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Tropical grass fertilized with wood ash in Cerrado Oxisol: Concentrations of calcium, magnesium and sulphur

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While nutrients such as calcium, magnesium and sulphur are required by plants in lower amounts than the amounts required of nitrogen, phosphorus, and potassium, these nutrients are as important as those required for the growth and development of plants. Varying concentrations of calcium and magnesium can be found in wood ash as residue, which may have a high percentage of these nutrients. This study aims to evaluate the concentration of calcium, magnesium and sulphur in *Brachiaria brizantha*, a genus of tropical grasses, as a function of the levels of wood ash. The experiment was conducted in a greenhouse. The experimental design was completely randomized in a factorial of 6 × 2, corresponding to 6 doses of wood ash (0, 3, 6, 9, 12 and 15 g dm^{-3}) and 2 cultivars of *B. brizantha* (Marandu and Xaraes), and was completed with 6 replicates. Experimental characteristics included the concentrations of calcium, magnesium and sulphur in the dry mass of the shoots and roots of Marandu and Xaraes. The variance of the results was analyzed using an F test at a 5% probability. For wood ash, we performed a regression analysis, and for tropical grasses, we performed a Tukey test at a 5% probability. In the three sections, the highest concentrations of calcium, magnesium and sulphur in the shoots and roots of Marandu and Xaraes are between the wood ash doses of 7.72 and 11.79 g dm^{-3}, respectively. The wood ash influences the nutritional characteristics of the grasses by increasing the concentrations of calcium and magnesium in the shoots of Marandu and Xaraes, respectively, in excess of 42 to 29% and greater than 77 and 39% increments for the roots. The average concentrations of magnesium in shoots of Marandu and Xaraes were 0.87 and 0.94 g kg^{-1}, respectively, while the roots had concentrations of 0.94 and 0.95 g kg^{-1}, respectively. Wood ash as a fertilizer promotes significant changes in the nutritional characteristics of the grasses Marandu and Xaraes when planted in Cerrado Oxisol.

Key words: *Brachiaria brizantha*, mineral nutrition, solid residue.

INTRODUCTION

In agricultural activities, fertilizer application is paramount for the correction or maintenance of soil fertility. The replenishment of soil nutrients in a proper range generally improves the nutritional status of the plants, thus

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increasing crop productivity. Soils of the Brazilian Cerrado, which have low natural fertility (Lopes and Guimaraes, 1994) and commonly dystrophic in nature, should be improved chemically by fertilization.

Fertilization practices, such as the use of wood ash as solid waste, have been used to fertilize and improve soil fertility. Wood ash is a residue capable of generating changes in the chemical properties of soils (Ferreira et al., 2012) because it is rich in calcium and magnesium (Mello, 1930). Chirenje and Ma (2002) reported that the solubility of carbonates in predominant ash follows the potassium sodium >> order >>> calcium > magnesium.

Park et al. (2012) used this waste (wood ash) as a nutrient for ryegrass (*Lolium perenne* L.) and oats (*Avena sativa*), and Pita (2009) applied wood ash on the dry matter production of maize (*Zea mays*). In these studies, the vegetal ash significantly increased the biomass production of these crops.

In this context, this study aimed to evaluate the concentrations of calcium, magnesium and sulphur in the shoots and roots of tropical grasses in 2 cultivars of *Brachiaria Brizantha* (Marandu and Xaraes) as a function of fertilizing Cerrado Oxisol soil with wood ash.

MATERIALS AND METHODS

The testing period of the experiment was from August to December, 2011 in a greenhouse (16°27'46" S; 54°34'49" W). The average temperature recorded during this period was 34°C. The soil was an Oxisol (Embrapa, 1999), which was collected in the 0.0 to 0.20 m layer in the Cerrado. The chemical characteristics of the soil at the beginning of the experiment were as follows: pH of $CaCl_2$ = 4.0, MO = 24.8 g dm^{-3}, P = 1.2 mg dm^{-3}, K = 40.0 mg dm^{-3}, Ca = 0.2 cmolc dm^{-3}, Mg = 0.1 cmolc dm^{-3}; Al = 1.3 cmolc dm^{-3}, V = 6.5%. The physical characteristics of soil were as follows: sand = 476 g kg^{-1}, clay = 441 g kg^{-1}, silt = 83 g kg^{-1}.

The wood ash used in the study was obtained from the boiler food industry, having the following characteristics: $CaCl_2$ pH = 10.90, N = 0.56%, P_2O_5 (Neutral Ammonium Citrate + Water) = 1.7%, K_2O = 2.72%, Zn = 0.01%, Cu = 0.01%, Mn (CNA + water) = 0.00, B = 0.02%, Ca = 2.7%, S = 1.49%.

The design of the experiment was completely randomized, consisting of a factorial of 6 × 2 (6 doses of wood ash: 0, 3, 6, 9, 12 and 15 g dm^{-3} and 2 tropical grasses of the genus *Brachiaria*, (Marandu and Xaraes cultivars) with 6 replicates. Each plot consisted of plastic pots with a capacity of 7 dm^3 of soil. The wood ash was incorporated into the soil and incubated for 30 days. Irrigation was performed using a gravimetric method, maintaining soil moisture at a maximum of 60% of its water holding capacity throughout the experimental period.

After the incubation period, the grasses were sowed at a depth of 2.5 cm and were planted using approximately 20 seeds per pot. When the plants reached 10 cm, they were thinned based on size, uniformity and arrangement within the vessels, resulting in five plants per pot.

All plots received nitrogen fertilization at a dose of 200 mg dm^{-3} using urea as the nitrogen source. This fertilization was repeated for every cut, in which the first fertilization occurred during the plant thinning, while the second and third occurred after each cut. During the first plant growth after thinning, fertilization was held with micronutrients boron, copper, zinc and molybdenum, with sources of boric acid, copper chloride, zinc chloride and sodium molybdate at doses of 1, 39, 2.61, 2.03 and 0.36 mg dm^{-3}, respectively (Bonfim-Silva et al., 2007).

Three cuts were made in the shoots at intervals of 30 days. The first cut was made 30 days after the emergence of forage grasses. The first and second cuttings of the shoots of the fodder was cut to 5 cm from the stem of each plant, while the third cutting was cut close to the stem of each plant.

After each cut, the plant material was collected to obtain a mass and were packed in paper bags to be properly identified and submitted for drying in a forced air oven at 65°C for 72 h until reaching a constant weight (Silva and Queiroz, 2002). The same procedure was repeated on the second and third sections of the plant.

For the third plant sections, the dry weight of each shoot was combined with the gathered plant roots. The roots were separated from the shoots by sieving (mesh sieve of 1.00 and 0.25 mm). The shoots and roots were placed in labelled, dry paper bags under glass using the same methodology of the shoot. After obtaining the mass of the dry material, the material was ground using the Wiley mill.

The concentrations of calcium, magnesium and potassium in the dry mass of the shoots and roots of tropical grasses were determined according to the methodology proposed by Malavolta et al. (1997).

The results were subjected to analysis of variance at 5% probability and significant when applied to regression test doses of wood ash and Tukey test for cultivars of *B.brizantha* using the statistical software Sisvar (Ferreira, 2008).

RESULTS AND DISCUSSION

The concentrations of calcium, magnesium and sulphur in the shoots Marandu and Xaraes were significant with interaction effect between tropical grasses and the dose of wood ash only to the calcium concentration. In the roots, an interaction between these factors occurred only regarding the calcium concentration, with isolated effect for the magnesium concentration and no significant effect was observed in the sulphur concentration (Table 1).

In the three sections of tropical grasses, the calcium concentrations in the shoots of Marandu and Xaraes were fitted to linear and quadratic regression models. In the first section, the highest concentration of calcium in the Marandu shoots was observed at the wood ash dose of 11.79 g dm^{-3}, with increments of 43.76 and 51.05% for Marandu and Xaraes, respectively, when treated with ash compared to plants with no application to this residue (Figure 1A).

In the second section, the calcium concentration was adjusted using a linear regression model. An increase of 42.54 % in the calcium concentration in the shoots of the tropical grasses was observed when comparing results observed from using the highest dose of wood ash of 15 g dm^{-3} to without treatment of wood ash residue (Figure 1B).

In the third section, an isolated effect for tropical grasses and a dose of wood ash was seen. The results were analyzed using a linear regression model. In the grass shoots, an increase of 69.44% in the calcium concentration was observed when compared with the

Table 1. Concentration of calcium, magnesium and sulphur in the shoots and roots of grasses Marandu and Xaraes a function of doses wood ash.

Nutrient	Source of variation			Cuts	Coefficient of variation (%)
	Grasses forage	Doses of wood ash	Interaction		
	0.2840^{ns}	0.0000***	0.0043*	1º	15.59
Calcium shoot	0.0011**	0.0001**	0.8109^{ns}	2º	28.04
	0.3053^{ns}	0.0000***	0.3716^{ns}	3º	15.31
Root	0.0000***	0.0000***	0.0000***	3º	21.49
	0.1324^{ns}	0.0008*	0.8691^{ns}	1º	18.76
Magnesium shoot	0.8525^{ns}	0.0014*	0.2154^{ns}	2º	18.38
	0.0000***	0.0000***	0.6199^{ns}	3º	15.73
Root	0.0001**	0.0000***	0.6598^{ns}	3º	15.15
	0.0815^{ns}	0.1313^{ns}	0.0713^{ns}	1º	6.83
Sulphur shoot	0.0000***	0.3727^{ns}	0.9083^{ns}	2º	7.06
	0.1818^{ns}	0.0095**	0.0980^{ns}	3º	5.95
Root	0.0644^{ns}	0.5822^{ns}	0.2754^{ns}	3º	4.14

ns, Not significant by F test at 0.05 probability. ***, ** and *; Significant at 0.1, 1 and 5% probability level by F test, respectively.

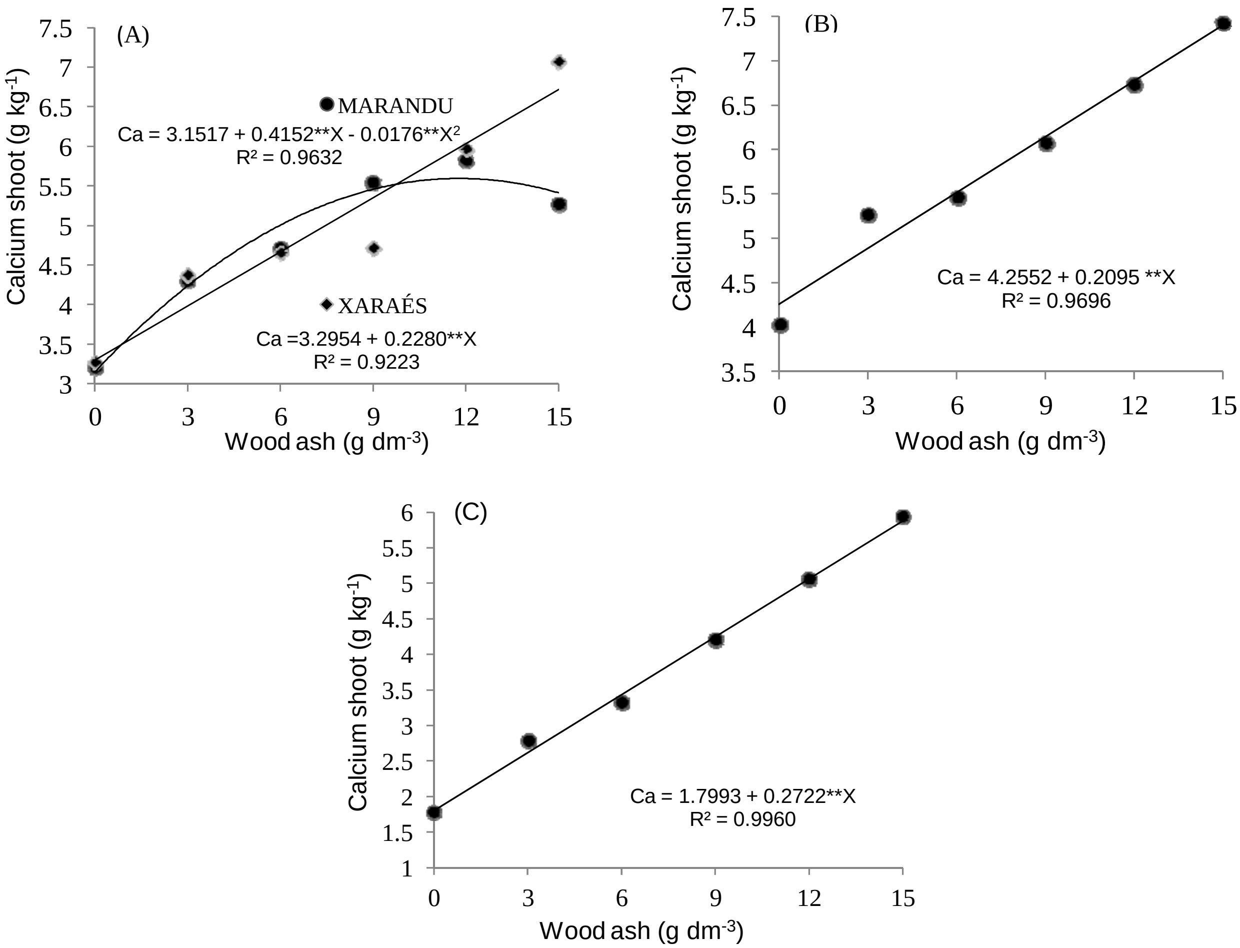

Figure 1. Concentration of calcium (Ca) in shoots of grasses Marandu and Xaraes a function of doses wood ash, on the first (A), second (B) and third (C) cuts. ***. ** and *: Significant at 0.1, 1 and 5% probability level, respectively.

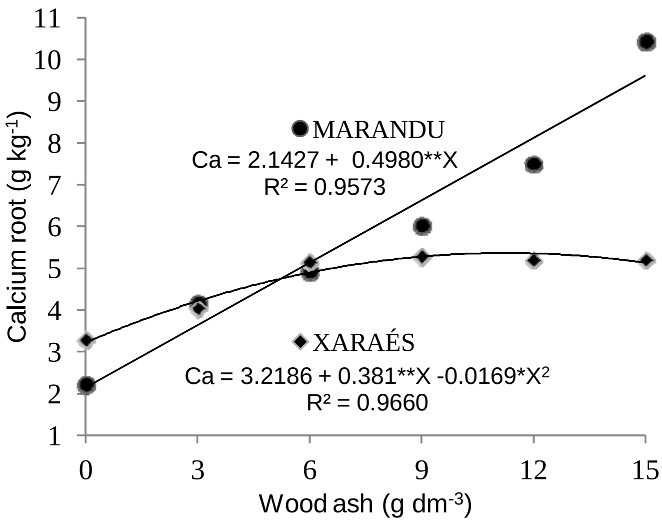

Figure 2. Concentration of calcium (Ca) in roots of grasses Marandu and Xaraes in function of the doses wood ash in third cut. ** and *: Significant at 1 and 5% probability level, respectively.

maximum dose of vegetal ash without fertilization of wood ash residue (Figure 1C).

In Gallo et al. (1974), normal concentrations of calcium in plants may vary from 2 to 4 g kg^{-1}. In *B. brizantha*, calcium concentration varies between 3 and 6 g kg^{-1} (Werner et al., 1996). Monteiro et al. (1995), who studied the Marandu grass with and without nutrients, found that calcium concentrations observed in the aerial part of the grass were 0.9 g kg^{-1} for the treatment without calcium and 8.5 g kg^{-1} for the complete treatment.

Souza Filho et al. (2000) evaluated Marandu's ability to absorb nutrients as a function of pH and observed calcium concentrations in shoots of 5.22 g kg^{-1}. In Xaraes grass, Costa et al. (2006) observed calcium concentrations of 4.82 and 4.27 g kg^{-1} at 30 and 60 days of growth, respectively.

In the present study, the calcium concentrations observed in shoots of Marandu and Xaraes were 5.88 and 7.40 g kg^{-1}, respectively, for both the second and third cuts. Thus, it is believed that fertilization with wood ash has increased the pH of the soil, providing nutrients and calcium assimilation for the plants, resulting in similar calcium concentrations as those found by Galo et al. (1974) and Werner et al. (1996) but returning higher concentrations than those reported by Costa et al. (2006) and Souza Filho et al. (2000).

At the roots of Marandu and Xaraes, there was a significant relation between tropical grasses and the dose of wood ash in regard to calcium concentration, as observed using linear and quadratic regression models. For Marandu, calcium concentrations increased by 77.73%; for Xaraes grass, the maximum concentration of calcium was observed at the dose of 11.27 g dm^{-3} for wood ash, increasing the concentration of calcium by 39.93% (Figure 2).

Monteiro et al. (1995), who subjected Marandu to treatments both with nutrients and without nutrients, observed calcium concentrations in the grass roots of 0.8 g kg^{-1} in treatments without calcium and 4.6 g kg^{-1} for the treatment with calcium.

In this study, the concentrations of calcium in the Marandu and Xaraes roots were 9.61 and 5.36 g kg^{-1}, respectively. While results show that the concentration of calcium supplied by fertilization exhibit no differences after treatment with wood ash for the aerial part of both the second and third cuts, the absorption of this nutrient is distinct in the roots of these grasses. Thus, the wood ash influences the calcium concentration in the roots of grasses Xaraes and Marandu, possibly contributing to the regulation of metabolism for these plants.

In plants, calcium is very important for the growth of meristematic tissues and proper functioning of the root apex; thus, indirect influences of this nutrient in crops may alter conditions for root growth. Calcium deficiency, an absence or disability of calcium, may lead to a decrease in the growth of roots, becoming darker and eventually dying (Dechen and Nachtigall, 2007).

In the present study, these symptoms of calcium deficiency were not observed because an adequate supply of calcium was provided by the plant fertilizer via the wood ash. Therefore, the concentration of calcium contained in the residue was satisfactory, noting that concentrations are above levels observed by Monteiro et al. (1995). The knowledge of these concentrations suggests that appropriate fertilizer management with wood ash allows for greater mass production of these crops.

For the magnesium concentration in the Marandu and Xaraes shoots, a significant isolated effect was observed between tropical grasses and the dose of wood ash based on linear and quadratic regression models. In the first cut of grass, the maximum concentration of magnesium in the shoots for both forages was observed at a dose of 11.23 g kg^{-1} at increments of 29.07%.

In the second section of the plants, the dose of wood ash of 7.72 g dm^{-3} provided the highest concentration of magnesium with an increase in the concentration of this nutrient in the grass shoots by 47.24% (Figure 3A and B). In the third section of the plants, the magnesium concentration in the Marandu and Xaraes shoots increased by 49.88% when comparing the treatment with the highest dose of wood ash (15 g dm^{-3}) with the treatment without the application with the wood ash residue. For the third section, the magnesium concentration in the grass shoots responded linearly with the dose of wood ash, ranging between 1.09 and 2.23 g kg^{-1} (Figure 3C).

In the present study, the magnesium concentration in the shoots of tropical grasses was 1.06 and 3.10 g kg^{-1} for the first and second cuts, respectively. Monteiro et al. (1995) observed a magnesium concentration of 4.9 g kg^{-1} in Marandu. Batista and Monteiro (2010), who evaluated

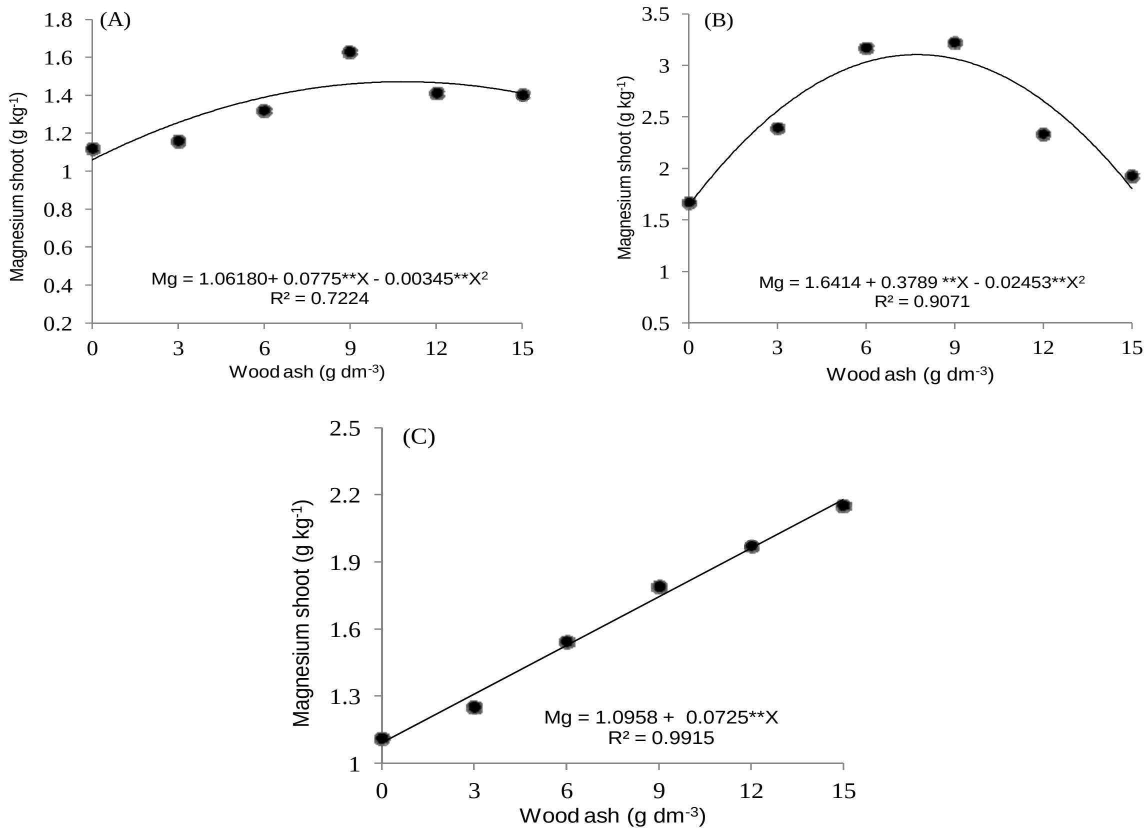

Figure 3. Concentration of magnesium (Mg) in shoots of grasses Marandu and Xaraes a function of doses wood ash, on the first (A), second (B) and third (C) cuts. ***. ** and *: Significant at 1% probability.

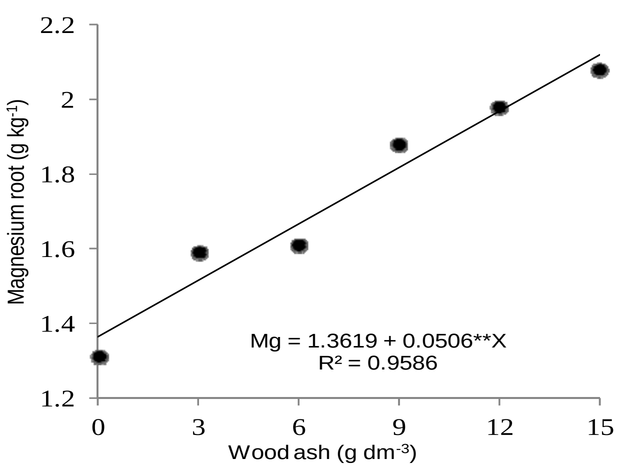

Figure 4. Concentration of magnesium (Mg) in roots of grasses Marandu and Xaraes in function of the doses wood.

concentrations of potassium, calcium and magnesium in Marandu grass that had been fertilized with nitrogen and sulphur, found magnesium concentrations in the leaves of the grasses to be 8.40 and 3.52 g kg^{-1} for the first and second harvests, respectively.

Costa et al. (2007) observed magnesium concentrations in shoots of Xaraes grass of 3.10 and 3.22 g kg^{-1} at 30 and 60 days of growth, respectively. Costa et al. (2010) found that Marandu grass exposed to rates and sources of nitrogen for a period of 3 years had a magnesium concentration of 2.83 g kg^{-1} at the highest nitrogen dose of 300 kg ha^{-1} year^{-1}.

The optimal magnesium concentrations for *B. brizantha* Marandu are between 1.5 and 4.0 g kg^{-1} (Werner et al., 1997). In this study, the concentration of magnesium in shoots of tropical grasses meets the range considered to be ideal by these authors.

For the magnesium concentration in the roots of grasses Marandu and Xaraes, a significant isolated effect between the tropical grasses and the dose of wood ash was observed using a linear regression model. Considering the experimental range, the magnesium concentration in the roots of tropical grasses ranged from 1.36 to 2.12 g kg^{-1}, resulting in an increase of 35.89% magnesium concentration in the roots of these grasses (Figure 4).

In studies of mineral nutrition, the required magnesium concentrations in the roots of Marandu grass were of 3.5 g kg^{-1} (Monteiro et al., 1995). For Van Raij (1991), the

Table 2. Sulphur (g kg^{-1}) in the shoot of the grasses Marandu and Xaraes, in second cut.

Cut	Sulphur (g kg^{-1})	
	Marandu	Xaraes
Second cut	0.87^b	0.94^a
CV%	7.06	

Means followed by lower case online differ by Tukey test at 5% probability. CV% = coefficient of variation.

requirements of magnesium by crops are relatively modest. Thereby the sulphur and magnesium in plant leaves generally varies between species, for which the magnesium concentration may range from 0.2 to 0.4%.

For the sulphur concentration in Marandu and Xaraes shoots and roots, there was no interactions effect in the levels of wood ash; significant differences only were observed with isolated effect for the tropical grasses in the second cut (Table 2). The mean magnesium concentrations observed in the shoots Marandu and Xaraes were 0.91 and 0.94 g kg^{-1}, respectively, for the first cut and were 0.91 and 0.93 g kg^{-1}, respectively, for the third section. At the root, the concentration of sulphur was 0.94 g kg^{-1} for Marandu and 0.95 g kg^{-1} for Xaraes.

The concentrations of sulphur deemed appropriate for *B. brizantha* Marandu grass are between 1.5 and 3.0 g kg^{-1}. Thus, in this study the concentration of sulphur in the Marandu and Xaraes shoots for three cuts were lower than the values referenced by previous authors.

In general, many organic sulphur compounds in parts of plants have vegetable proteins containing sulphur and nitrogen, and these nutrients are related in a range of proportions, indicating a proper nutrition for each culture.

Generally, the N:S ratio can range from 13:1 to 14:1. In the present study, the dose of nitrogen (urea) of 200 mg dm^{-3} increased by 0.56% from using wood ash and the sulphur content provided by manure with wood ash increased by 1.49% (not considering the organic matter ground), which may indicate that the nitrogen and sulphur contents are below the relative proportion observed by Werner and Monteiro (1988). This low ratio may be explained by the concentration of sulphur being outside of the range considered adequate for these crops.

Cultures generally rely proportionally on more sulphur in soil, with an ideal of 5% organic matter in the soil, that is, 50 g dm^{-3}, and these levels in tropical soils are generally low.

Conclusions

The concentrations of calcium and magnesium in the tropical grasses Marandu and Xaraes were measured in relation to the levels of wood ash. Marandu and Xaraes were planted in Cerrado Oxisol soil and the levels were consistent with concentrations considered suitable for these grasses.

To obtain an adequate concentration of sulphur in tropical grasses, the use of wood ash as a source of fertilizer requires more research but can act as a supplement when combined with mineral fertilizer.

Wood ash as a fertilizer promotes significant changes in the nutritional characteristics of the grasses Marandu and Xaraes when planted in Cerrado Oxisol.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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