Nutrient extraction by mombaça grass submitted to sources and doses of nitrogen

Extracción de nutrientes por el capín mombaça sometido a fuentes y dosis de nitrógeno

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ABSTRACT

The extraction of nutrients from the soil by plants depends on soil fertility, plant management and plant production. The objective of this study was to evaluate the effect of the application of sources and doses of nitrogen on macronutrient extraction by *Panicum maximum* cv. Mombaça. The experiment was conducted from 1 October 2011 to 14 April 2012 in the Federal Institute of Espírito Santo, Santa Teresa Campus. The experimental design was a randomised block design with three repetitions in a 3 × 6 factorial scheme, with three nitrogen fertilisers (urea, ammonium sulphate and calcium nitrate) and six nitrogen doses (0, 120, 240, 360, 480 and 600 kg ha^{-1}). The established nitrogen doses were divided equally and applied every 28 days after the mombaça grass was cut, resulting in a total of seven applications during the 196-day experimental period. It was observed than nutrient extraction depends on forage plant production and was highest with the higher doses of nitrogen because of the greater dry matter production. The application of high doses of nitrogen in the form of calcium nitrate caused a reduced absorption of magnesium. Nitrogen fertilisation in pastures should be accompanied by the management of other nutrients to avoid nutritional imbalances or the depletion of soil fertility.

Key words: *Panicum maximum,* nitrogen fertilisers, macronutrient absorption, interaction between ions.

RESUMEN

La extracción de nutrientes depende de la fertilidad del suelo, de cómo las plantas son tratadas y de su producción. El objetivo del presente trabajo es evaluar el efecto de la aplicación de fuentes y dosis de nitrógeno sobre la extracción de macronutrientes por el Panicum maximum *cv. Mombaça. El experimento se llevó a cabo entre el 1 de octubre de 2011 y el 14 de abril de 2012, en el Instituto Federal do Espíritu Santo, Campus Santa Teresa. En la delineación experimental se utilizaron bloques aleatorios, con tres repeticiones, en un esquema factorial 3 x 6: tres fertilizantes nitrogenados (urea, sulfato de amonio y nitrato de calcio) y seis dosis de nitrógeno (0, 120, 240, 360, 480 y 600 kg ha^{-1}). Las dosis de nitrógeno establecidas se dividieron y se aplicaron de igual forma cada 28 días, siempre después del corte del capín mombaca, con un total de siete aplicaciones durante el período experimental de 196 días. Se observó que la extracción de nutrientes depende de la producción del forraje, y es mayor para las dosis más elevadas de nitrógeno, debido a la mayor producción de materia seca. La aplicación de elevadas dosis de nitrógeno, en la forma de nitrato de calcio, promovió la reducción de la absorción de magnesio. La fertilización nitrogenada en pastos debe estar acompañada por el manejo de los demás nutrientes, tratando de evitar el desequilibrio nutricional o el agotamiento de la fertilidad del suelo.*

Palabras clave: Panicum máximum*, fertilizantes nitrogenados, absorción de macronutrientes, interacción entre iones.*

Introduction

The ability to graze livestock is, without a doubt, one of the greatest reasons for the success of the Brazilian cattle industry, as it allows for lower production costs and increases the competitiveness of national livestock production while helping producers overcome health problems that could

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constitute barriers to entry into the international market (Almeida *et al.*, 2011). However, meat and milk production could reach higher levels than the currently observed levels. This has not occurred because, among other reasons, the low production and quality of the forage given to the animals limits their performance (Santos *et al.*, 2016).

Numerous factors contribute to the low productivity of Brazilian pastures. However, the factors related to the management of soil fertility are worth mentioning. Forage production is not only impaired by the absence of nutrients; multiple management-related deficiencies, including the absence of soil acidity correction and fertiliser use, also limit the productivity of pastures (Barcellos *et al.*, 2008).

Nitrogen (N) is one of the most important nutrients that limits production in tropical forage grasses, as it is quantitatively the most important nutrient for plant growth (Primavesi *et al.*, 2005). It is essential to plants because it is found in some of the most important plant biomolecules, including amino acids, proteins, nucleic acids, hormones, enzymes, coenzymes, phytochromes, chlorophyll, ATP, NADH and NADPH (Taiz & Zeiger, 2009). N deficiency limits the productivity of forage grasses, which results in a sharp decline in the stocking rate of pastures and consequently reduced animal weight (Alves *et al.*, 2015).

In an attempt to increase pasture productivity, nitrogen fertilisers have been used to increase forage production. However, according to Primavesi *et al.* (2004), inadequate N management in pastures could produce negative effects on soil fertility, as an increase in forage production due to nitrogen fertilisers results in greater extraction of other nutrients from the soil, which if not replaced could limit the future efficiency of the nitrogen fertiliser and promote soil depletion and degradation.

Thus, knowledge of the absorption and extraction of nutrients in pastures is fundamentally important for improving the management of soil fertility in areas where nitrogen fertilisation is applied. The objective of this study was to evaluate the effect of the application of sources and doses of nitrogen on macronutrient extraction by mombaça grass (*Panicum maximum* Jacq.).

Materials and Methods

The experiment was conducted from 1 October 2011 to 14 April 2012, at the Federal Institute of Espírito Santo, Santa Teresa Campus, located at coordinates 19º48'36'' S and 40º40'48'' W at an average altitude of 150 m in Santa Teresa, ES. The regional climate is humid temperate with a dry winter and hot summer and the region is classified as Cwa according to the Köppen classification.

The pasture was 1200 m² with 6 m² plots totalling 324 m². The mombaça grass had been established for more than four years and was highly productive. Soil fertility was managed according to technical recommendations for irrigated pastures with high nutritional requirements (Prezotti *et al.*, 2007).

The soil was a yellow Oxisol with a clay texture (Santos *et al.*, 2013) and 343, 170 and 487 g kg^{-1} of sand, silt and clay, respectively. Four months before the experiment began, the soil was chemically analysed and limed 110 days before the beginning of the experiment with 1000 kg ha^{-1} of dolomitic limestone. The fertilisation (without N) occurred 90 days after the liming, according to the recommendations for mombaça grass of the Manual of Liming and Fertilisation of Espírito Santo (Prezotti *et al.*, 2007). A total of 463 kg ha^{-1} of triple superphosphate, 434 kg ha^{-1} of potassium chloride and 60 kg ha^{-1} of FTE BR-10 were applied to the experimental area. The liming and fertilization were broadcast on the surface, without incorporation. Immediately before beginning the experiment, a new soil sample was taken from the experimental area at depths of 0-0.2 and 0.2-0.4 m (Table 1).

The experimental design was a randomised block design. A 3 x 6 factorial scheme was adopted with three nitrogen fertilisers (urea, ammonium sulphate and calcium nitrate), six N doses (0, 120, 240, 360, 480 and 600 kg ha^{-1}) and three repetitions, totalling 54 experimental units.

The established N doses were divided equally and applied every 28 days after the mombaça grass was cut, resulting in a total of seven applications during the 196-day experimental period.

Plots of 3 x 2 m were demarcated with a 1-m border. Subsequently, the entire area was uniformly cut with a brush cutter and the treatments were applied. The treatments (sources and doses of N) were dissolved in 10 L of water and applied to the plots with a sprinkler to best distribute the nitrogen fertilisers. Immediately after applying the nitrogen fertilisers, 8 mm of water were applied to the entire experimental area using spray irrigation system with 74% application efficiency.

Table 1. Chemical soil characterisation of the experimental area at depths of 0-0.2 and 0.2-0.4 m before and after liming and soil fertilisation.

Before liming and soil fertilisation												
Depth	pH[1]	Ca	Mg	Al	H+Al	CEC	SB	P	K	S-SO$_4^{2-}$	OM	V
m		--------------cmol$_c$ dm^{-3}--------------						------mg dm^{-3}-------			g kg^{-1}	%
0-0.2	5.0	1.7	0.6	0.3	3.1	5.5	2.4	11.0	30	6.2	26	43
0.2-0.4	5.4	1.9	0.6	0.1	2.8	5.4	2.6	3.4	22	5.5	22	48
After liming and soil fertilisation												
Depth	pH[1]	Ca	Mg	Al	H+Al	CEC	SB	P	K	S-SO$_4^{2-}$	OM	V
m		--------------cmol$_c$ dm^{-3}--------------						------mg dm^{-3}------			g kg^{-1}	%
0-0.2	5.6	3.2	1.1	0.0	1.2	5.9	4.7	32.0	155	10.2	25	80
0.2-0.4	5.3	2.1	0.9	0.1	2.5	5.6	3.2	0.3	14	4.4	16	56

[1] pH in H$_2$O 1:2.5; P and K: extracted by Mehlich; Ca, Mg and Al: extracted by KCl; H+Al: extracted by calcium acetate; CEC: cation exchange capacity at pH 7.0; SB: sum of bases; S-SO$_4^{2-}$: extracted by barium chloride; OM: organic matter; V: percentage saturation by bases.

Throughout the study period, when the rainfall was insufficient the pasture was irrigated and the water depth was maintained and calculated as a function of evapotranspiration of the culture (ETc). The meteorological information observed during the study period used to calculate ETc was provided by an automatic weather station located 550 m from the experimental area (Figure 1).

The period between 1 October and 24 December, which encompasses the first three cuttings, was used for pasture adaptation. As was done before the liming, the pasture was intensively managed

and received high doses of N. This period was used as an adaptation period to reduce the N in the soil so that the mombaça grass would respond to the treatments and not the N available in the soil.

To evaluate the last four cuttings, the plants were collected with a 0.5×0.5 m metal square and cut with steel scissors 0.3 m from the soil surface. After each experimental cutting, the entire study area was uniformly cut at the same height, and the resulting waste was removed. The material collected in each 0.25 m^2 cutting was placed in a plastic bucket, identified and immediately weighed, thus
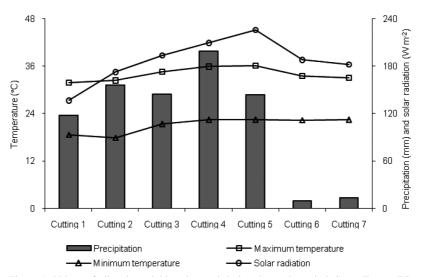

Figure 1. Values of climatic variables observed during the study period. Santa Teresa, ES. October/2011 to April/2012.

providing the fresh weight of the grass. Subsequently, a representative sample of approximately 0.4 kg of the forage was taken from the collected material, placed in a paper bag, identified and placed in a forced air oven with a temperature between 60-65 ºC until reaching a constant weight to determine the pre-drying mass. After drying, the samples were ground in a Willey grinder with a 1-mm sieve and placed in polyethylene bags. Subsequently, the ground material was placed in the oven again to remove the residual moisture. Dry matter production (DMP) per hectare was determined with the fresh weight of the material collected from the 0.25 m² plot and the level of dry matter obtained after processing the sample according to the following formula: DMP = [% DM x (FM x 40000)]/100, where DMP is dry matter production in kg ha⁻¹; % DM is percent dry matter of the sample after processing; FM is fresh matter in kg, collected from the 0.25 m² plot; and 40000 is a factor used to convert production into hectares.

The above-ground plant matter was chemically analysed to determine the concentrations of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur according to the method described by Malavolta *et al*. (1997). Data from the chemical analysis of the forage plants and DMP were used to calculate the nutrient extraction in each cutting using the formula: NE = 0.001 x (DM x CN), where NE is nutrients extracted in kg ha⁻¹; DM is dry matter in kg ha⁻¹; NC is nutrient concentration in g kg⁻¹; and 0.001 is a factor used to convert nutrient extraction into kg ha⁻¹. The results represent the sum of the nutrient extractions of the last four cuttings.

The data were subjected to an analysis of variance and regression equations were fitted according to the significance of the variables. A significance level of 5% was adopted in all of the statistical tests and tests were performed using the program SAS.

Results and Discussion

The increased supply of N resulted in greater DMP of mombaça grass (Figure 2). Calcium nitrate produced the highest DMP response for increasing doses of N, followed by ammonium sulphate and urea. At the maximum dose of N, the application of ammonium sulphate and calcium nitrate produced a DMP 14 and 27% greater than that produced by urea, respectively.

The increase in the DMP of tropical pasture grass plants as a function of increasing doses of N was presented by Martuscello *et al*. (2015) and Cunha *et al*. (2012). According to Fagundes *et al*. (2006), the supply of this nutrient is indispensable in pasture production systems, when N resulting from soil organic matter mineralization is not sufficient
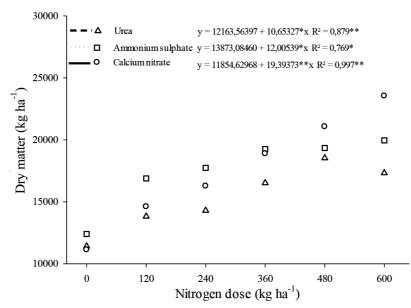

Figure 2. Accumulated production of dry matter from mombaça grass submitted to sources and doses of nitrogen. * and **: p < 0.05 and p < 0.01 respectively.

to assist the Gramineae plant demand with high productive potential.

According to the presented results, the DMP using calcium nitrate as a source of N was higher than the other sources in the elevated N doses. This probably is due to the nitrate in the soil dynamics and its chemical characteristics, reducing N losses significantly with its application.

Compared to the other sources, urea application promoted inferior response to DMP. Similar results were presented by Costa *et al.* (2010), evaluating *Brachiara brizantha* production, using urea and ammonium sulphate as N sources. According to Costa *et al.* (2003), the transformations which occur with this soil fertilizer, the possibilities of N losses, mainly through ammonium volatilization may explain the presented results, even with the management adopted during the dose applications.

N extraction was influenced by the sources and doses of N. An increase in the applied N dose resulted in a greater extraction of this nutrient by the plants (Figure 3). The greatest N extraction was obtained with the application of calcium nitrate, followed by ammonium sulphate and urea, which corroborates the relationship between DMP and nutrient extraction observed by Costa *et al.* (2008) for *Brachiaria brizantha* cv. Xaraés. An increase in N extraction with higher doses of N was also reported by Costa *et al.* (2010) for *Brachiaria brizantha* cv. Marandu. Figure 3 shows that the data best fit a quadratic model; Primavesi *et al.* (2004) reported

similar observations in pastures of *Coastcross* grass. In the treatments that received the maximum N dose, N extraction by mombaça grass was 148, 160 and 197% greater than that of the control for urea, ammonium sulphate and calcium nitrate, respectively, which shows that this crop requires high levels of this nutrient to maintain high forage production levels.

Phosphorus (P) extraction by mombaça grass was influenced by the different sources and doses of N (Figure 4). For the N sources calcium nitrate and urea, the data fit a linear model in which the increase in the dose of N promoted greater P extraction. The increase in P extraction with higher N doses is due to the greater DMP of mombaça grass, which requires greater quantities of P to promote increased production. These results agree with results obtained by Costa *et al.* (2008) and Costa *et al.* (2010) who evaluated nutrient extraction in *Brachiaria brizantha* cv. Marandu and *Brachiaria brizantha* cv. Xaraés, respectively.

The existing synergism between N and P contributed to the increased P extraction with the higher doses of N. Similar results were obtained by Franco *et al.* (2007), who documented the synergistic effect of these two nutrients. These authors believe that an increase in N supply favoured P absorption in sugar cane. According to Malavolta *et al.* (1997), the interaction between nutrients, i.e. the capacity that a specific nutrient has to alter the absorption of another because of antagonism, inhibition or
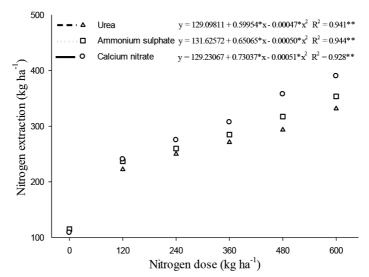

Figure 3. Accumulated nitrogen extraction in mombaça grass plant mass submitted to sources and doses of nitrogen. * and **: $p < 0.05$ and $p < 0.01$ respectively.
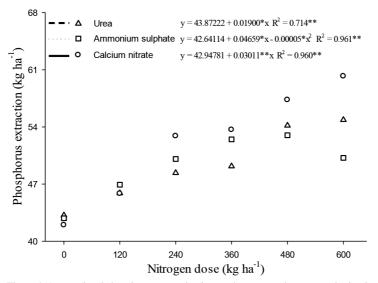
Figure 4. Accumulated phosphorus extraction in mombaça grass plant mass submitted to sources and doses of nitrogen. * and **: $p < 0.05$ and $p < 0.01$ respectively.

existing synergism between the two should also be considered.

The application of 600 kg ha-1 of N in the form of urea and calcium nitrate promoted an increase of 26 and 42% in P extraction, respectively. The application of high doses of N (over 465 kg ha-1) in the form of ammonium sulphate reduced P extraction in the plants. These results can be explained by the changes in soil pH caused by this fertiliser. Sarmento *et al.* (2008) observed that the application of ammonium sulphate caused a reduction in the levels of P in pastures of *Panicum maximum* at the end of the experiment due to the reduced soil pH and the subsequent formation of insoluble phosphates of Fe and Al. Thus in the present study, the soil acidification, the increased concentration of aluminium and the reduced availability of P caused by the application of ammonium sulphate contributed to the reduced availability of P in the soil and the consequent reduced extraction of this nutrient by the plants at higher doses of N. Furthermore, the increased concentration of sulphur in the soil caused by the application of high doses of ammonium sulphate could have contributed to the reduced P extraction due to the existing antagonism between these nutrients.

The increased N supply in the different sources caused a linear increase in the extraction of potassium (K) and calcium (Ca), except in the case of calcium nitrate. For both nutrients, calcium nitrate produced greater rates of extraction followed by ammonium sulphate, which shows that these results are intimately connected with the DMP of the forage plant (Figures 5 and 6).

When 600 kg ha-1 of N in the form of calcium nitrate were applied to the mombaça grass, 11% more K was extracted than when urea was applied. For ammonium sulphate, the K extraction was 5% higher than when urea was used. Experiments showing differences in K extraction due to differences in N source by tropical forage plants were presented by Costa *et al.* (2009). These authors observed a higher K extraction in *Brachiaria brizantha* cv. Marandu with ammonium sulphate than with urea. These results were attributed to the higher DMP of the forage plants with the use of ammonium sulphate.

The existing synergistic effect between N and K and between N and Ca could have contributed to the increased extraction of the cations K and Ca by mombaça grass. Cantarela (2007) reported the synergism existing between N and K and between N and Ca. Faroni *et al.* (2009) observed that increased nitrogen fertilisation resulted in increased K absorption in sugar cane plants, and the author attributed this behaviour to the synergism between the nutrients. When calcium nitrate was used, Ca extraction by the plants occurred in a quadratic manner, with greater extraction values reported with calcium nitrate than with other sources of N. These results can be explained by the indirect supply of
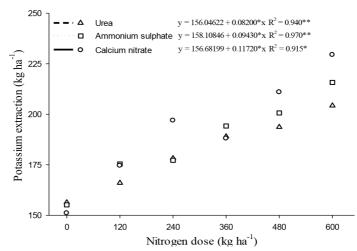
Figure 5. Accumulated potassium extraction in mombaça grass plant mass submitted to sources and doses of nitrogen. * and **: $p < 0.05$ and $p < 0.01$ respectively.
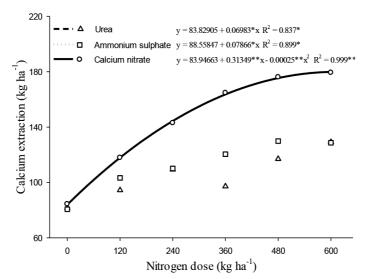

Figure 6. Accumulated calcium extraction in mombaça grass plant mass submitted to sources and doses of nitrogen. * and **: $p < 0.05$ and $p < 0.01$ respectively.

Ca to the soil through the nitrogen fertiliser, which allows a greater absorption of this nutrient by plants.

The application of N in the form of urea and ammonium sulphate caused a linear increase in magnesium (Mg) extraction (Figure 7). The application of 600 kg ha^{-1} of N in the form of urea and ammonium sulphate promoted an increase of 44 and 72% in Mg extraction, respectively.

High doses of N (over 363 kg ha^{-1}) in the form of calcium nitrate reduced Mg extraction in the plants. This reduction can be explained by the increased Ca concentration in the soil and the

consequent reduction in Mg absorption. Calcium nitrate contains 19% Ca; therefore 735 kg ha^{-1} of Ca were indirectly supplied to the soil in the treatment where the maximum N dose was applied. According to Malavolta (2006), Ca and Mg ions compete for the same absorption sites in plants. Therefore, the excess of one element results in the decreased absorption of the other because of competitive inhibition. Medeiros *et al.* (2008) and Salvador *et al.* (2011) showed that decreased Mg absorption occurred in corn and soy, respectively, in the presence of increased soil concentrations of Ca.
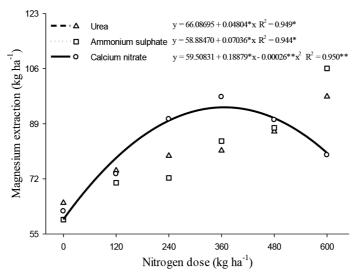
Figure 7. Accumulated magnesium extraction in mombaça grass plant mass submitted to sources and doses of nitrogen. * and **: p < 0.05 and p < 0.01 respectively.

Doses and sources of N had a significant impact on sulphur (S) extraction by mombaça grass. For all N sources, S extraction increased linearly with increasing N doses (Figure 8). A similar result was found by Batista & Monteiro (2006) in a study of *Brachiaria brizantha* cv. Marandu. These authors observed marked increases in S extraction with increasing N doses in plants.

For the greatest dose of N, S extraction was 103% greater with ammonium sulphate than with urea. Similar results were observed by Costa *et al.* (2009). These authors found that 105% more S was extracted when the highest dose of N (300 kg ha⁻¹) was applied in the form of ammonium sulphate than urea. According to Primavesi *et al.* (2004), this sharp increase in S extraction with ammonium
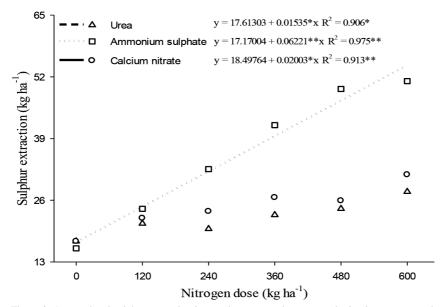

Figure 8. Accumulated sulphur extraction in mombaça grass plant mass submitted to sources and doses of nitrogen. * and **: p < 0.05 and p < 0.01 respectively.

sulphate is due to the fact that 24% of this fertiliser is S, which is indirectly supplied to the soil and made available to the plants.

Conclusions

The increase in nitrogen supply results in greater nutrient extraction by mombaça grass due to a higher dry matter production.

The nutrients which are associated with nitrogen in the nitrogen fertilizers may, through synergism or antagonism, potentiate or reduce other nutrient extraction by mombaça grass.

The nitrogen fertilization on pastures may be followed by other nutrient management considering the characteristics of each nitrogen source that is used, aiming to avoid the nutritional imbalance or the depauperation of soil fertility.

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