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Concentration of nitrogen, phosphorus and potassium in tropical grasses fertilised with wood ash in cerrado oxisol

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Nitrogen, phosphorus and potassium are nutrients that are directly involved in the entire life cycle of plants. Wood ash is solid with high or low concentrations of phosphorus and potassium depending on the material of vegetable origin. The objective of the present study was to evaluate the concentrations of nitrogen, phosphorus and potassium in tropical grasses in 2 cultivars of *Brachiaria brizantha* resulting from differing doses of wood ash. Completely randomised design in a 6x2 factorial with 6 doses of vegetable ash (0; 3; 6, 9; 12 and 15 g dm^{-3}) and 2 cultivars of *B. brizantha* (Marandu and Xaraes) with 6 replications. In the first cut, the nitrogen concentration in the shoots of Marandu grass increased by 65.13%, and the potassium concentration increased by 36.12 and 42.37% in the Marandu and Xaraes grasses, respectively. In the third section, the phosphorus concentration in the shoots of both grasses increased 38.78%. In the roots of the Marandu and Xaraes grasses, the concentrations of phosphorus and potassium increase by 25.17 and 35.93%, respectively. The wood ash as fertiliser improves the concentrations of nitrogen, phosphorus and potassium in the shoots and roots of the tropical grasses Marandu and Xaraes.

Key words: *Brachiaria Brizantha*, fertiliser alternative, solid waste.

INTRODUCTION

The use of solid waste such as the ash plant in agriculture has enabled an alternative form of fertilisation and a way to replace nutrients in the soil, consequently affecting the crop. This residue contains varying concentrations of minerals (Mello, 1930) and, once in the soil, works as a corrective fertiliser (Ferreira et al., 2012), improving the soil fertility.

Soils under Cerrado have a naturally low fertility, and in this case, it may be feasible to use wood ash as a fertiliser. The ash improves the soil characteristics and can provide better crop growth as it meets the recommendations for crop need, fertiliser dose and soil class.

These aspects that relate to alternative forms of fertiliser are relevant for sustainable development, which aims to increase agricultural production and improve the

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nutritional quality of plants while offering another option to dispose of by products that are produced in large quantities.

Wood ash usually presents a relatively low percentage of nitrogen, as this element is lost by combustion (Rigau, 1960). In contrast, this residue generally contains moderate amounts of phosphorus (Osaki and Darolt, 1991) and high concentrations of potassium (Zimmermann and Frey, 2002; Feitosa et al., 2009).

In this context, to increase the productivity of pastures, it is essential to adopt a management system that meets the needs of the grass and that, if well-managed, will result in good production rates. One of the ways to increase crop productivity is by providing an adequate supply and replenishment of nutrients to the soil, allowing for the good production of forage with nutritional quality.

Thus, nitrogen is the main nutrient for the maintenance of the yield of forage grasses and for the formation of essential proteins, chloroplasts and other compounds that actively participate in the synthesis of organic compounds. Phosphorus is the nutrient most often cited as the main cause of the low productivity of pastures on acidic soils of low fertility and is considered the most important nutrient for cattle pastures.

However, as grasses require significant amounts of potassium, fertilisation is necessary so as not to limit the response to nitrogen. Thus, the objective of the present study was to evaluate the concentrations of nitrogen, phosphorus and potassium in the shoots and roots of the Marandu and Xaraes grasses in response to varying doses of wood ash.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse from August to December 2011. The average temperature during the experimental period was 34°C. The soil was an Oxisol that was collected in the 0 to 0.2 m layer in an area under Cerrado vegetation.

The chemical characteristics of the soil were as follows: pH in $CaCl_2$ = 4.0, MO = 24.8 g dm^{-3}, P-resin = 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} and V = 6.5%. The particle size characteristics of the soil were as follows: sand = 476 g kg^{-1}, clay = 441 g kg^{-1} and silt = 83 g kg^{-1}.

The wood ash that was used was from the boiler food industry, and its bioenergy were as follows: pH in $CaCl_2$ = 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% and S = 1.49%.

The experimental design was completely randomised in a 6x2 factorial design with 6 doses of vegetal ash (0; 3; 6; 9; 12 and 15 g dm^{-3}) and 2 cultivars of *Brachiaria brizantha*, Marandu and Xaraes, with 6 replications. Each plot consisted of plastic pots with a 7-dm^3 soil capacity. The ash was incorporated into the plant soil and incubated for 30 days. Liming was not performed.

Irrigation was performed via the gravimetric method, and throughout the experimental period, the soil moisture was maintained at 60% of the maximum capacity of water retention. After the incubation, the grasses were sown at an approximate depth of 2.5 cm with 20 seeds per pot, and when the plants were 10 cm high, thinning was performed based on the criteria of size, uniformity and homogeneity, leaving five plants per pot.

All of the plots received nitrogen fertiliser equivalent to 200 mg dm^{-3} using urea as a nitrogen source. This fertilisation was repeated with each cut and was performed during the first thinning of the plants 14 days after sowing and the second and third after each cut.

In the first growth of the plants after thinning, the soil was fertilised with the micronutrients boron, copper, zinc and molybdenum, whose sources were boric acid, copper chloride, zinc chloride and sodium molybdate in doses of 1.39, 2.61, 2.03 and 0.36 mg dm^{-3}, respectively.

Three cuts were made in the shoots of the grasses at intervals of 30 days. The first cut was made 30 days after plant emergence. The shoots were cut 5 cm from the stem of each plant for the first and second cuts, and near the lap of the plant in the third cut.

After each cut, the plant material was harvested, packed in paper bags, properly identified and subjected to oven drying by forced air circulation at 65°C for 72 h until a constant mass (Silva and Queiroz, 2002), after which it was weighed to determine the dry weight. The same procedure was repeated for the second and third cuts.

In the third grass cutting, the shoot mass was also retained to collect the plant roots. The roots were separated from the shoots and washed in water under a set of sieves of 1.00 and 0.25 mm to remove the earth. The shoots and roots were placed in paper bags, labelled, weighed and dried in an oven using the same methodology as that of the shoot. The concentrations of nitrogen, phosphorus and potassium in the shoots and roots of grasses were determined according to the methodology proposed by Malavolta et al. (1997). The variables were the concentrations of nitrogen, phosphorus and potassium in the shoots and roots of the Marandu and Xaraes grasses.

The results were subjected to an analysis of variance at a 5% probability, and a regression test for quantitative variables (dose wood ash) and Tukey's test for qualitative variables (*B. brizantha*) were applied through the statistical application Sisvar (Ferreira, 2008).

RESULTS AND DISCUSSION

The concentrations of nitrogen, phosphorus and potassium in the shoots and roots of the Marandu and Xaraes grasses were significant. In the shoots, there was an interaction effect between the grasses and wood ash doses regarding the concentrations of nitrogen and potassium. In the roots, an interaction between these factors occurred only regarding the nitrogen concentration (Table 1).

In the three sections of the plants, the nitrogen concentrations in the shoots were adjusted to model linear and quadratic regressions. In the first cut of grasses, the nitrogen concentration in the shoots of Xaraes increased by 65.13% when treated with 15 g dm^{-3} ash compared to plants with no application to this residue (Figure 1A). For the Marandu grass, the results were not reported by any regression model.

In the second cut, the nitrogen concentrations in shoots were adjusted to model a linear regression (Figure 1B); this concentration was adjusted to model linear and quadratic regressions in the third cut. In the second and third cuts, the concentration of nitrogen the shoots of Marandu and Xaraes decreased (Figure 1C).

The concentration of nitrogen in the first cut of the plants increased in Xaraes from 8.29 to 23.77 g kg^{-1}

Table 1. Concentration of nitrogen, phosphorus and potassium in the shoots and roots of grasses Marandu and Xaraes a function of doses wood ash.

Nutrient	Source of variation			Cuts	Coefficient of variation (%)
	Grass forage	Doses of wood ash	Interaction		
Nitrogen shoot	0.0000***	0.0000***	0.0000***	1º	15.56
	0.3707^{ns}	0.0000***	0.0004**	2º	15.50
	0.2723^{ns}	0.0000***	0.0742 ^{ns}	3º	15.85
Root	0.0000***	0.0000***	0.0004**	3º	17.72
Phosphorus shoot	0.0013**	0.4537^{ns}	0.5819^{ns}	1º	32.46
	0.0000***	0.0769^{ns}	0.1583^{ns}	2º	33.01
	0.0000***	0.0000***	0.1000^{ns}	3º	24.41
Root	0.0698^{ns}	0.0009**	0.1023^{ns}	3º	17.73
Potassium shoot	0.6446^{ns}	0.0000***	0.0195*	1º	10.82
	0.6881^{ns}	0.0004**	0.9925^{ns}	2º	9.95
	0.0925^{ns}	0.0011*	0.8488^{ns}	3º	11.54
Root	0.3516^{ns}	0.0000***	0.2923^{ns}	3º	4.14

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

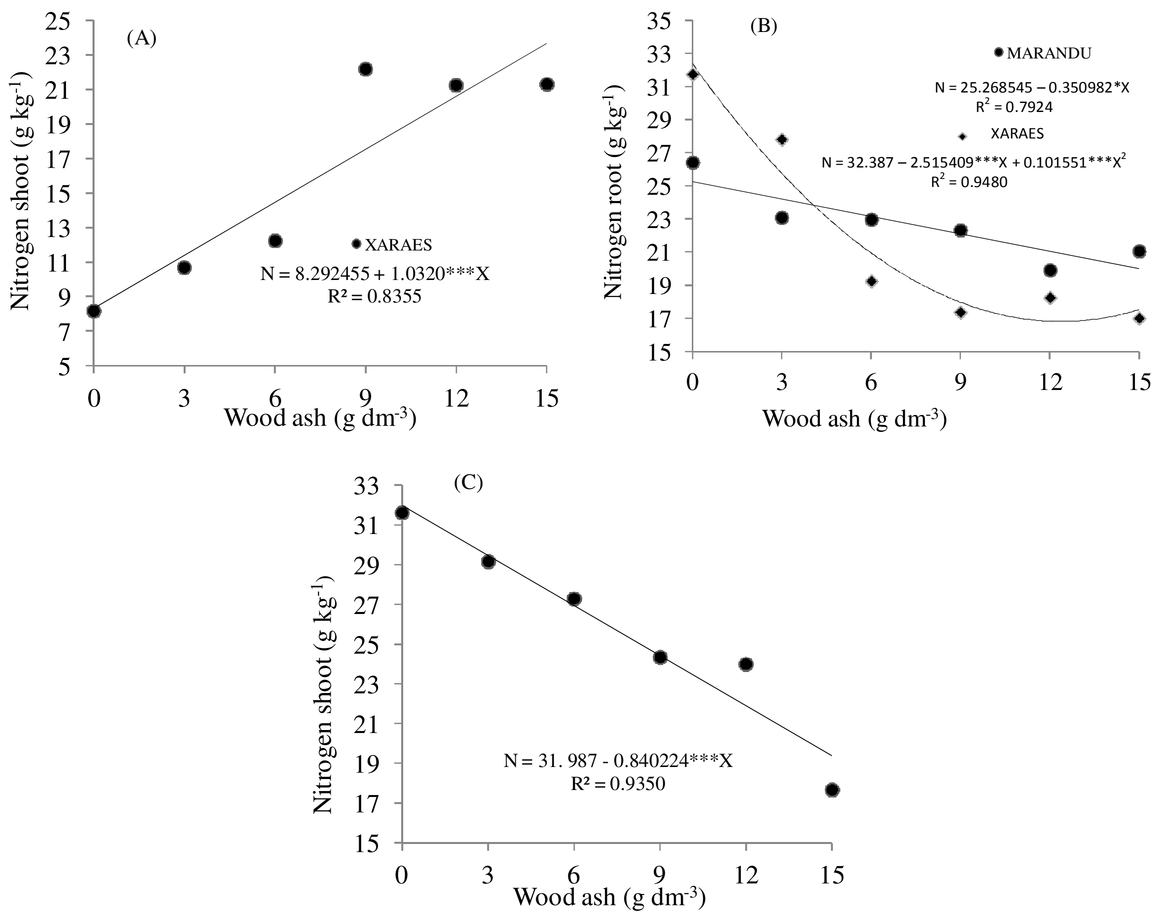

Figure 1. Nitrogen concentration in shoots of grasses marandu and xaraes a function of doses wood ash on the first (A), second (B) and third (C) cuts. ***. **. * Significant at 0.1, 1 and 5% probability level, respectively.

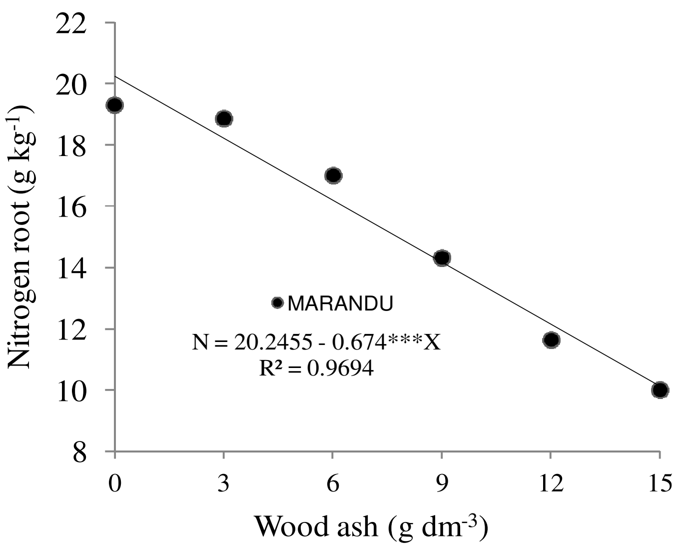

Figure 2. Concentration of nitrogen in root Marandugrass in function of the doses wood ash in third cut. *** Significant at 0.1% probability.

depending on the doses of wood ash up to 15 g dm^{-3}. Thus, as all of the plots were fertilised with 200 mg dm^{-3} nitrogen, the fertilisation with the wood ash contributed to the uptake of nitrogen by this forage.

Costa et al. (2009) observed in the shoots of Marandu grass a nitrogen concentration of 16.18 g kg^{-1} at a dose of 200 kg ha^{-1} $year^{-1}$. Oliveira et al. (2005) and Cesar et al. (2006) found foliar nitrogen concentrations of 19.50 and 19.80 g kg^{-1}, respectively, for the Marandu and Xaraes grasses at nitrogen levels of 210 and 200 kg ha^{-1}.

In the experimental interval of the doses of vegetable ash in this study, a 3 to 15 g dm^{-3} concentration of nitrogen at a dose of 9 g dm^{-3} corresponds to 17.58 g kg^{-1}. Thus, it appears that, on average, fertilisation of the Marandu and Xaraes grasses with vegetal ash helped the plants to absorb nitrogen in amounts similar to those observed by Costa et al. (2009), Oliveira et al. (2005) and Cesar et al. (2006), who used mineral fertiliser.

In the second cut of grasses, the nitrogen concentration decreased from 25.27 to 20 g kg^{-1} depending on the dose of wood ash. In the third cut, the nitrogen concentration in the Marandu and Xaraes grasses decreased from 31.99 to 19.38 g kg^{-1}. The concentration of nitrogen in the leaves of the Marandu grass is between 13 and 20 g kg^{-1} (Werner et al., 1997); therefore, nitrogen concentrations in shoots of the three cuts of grasses were within the range proposed by this author.

The nitrogen concentrations of roots of the Marandu grass were adjusted to a linear regression model. There was a decrease of 99.70% nitrogen in the roots of this grass when comparing the dose of 15 g dm^{-3} wood ash treatment with no application of this residue. For the corresponding Xaraes grass, there was no adjustment to a regression model (Figure 2).

In the roots of the Marandu and Xaraes grasses, the concentration of nitrogen decreased from 20.24 to 10.13 g kg^{-1}. Bonfim-Silva and Monteiro (2010), studying combinations of nitrogen and sulphur in the roots of signal grass, observed as a result of a nitrogen dose of 275 mg dm^{-3} in isolated effect, a concentration of 8.42 g kg^{-1} the roots of this grass. In the present study, the wood ash promoted significant changes in the nitrogen concentration in the roots of the Marandu grass, indicating the need for studies of the influence of this residue on the mineral nutrition of this grass.

The concentration of phosphorus in the shoots of the Marandu and Xaraes grasses had an isolated effect. The phosphorus concentration in the shoots increased significantly in all of the cuts and was significant in the Marandu grass, thus evidencing the distinct nutritional needs of *B. brizantha* in the absorption and assimilation of phosphorus (Table 2).

The phosphorus concentration in the shoots of the Marandu grass indicated by Werner et al. (1997) is between 0.8 and 3.0 g kg^{-1}. Malavolta et al. (1997) reported that the required phosphorus for plant varies from 1 to 5 g kg^{-1}. The phosphorus concentration observed in the present study in the first cut of the plants (Table 2) is below the range described by these authors.

The lower concentration of phosphorus in the first cut of grasses when compared to the other cuts may be due to the application of this nutrient for forage for the formation of the root system, resulting in lower concentrations in the shoots in the first cut. Thus, the phosphorus concentration in third cut is within the range considered adequate for forage.

When the phosphorus concentration of the Marandu and Xaraes grasses was adjusted to the linear regression model, 38.78% of this increase occurred in both nutrient forages when comparing the 15 g dm^{-3} treatment with no application of wood ash (Figure 3).

For the phosphorus concentration in the roots of the Marandu and Xaraes grasses, the effect of the wood ash dose on the grasses was significant when adjusted to a quadratic regression model with a maximum wood ash concentration of 12 g dm^{-3}. The concentration of phosphorus increased by 25.17% in the roots of these grasses when comparing the 15 g dm^{-3} dose with treatment without this residue (Figure 4).

The potassium concentration in the shoots of the Marandu and Xaraes grasses significantly interacted with the grasses and wood ash doses in the first cut. The potassium concentration in the shoot was adjusted to a quadratic model of regression. In the first cut, the maximum concentration of potassium in the shoots of the Marandu grass was observed at a dose of wood ash of 11.93 g dm^{-3}, with increases in the potassium concentration as a function of the doses of wood ash of 36.12 and 42.70%, respectively, for the Marandu and Xaraes grasses (Figure 5A).

In the second and third cuts, the potassium concentration in the shoots was adjusted to a linear

Table 2. Phosphorus (gkg^{-1}) in the shoot of the grasses Marandu and Xaraes in first, second and third cuts.

Phosphorus shoot (gkg^{-1})			
Cuts	**Marandu**	**Xaraes**	**CV%**
First cut	0.40^a	0.26^b	32.46
Second cut	1.37^a	0.93^b	33.61
Third cut	1.92^a	1.27^b	24.41

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

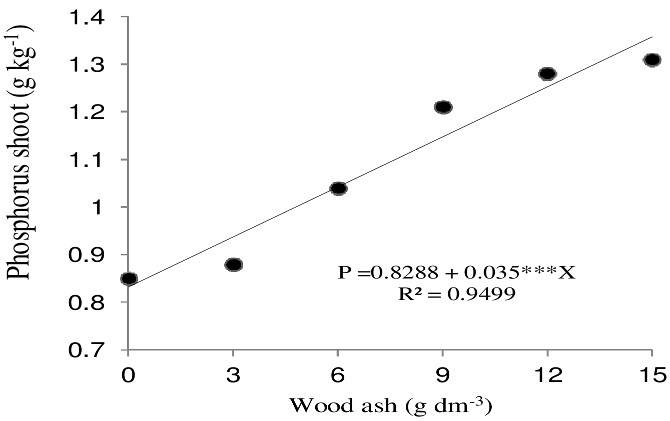

Figure 3. Concentration of phosphorus in shoots of grasses Marandu and Xaraes on third cut, in function of the doses of wood ash. *** Significant at 1% probability.

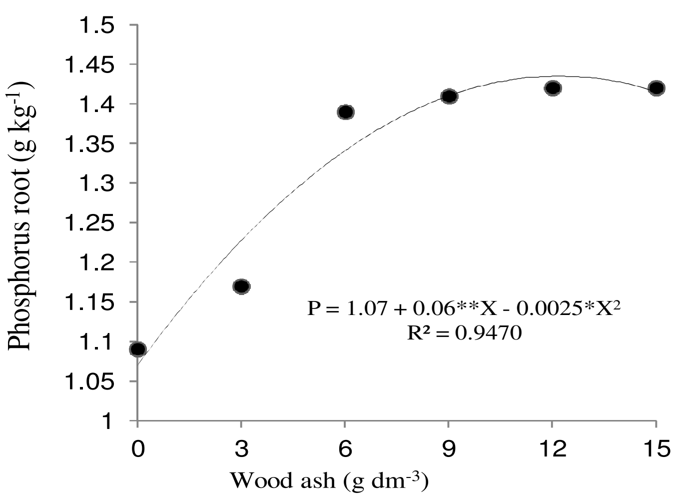

Figure 4. Concentration of phosphorus in roots of grasses Marandu and Xaraes on function of the doses wood ash, in the third cut. **, * Significant at 1 and 5% probability level, respectively.

regression model. There was a reduction of 17.99% potassium in the shoots of the grasses (Figure 5B). In the third cut, the potassium concentration in the shoots of the Marandu and Xaraes grasses increased from 9.48 to 11.46 g kg^{-1}, an increase of 17.28%, when comparing the highest dose of wood ash, 15 g dm^{-3}, and treatment without fertilisation (Figure 5C).

In the first cut of the Xaraes grass, the potassium concentration was between 17.47 and 30.32 g kg^{-1} by comparing the maximum dose of wood ash and treatment without application with this residue. In the second cut, there was a reduction of potassium of 13.38 to 11.34 g kg^{-1} in both forages; however, in the third cut, this nutrient increased in the shoots as a function of the dose of wood ash (Figure 5C).

Mattos and Monteiro (1998), under the controlled cultivation of the *B. brizantha* Marandu grass, observed in a nutrient solution of the leaves of this grass decreases in the potassium concentration from 20 to 10% and from 26 to 9%, respectively, in the first and second cuts of forage.

For Werner et al. (1997), the potassium concentrations considered adequate for Marandu grass sheets ranged from 12 to 30 g kg^{-1}. Ferrari Neto (1991) specifies as suitable potassium concentrations of 11 g kg^{-1} in all aerial parts of *B. brizantha*. Thus, the potassium concentrations in the shoots of Marandu grass in the three cuts in this study are in agreement with the value proposed by Ferrari Neto (1991).

The potassium concentration in the roots of grasses was significant only when adjusted to the quadratic regression model, and greater concentrations were observed at a dose of wood ash of 13.58 g dm^{-3}. Increments of 35.93% provided the highest concentration of potassium in the shoots of grasses treated without fertilisation with this residue (Figure 6).

A potassium concentration of 25 g kg^{-1} in the roots of the Marandu grass at a dose of potassium in mineral fertiliser of 234 mg L^{-1} was observed by Monteiro et al. (1995). In the present study, the concentration of potassium in the roots of grasses is 29.17 g kg^{-1}; this result can be attributed to considerable amounts (compared to other nutrients) of potassium in the constitution of the wood ash used in this study.

Conclusions

The concentrations of nitrogen, phosphorus and

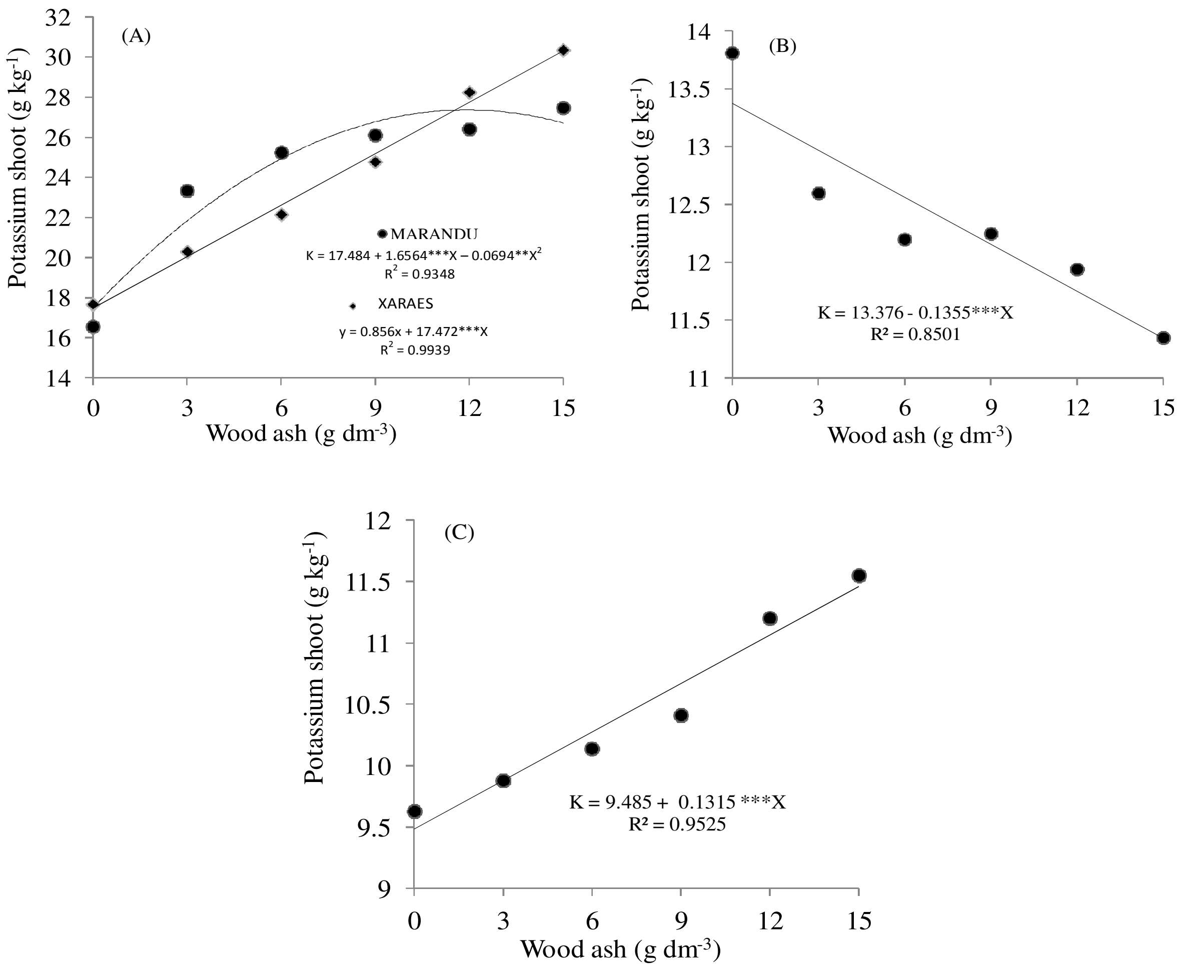

Figure 5. Concentration of potassium in the shoots of grasses marandu and xaraes on function of the doses the wood ash, in the first, second and third cut. *** Significant at 0.1 and 1% probability.

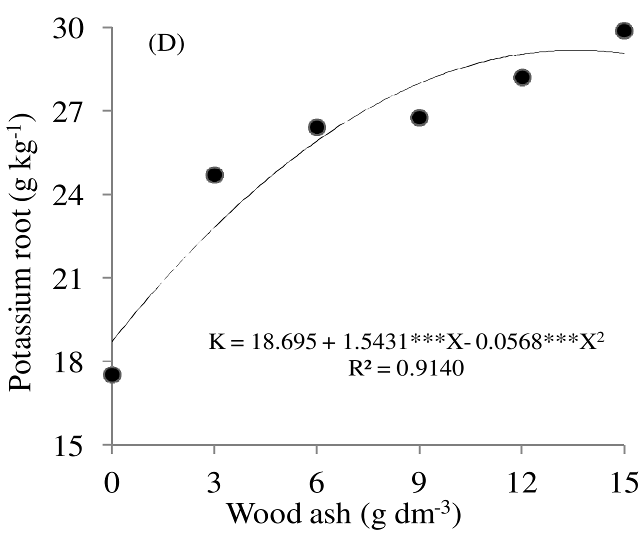

Figure 6. Concentration of potassium in the roots of grasses Marandu and Xaraes on function of the doses the wood ash, in the third cut. *** Significant at 0.1 % probability level, respectively.

potassium in the shoots of the tropical Marandu and Xaraes grasses as a function of the dose the wood ash are in accordance with the concentration ranges considered appropriate for the grasses studied.

The wood ash as fertiliser promotes significant changes in the nutritional characteristics of the tropical Marandu and Xaraes grasses, increasing the concentrations of nitrogen, phosphorus and potassium in forage grasses.

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