DOI: 10.5433/1679-0359.2012v33n5p1745

Doses and sources of nitrogen fertilizer and their effects on soil chemical properties and forage yield of *Brachiaria brizantha* cv. Xaraés

Doses e fontes nitrogenadas e seus efeitos nos atributos químicos do solo e na produção de forragem da *Brachiaria brizantha* cv. Xaraés

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Abstract

Forage plants, particularly the *Brachiaria* genus, are the main source of nutrients for cattle and are at times the only feed offered. The concentration of elements in the plant is related to the soil, fertilization, climate, season, variety, and cultural practices. An experiment on dystrophic Red-Yellow Latosol soil in Araçatuba, São Paulo was performed to evaluate the effects of the doses and sources of nitrogen fertilizers on the chemical properties of the soil and the dry matter yield of the grass *Brachiaria brizantha* cv. Xaraés. A randomized block design was employed involving three replicates in a 3 x 3 factorial, with three doses (100, 200 and 400 kg ha^{-1} year^{-1}) and three sources (Ajifer® L40, ammonium sulfate and urea) of nitrogen and a control treatment without nitrogen (zero). The greatest effects on the chemical properties of the soil as a function of nitrogen fertilization in the Xaraés grass were observed in the topsoil. The use of Ajifer® L40 and ammonium sulfate as sources of nitrogen had similar effects, with an increase in the sulfur content and a reduction in the soil pH at the superficial layer. The use of the fertilizers Ajifer® L40, ammonium sulfate and urea did not affect the micronutrient contents, except for Fe and Mn, and did not alter the sodium concentration or electrical conductivity of the soil. The dry matter yield of Xaraés grass was similar for all three nitrogen sources.

Key words: Ajifer® L40, forage plant, plant nutrition, pasture, ammonium sulfate, urea

Resumo

As forrageiras, entre as quais se destaca o gênero *Brachiaria*, constituem a principal fonte de nutrientes para os bovinos e às vezes, o único alimento oferecido. A concentração de elementos na planta está relacionada com o solo, a adubação, o clima, a época, a variedade e as práticas culturais. Com o objetivo de avaliar os efeitos de doses e fontes nitrogenadas sobre os atributos químicos do solo e a produção de massa seca do capim *Brachiaria brizantha* cv. Xaraés realizou-se um experimento em solo classificado como Latossolo Vermelho Amarelo distrófico, em Araçatuba, São Paulo. Utilizou-se o delineamento experimental em blocos casualizados com 3 repetições em esquema fatorial 3 x 3, sendo três doses de nitrogênio (100, 200 e 400 kg ha^{-1} ano^{-1}) e três fontes (ajifer® L40, sulfato de amônio, uréia), acrescido

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Recebido para publicação 14/03/11 Aprovado em 03/07/11

do tratamento controle com dose 0 (zero) de N. Os maiores efeitos nos atributos químicos do solo em função da adubação nitrogenada no capim Xaraés foram observados na camada superficial do solo; as fontes nitrogenadas ajifer® L40 e sulfato de amônio apresentaram comportamento semelhante, com aumento no teor de enxofre e redução do pH do solo na camada mais superficial frente à fonte uréia; a utilização dos fertilizantes ajifer® L40, sulfato de amônio e uréia não afetou o teor de micronutrientes, exceto o teor de Fe e Mn, e não alterou a concentração de sódio e a condutividade elétrica no solo; a produção de matéria seca do capim Xaraés foi semelhante para as três fontes nitrogenadas.

Palavras-chave: Ajifer® L40, forrageira, nutrição de plantas, pastagem, sulfato de amônio, uréia

Introduction

In Brazil, grasses of the genus *Brachiaria* occupy more than 70% of the cultivated pasture areas because of their adaptability to a wide variety of soil and climate conditions. In 1996, the evaluation and selection of some *Brachiaria* accessions in the germplasm bank of the International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical - CIAT) were initiated. One of the results of this selection was the cultivar Xaraés of *Brachiaria brizantha*. The most important characteristics of this cultivar are its high forage yield, drought resistance, rapid regrowth after grazing, tolerance to poorly drained soils, and good nutritional quality (EMBRAPA, 2004).

Nitrogen (N) is recognized among the production factors as one of the most important nutrients, as it is the major nutrient involved in maintaining the productivity of forage grasses. Nitrogen is found in small amounts in most soils and actively participates in the synthesis of organic compounds that form the structure of the plant. Furthermore, nitrogen is also responsible for the emergence and development of tillers and the size of the leaves and culms (NABINGER, 1997).

Costa et al. (2008) analyzed the use doses and sources of nitrogen in marandu grass and observed an increase in the aluminum content from 0.5 to 4.1 $\text{mmol}_c\ \text{dm}^{-3}$. In contrast, the soil pH decreased with the application of nitrogen, and ammonium sulfate was more acidifying than urea. The same authors reported increases in the levels of soil organic matter and total N, N-NO_3^-, and N-NH_4^+, with higher values of ammonium compared to nitrate.

In this context, this study aimed to evaluate the effects of different doses and sources of nitrogen (Ajifer® L40, ammonium sulfate and urea) on the chemical properties of the soil and the dry matter yields of the grass *Brachiaria brizantha* cv. Xaraés.

Materials and Methods

The experiments were carried out from September, 2005 through May, 2006 using *Brachiaria brizantha* cv. Xaraés grass sown five years beforehand in the Rural Union area of the municipality of Araçatuba, located in the Upper Northwest region of the State of São Paulo, situated at 21°08’ south latitude, 50°25’ west longitude and 415 meters altitude.

The local climate, according to Koppen’s classification, is type Aw, characterized by seasons with a hot climate and dry winters and increased precipitation from November to March. The average annual temperature, precipitation, and relative humidity are, respectively, 23.6°C, 1,281 mm, and 64.8%.

The experimental area soil was classified as dystrophic Red-Yellow Latosol (EMBRAPA, 1999) with good drainage. At the beginning of the experiment, soil was collected at depths of 0-10 cm and 10-20 cm, homogenized, dried under shade, and analyzed. The results are presented in Table 1.

On October 19, 2005, after the first rain, a uniformization cut was performed in all plots involving the removal of the plant residues. Plots were allocated with dimensions of 4 x 3 m, a 2-m walking strip between them and a 0.5-m edging on all sides of the plots. A usable planted area of 8.75 m^2 (3.5 m x 2.5 m) was generated.

Table 1. Physical and chemical properties of soil at the 0-10 cm and 10-20 cm depths at the establishment of the experiment. Araçatuba, SP. Crop year 2005/2006.

Properties	Depth (cm)	
	0 - 10	10 - 20
pH ($CaCl_2$)	4.5	4.4
Organic matter (g dm^{-3})	23	20
P (mg dm^{-3})	4	3
S (mg dm^{-3})	11	11
K ($mmol_c$ dm^{-3})	6	3.3
Ca ($mmol_c$ dm^{-3})	19	17
Mg ($mmol_c$ dm^{-3})	8	7
Cation exchange capacity ($mmol_c$ dm^{-3})	55	52.3
Base saturation (%)	60	52
Aluminum saturation (%)	13	18
B (mg dm^{-3})	0.84	0.84
Cu (mg dm^{-3})	0.80	0.80
Fe (mg dm^{-3})	62	44
Mn (mg dm^{-3})	14.30	12.20
Zn (mg dm^{-3})	1.70	0.70
Na (mg dm^{-3})	9.2	11.5
Electric conductivity (dS m^{-1})	0.14	0.1
Clay (%)	18	16
Silt (%)	4	8
Sand (%)	78	76

P, K, Ca and Mg: Resin; S: NH_4OAc 0.5 N in HOAc 0.25 N; B: $BaCl_2.2H_2O$ 0.125%; Cu, Fe, Mn and Zn: DTPA.
Source: Elaboration of the authors.

After the uniformization cut, phosphorus maintenance fertilization (60 kg P_20_5 ha^{-1}) in the form of simple superphosphate was applied by throwing, while potassium fertilization was not performed because the levels in the soil were already high, as can be observed in Table 1 (RAIJ et al., 1996).

The experimental design used in the present study was a randomized block with three replicates, and the treatments were arranged in a 3 x 3 factorial with three nitrogen doses (100, 200 and 400 kg ha^{-1} $year^{-1}$). The applications were performed in five installments; the first application was after the uniformization cut and the subsequent four, after each cut. Three nitrogen sources were used (Ajifer® L40, ammonium sulfate and urea) along with a control treatment without N (zero dose), comprising the following treatments: 1) control, 0 kg ha^{-1} N; 2) 100 kg ha^{-1} N via Ajifer® L40; 3) 200 kg ha^{-1} N via Ajifer® L40; 4) 400 kg ha^{-1} N via Ajifer® L40; 5) 100 kg ha^{-1} N via ammonium sulfate; 6) 200 kg ha^{-1} N via ammonium sulfate; 7) 400 kg ha^{-1} N via ammonium sulfate; 8) 100 kg ha^{-1} N via urea; 9) 200 kg ha^{-1} via urea; and 10) 400 kg ha^{-1} via urea.

Within the usable area of each plot, the forage was randomly sampled within a square meter cut at 15 cm of soil at intervals of 28 days for the first four cuts and 30 and 42 days, respectively, for the fifth and sixth cuts. Immediately after sampling, the material was weighed to obtain the green mass yield, followed by homogenization to generate a composite subsample, which was again weighed and dried in a forced air oven at 65°C to constant weight. The result was then transformed into amount of forage yield per hectare.

At the end of the experiment, soil was collected from five random points within the usable area of each plot, homogenized and subsequently analyzed in the laboratory.

The data were analyzed using the SAS statistical software (SAS, 1999) and subjected to analysis of variance. The means were compared by Tukey's test at 5% probability levels, while regression analyses were performed for the nitrogen doses (PIMENTEL-GOMES; GARCIA, 2000).

Results and Discussion

Tables 2 and 3 present the chemical properties of soil at the 0-10 cm and 10-20 cm layer depths, respectively, after an annual cycle with the application of the treatments in a Xaraés grass pasture subjected to six cuts. It was observed that in the 0-10 cm layer, there was interaction among the sources and doses of nitrogen in the levels of P, K^+, Ca, Mg, H + Al^{+3}, the total bases, aluminum saturation, and base saturation. However, in the 10-20 cm layer, an interaction was only observed in the concentrations of K^+ and aluminum saturation. Thus, there was a differential effect on the concentration of elements in the soil as a function of the doses and sources of nitrogen used.

The soil pH showed no interaction between the sources and doses of nitrogen; however, the Ajifer® L40 and ammonium sulfate treatments reduced the soil pH compared to urea (Table 4), especially in the superficial layer of the soil. These results are justified by the release of H^+ into the soil by nitrogen oxidation predominantly by the two fertilizers studied because the nitrogen in the ammonium sulfate is 100% ammoniacal and of that in the Ajifer L40, approximately 40% is in the organic form and 60% is in the NH_4^+ form (VITTI; HEINRICHS, 2007). Based on the evaluation of the effect of the nitrogen doses, the average soil pH in response to the three sources also decreased (Table 2), primarily in response to Ajifer L40 and ammonium sulfate, as described above and confirmed by Costa et al. (2008). These authors assessed the use of nitrogen fertilizers in the recovery of marandu grass pastures grown in dystrophic Red Latosol. It is noteworthy that the variations in the soil pH as a function of nitrogen fertilization only occurred in the superficial layer of the soil, as described by Heinrichs et al. (2005), as this is the layer that presents cumulative effects because it is not revolved.

The levels of phosphorus in the soil were low throughout the experiment, with the lowest valuesof approximately 3 mg dm^{-3} in the 0-10 cm deep layer observed in the treatments without nitrogen application (Table 1), as evident based on the coefficient of intersection. This result can be attributed to the effect of the acidification of the environment caused by nitrogen fertilization, the increased production and mineralization of organic matter, especially in roots and the presence of nutrients when Ajifer® L40 (0.14% P_2O_5) was used.

The soil potassium exhibited interactions between the sources and doses of nitrogen. In the upper soil layer, potassium was found at higher concentrations in the treatment without nitrogen application, especially compared to the treatments with Ajifer L40 and ammonium sulfate. This result was validated by the negative value of the regression coefficient (Tables 2 and 3), which can be attributed to a decrease in the pH and a consequent reduction in nutrient availability (COSTA et al., 2008). Similar results were observed with respect to calcium and magnesium, which decreased with increased doses of nitrogen, especially in the 0-10 cm depth layer, in response to the ammonium-containing Ajifer L40 and ammonium sulfate, which has more acidifying action compared to other sources of nitrogen (Tables 2 and 3).

Table 2. Chemical properties of soil fertilized with different doses and sources of nitrogen at three depths, following an annual cycle with six cuts.

Properties	Depth (cm)
	0 – 10
pH[2] (CaCl$_2$)	$y = 4.52 - 0.0015X$ $R^2 = 0.99^{**}$
Organic matter[1] (mg kg^{-1})	ns (21.22 ± 1.52)
P (mg kg^{-1})	Ajifer® L40 $y = 2.63 + 0.0415X + 9.1x10^{-5}X^2$ $R^2 = 0.72^{**}$ Ammonium sulfate $y = 3.28 + 0.0261X + 7.1x10^{-5}X^2$ $R^2 = 0.50^{*}$ Urea $y = 3.25 + 0.0217X + 6.1x10^{-5}X^2$ $R^2 = 0.46^{*}$
K (mmol$_c$ dm^{-3})	Ajifer® L40 $y = 2.06 - 8.2x10^{-3}X + 1.3x10^{-5}X^2$ $R^2 = 0.80^{**}$ Ammonium sulfate $y = 1.89 - 7.6x10^{-3}X + 1.4x10^{-5}X^2$ $R^2 = 0.91^{**}$ Urea $y = 1.7x10^{-3}X + 1.86$ $R^2 = 0.80^{**}$
Ca (mmol$_c$ dm^{-3})	Ajifer® L40 $y = 11.58 + 0.01X - 5x10^{-5}X^2$ $R^2 = 0.79^{*}$ Ammonium sulfate $y = 11.04 - 0.0094X$ $R^2 = 0.88^{*}$ Urea ns (13.05 ± 1.83)
Mg (mmol$_c$ dm^{-3})	Ajifer® L40 $y = 5.50 - 0.0087X$ $R^2 = 0.89^{*}$ Ammonium sulfate $y = 5.14 - 0.0072X$ $R^2 = 0.82^{*}$ Urea ns (5.55 ± 0.41)
H + Al (mmol$_c$ dm^{-3})	Ajifer® L40 $y = 25.33 + 0.049X$ $R^2 = 0.82^{**}$ Ammonium sulfate $y = 26.93 + 0.040X$ $R^2 = 0.72^{**}$ Urea ns (27.75 ± 3.77)
Sum of bases (mmol$_c$ dm^{-3})	Ajifer® L40 $y = 20.06 + 0.023X$ $R^2 = 0.72^{**}$ Ammonium sulfate $y = 17.86 - 0.018X$ $R^2 = 0.68^{**}$ Urea ns (20.3 ± 2.32)
Aluminum saturation (%)	Ajifer® L40 $y = 5.40 + 0.054X$ $R^2 = 0.81^{**}$ Ammonium sulfate $y = 8.00 + 0.057X$ $R^2 = 0.77^{**}$ Urea ns (6.47 ± 1.45)
Base saturation (%)	Ajifer® L40 $y = 43.93 - 0.063X$ $R^2 = 0.88^{**}$ Ammonium sulfate $y = 39.86 - 0.052X$ $R^2 = 0.68^{**}$ Urea ns (42.30 ± 4.17)
Na[1] (mg dm^{-3})	ns (0.22 ± 0.03)
Electrical conductvity[1] (dS m^{-1})	ns (0.20 ± 0.03)

ns: not significant; *significant $p \leq 0.05$; **significant $p \leq 0.01$; y = soil properties; x = dose of N, with an amplitude of 0 to 400 kg ha^{-1}; [1]Did not present significant interaction between the sources and doses of nitrogen. [2]Significant only at the averaged doses. In parentheses are the average values with the standard deviations when not significant.

Source: Elaboration of the authors.

Table 3. Chemical properties of soil fertilized with different doses and sources of nitrogen at three depths, following an annual cycle with six cuts.

Properties	Depth (cm)
	10 – 20
pH[1] ($CaCl_2$)	ns (4.25 ± 0.10)
Organic matter[1] (mg kg^{-1})	ns (14.82 ± 0.62)
P[1] (mg kg^{-1})	ns (3.17 ± 0.60)
K ($mmol_c$ dm^{-3})	Ajifer® L40 ns (0.75 ± 0.40) Ammonium sulfate $y = 0.82 – 1.1x10^{-3}X$ $R^2 = 0.67$** Urea $y = 0.75 + 1.1x10^{-3}X$ $R^2 = 0.63$**
Ca[1] ($mmol_c$ dm^{-3})	ns (10.62 ± 0.40)
Mg[2] ($mmol_c$ dm^{-3})	$y = 4.64 – 0.0025X$ $R^2 = 0.74$*
H + Al[1] ($mmol_c$ dm^{-3})	ns (27.62 ± 1.54)
Sum of bases[1] ($mmol_c$ dm^{-3})	ns (15.77 ± 0.85)
Aluminum saturation (%)	Ajifer® L40 $y = 10.93 + 0.032X$ $R^2 = 0.61$** Ammonium sulfate ns (10.3 – 21.0) Urea ns (10.37 ± 1.77)
Base saturation[1] (%)	ns (36.45 ± 1.74)
Na[1] (mg dm^{-3})	ns (0.26 ± 0.06)
Electrical conductivity[1] (dS m^{-1})	ns (0.17 ± 0.01)

ns: not significant; *significant $p \leq 0.05$; **significant $p \leq 0.01$; y = soil properties; x = dose of N, with an amplitude of 0 to 400 kg ha^{-1}; [1]Did not present a significant interaction between sources and doses of nitrogen. [2]Significant only at the averaged doses. In parentheses are the average values with the standard deviations when not significant.
Source: Elaboration of the authors.

Table 4. Average soil pH index of different nitrogen doses for each nitrogen source at the 0-10 cm and 10-20 cm depths. Araçatuba, SP. Crop year 2005/2006.

Nitrogen source	pH (0 – 10 cm)	pH (10 – 20 cm)
Ajifer® L40	4.2 b	4.2 ^{ns}
Ammonium sulfate	4.1 b	4.2
Urea	4.5 a	4.4

Averages followed by different letters differ by Tukey's test at 5% probability. ns: not significant.
Source: Elaboration of the authors.

The H + Al and aluminum saturation values increased with the use of Ajifer® L40 and ammonium sulfate, while the base saturation decreased (Table 2). These results confirm the acidifying effect of the two nitrogen sources, especially in the superficial soil layer, and corroborate the description of Costa et al. (2008).

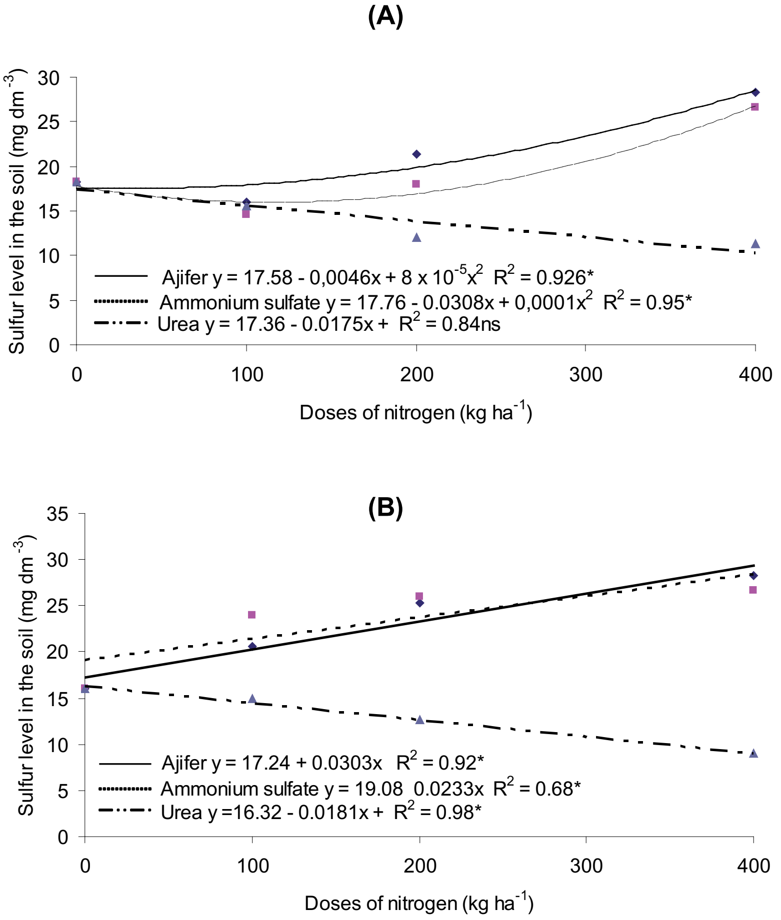
The harmful effects of sodium on the soil structure results from two related processes: clay expansion and dispersion (HALLIWELL; BARLOW; NASH, 2001). However, the magnitude of the negative impact of the ion on the soil structure depends on the amount and efficiency of the rainfall, which promotes leaching of the element (SPEIR et al., 1999). The levels of Na^+ in the soil after a year of study were too low, remaining on average at 0.22 mg dm^{-3} and 0.26 mg dm^{-3}, respectively, at the depths of 0-10 cm and 10-20 cm (Tables 2 and 3).

According to Tisdale, Nelson and Beaton (1985), 5 mg dm^{-3} Na is representative in of the composition of non-saline soils in temperate regions.

The electrical conductivity was low, with values of 0.20 and 0.17 dS m^{-1}, respectively, at the 0-10 cm and 10-20 cm depth layers (Tables 2 and 3). Measurements of electrical conductivity are often used to evaluate the concentration of soluble salts in the soil. According to Marschner (1995), saline soils are characterized by concentrations of 2 dS m^{-1}. Nutritional imbalances occur in these cases, particularly involving difficulties in the absorption of water and nutrients due to increased pressure in the soil solution.

The determinations of the sulfur levels in the soil as a function of nitrogen fertilization are presented in Figure 1. There were interactions between the sources; a similar response was observed for Ajifer® and ammonium sulfate sources, which can be used as sulfur suppliers in the system. In turn, when urea was used as a nitrogen source, the levels of sulfur in the soil decreased with the application of higher doses, possibly as a result of increased nutrient extraction by the plants due to increased forage yield. However, the levels were above 10 mg dm^{-3} for all treatments. These levels are considered suitable according to Raij et al. (1996).

Figure 1. Sulfur levels in the soil (SO_4^-) in the 0-10 cm (A) and 10-20 cm (B) layers as a function of the nitrogen dose and source. Araçatuba, SP. Crop year 2005/2006.



Source: Elaboration of the authors.

In terms of the micronutrients, interactions between the doses and sources of nitrogen fertilizers were observed in the levels of iron in the 0-10 cm depth layer. However, although the results were not significant, the overall values were within the same range of interpretation; i.e., the nitrogen fertilization did not affect iron availability. Manganese showed significance in the average of the doses at both studied depths, with a higher concentration in the superficial layer of the soil, which can be attributed to the physical and chemical variations in the soil caused by the fertilizers, as the area was a grazing area without soil rotation. The levels of boron, copper and zinc showed no significant variation due to the nitrogen sources and doses (Table 5).

Table 5. Micronutrients in the soil fertilized with different doses and sources of nitrogen at two depths, after an annual cycle with six cuts. Araçatuba, SP. Crop year 2005/2006.

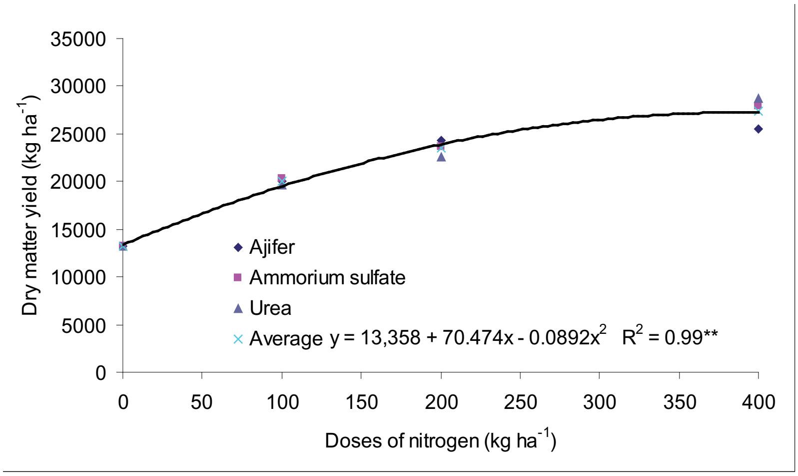
Property	Depth (cm)	
	0 - 10	10 – 20
B[1] (mg dm^{-3})	ns (0.13 ± 0.009)	ns (0.20 ± 0.02)
Cu[1] (mg dm^{-3})	ns (0.78 ± 0.06)	ns (0.67 ± 0.03)
Fe (mg dm^{-3})	Ajifer® L40 $y = 81.80 + 0.154X$ $R^2 = 0.47^{**}$ Ammonium sulfate $y = 93.60 + 0.126X$ $R^2=0.37^{*}$ Urea ns (90.49 ± 6.34)	ns (56.27 ± 5.20)
Mn[2] (mg dm^{-3})	$y = 20.10 + 1.5x10^{-3}X$ $R^2 = 0.84^{*}$	$y = 13.03 + 2.2x10^{-3}X$ $R^2 = 0.93^{**}$
Zn[1] (mg dm^{-3})	ns (0.90 ± 0.07)	ns (0.55 ± 0.19)

ns: not significant; *significant $p \leq 0.05$; **significant $p \leq 0.01$; y = soil properties; x = dose of N, with an amplitude of 0 to 400 kg ha^{-1}; [1]Did not present a significant interaction between the sources and doses of nitrogen. [2]Significant only at the averaged doses. In parentheses are the average values with the standard deviations when not significant. Araçatuba, SP. Crop year 2005/2006.
Source: Elaboration of the authors.

Figure 2 shows the data on the dry matter yield as a function of the doses and nitrogen sources. The interaction analysis showed no significant effect. These results indicate that nitrogen can be supplied to Xaraés grass using the three sources studied (Ajifer® L40, ammonium sulfate and urea) without a decrease in the forage yield, corroborating the findings of Costa, Faquin and Oliveira (2010), who reported similar yields in marandu fertilized with ammonium sulfate or urea.

The estimated dose, calculated by applying the derivation of the median quadratic equation to the data was 395.90 kg ha^{-1} N, applied in five doses during the rainy season, for a maximum yield of 27,307 kg ha^{-1} of dry Xaraés grass.

Figure 2. Nitrogen doses and sources and Xaraés grass dry matter yield, accumulated from six cuts. Araçatuba, SP. Crop year 2005/2006.



Source: Elaboration of the authors.

Conclusions

The greatest effect on the soil chemical properties as a function of nitrogen fertilization in Xaraés grass was observed in the superficial soil layer.

The nitrogen sources Ajifer® L40 and ammonium sulfate exhibited similar behavior, with an increase in the sulfur content and a decrease in the soil pH in the superficial layer compared to urea.

The use of the fertilizers Ajifer® L40, ammonium sulfate and urea did not affect the levels of micronutrients, except for Fe and Mn, and did not alter the concentration of sodium or the electrical conductivity of the soil.

The dry matter yield of Xaraés grass was similar for the three nitrogen sources.

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