant fertilizers makes it possible to meet nutrient demand of single or multiple crops, through a single application or several applications at different times. Some studies [2-5] demonstrated that the use of nitrogen fertilization is essential in the formation and maintenance of tropical pastures. Thus, the application of nitrogen to *Brachiaria ruziziensis* should be considered in correction of soil fertility using the consortium system. However, the lack of quantitative information on nitrogen management (dose and form of application of N) causes nitrogen to be used not as efficiently as possible [6]. So, knowledge of the effects of nitrogen fertilization on soil chemical properties is important to ensure an appropriate management of the nutrient [3].

According to some studies, for one given dose of fertilizer N (ammonium nitrate or starch) applied in pastures, pH is affected by soil buffering capacity and cation exchange capacity (CEC) [7]. The soil chemical properties that influence the losses of N-NH_3 by volatilization are pH, CEC and soil organic matter [8]. Nitrogen fertilization alters soil pH, and Zn, Fe and Mn accumulations decrease significantly with pH increase [9].

Therefore, studies on the fertilization of tropical grasses, in general, have shown the importance of nitrogen application [10,11]. This study aimed to determine the effects of nitrogen fertilization on the chemical properties of Oxissol (Red Latosol), in an area cultivated with *Brachiaria ruziziensis* cv. Common where crop succession system was used (“safrinha” corn (second growing season) planted in succession to soybean) in no-tillage system, regarding the combinations of nitrogen doses.

2. MATERIALS AND METHODS

The experiment was conducted in a greenhouse of Instituto de Zootecnia, Nova Odessa-SP, with cultivation of the foraging species *Brachiaria ruziziensis* cv. Commun from September to December 2011. Also, it was conducted under controlled conditions to avoid extra fertilization interference in nitrogen supply (ex. transfer of nutrients from other areas via animal waste) and ensure proper supply of water or ensure adequate supply of water and room temperature for the normal development of the grass.

The soil of the experiment was classified as Oxissol (Red Latosol), according to the Brazilian System of Soil Classification [12] and was collected on a farm (latitude 23°35’08”S; longitude 48°02’50”W and altitude 636 m); where soybean - “safrinha” corn (second growing season) succession in no-tillage system has been used for 10 years. Soil collection was performed immediately after soybean harvest and before planting the corn, at 0-20 cm depth.

The soil sample was then packed, dried, sieved and weighed and then placed in earthen pots of 5 kg capacity.

A sample of this soil was analyzed for its initial fertility and showed the following results: pH in $CaCl_2$=5.8; organic matter=38.0 g dm^{-3}; P (resin)=132.0 mg dm^{-3}; K (resin)=4.9 mmolc dm^{-3}; Ca (resin)=60.0 mmolc dm^{-3}, Mg (resin)=16.0 mmolc dm^{-3}; Al=0 mmolc dm^{-3}; H+Al=31.0 mmolc dm^{-3}; SO4=6.0 mg dm^{-3}; SB=80.9 mmolc dm^{-3}; CEC=112.0 mmolc dm^{-3} and V=72.0%. According to [13], correction of soil acidity and fertilization with macro and micronutrients were not necessary during grass sowing. Particle size analysis of soil showed the following results: Very coarse sand= 14 g kg^{-1}, coarse sand= 30 g kg^{-1}, medium sand= 64 g kg^{-1}, fine sand= 40 g kg^{-1}, very fine sand= 14 g kg^{-1}, total sand= 161 g kg^{-1}, silt= 137 g kg^{-1}, clay= 702 g kg^{-1} and textural class= very clayey soil.

The experimental treatments were defined according to the observations of [14], with two doses of N (0 and 15 mg dm^{-3}) applied during the sowing of grass *Brachiaria ruziziensis* and four doses of N applied soon after the first grass cut (0, 15, 30 and 45 mg dm^{-3}). Thus, the treatments were arranged in 2x4 factorial design, as follows: 0.0; 0.15; 0.30; 0.45; 15.0; 15.15; 15.30 and 15.45 mg dm^{-3}. The combinations were distributed in the greenhouse according to a randomized complete block design with four repetitions. For the sowing of grass *Brachiaria ruziziensis* fifty seeds were placed in each pot, and one week after germination, the plants were thinned, leaving only five plants per pot.

Two cuts were performed in the plants: the first was made 39 days after germination of *Brachiaria ruziziensis* and the second 27 days after the first grass cut. After the first cut, topdressing fertilization with 40 mg dm^{-3} de P_2O_5 in the form of potassium dihydrogen phosphate (KH_2PO_4), 83 mg dm^{-3} of K_2O, with 384 mg dm^{-3} in the form of KH_2PO_4 and 186.3 mg dm^{-3} in the form of potassium chloride (KCl). The application of potassium was necessary due to the onset of symptoms of deficiency of this nutrient during the first growth, whereas phosphate was applied to avoid the decline in the response to applied nitrogen levels. On the day following the first grass cut, the nitrogen doses of 0, 15, 30 and 45 mg dm^{-3} were applied in the form of ammonium nitrate, forming the combinations of doses of nitrogen in the planting and after the first cut.

After the second cut of *Brachiaria ruziziensis*, a composite soil sample was taken from each pot and sent to the laboratory for analysis of fertility status, organic matter, sulfate and micronutrients (boron, iron, manganese and zinc) in soil. In the analysis of fertility, the organic matter content was determined by the colorimetric method [15]. The properties pH in $CaCl_2$, the potential acidity by SMP buffer and extraction of P, K, Ca and Mg through ion exchange resin were determined using the methods described by [16]. In turn, sulfate was determined by the calcium phosphate method described by [17]. Regarding the assessment of micronutrients, boron determination was performed in warm water using microwave heating according to the method described by [18]. Copper, iron, manganese and zinc measurements were performed using DTPA solution (pH 7.3) [19].

The data were analyzed by SAS - System for Windows 9.2 [20]. For analysis of variance, the GLM procedure was used, at the 5% level of significance. F test was used for comparisons of the means of nitrogen treatments at planting, and regression analyzes were used for the nitrogen treatments after the first grass cut.

3. RESULTS AND DISCUSSION

3.1 Effect of Nitrogen Fertilization at the Levels of ph, Organic Matter, Phosphorus and Sulfate in the Soil

pH, organic matter, phosphorous and sulfate levels in soil were not significant for the interaction N doses at planting x N doses after the first cut of *Brachiaria ruziziensis* (Table 1). The individual doses of nitrogen applied at planting and after the first cut of *Brachiaria ruziziensis* also did not change pH, organic matter and phosphorus levels (Fig. 1a, 1b, 1c, 2a, 2b and 2c). Sulfate concentration in the soil did not differ for the N doses supplied at planting (Fig. 1c), but only for N doses applied after the first grass cut, adjusting to quadratic regression model (Fig. 2d).

The levels of pH in soil ranged from 5.1 to 5.3 corresponding to a medium soil acidity [21] (Table 1). In addition to the application of nitrogen doses, these values must consider the charges resulting from the balance between mineralization and nitrification of the organic nitrogen added by the soybean crop that may have been favored by N application to the soil

[22]. The content of soil organic matter at the end of the experimental period ranged from 36.5 to 39.0 g dm^{-3} (Table 1). These organic matter contents can be related to the intensity of waste decomposition processes, depending on the application of N (Rangel et al., 2008). Phosphorous (P) content in the soil (204 to 225 mg dm^{-3}) is very high [21], which can be explained by the fact that the studied soil sample was obtained from an area that has been used in no-tillage system for around 10 years (Table 1). Greater availability of P in soils from no-tillage system is common, due to the presence of waste from the previous crop: because of the P present in the waste and competition of organic compounds in the waste for exchange sites in the soil [22,23]. The minimum sulfate content in the soil was 4.94 mg dm^{-3} for the dose of 36.3 mg dm^{-3} of N (Fig. 2d). This sulfate content indicates that nitrogen fertilization may have interfered with the N:S ratio, because high values of N may cause immobilization of sulfur in the soil due to lack of balance between both nutrients [24] (Fig. 2d), resulting in a low sulfate content in the soil.

3.2 Effect of Nitrogen Fertilization on Potassium, Calcium, Magnesium, Cation Exchange Capacity, Potential Acidity and Base Saturation Values

Regarding the values of potassium, calcium, magnesium, cation exchange capacity (CEC), potential acidity (H+Al) and base saturation (V%) in soil no significance was observed for the interaction N doses applied at planting x N doses applied after the first grass cut (Table 2). These variables also did not show significant responses for the individual doses of N applied at planting (Figs. 3a, 3b and 3c). However, the values of potassium, calcium, magnesium, cation exchange capacity, H+Al and base saturation responded to the individual doses of N applied after the first grass cut, adjusting to the linear model (Figs. 4a, 4b, 4c, 4d, 4e and 4f).

The decrease of K^+, Ca^{2+} and Mg^{2+} in the soil response to the increase in N doses (Fig 4a, 4b and 4c) can be associated to the reactions that produce H^+ (nitrification) and, as a consequence, reduce the levels of cations [25]. Thus, the reduction of cations K^+, Ca^{2+} and Mg^{2+} in the soil can be explained by the fact that they are acting as buffer against acidification [26]. It should be stressed that during the experimental period, visual symptoms of deficiency of K^+ were observed in the aerial part of Brachiaria ruziziensis following application of the highest doses of N (Fig 4a). Regarding the decrease in CEC values depending on the doses of N (Fig. 4d), it is known that in soils with low CEC, the rate of loss of N-NH3- by volatilization can be maintained for a longer period of time after nitrogen fertilization. Additionally, the higher the CEC value of soil, the lower the concentration of NH4+ in the soil solution, and hence lower losses by volatilization will occur [8]. The content of H+Al increased with increasing doses of nitrogen

Table 1. pH, organic matter, phosphorous and sulfate contents in soil cultivated with grass of the species *Brachiaria ruziziensis* regarding nitrogen doses applied at planting and after the first grass cut

N plantio	N cobertura (mg dm^{-3})				Teste F para regressão	
(mg dm^{-3})	0	15	30	45	L	Q
pH $CaCl_2$						
0	5.32	5.32	5.35	5.22	NS	NS
15	5.22	5.32	5.25	5.12	NS	NS
CV(%)	2.42					
organic matter (g dm^{-3})						
0	38.25	36.50	38.00	36.50	NS	NS
15	39.00	37.75	37.75	38.00	NS	NS
CV(%)	5.78					
phosphorus (mg dm^{-3})						
0	222.25	207.00	217.75	204.00	NS	NS
15	225.00	223.50	208.25	205.50	NS	NS
CV(%)	9.91					
sulfate(1) (mg dm^{-3})						
0	37.25	13.00	7.50	6.25	NS	NS
15	18.00	9.50	6.50	5.50	NS	NS
CV(%)	24.24					

Regression test: NS – not significant (P> 0.05); (1) statistics on log-transformed data (x)

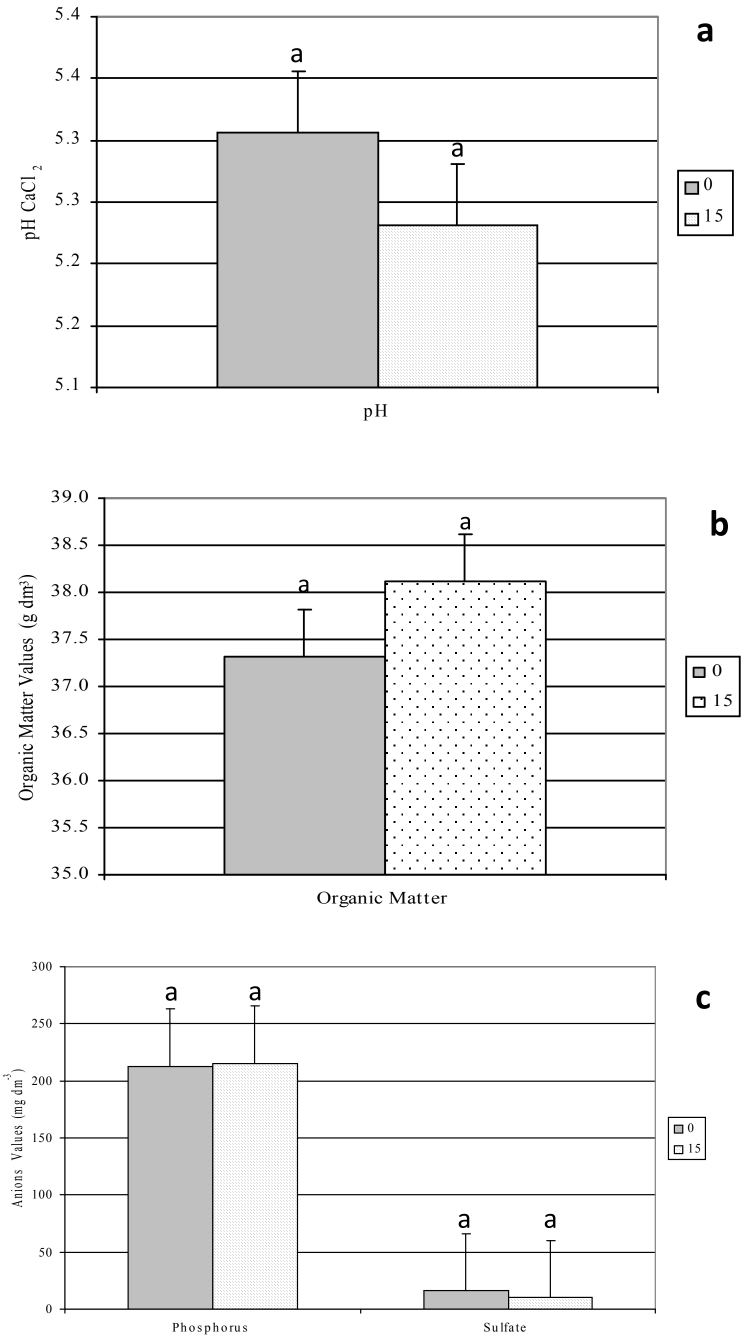


Fig. 1. Values for pH (a), organic matter (b), phosphorous (c) and sulfate (c) in soil cultivated with *Brachiaria ruziziensis* regarding doses of nitrogen applied at grass planting (0 and 15 mg dm^{-3});

Means followed by the same lower case letter in the columns do not differ by F test (P>0.05)

(Fig. 4b). The inverse behavior of H+Al contents regarding Ca2+, Mg2+ and K+ cations indicates that replacement of cations Ca2+, Mg2+ and K+ by H and Al in the cation exchange complex was accelerated by the supply of nitrogen [27]. In addition to the interference of nitrogen dose, the time of cultivation of *Brachiaria ruziziensis* in greenhouse may have increased H+Al contents in the soil due to the extraction of bases by the plants, exudation of organic acids by the roots and hydrolysis of Al [28]. Soil base saturation was negatively affected by the addition of N doses, ranging from 55 to 66 %. These values favored the formation and maintenance of *Brachiaria* pastures [13].

3.3 Effect of Nitrogen Fertilization on the Micronutrient Content in the Soil

Regarding the contents of boron, iron, manganese and zinc in the soil at the end of the experimental period, no significance was observed for the interaction N doses applied at planting x N doses applied after the first cut of *Brachiaria ruziziensis* (Table 3). Also, no isolated significant responses to the doses of N were observed (Figs. 5a and 5b). Regarding the copper content in the soil, significance was observed for the interaction N doses applied at planting x N doses applied after the first grass cut (Figs. 6a and 6b).

For the copper content in the soil, when there was no application of N at planting, the doses of N applied after the first grass cut adjusted to the quadratic regression model, and the N dose of 28.5 mg dm^{-3} was responsible for the highest copper content in the soil (4.14 mg dm^{-3}) (Fig. 6a). In turn, when a dose of 15 mg dm^{-3} of N was applied at planting, the doses of N applied after the first grass cut adjusted to linear regression model, according to which increase in N doses after the first grass cut led to increase in copper content in the soil. (Fig. 5b). Regarding the other micronutrients, the boron content in the soil ranged from 0.21 to 0.25 mg dm^{-3} and were classified as low [21], while the iron (26.3 to 33.75 mg dm^{-3}), manganese (7.7 to 9.6 mg dm^{-3}) and zinc (2.87 to 3.07 mg dm^{-3}) content in the soil were classified as high [21]. The contents of iron, manganese and zinc corroborated the pH values observed (Table 1), because according to the distribution of the elements in relation to pH, the greatest availability of these micronutrients was observed for pH=5. Boron deficiency in the soil is important, since this element participates in the transport of indoleacetic acid, ATPase activity, cell wall synthesis, phenolic, RNA and carbohydrate metabolism, [29].

Table 2. Values for potassium, calcium, magnesium, cation exchange capacity, potential acidity (H+Al) and base saturation in soil cultivated with *Brachiaria ruziziensis* regarding doses of nitrogen applied at planting and after the first grass cut

N plantio	**N cobertura (mg dm^{-3})**				**Teste F para regressão**	
(mg dm^{-3})	**0**	**15**	**30**	**45**	**L**	**Q**
Potassium (mmolc dm^{-3})						
0	7.65	4.60	3.45	2.25	NS	NS
15	6.35	4.97	2.77	1.77	NS	NS
CV(%)	17.82					
Calcium (mmolc dm^{-3})						
0	55.75	55.50	54.00	49.25	NS	NS
15	8.25	52.50	51.50	48.50	NS	NS
CV(%)	7.98					
Magnesium (mmolc dm^{-3})						
0	10.25	10.00	9.25	8.25	NS	NS
15	10.00	9.25	8.50	7.50	NS	NS
CV(%)	10.96					
Cation exchange capacity (mmolc dm^{-3})						
0	111.55	111.90	107.82	105.45	NS	NS
15	113.65	108.70	105.25	104.97	NS	NS
CV(%)	4.88					
Potential acidity (H+Al) (mmolc dm^{-3})						
0	38.00	41.50	41.25	45.75	NS	NS
15	39.00	42.25	42.50	47.00	NS	NS
CV(%)	10.10					
Base saturation (%)						
0	66.00	62.75	61.75	56.50	NS	NS
15	65.50	61.00	59.75	55.00	NS	NS
CV(%)	7.56					

Regression test: NS – not significant (P> 0.05)

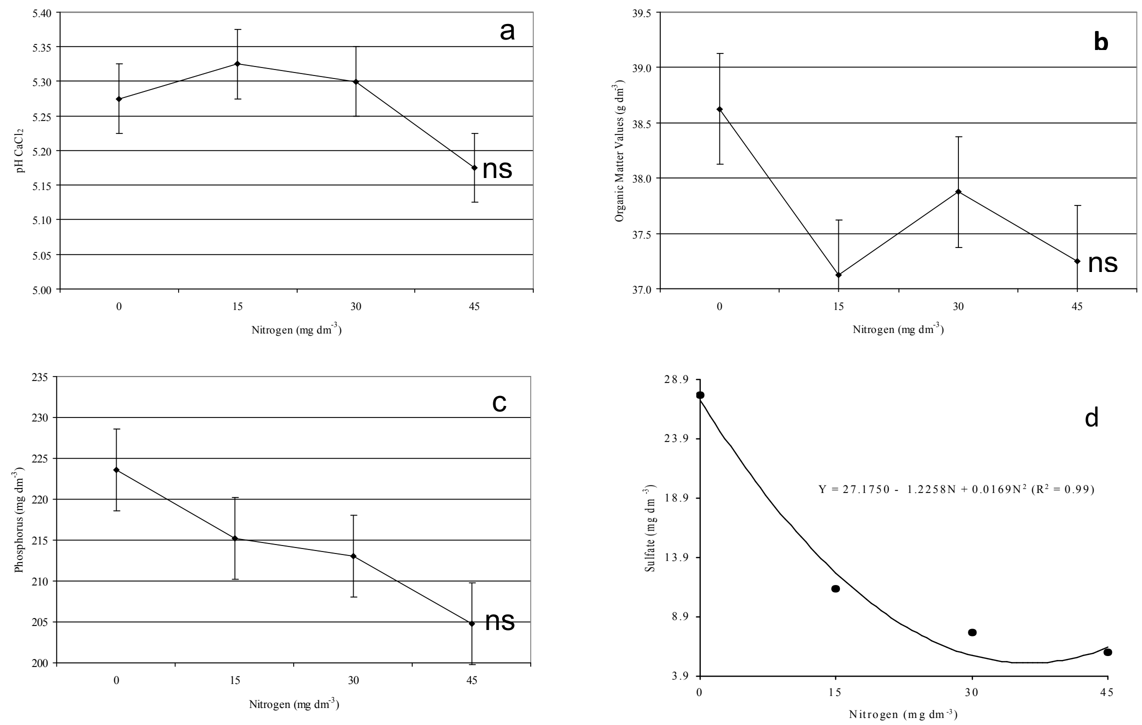
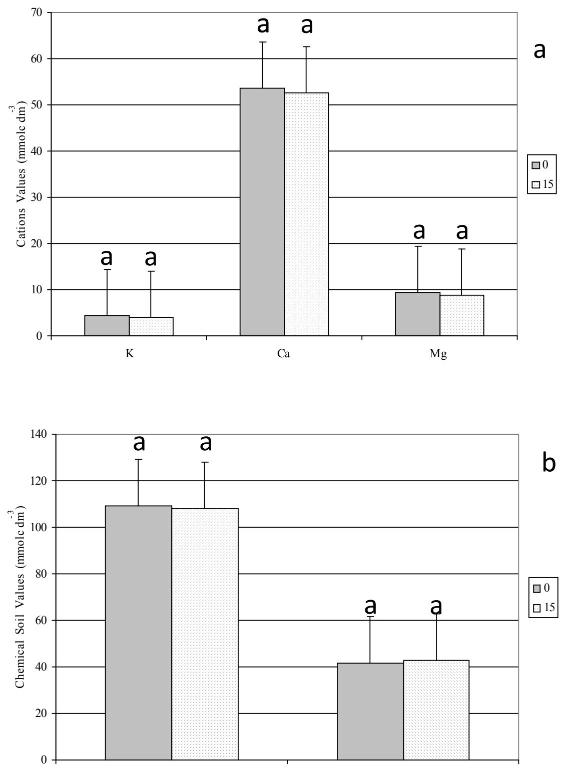


Fig. 2. Values for pH (a), organic matter (b), phosphorous (c) and sulfate (c) in soil cultivated with *Brachiaria ruziziensis* regarding doses of nitrogen applied after the first grass cut (0, 15, 30 and 45 mg dm^{-3});
ns: not significant (P>0.05)



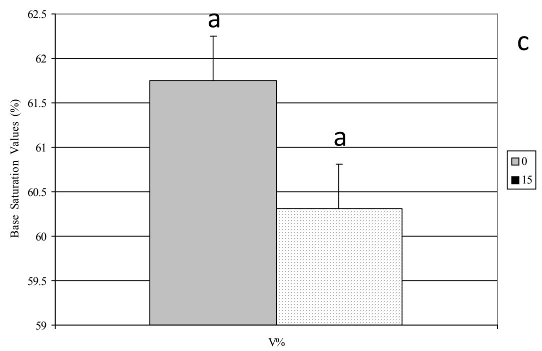


Fig. 3. Values of cations (a), cation exchange capacity (CEC) (b), potential acidity (H+Al) (b) and base saturation (c) in soil cultivated with *Brachiaria ruziziensis* regarding the doses of itrogen applied at grass planting (0 and 15 mg dm-3);

Means followed by the same lower case letter in the columns do not differ by F test (P>0.05)

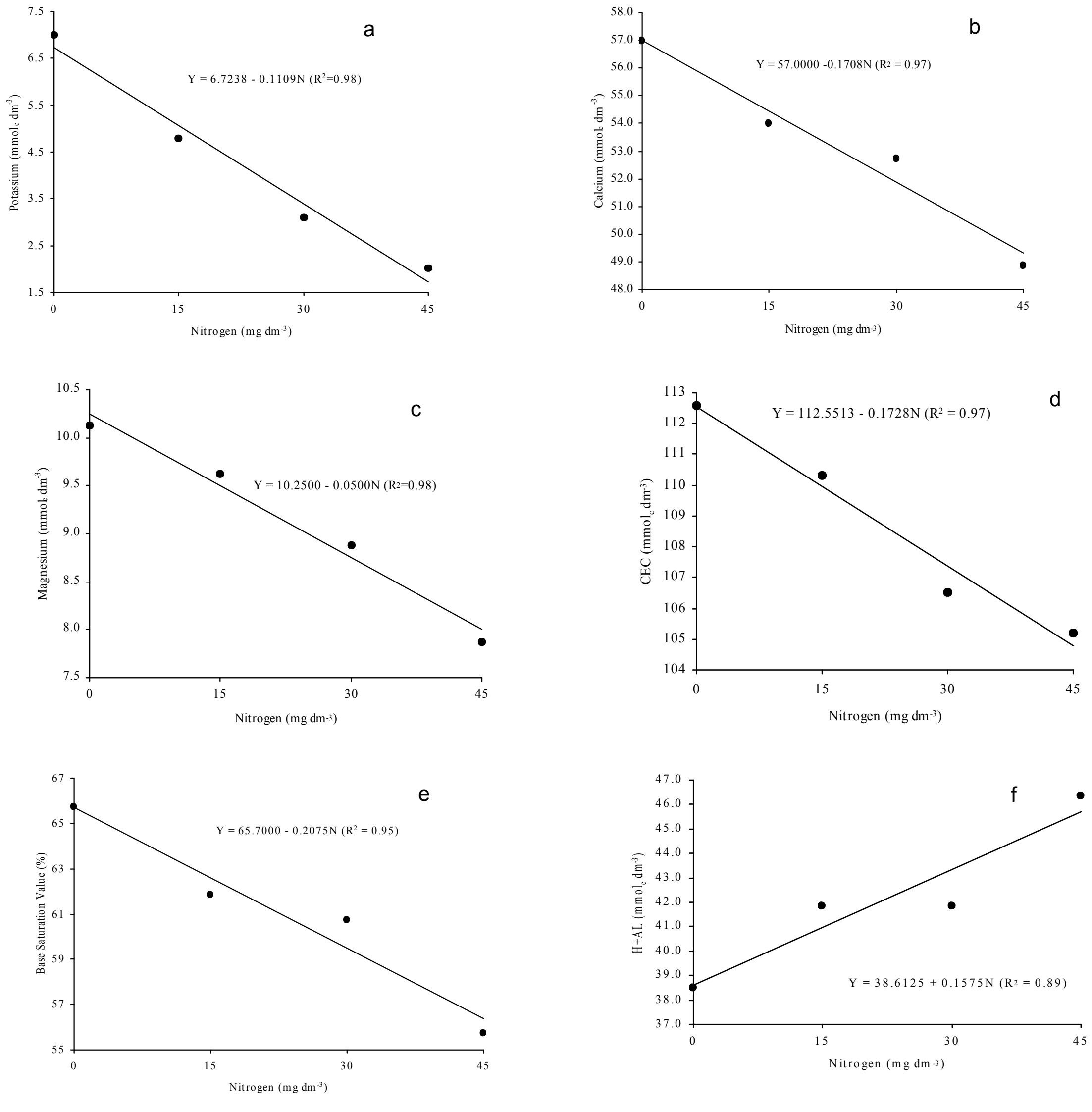


Fig. 4. Values of potassium (a), calcium (b), magnesium (c), cation exchange capacity (CEC) (d), base saturation (e) and potential acidity (H+AL) (f) in soil cultivated with *Brachiaria ruziziensis* regarding the doses of nitrogen applied after the first grass cut (0, 15, 30 and 45 mg dm^{-3})

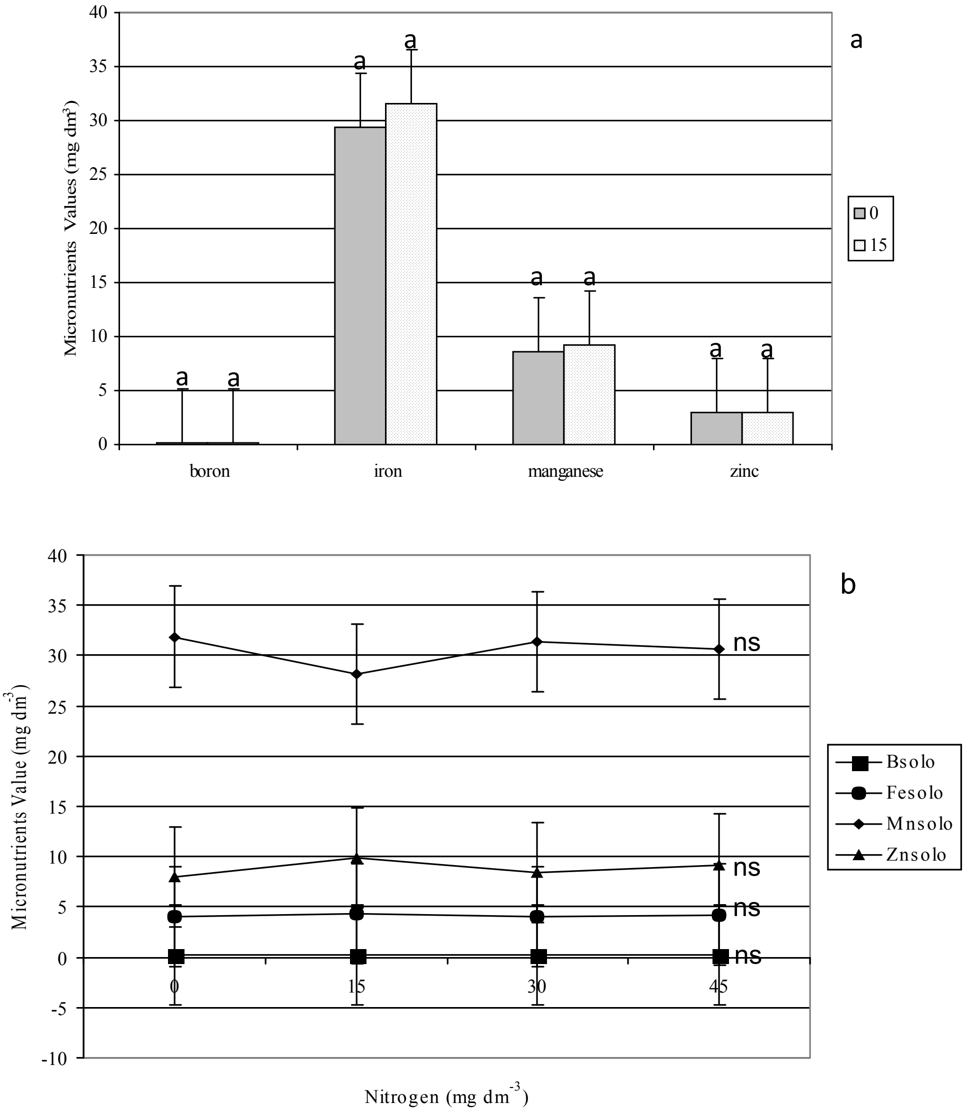


Fig. 5. Values of boron, iron, manganese and zinc in soil cultivated with *Brachiaria ruziziensis* regarding the doses of nitrogen applied at planting (0 and 15 mg dm^{-3}) (a) and after the first grass cut (0, 15, 30 and 45 mg dm^{-3}) (b); *Means followed by the same lower case letter in the columns do not differ by F test (P> .05)*

ns: not significant (P>0.05)

Table 3. Contents of micronutrients in soil cultivated with Brachiaria ruziziensis regarding doses of nitrogen applied at planting and after the first grass. Regression

N plantio	N cobertura (mg dm^{-3})				Teste F para regressão	
(mg dm^{-3})	0	15	30	45	L	Q
Boron						
0	0.22	0.22	0.21	0.24	NS	NS
15	0.23	0.22	0.23	0.25	NS	NS
Iron [1]						
0	31.50	26.25	29.00	31.00	NS	NS
15	32.25	30.00	33.75	30.25	NS	NS
Manganese						
0	7.70	8.77	8.75	8.90	NS	NS
15	8.25	11.05	8.15	9.55	NS	NS

N plantio	N cobertura (mg dm^{-3})				Teste F para regressão	
(mg dm^{-3})	0	15	30	45	L	Q
Zinc						
0	2.92	3.07	2.92	2.87	NS	NS
15	3.00	3.07	3.00	3.00	NS	NS
Copper						
0	3.80	4.12	4.10	4.07	**	**
15	4.22	4.22	4.27	4.37	*	NS

*Regression test: NS – not significant (P>0.05); statistics on log-transformed data (x); **Significant at 1%; *Significant at 5%*

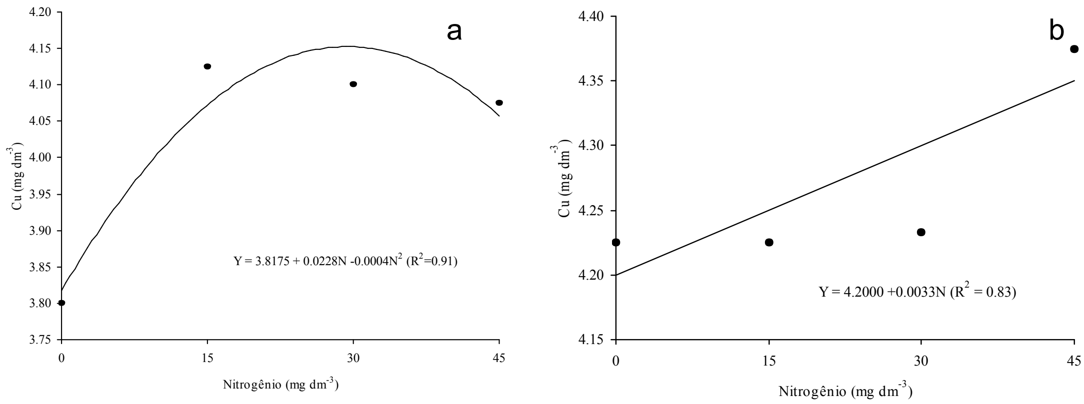


Fig. 6. Values of copper in soil cultivated with *Brachiaria ruziziensis* regarding the interaction Nitrogen not applied at grass planting (a) or with application of 15 mg dm^{-3} (b) of N at grass planting x doses of N applied after the first grass cut

4. CONCLUSION

1. The nitrogen fertilization does not interfere in the values of pH, organic matter, phosphorus, boron, iron, manganese and zinc of the soil cultivated with *Brachiaria ruziziensis*.
2. It is necessary to monitor the contents of K, Ca, Mg and B in the soil when nitrogen is applied to *Brachiaria ruziziensis*.
3. The minimum sulfate content in soil cultivated with *Brachiaria ruziziensis* is 4.94 mg dm^{-3} for the dose of 36.3 mg dm^{-3} of nitrogen.
4. The non-application of nitrogen at planting associated to the application of 28.5 mg dm^{-3} of nitrogen after the first grass cut results in higher copper content in soil (4.14 mg dm^{-3}).
5. The application of 15 mg dm^{-3} of nitrogen at planting associated to the increase in N doses after the first grass cut led to increase in copper content.

ACKNOWLEDGEMENTS

The authors wish to thank FAPESP for financial support and Instituto de Zootecnia for institutional support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dabney SM, Delgado JA, Reeves DW. Using winter cover crops to improve soil and water quality. Commun Soil Sci Plant Anal. 2001;32(7&8):1221-1250. DOI:101081CSS100104110.
2. VR Silva, Reinert DJ, Reichert, JM. Soil bulk density, chemical attributes and corn root distribution as affected by grazing and soil management. R. Bras. Ci. Solo. 2000;24(1):191-199. DOI:10.1590/S0100-06832000000100021.
3. Primavesi AC, The Primavesi, Corrêa LA, Silva AG, Cantarella H. Nutrient content in marandu grass biomass due to nitrogen sources and levels. Ci. Agrotec. 2006;30 (3):562-568. DOI:10.1590/S1413-70542006000300024.
4. Costa KAP, Faquin V, Oliveira IP, Rodrigues C, Severiano EC. Nitrogen doses and sources in marandu pasture: I -

Changes in soil chemical properties. R. Bras. Ci. Solo. 2008;32(4):1591-1599. DOI:10.1590/S0100-06832008000400023.
5. Maranhão CMA, P Bonomo, Pires LBA, Costa ACPR, Martins GCF, Cardoso EO. Productive traits of Brachiaria grass subject to cutting intervals and nitrogen fertilization over three seasons. Acta. Sci. Anim. Sci. 2010;32(4):375-384. DOI: 10.4025 / actascianimsci.v32i4.8574.
6. Martha Junior GB, Corsi M, Trivelin PCO, Vilela L, Pinto TLF, Teixeira GM, Manzoni CS, Barioni LG. Ammonia volatilization loss in tanzaniagrass pasture fertilized with urea in the summer. R. Bras. Zootec. 2004;33(6):2240-2247. DOI:10.1590/S1516-35982004000900009.
7. Whitehead DC, Raistrick N. Ammonia volatilization from five nitrogen compounds used as fertilizers following surface application to soils. J. Soil Sci. 1990;41(3): 387-394. DOI:10.1111/j.1365-2389.1990.tb00074.x
8. Freney JR, Simpson JR, Denmead OT. Volatilization of ammonia. In: Freney JR, Simpson JR, editors. Gaseous loss of nitrogen from plant soil systems. Netherlands: Martinus Nijhoff/Dr. W. Junk Publisher; 1983.
9. Fageria NK. Upland rice response to soil acidity in cerrado soil. Pesq. Agropec. Bras. 2000;35(11):2303-2307. DOI:10.1590/S0100-204X2000001100024.
10. Bouman BAM, Nieuwenhuyse A, Ibrahim M. Pasture degradation and restoration by legumes in humid tropical Costa Rica. Trop. Grasslands. 1999;33(2):98-110.
11. Boschma SP, Murphy SR, Harden S. Herbage production and persistence of two tropical perennial grasses and forage sorghum under different nitrogen fertilization and defoliation regimes in a summer-dominant rainfall environment, Australia. Grass Forage Sci. 2014;1365-2494. DOI:10.1111/gfs.12130
12. Santos HG, Jacomine PKT, Angels LHC, Oliveira VA, Oliveira JB, Coelho MR, Lumbreras JF, Cunha TJF. Brazilian system of soil classification. 2nd ed. Rio de Janeiro: Embrapa Soils; 2006.
13. Werner JC, Paulino VT, Cantarella M, Andrade NO, Quaggio JA. Forage. In: Raij Bvan; Cantarella H, Quaggio JA, Furlani AMC, editors. Recommendations fertilization and liming for the state of São Paulo. 2th ed. Campinas Agronomic Institute & Foundation IAC; 1997.
14. Batista K, Duarte AP, Ceccon G, Maria IC, Cantarella H. Nitrogen fertilization in the intercropping of corn with two Brachiaria species in a no-tillage system. Pesq. Agropec. Bras. 2011;46(10):1154-1160. DOI:10.1590/S0100-204X2011001000006.
15. Quaggio JA, Raij Bvan. Comparison of rapid methods for determining organic matter in soils. R. Bras. Ci. Solo. 1979; 3(3):184-187.
16. Raij Bvan, Quaggio JA, Cantarella H, Ferreira ME, AS Lopes, Battaglia OC. Chemical analysis of soil fertility purposes. Campinas: Cargill Foundation;1987.
17. Fox RL, Olson RAO, Rhoades HF. Evaluating the sulfur status of soils by plants and soil tests. Soil Sci. Soc. Am. Proc. 1964;28:243-246.
18. MF Abreu, Abreu CA, Andrade JC. Determination of boron in hot water using microwave heating. In: Raij Bvan, Andrade JC, H Cantarella, JA Quaggio editors. Chemical analysis to evaluate the fertility of tropical soils. Campinas Agronomic Institute; 2001.
19. Abreu MF, Abreu CA, Andrade JC. Determination of copper, iron, manganese, zinc, cadmium, chromium, nickel and lead in soil using the solution of DTPA pH 7.3. In: Raij Bvan, Andrade JC, Cantarella H, Quaggio JA, editors. Chemical analysis to evaluate the fertility of tropical soils. Campinas Agronomic Institute; 2001.
20. SAS Institute. SAS user's guide: Statistics. Cary; 2001.
21. Raij Bvan, Cantarella H, Quaggio NOW, Furlani AMC. Recommendations fertilization and liming for the state of São Paulo. 2th ed. Campinas Agronomic Institute; 1997.
22. Silveira PM, Cunha PCR, Stone LF, Santos GG. Soil Chemical attributes of a soil cultivated with different cover crops. Pesq. Agropec. Trop. 2010;40(3):283-290.
23. Rheinheimer DS, Kaminski J, Lupatini GC, Santos EFS. Changes in chemical attributes of sandy soil under no-tillage. R. Bras. Ci. Solo. 1998;22(4):713-722.
24. Jamal A, Moon YS, Abdin MZ. Sulphur-a general overview and interaction with nitrogen. Australin Journal of Crop Science. 2010;4(7):523-529.
25. Tisdale SL, Nelson WL, Beaton JD. Soil fertility and fertilizers. 4th ed. New York: MacMilan Publ; 1985.

26. Tian D, Niu S. A global analysis of soil acidification caused by nitrogen addition. Environ. Res. Lett. 2015;10:01-10. DOI:10.1088/1748-9326/10/2/024019
27. Pavan MA, Bingham FT, Pratt PF. Redistribution of exchangeable calcium, magnesium, and aluminum following lime or gypsum applications to a Brazilian Oxisol. Soil Sci. Soc. Am. J. 1984;48(1): 33-38. DOI:10.2136/sssaj1984.03615995004800010006x
28. Taiz L, Zeiger E. Plant Physiology. Porto Alegre: Artmed; 2004.
29. Goldbach HE, Yu Q, Wingender R, Schulz M, Wimmer M, Findeklee P, Baluska R. Rapid response reactions of roots to boron deprivation. J. Plant Nutr. Soil Sci. 2001;164(2):173-181.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=1095&id=24&aid=9201