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DIVISÃO 3 - USO E MANEJO DO SOLO

Comissão 3.1 - Fertilidade do solo e nutrição de plantas

Brachiaria sp YIELD AND NUTRIENT CONTENTS AFTER NITROGEN AND SULPHUR FERTILIZATION[1]

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SUMMARY

Among the production factors, adequate fertilization is an important tool to raise the productivity of pastoral systems and consequently increase the share of Brazil in the supply chain of primary agricultural products at the global level. The objective of this study was to evaluate the interaction of nitrogen and sulfur fertilization in *Brachiaria decumbens* Stapf. The experiment in pots with Dystrophic Oxisol was evaluated in a completely randomized design with four replications in a 5 x 3 factorial arrangement, involving five N doses (0, 100, 200, 400, and 800 mg dm^{-3}) in the form of ammonium nitrate and three S doses (0, 20 and 80 mg dm^{-3}) in the form of calcium sulfate, with a total of 15 treatments. In the treatments with low S dose, calcium was provided as calcium chloride, to ensure a homogeneous Ca supply in all treatments. The results showed that the tiller production and dry weight of green leaves and of stems + sheaths and total dry weight were favored by the combination of N and S fertilizer, while the proportion of dry leaves was reduced. Nitrogen fertilization raised the N contents in green leaves and stems + sheaths and reduced K contents in fresh and dry leaves. The response to S rates in the N content of green leaves was quadratic.

Index terms: fertilization, *Brachiaria decumbens*, plant nutrition, forage plants.

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RESUMO: *PRODUÇÃO E TEORES DE NUTRIENTES NO CAPIM BRAQUIÁRIA ADUBADO COM NITROGÊNIO E ENXOFRE*

A adubação adequada é, entre os fatores de produção, importante ferramenta para aumentar a produtividade nos sistemas pastoris e consequentemente elevar a participação do Brasil no cenário mundial da cadeia produtiva primária. Com o objetivo de avaliar a interação da adubação com nitrogênio e enxofre na Brachiaria decumbens Stapf.*, foi conduzido em vasos com Latossolo Vermelho-Amarelo distrófico um experimento em delineamento inteiramente casualizado com quatro repetições, arranjado em esquema fatorial 5 x 3, envolvendo cinco doses de nitrogênio (0, 100, 200, 400 e 800 mg dm^{-3}) na forma de nitrato de amônio e três doses de enxofre (0, 20 e 80 mg dm^{-3}) na forma de sulfato de cálcio, perfazendo o total de 15 tratamentos. Nos tratamentos com menor dose de enxofre, o cálcio foi fornecido na forma de cloreto de cálcio, assegurando homogeneidade no fornecimento de Ca em todos os tratamentos. Na análise dos resultados, observou-se que a produção de perfilhos e matéria seca de folhas verdes, hastes + bainhas e total foi beneficiada com a adubação conjunta de nitrogênio e de enxofre, reduzindo a proporção de folhas secas. A adubação nitrogenada influenciou de modo positivo os teores de N nas folhas verdes e nas hastes + bainhas e negativamente o teor de K nas folhas verdes e secas; o teor de N nas folhas verdes apresentou resposta quadrática às doses de S.*

Termos de indexação: adubação, Brachiaria decumbens*, nutrição de plantas, plantas forrageiras.*

INTRODUCTION

The indices of meat and milk production in Brazil are still very low. One of the essential production factors is an adequate forage fertilization, to increase productivity and, consequently, expand the share of Brazil in the supply chain of primary agricultural products at the global level (Magalhães et al., 2007).

Fagundes et al. (2005) reported that soil N contents are usually insufficient to meet the demand of grasses. However, when completed with N fertilization, large increases in rates of dry matter accumulation of the forage grass *Brachiaria* are observed in the long term.

Nitrogen is an essential element directly related to forage quality (Teixeira et al., 2011), for participating in the synthesis of organic compounds that form the plant structure, for example: amino sugars, amines, amides, vitamins, pigments, amino acids, proteins, nucleic acids, and chlorophyll (Mengel & Kirkby, 2001). In addition, N is responsible for tillering, size of leaves and stems and for protein formation (Epstein & Bloom, 2005). With regard to sulfur, Baker et al. (1973) reported that S application along with N contributes to reduce the nitrate levels, which can be detrimental to animal health when very high. It is an essential nutrient for protein formation, since three protein amino acids contain sulfur.

The interaction between nutrients should be considered for forage production, as well as the balance of plant nutrition, at proportions of 15.5-18.0 g kg^{-1} N to 0.5-2.0 g kg^{-1} S, as recommended by Maynard et al. (1979). Batista & Monteiro (2008) showed the effects of S to enhance the response of marandu grass to N fertilization, with an increase in tiller and leaf number and total dry matter production. In turn, Batista & Monteiro (2010) reported a negative correlation between N and S fertilizer and K content in newly expanded brachiaria leaf blades.

This study aimed to evaluate the effect of N and S rates on dry matter yield, tiller number and the contents of N, P, K and S in shoots of *Brachiaria decumbens* Stapf.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse of the Universidade Estadual Paulista, Campus de Dracena (21º 29' longitude South and 51º 32' latitude West; 396 m altitude), State of São Paulo, using the forage grass *Brachiaria decumbens* Stapf.

The soil was classified as a dystrophic Oxisol, with Cerrado vegetation (Embrapa, 1999), with the following chemical properties: pH ($CaCl_2$ 0.1 mol L^{-1}) 4.1; 15 g dm^{-3} organic matter; 1 mg dm^{-3} P (resin-extracted); 3 mg dm^{-3} S-SO_4; 0.5 mmol$_c$ dm^{-3} K; 1 mmol$_c$ dm^{-3} Ca; 1 mmol$_c$ dm^{-3} Mg; 5 mmol$_c$ dm^{-3} Al; 15 mmol$_c$ dm^{-3} H; 2.5 mmol$_c$ dm^{-3} S; 22.5 mmol$_c$ dm^{-3} T; 11 % V; 0.13 mg dm^{-3} B; 1.0 mg dm^{-3} Cu; 27 mg dm^{-3} Fe; 13.0 mg dm^{-3} Mn; and 0.6 mg dm^{-3} Zn. For the experiment, soil was sampled from a depth of 0-20 cm for a composite sample; the soil was crumbled, air-dried and sieved (2 mm).

The experiment was arranged in a completely randomized design with four replications. The 5 x 3 factorial treatments consisted of five N rates (0, 100, 200, 400, and 800 mg dm^{-3}) in the form of ammonium nitrate and three S rates (0, 40, 80 mg dm^{-3}) in the form of calcium sulphate, i.e., a total of 15 treatments. In the treatment with lowest sulfur dose, calcium was provided as calcium chloride, to ensure a homogeneous Ca supply in all treatments.

Base saturation was increased to 40 % (Raij et al., 1996) by adding $CaCO_3$ and MgCO3, p.a. reagents at 3:1. Then, the soil was incubated for 30 days in the pots, maintaining moisture at 80 % field capacity.

After the incubation period, the soil was dried for seven days again. The soil of each pot was filled in plastic trays where the treatments and fertilizers were applied: $Ca(H_2PO_4)_2$, with 200 mg dm^{-3} P; K_2SO_4, with 180 mg dm^{-3} K; H_3BO_3, with 0.5 mg dm^{-3} B; $CoCl_2$, with 0.05 mg dm^{-3} Co; $CuSO_4$, with 1.0 mg dm^{-3} Cu; H_2MoO_4, with 0.05 mg dm^{-3} Mo; $NiSO_4$, with 0.05 mg dm^{-3} Ni; $MnSO_4$, with 10 mg dm^{-3} Mn and $ZnSO_4$, with 3.0 mg dm^{-3} Zn. The N and S sources were NH_4NO_3 and $CaSO_4$, respectively. Nitrogen was applied in three applications (at sowing and 20 and 40 days after sowing).

Then 4 dm^3 of the treated soil was transferred to the labeled pots and after four days *Brachiaria decumbens* was sown and the seeds were evenly covered with a thin soil layer. After two weeks, the plants were thinned to five plants per pot. Soil moisture was maintained close to 80 % field capacity by daily irrigation with deionized water. The amount of water to be added was determined by weighing five pots.

The plants were cut 5 cm above the soil 60 days after sowing. The seedlings were separated in green leaves (leaf blade), stems + sheaths and dry leaves, and dried at 65 °C to constant weight to determine the dry mass. The number of tillers was counted at cutting. The dried plant material was ground in a Willey mill and the content of N, P, K, and S determined, as described by Malavolta et al. (1997).

The results were evaluated by analysis of variance, regression and interactions (Pimentel-Gomes & Garcia, 2002).

RESULTS AND DISCUSSION

The results showed a positive interaction between N and S, with a maximum total dry matter yield at doses of 756 mg dm^{-3} N and 59 mg dm^{-3} S, and an average of 56 tillers per pot with five plants (Figure 1). The increase in dry matter production and tillering resulting from the supply of both nutrients was also verified by Batista & Monteiro (2006), who attributed the effect to cell differentiation and vegetative growth. However, Silva et al. (2009) described a different response to N fertilization in tillering of *Brizantha* and *Decumbens* species.

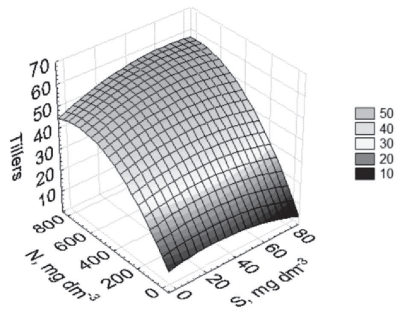
The dry mass (DM) of green leaves, stems + sheaths and total dry matter was affected by the interaction between nitrogen and sulfur (Figure 1). It is noteworthy that the application of 523 mg dm^{-3} N and 49 mg dm^{-3} S resulted in a higher production of leaf DM, which are higher rates than those that induced highest stem and sheath production (456 mg dm^{-3} N and 6 mg dm^{-3} S), showing a stimulus of the production of new leaves by high N doses. In turn, at the lowest N levels, the proportions of dry leaves were highest, and with increasing N levels up to 512 mg dm^{-3} N, associated with 39 mg dm^{-3} S, the proportions of dry leaves decreased to the minimum (Figure 2). This result is important because the nutritional quality of a forage is given mainly by the proportion of green leaves, whose growth is stimulated by the production of new cells, which has a positive impact on the number of leaves per plant (Silva et al., 2009; Heinrichs, 2010).

An interaction of the N and S rates with the levels of N, P and S was observed in the dry leaves, of S with the green leaves and of K with the stems + sheaths, although the critical points were not found (Figure 3). This fact shows that the point is considered a saddle point (Charnet et al., 2008), with no maximum or minimum, but a correlation, showing dependence between the variables or that the tested doses did not reach the critical points. The nutrient concentrations in the shoots of the fertilized plants were within the range defined as adequate by Werner et al. (1996).

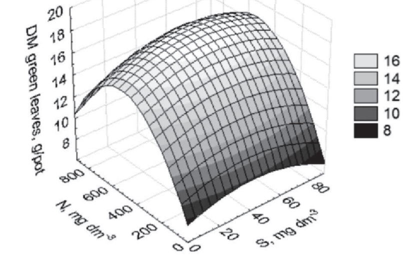
The leaf DM was significantly influenced by the N rates, and was maximized by the application of 392 mg dm^{-3} N (Figure 4). As described above, for the proportion between the three evaluated segments (dry leaves, green leaves and stems + sheaths) it was found that the relation of dry leaves was lowest at the highest N rates (Figure 2). These results are important for the quality of forage production, since the increase in dry leaves was due to the increased production of *Brachiaria decumbens*, attributed to the increase in the quantity and quality of this forage induced by N fertilization.

There was no effect of interaction between S and N fertilization on the content of N and S in green leaves and stems + sheaths, but there were isolated effects of both. The N content in green leaves increased up to a supply of 42.5 mg dm^{-3} S (Figure 5). In the S content in stems + sheaths, there was an increased response according to the rates of the same nutrient (Figure 5). The protein content in food crops is directly related to the presence of N. Thus, the results suggest that the protein content in this forage can be increased by fertilizing the nutrient, emphasizing the need for the metabolism of the sulfur amino acids methionine and cystine, and cysteine.

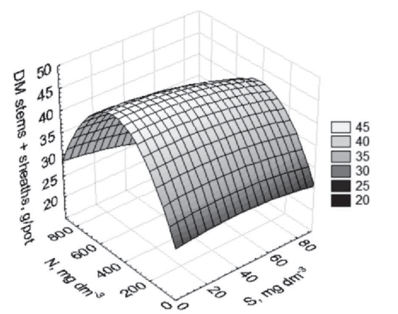
Nitrogen rates increased the N contents in green leaves and stems + sheaths linearly up to a dose of 800 mg dm^{-3} (Figure 6). The variation between the levels found in non-fertilized plants and those treated with the maximum N rate was 18.1 and 26.9 g kg^{-1}, respectively, in stems and green leaves + sheaths. It was observed that the leaves are much more sensitive to variations in nutrient supply than stems + sheaths. The fluctuation in our results was greater than found by Bonfim-Silva & Monteiro (2010) who reported a



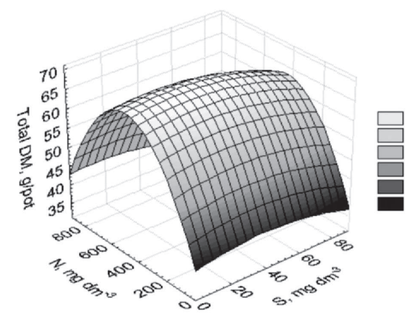
Tillers= 15.6985+0.1348*S+0.0972*N-0.0024*S^2+ 0.0002*S*N - 7.2157x10^{-5}*N^2 R^2 = 0.72
Maximum: S=59.58; N:756.11; Tillers: 56.46



DM green leaves = 7.6192+0.0617*S+0.0324*N-0.0008*S^2+ 3.425x10^{-5}*S*N - 3.2566x10^{-5}*N^2 R^2 = 0.78
Maximum: S= 49.77; N: 523.62; DM green leaves: 17.64 g/pot

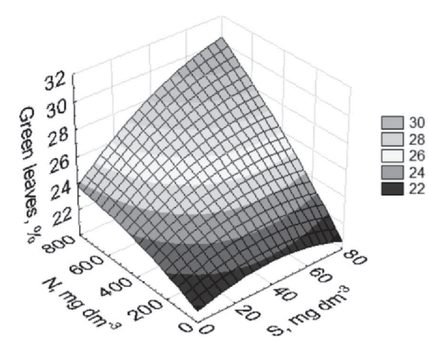


DM stems + sheaths = 26.7854+0.0537*S+0.0877*N-0.0007*S^2- 9.7656x10^{-5}*S*N-9.5381x10^{-5}*N^2 R^2 = 0.81
Maximum: S= 6.52; N: 456.41; DM stems + sheaths: 46.97 g/pot

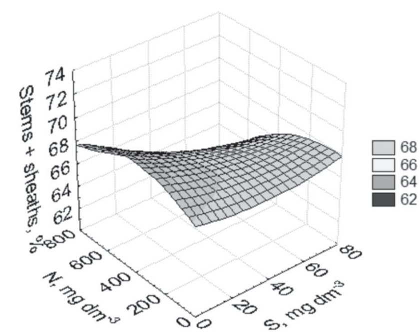


Total DM = 38.7098+0.1153*S+0.125*N-0.0015*S^2- 7.025x10^{-5}*S*N - 0.0001*N^2 R^2 = 0.79
Maximum: S: 24.00 ; N: 616.57; Total DM: 78.68 g/pot

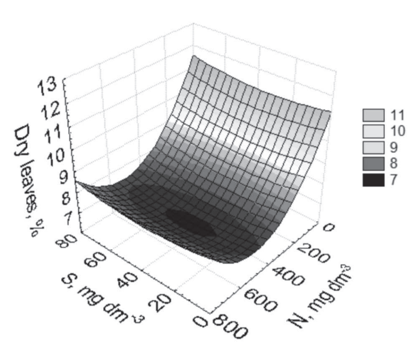
Figure 1. Production of tillers and dry matter (DM) of green leaves and of stems + sheaths and total DM of *Brachiaria decumbens* fertilized with nitrogen and sulfur.



Green leaves (%) = 20.8463 + 0.0502*S + 0.0062*N - 0.0007*S^2+ 0.0001*S*N - 3.1865x10^{-6}*N^2 R^2 = 0.57
Critical point not found.

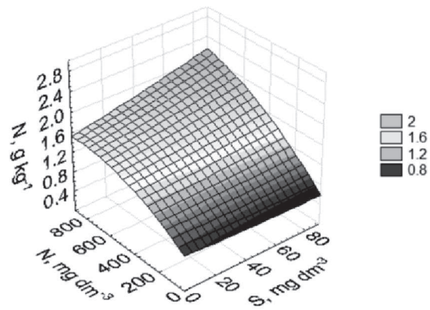


Stems + sheaths (%) = 67.8221-0.0361*S + 0.0098*N + 0.0004*S^2- 0.0001*S* -1.256x10^{-5}*N^2 R^2 = 0.60
Critical point not found.

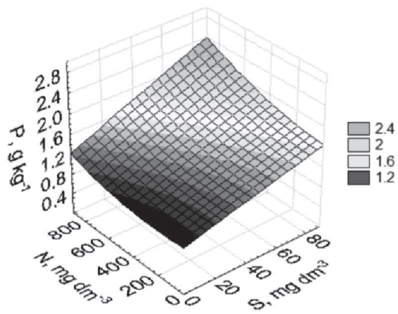


Dry leaves (%)= 11.3169-0.0141*S-0.016*N+0.0002*S^2- 2.9063x10^{-6}*S*N +1.5733E-5*N^2 R^2 = 0.69
minimum: S= 38.97; N: 512.08; Dry leaves: 6.95%

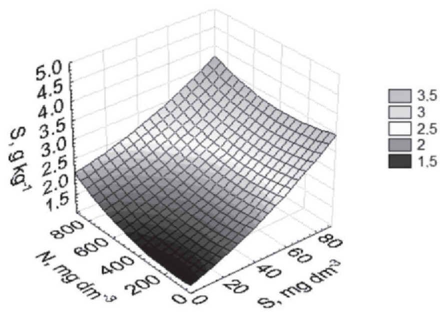
Figure 2. Percentage of aerial segments of *Brachiaria decumbens* in response to nitrogen and sulfur.



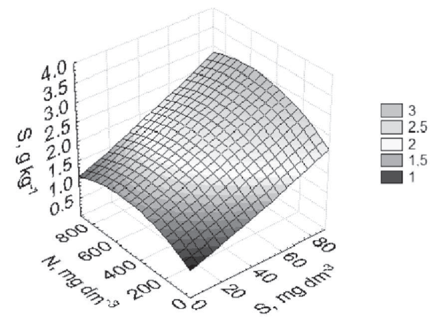
N in dry leaves = 0.7175-0.0025*S+0.002*N+ $1.1875x10^{-5}*S^2$ + $9.375x10^{-6}*S*N-1.1964X10^{-6}*N^2$ $R^2 = 0.47$
Critical point not found.



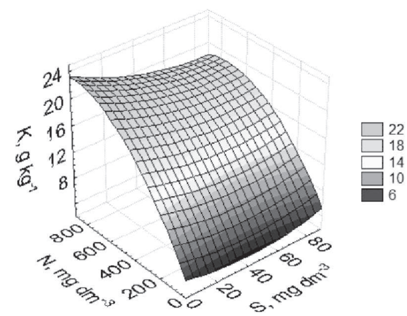
P in dry leaves = 0.933+0.0083*S-0.0003*N-$5x10^{-6}*S^2$+ $5.9375x10^{-6}*S*N+6.5798X10^{-7}*N^2$ $R^2 = 0.51$
Critical point not found.



S in dry leaves = 1.2294+0.0148*S-0.0005*N+$0.0001*S^2$- $7.4375x10^{-6}*S*N+1.6183x10^{-6}*N^2$ $R^2 = 0.55$
Critical point not found.



S in green leaves= 0.7384+0.0132*S+0.0025*N+$2.5625X10^{-5}*S^2$+ $4.5313X10^{-6}*S*N-2.3445X10^{-6}*N^2$ $R^2 = 0.60$
Critical point not found.



K in stems + sheaths = 4.7242-0.0567*S+0.0421*N+ $0.0007*S^2$- $6.9562X10^{-5}*S*N-2.3846X10^{-5}*N^2$ $R^2 = 0.48$
Critical point not found.

Figure 3. Nutrient contents in shoots of *B. decumbens* after fertilization with nitrogen and sulfur.

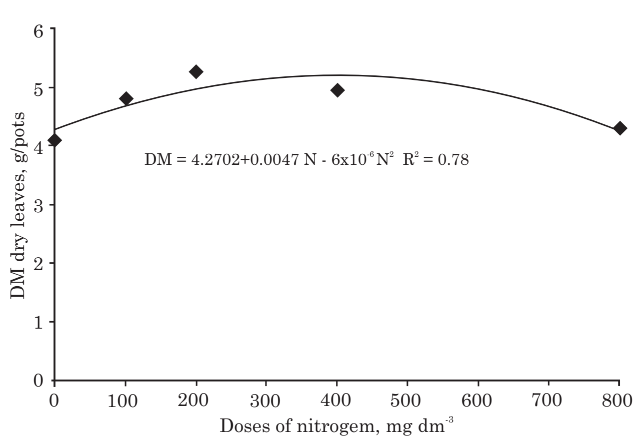


Figure 4. Influence of nitrogen fertilization on dry mass (DM) of dry leaves of *Brachiaria decumbens*.

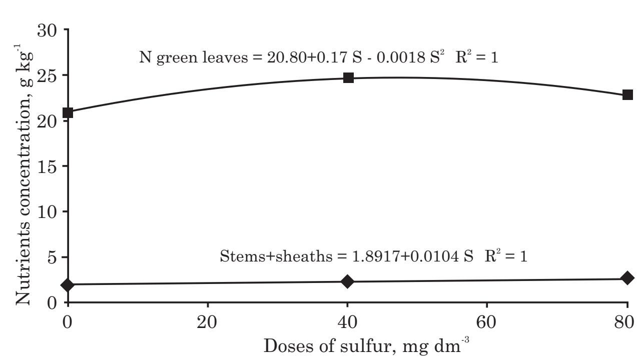


Figure 5. Influence of sulfur fertilization on N concentration in green leaves and sulfur in stems + sheaths of *Brachiaria decumbens*.

difference of 16.4 g kg^{-1} N between the leaf contents of *Brachiaria brizantha* fertilized and non-fertilized with N.

The K contents found in green and dry leaves of *Brachiaria decumbens* were in compliance with the adequate range (12-25 g kg^{-1}) determined by Werner et al. (1996), decreasing with increasing N (Figure 7). The negative relationship between K contents in *Brachiaria* leaves and N fertilization rates was also verified by Ferragine (1998) and Batista & Monteiro (2010). This result can be explained by the dilution effect caused by the greater vegetative growth of the forage (Mengel & Kirby, 2001).

The P content in green leaves increased with N application to the system (Figure 8). The fertilized N possibly induced greater root development, improving soil exploitation and consequent P uptake, since the contact of P in the soil-root system occurs mainly via diffusion and/or by soil acidification, releasing P forms that are not available to plants at higher pH (Ramos Jr. et al., 2009). The average levels of nutrients that were not significant in terms of treatments and standard deviation are summarized in table 1.

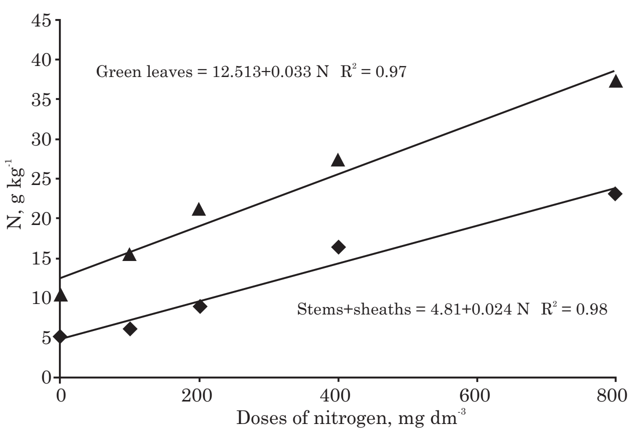


Figure 6. Influence of nitrogen fertilization on N concentration in green leaves and stems + sheaths of *Brachiaria decumbens*.

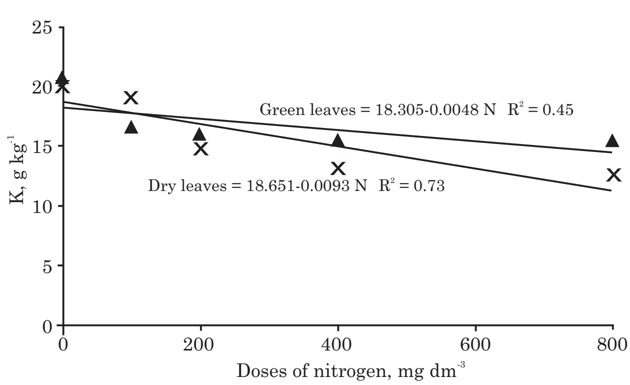


Figure 7. Influence of nitrogen fertilization on K concentration in green leaves and dry leaves of *Brachiaria decumbens*.

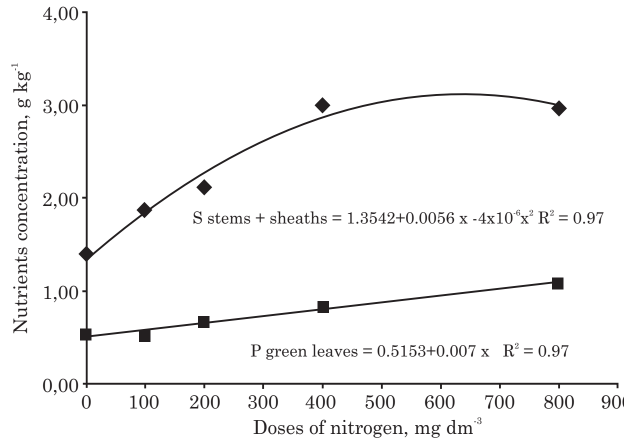


Figure 8. Influence of nitrogen fertilization on P concentration in green leaves and S concentration in stems + sheaths of *Brachiaria decumbens*.

Table 1. Average dry matter and nutrient contents with standard deviation of variables that were not significantly affected by nitrogen and sulfur application

Treatment	Parameter evaluated	Mean
S doses	Dry mass leaves (g/pot)	4.70 (± 0. 11)
	K leaves (g kg^{-1})	16.38 (± 0.39)
	P green leaves (g kg^{-1})	0.74 (± 0.02)
	K green leaves (g kg^{-1})	16.56 (± 1.65)
	N stems + sheaths (g kg^{-1})	12.20 (± 0.70)
	P stems + sheaths (g kg^{-1})	3.66 (± 0.30)
N doses	P stems + sheaths (g kg^{-1})	3.65 (± 0.30)

The results showed the response of tillering, dry matter production, proportion of leaves and of stems + sheaths, and nutrient contents in *B. decumbens* to N and S fertilization.

CONCLUSIONS

1. The tiller production and dry weight of green leaves, of stems + sheaths and total dry weight of *Brachiaria decumbens* were favored by the combination of N and S fertilization.

2. The combined N and S fertilizer reduced the proportion of dry leaves.

3. The N fertilization raised N contents in green leaves and stems + sheaths and reduced K contents in fresh and dry leaves.

4. The response to S rates in the N content of green leaves was quadratic.

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