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Concentration of macronutrients in degraded tropical pasture in recovery rainy periods using wood

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Abstract

The objective of this study was to evaluate the average concentration of macronutrients in the rainy periods in *Urochloa brizantha* pasture fertilized with doses of wood ash associated with application management. Experiment was carried out in the field condition in two years at a degraded pasture in the Brazilian Cerrado (Tropical savanna). Experimental design was a 6x2 factorial scheme, corresponding to six doses of plant ash (0, 3, 6, 9, 12 and 15 t ha^{-1}) associated with two treatments of wood ash: light application and superficial grade (without incorporation) with four replicates. The wood ash was derived from the industrial boiler combustion of plant materials. Average concentration of the macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) were measured in plants. The analyzes of Marandu grass during the rainy season was evaluated from each evaluation year. The mean nutrient concentrations per year were calculated after the nutritional evaluation of four pasture cuttings. It was verified that the wood ash improves the nutritional quality of the recovering pasture. the wood ash doses between 9 and 12 t ha^{-1} presented greater nutrient concentration in plants. The incorporation of the wood ash in the soil assisted to better nutrient availability to the Marandu grass. The nutritive value of pasture depends on the applied ash quality as an alternative fertilizer.

Keywords: pasture recovery, residue in agriculture, *Urochloa brizantha*.
Abbreviations: pH_Hydrogen Potential; P_Phosphorus; K_Potassium; Ca_ Calcium; Mg_Magnesium; H_Hydrogen; RTNP_Relative total neutralizing power SB_Sum of Bases; CEC_Cation exchange capacity; V_ Bases saturatio; O.M _Organic matter; Zn: zinc; Cu_copper; Fe_ airon; Mn_Manganese; B_Boron; S_Sulfur; CV_coefficient of variation; wood ash_ wood ash incorporated into the soil; NI_wood ash superficial (without incorporation).

Introduction

Degraded pasture is the evolutionary process of losing vigor, productivity and the natural recovery capacity of a pasture. It makes it incapable of sustaining the production and quality levels required by the animals, as well as overcoming the harmful effects of pests, diseases, and invasives (Macedo, 1999). In Brazil, only 40% of the pastures are considered economically viable (Brazil-CNPC, 2014). This is because Brazilian pastures are conducted without proper replenishment of necessary nutrients in the soil.
The soil fertility will contribute to forage productivity and quality (Bonfim-Silva and Monteiro, 2006). In the meantime, soil nutrient replacement is important for increasing pasture productivity for cattle grazing (Dias-Filho, 2014). Thus, application of new sources of fertilizers and the efficiency of new management techniques for their application is necessary for cattle grazing. In this perspective, plant ash can be applied as alternative fertilizer because it contains considerable amounts of the major nutrients required for plant growth, such as calcium, magnesium and potassium (Etiégni and Campbell, 1991; Saarsalmi et al., 2001; Santos et al., 2014; Bonfim-Silva et al., 2015; Iqbal and Lewandowski, 2016), low nitrogen (Saarsalmi et al., 2001) and phosphorus (Hakkila and Halaja, 1983; Santos et al., 2014).
As soil corrective and alternative or even complementary fertilizer, plant ash is widely studied (Adriano et al., 1980; Vance, 1996; Demeyer et al., 2001; Füzesi et al., 2015; Bezerra et al., 2016; Pereira et al., 2016) and are still scarce in relation to tropical grasses. The use of this biomass for the production of thermal energy, producing wood ash, commonly used in industries, is growing worldwide due to the need to use renewable energy sources in response to concerns about climate change (McKendrey, 2002), higher oil prices and the need for energy security of the countries (EU, 2009, Titus et al., 2010).
The use of wood ash becomes a low-cost alternative for crop fertilization (Bonfim-Silva et al., 2011) and ecologically correct, due to the use of the residue, but still less studied as a source of macronutrients in area fertilization of degraded pastures (Espirito Santo et al., 2018). The macronutrients

provided by the wood ash can influence the nutritional quality of the pasture.

In this context, the objective of this study was to evaluate the average macronutrients concentration during the rainy season in the Marandu Grass (*Urochloa brizantha*) pasture fertilized with wood ash doses associated with the application of the soil through soil grazing.

Results and Discussion

Nitrogen in the plant

The average nitrogen concentration in the Marandu grass during the first year of using application of wood ash and its management in the pasture presented significant difference only for recovery management (Table 1), but in the second year, a significant difference was observed presenting a nitrogen average of 25.29 g kg^{-1}.

The incorporation of the wood ash to the soil, in the first year, gave the highest average nitrogen concentration in the leaves. This was probably due to soil uptake to provide greater mineralization of organic matter in the soil (Six et al., 2000) and consequently nitrogen release to the plants. In addition, Allison (1961) described that soil tillage increases the water infiltration rate, decreases nitrogen loss by volatilization, which may favor nitrogen utilization by plants.

However, both forms of the application provided pasture with sufficient amount of nitrogen for its development. The concentration of 17.0 g kg^{-1} of nitrogen in the Marandu grass is considered sufficient for the good nutritional stage associated with a good development of the plant (Malavolta et al., 1997).

Marandu grass cultivated in dystrophic Red Latosol, fertilized with nitrogen at the dose of 200 kg ha^{-1} cut^{-1} urea source, verified that the plant had a nitrogen concentration of 24.0 g kg^{-1} (Primavesi et al., 2006). This value is close to that verified in the present study, which applied only nitrogen fertilization of 100 kg ha^{-1} $year^{-1}$, but the fertilization with wood ash contributed to increase the availability and efficiency of nitrogen absorption by the forage grass, providing savings in mineral fertilization nitrogen.

Eguchi et al. (2017) evaluated doses of chicken manure and scarification and non-scarification of the soil after the application of this fertilizer in pasture and found that the soil scarification kept the concentration of nitrogen in the Marandu grass constant even with an increased dose of manure.

Phosphorus in the plant

The average concentration of phosphorus in the Marandu grass in the first year of the evaluation was influenced by the interaction of the wood ash oses and the wood ash treatments in the pasture (Fig 1 and Table 2). In order to evaluate the effect of the wood ash doses on the treatments (Fig 1), the ash incorporation had the highest average concentration of phosphorus (1.30 g kg^{-1}) in the wood ash dose of 10.57 t ha^{-1} (Fig 1A), when compared to the surface ash application (Fig 1B).

The wood ash application management also presented the highest average concentration of phosphorus in the plant, with a statistical difference, when the application management was evaluated as function of the wood ash doses (Table 2).

In the second year of Marandu grass evaluation, the average phosphorus concentration in the plants was significant for plant ash doses and isolated application treatments. The wood ash dose of 9.85 t ha^{-1} provided the highest phosphorus concentration of 0.64 g kg^{-1} in the Marandu grass (Fig 2) and the management of the wood ash incorporated with the soil, has given a higher average phosphorus concentration (0.59 g kg^{-1}), when compared to surface application (Table 3).

However Megda and Monteiro (2010) pointed out that the value of 1.2 g kg^{-1} of phosphorus in the leaves of *U. brizantha* cv. Marandu is at the critical level for the plant development. Thus, plant ash doses above 9 t ha^{-1} were able to present this value in the plant in the first year of evaluation. In the second year, the phosphorus extraction by the plants did not reach adequate levels, possibly due to the low amount of available phosphorus in the applied ash approximately 3.10 g kg^{-1} of P_2O_5 (Table 10). Bonfim-Silva et al. (2003) reported that the critical level of phosphorus in the soil is 2.07 to 62.31 mg dm^{-3}, after two cuts of *U. brizantha*, quantified in six types of soils and six phosphorus doses.

In acid soils, phosphorus has high adsorption and precipitation with iron and aluminum oxides. So, this is one of the most difficult nutrients to be made available to plants (Whitehead, 2000). Thus, maintaining adequate levels of phosphorus in the soil for the plants is important, especially in the early stage of forage, where there is intense meristematic activity, due to root development, tillering and stolons emission (Cantarutti et al., 2002).

The importance of increasing the phosphorus availability by fertilization with wood ash added as an alternative fertilizer in the recovering pasture can provide higher phosphorus concentrations in the Marandu grass and improves the nutritional quality of the forage grass.

Potassium in the plant

The average potassium concentration in the recovering pasture in the first year was influenced by the interaction of the plant ash doses and the ash application to the soil (Fig 3 and Table 4). In order to evaluate the plant ash management, the incorporation of the ash in the soil presented the highest potassium concentration of 38.43 g kg^{-1} in the dose of 11.13 t ha^{-1} (Fig 3A). The wood ash dose of 13.53 t ha^{-1} presented the highest potassium concentration of 36.53 g kg^{-1}, when the ash application management on the surface was observed in the leaves of the Marandu grass (Fig 3B). Thus, the incorporation of the wood ash provided a higher potassium concentration in the plant with a lower amount of wood ash applied.

Only the wood ash dose of 9 t ha^{-1} presented statistical difference in K concentration, whereas the incorporation of the wood ash to the soil demonstrated the greater potassium concentrations in the plant (Table 4).

In the second year of the experiment, the average potassium concentration was significant independent from wood ash doses and soil application.

Table 1. Average concentration of nitrogen (g kg^{-1}), of four cuts in the diagnostic leaves (leaves +1 and +2), of *U. brizantha* cv. marandu in the first (1^{st}) experimental year, after application of managements. CV: 3.44%

Year	Mean Nitrogen Concentration (g kg^{-1})	
	Wood ash Built-in not only	Wood ash on Soil surface
1	24.41 a	21.18 b

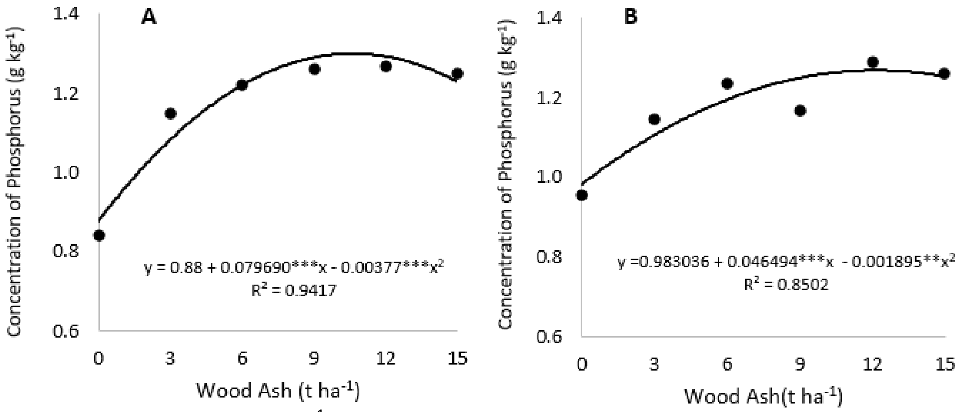

Fig 1. Mean concentration of phosphorus (g kg^{-1}) in *U. brizantha* cv. Marandu as a function of the doses of wood ash (t ha^{-1}) in the first (1^{st}) experimental year. Applied wood ash: A - incorporated and B - superficial. CV: 4.67%. ***; ** Significant at 0.1 and 1% probability, respectively.

Table 2. Mean concentration of phosphorus (g kg^{-1}) in U. brizantha cv. Marandu in the first (1^{st}) experimental year. Forms of application of the wood ash in the soil - incorporated and superficial, within the wood ash doses. CV: 4.67%.

Wood ash (t ha^{-1})	Mean concentration of phosphorus (g kg^{-1})	
	Wood ash Built-in not only	Wood ash on Soil surfasse
0	0.84 b	0.96 a
3	1.15 a	1.15 a
6	1.23 a	1.24 a
9	1.26 a	1.17 b
12	1.27 a	1.29 a
15	1.25 a	1.26 a

The averages followed by distinct letters in the line differ statistically from each other by the Tukey test at 5% probability.

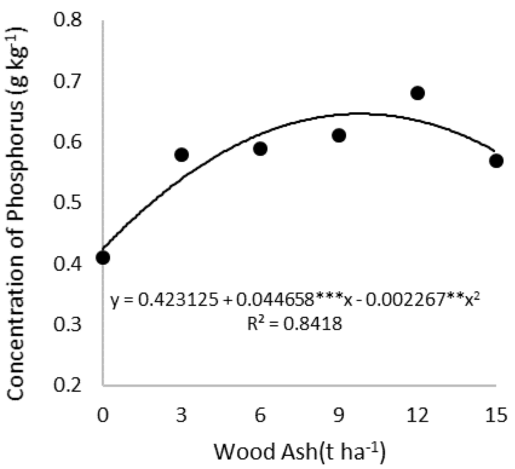

Fig 2. Mean concentration of phosphorus (g kg^{-1}) in *U. brizantha* cv. Marandu as a function of the doses of wood ash (t ha^{-1}) in the second (2^{nd}) experimental year. CV: 16.21%. ***; ** Significant at 0.1 and 1% probability. respectively.

Table 3. Mean concentration of phosphorus (g kg^{-1}) in leaves of *U. brizantha* cv. Marandu in the second (2^{nd}) experimental year. due to the wood ash application. CV: 4.41%.

Year	Mean Phosphorus Concentration (g kg^{-1})	
	Wood ash Built-in not only	Wood ash on Soil surface
2º	0.59 a	0.55 b

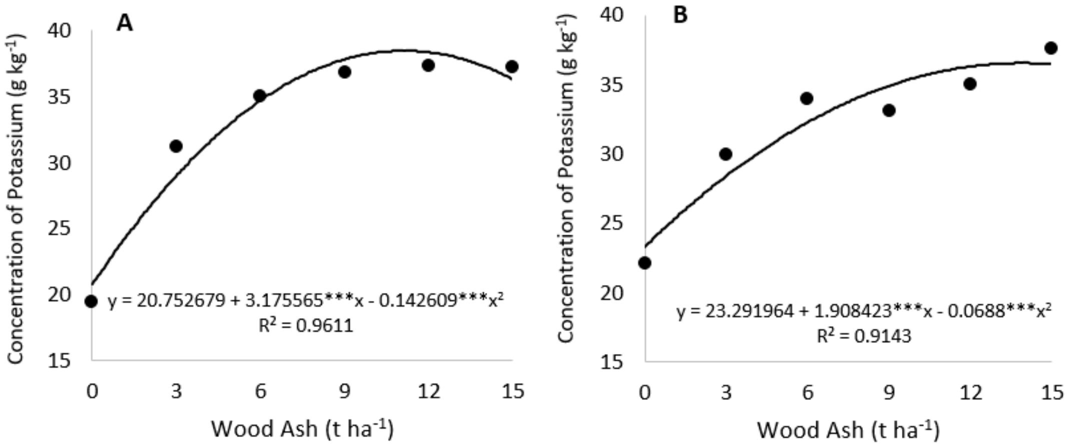

Fig 3. Average concentration of potassium (g kg^{-1}) in *U. brizantha* cv. Marandu as a function of the wood ash doses (t ha^{-1}) in the first (1^{st}) experimental year. Applied wood ash: A - incorporated to soil and B - superficial to the soil. CV: 5.34%. *** Significant at 0.1% probability.

Table 4. Average concentration of potassium (g kg^{-1}) in U. brizantha cv. Marandu in the first (1^{st}) experimental year. Management of soil ash application - incorporated and superficial, within the doses of wood ash. CV: 5.34%.

Wood ash (t ha^{-1})	Mean concentration of potassium (g kg^{-1})	
	Wood ash Built-in not only	Wood ash on Soil surface
0	19.48 a	22.08 a
3	31.15 a	29.90 a
6	34.98 a	33.93 a
9	36.73 a	33.08 b
12	37.30 a	35.03 a
15	37.20 a	37.58 a

The averages followed by distinct letters in the line differ statistically from each other by the Tukey test at 5% probability.

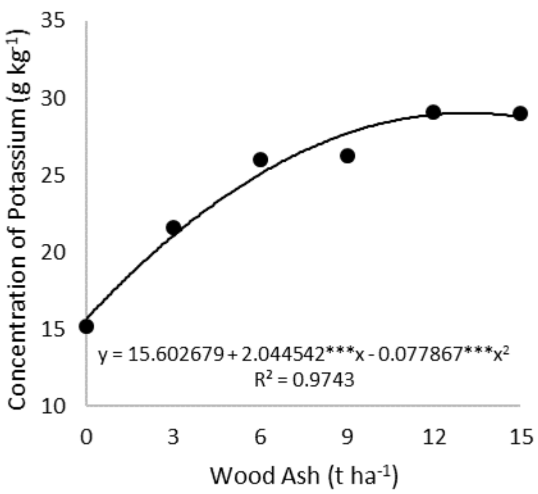

Fig 4. Average concentration of potassium (g kg^{-1}) in *U. brizantha* cv. Marandu as a function of the wood ash doses (t ha^{-1}) in the second (2^{nd}) experimental year. CV: 8.66%. *** Significant at 0.1% probability.

Table 5. Average potassium concentration (g kg^{-1}) in leaves of *U. brizantha* cv. Marandu in the second (2nd) experimental year, due to the application of the wood ash. CV: 13.30%.

Year	Mean Concentration Potassium (g kg^{-1})	
	Wood ash Built-in not only	Wood ash on Soil surface
2º	26.07 a	22.95 b

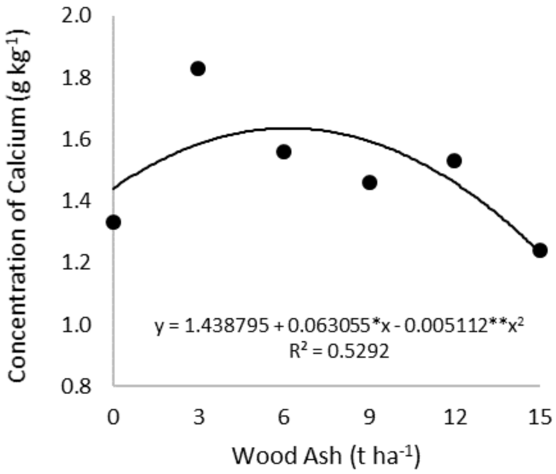

Fig 5. Average concentration of calcium (g kg^{-1}) in *U. brizantha* cv. Marandu as a function of the wood ash doses (t ha^{-1}) in the second (2nd) experimental year. CV: 14.31%. *, ** Significant at 5 and 1% probability, respectively.

Table 6. Average concentration of sulfur (g kg^{-1}) in U. brizantha cv. Marandu in the first (1st) experimental year. Management of soil ash application - incorporated and superficial, within the wood ash doses. CV: 12.44%.

Wood ash (t ha^{-1})	Average sulfur concentration (g kg^{-1})	
	Wood ash Built-in not only	Wood ash on Soil surface
0	1.17 a	1.07 a
3	1.19 a	1.09 a
6	1.44 a	1.25 a
9	1.61 a	1.20 b
12	1.35 a	1.54 a
15	1.59 a	1.28 b

The averages followed by distinct letters in the line differ statistically from each other by the Tukey test at 5% probability.

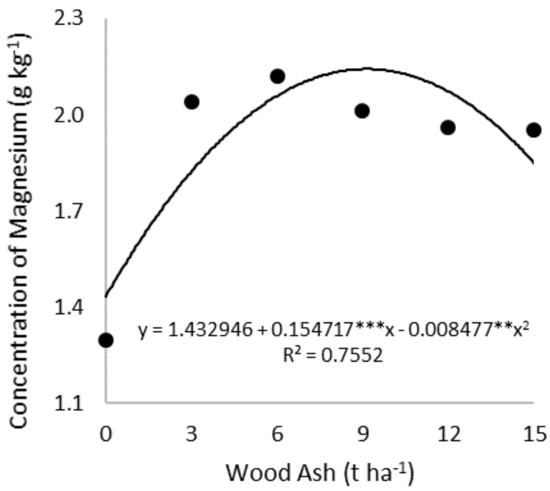

Fig 6. Average concentration of magnesium (g kg^{-1}) in *U. brizantha* cv. Marandu as a function of the wood ash doses (t ha^{-1}) in the second (2nd) experimental year. CV: 18.87%. **, *** Significant at 1 and 0.1% probability, respectively.

Table 7. Average concentration (g kg^{-1}) of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) in *U. brizantha* cv. Marandu, comparing the evaluation years.

Year	Averege Concentration (g kg^{-1})					
	N***	P***	K***	Ca***	Mg***	S^{ns}
1	22.80 b	1.17 a	32.37 a	3.81 a	4.48 a	1.31 a
2	25.29 a	0.57 b	24.51 b	1.49 b	1.92 b	1.26 a
CV (%)	9.55	11.06	8.35	17.90	17.82	19.57

The averages followed by distinct letters in the column differ statistically from each other by the Tukey test up to 5% probability.*** Significant at 0.1% probability. ns Not Significant.CV: Coefficient of Variation

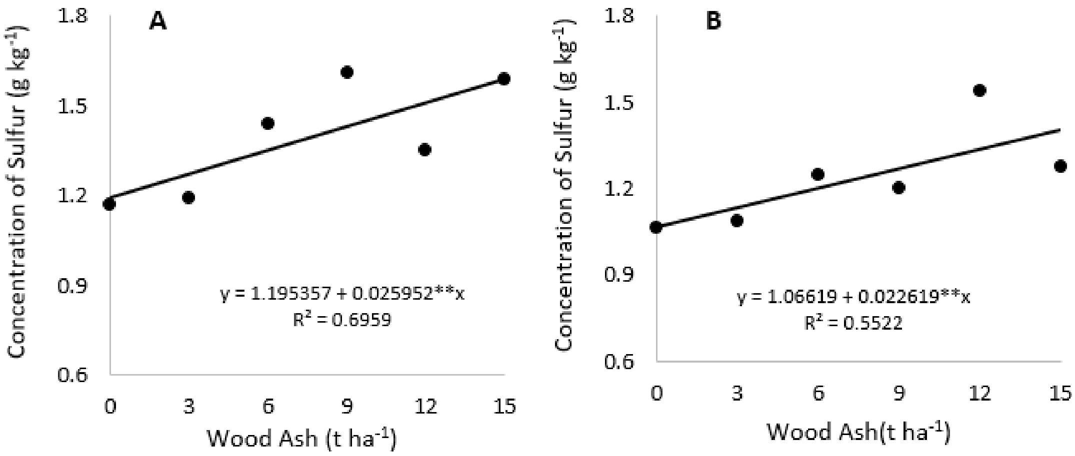

Fig 7. Average concentration of sulfur (g kg^{-1}) in *U. brizantha* cv. Marandu as a function of the wood ash doses (t ha^{-1}) in the first (1st) experimental year. Applied wood ash: A - incorporated into the soil and B - superficial to the soil. CV: 12.44%. ** Significant at 1% probability.

Table 8. Chemical characterization of the soil, Quartzarenic Neosol, before the experiment.

Camada	pH	Ca	Mg	Al	H	CEC	O.M	P	K	Zn	Cu	Fe	Mn	B	S	V
(m)	$CaCl_2$	---------------cmol$_c$ dm^{-3}----------------					g dm^{-3}	----------------------------------mg dm^{-3}------------------------------ ----								%
0.0–0.2	4.1	0.2	0.2	0.8	3.0	4.2	12.3	1.1	12	0.7	0.3	128	3.6	0.49	7.1	10.4
0.2–0.4	4.1	0.2	0.1	0.8	2.1	3.2	8.7	0.6	9	0.6	0.2	131	2.2	0.41	8.2	10.0

pH: Hydrogen Potential; P: Phosphorus; K.: Potassium; Ca: Calcium; Mg: Magnesium; H: Hydrogen; SB: Sum of Bases; CEC: Cation exchange capacity; V: Saturation by Bases; O.M: Organic matter; Zn: zinc; Cu:copper; Fe: airon; Mn: Manganese; B; Boron; S: Sulfur

Table 9. Chemical characterization of the soil, Quartzarenic Neosol, in the layer of 0.0-0.20 m, in each subplot of the experimental area, after the end of the experiment.

Treatment	pH	Ca	Mg	Al	H	CEC	O.M	P	K	Zn	Cu	Fe	Mn	B	S	V
	$CaCl_2$	---------------cmol$_c$ dm^{-3}--------------					g kg^{-1}	-----------------------------mg dm^{-3}----------------------------								%
0 I	3.9	0.1	0.1	0.8	2.8	4.0	14.60	3.6	15.0	0.1	0.1	49.0	3.5	0.11	5.0	5.9
0 NI	3.9	0.1	0.1	0.9	2.8	3.9	10.50	2.5	17.0	0.1	0.2	53.0	3.2	0.12	4.0	6.1
3 I	3.9	0.1	0.1	0.9	2.9	4.1	14.30	4.7	22.0	0.1	0.2	51.0	3.8	0.14	4.0	6.4
3 NI	4.1	0.1	0.1	0.8	2.8	3.9	13.70	4.1	24.0	0.1	0.1	39	4.3	0.11	3.0	6.7
6 I	4.0	0.2	0.1	0.8	3.0	4.2	15.60	8.5	34.0	0.1	0.1	43.0	6.0	0.17	3.0	9.3
6 NI	4.1	0.2	0.2	0.8	2.8	4.1	14.80	5.6	33.0	0.2	0.2	46.0	4.1	0.15	4.0	11.8
9 I	4.5	0.7	0.6	0.2	2.7	4.5	16.10	32.7	106	0.9	0.4	55.0	8.9	0.20	3.0	35.1
9 NI	4.0	0.1	0.1	0.8	3.0	4.1	16.90	7.8	38	0.1	0.1	51.0	4.2	0.17	4.0	7.3
12 I	4.1	0.2	0.2	0.7	3.3	4.6	13.70	13.9	59	0.1	0.1	50.0	6.1	0.14	3.0	12.1
12 NI	4.0	0.2	0.1	0.8	3.0	4.2	13.20	10.6	43.0	0.2	0.1	51.0	4.8	0.13	5.0	9.7
15 I	4.6	0.9	0.7	0.2	2.9	5.1	15.10	50.2	159	0.6	0.3	66.0	8.7	0.21	4.0	39.3
15 NI	4.5	0.7	0.6	0.2	2.7	4.4	17.00	24.2	90.0	0.3	0.2	59.0	9.9	0.18	3.0	34.5

Treatment: 0, 3, 6, 9, 12 e 15 t ha^{-1} the wood ash; I: wood ash incorporated into the soil; NI: wood ash superficial (without incorporation). pH: Hydrogen Potential; Ca: Calcium; Mg: Magnesium; Al: Aluminum; H: Hydrogen; CTC: Cation exchange capacity; O.M: Organic matter; P: Phosphorus; K.: Potassium; Zn: Zinc; Cu: Copper; Fe:Iron; Mn: Manganese; B: Boron; S: Sulfur; V: Saturation by Bases;

Table 10. Chemical composition of the wood ash used in fertilization. First (1°) and second (2°) year of the experimente.

	pH	PN	RTNP	RE	N	P_2O_5	K_2O	Ca	S	Mn	B	Zn	Cu
	---------------------%----------------				--g kg^{-1}---								
1° year	10.7	20.3	17.12	84.3	2.8	29.8	33.2	31.5	1.5	0.70	0.15	0.11	0.11
2° year	6.6	7.80	8.78	112	3.8	3.10	4.2	1.7	0.4	0.331	0.006	0.011	0.006

pH: Hydrogen Potential; PN: Neutralizing power; RTNP: Relative total neutralizing power; RE: Reactivity; N: Nitrogen; P_2O_5: Phosphorus pentoxide; K_2O: Potassium Oxide; Ca: Calcium; S: Sulfur; Mn: Manganese; B: Boron; Zn: Zinc; Cu: Copper.

The wood ash dose of 13.13 t ha^{-1} gave the highest mean potassium concentration of 29.02 g kg^{-1} in the leaves of the Marandu grass (Fig 4), presenting an increase of 91.05% in relation to the mean potassium concentration in the control treatment plants. By incorporating the wood ash in the soil, it produced highest potassium concentration of 26.07 g kg^{-1} when compared with the wood ash application on the surface (Table 5).

According to Werner et al. (1996) and Embrapa (2009), the adequate potassium concentration in the Marandu grass is 12 to 30 g kg^{-1}. Thus, the ash in the two years of the application was able to increase the amount of potassium in the soil and supply the crop demand aiding in the recovery of the degraded pasture. However, potassium concentrations above 30 g kg^{-1}, indicate consumption by luxury plants (Embrapa, 2009).

In the first year of evaluation of wood ash doses, treatments above 6 t ha^{-1} presented luxury consumption. However, this was not verified in the second year with the highest dose of plant ash (15 t ha^{-1}). This may be directly related to composition of wood ashes that were applied in each year of pasture recovery (Table 10). Bonfim-Silva et al. (2014) verified the highest concentration of potassium (27.36 g kg^{-1}) in the wood ash dose of 11.94 mg dm^{-3}, in a greenhouse experiment.

Calcium in the plant

The average calcium concentration in the Marandu grass during the first year of the evaluation was not significant, presenting a mean of 3.81 g kg^{-1}. However, in the second year it varied according to the applied ash dose. The plant ash dose of 6.17 t ha^{-1} presented the highest mean calcium concentration of 1.63 g kg^{-1} in the recovering pasture (Fig 5).

In the first year of the wood ash application, the available calcium in the wood ash undertook the function of the soil corrective treatment (Insam et al., 2009; Saunders, 2014; Füzesi et.al, 2015; Bezerra et al., 2016; Pereira et al., 2016). Thus, possibly little calcium was made available to the plants. The appropriate nutritional values of *U. brizantha* are 3.0 to 6.0 g kg^{-1} calcium in the leaves (Embrapa, 2009). The low amount of calcium extracted by the plant in the second year of evaluation may be directly related to the low calcium amount available in the second experimental year, which was 1.7 g kg^{-1}. Calcium is essential for plant cell plasma membrane integrity, specifically for ion transport selectivity (Epstein and Bloom, 2005), on hormone reactions, enzymatic activation and secondary messenger of plants (Malavolta et al., 1997).

Magnesium in the plant

The average magnesium concentration in the Marandu grass was not statistically significant for the applied treatments of doses of wood ash and pasture recovery management, presenting an average of 4.48 g kg^{-1} in the first year of evaluation.

However, in the second year, the mean magnesium concentration was significant for the plant ash doses, and the Marandu grass plants submitted to a dose of 9.13 t ha^{-1} showed the highest concentration of magnesium (2.14 g kg^{-1}) (Fig 6).

The magnesium concentration in forage grasses can range from 1.8 to 3.6 g kg^{-1} (Werner et al., 1996) for their adequate nutrition. Thus, the wood ash provided enough magnesium for a good development of the Marandu grass, during the two years of pasture recovery.

Eguchi et al. (2017) verified magnesium extraction by Marandu grass, quantified increasing linear uptake up to the highest dose of chicken manure (6.22 t ha^{-1}) applied to the pasture when the plant had a magnesium concentration of 10.27 g kg^{-1}.

Sulfur in the plant

The average concentration of sulfur in the pasture in the first year of the experiment was statistically influenced by the experimental factors interaction (wood ash doses and application management) (Fig 7 and Table 6). The highest sulfur concentrations of 1.58 g kg^{-1} was observed in the dose of 15 t ha^{-1} wood ash with the incorporation of the wood ash into the soil (Fig 7A). However, when application management was verified within the doses of plant ash, the incorporation of the wood ash in the dose of 9 t ha^{-1} presented the highest average sulfur concentration in the plants (1.61 g kg^{-1}) (Table 6). In the second year of the experiment, the sulfur concentration in the recovering pasture was not significant, presenting a mean of 1.26 g kg^{-1}. Embrapa (2009) describes sulfur concentrations of 0.8 to 2.5 g kg^{-1} as parameters for adequate nutrition of *U. brizantha*. Thus, the use of the wood ash as fertilizer vegetable source of sulfur for the plant was enough for the nutritional recovery of the pasture.

Comparison between the evaluation years

Comparing the mean concentrations of nutrients in the recovering pasture in the two years of evaluation, the highest nutrients concentrations in plant were occur in the first year of evaluation (Table 7). This was possibly due to the difference in the quality of the applied ash in the two years. However, in the first year of evaluation of the experimente, the wood ash had a higher amount of nutrients (Table 10), which probably favored a greater availability of nutrients for the plant. In the same year, the rainfall was increased, which may have helped in the release of nutrients in the soil and the absorption by the plants.

The doses and management of the wood ash application provided significant differences in the average nutrients concentration in the plant, well as its property as a soil corrective agent (Bezerra et al., 2016; Pereira et al., 2016).

The wood ash presented as a viable fertilizer for degraded pasture, increasing the availability and consequently the absorption of macronutrients by the Marandu grass, corroborating with Bonfim-Silva et al. (2015), who stated that plant ash improves soil fertility.

Materials and Methods

Location of the experiment

The experiment was carried out in the field in two consecutive years (2015 and 2016) at the experimental farm of the Instituto Mato Grosso do Algodão (IMA) (16º 33 'S and 54º 37' O), with an average elevation of 314 m in the Rondonópolis Municipality, State of Mato Grosso - Brazil.
In the first experimental period (December 2014 to April 2015) the average temperature was 27.47 °C, with total precipitation of 918.50 mm. During the second experimental year (January to May 2016) the average temperature was 27.83 °C, with total precipitation of 430 mm (INMET, 2016).

Experimental design

The experimental design was a 6x2 factorial scheme, corresponding to six gray doses (0, 3, 6, 9, 12 and 15 t ha^{-1}) and two treatments of ash application, incorporated with the soil and superficial (without soil mixing) with four replications, making a total of 24 plots and 48 subplots.
The experimental plots with 240 m^2 (8m x 30 m) received the wood ash doses, while the subplots with 120 m^2 (8m x 15 m) received application management, totaling 5,760 m^2 of the experimental area.

Characterization of the area

The implantation of the experiment was conducted fifteen years earlier (ago) as Marandu grass pasture. This area was renewed in 2003, in which the Urochloa brizantha cv. Marandu was cultivated. Since then there was no management with conservationist practices of edaphic or mechanical character.
Characterization of experimental area showed that the pasture was low with 21-50% presence of invasive plants (spontaneous plants). Thus, before applying the treatments, it was necessary to perform a standardization cut at the height of the Marandu grass, at a mean height of 15 cm from the soil surface. The cut vegetative material was removed from the area with the aid of a raker manually. Soil analysis, showed a Quartzarenic Neosol of the degraded pasture before the experiment (Table 8 and two years Table 9).

Characterization of wood ash

Wood ashes used were from the combustion of vegetable material in a boiler (± 800 °C) and ceramic kiln (± 600 °C), for the first and second years respectively. Wood ash was analyzed as a corrective and as a fertilizer (Darolt et al., 1993) (Table 10).

Conducting the experiment

The plant ash was applied 30 days before the first evaluation every year. The incorporation of the vegetal ash in the soil was carried out with light grid with average depth of 10 cm. Nitrogen fertilization of 100 kg ha^{-1} $year^{-1}$ was applied in a single dose in all experimental plots, using urea nitrogen (45% N) as a source of nitrogen, after application of wood ash.
In each experimental year, four evaluation cuts of the plants were carried out in the aerial part, during the rainy season (spring-summer), in an average interval of 30 days between each cut.
After cutting of plants for nutritional evaluation, all experimental area was standardized with lowering of the plants to 15 cm from the surface of the soil simulating; thus, the cattle grazing for this forage grass. This standardization was performed with brushcutter coupled to the tractor and shortly after cutting, the cut grass was removed from the experimental area.
To analyze the nutritional characteristics of the Marandu grass, two samples were collected in each subplot. Each single plant sample was cut from the area delimited by an iron rectangle with dimensions of 1.00 m x 0.25 m (0.25 m2), randomly flipped.

Analysis of plants

A sampling of forage grass to evaluate the nutritional macronutrients status was performed at 5 cm height from the soil surface. The evaluations were carried out within the useful area of each subplot, surrounded by a border area of 1 m.
The average concentration of nutrients, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) in each evaluation year was measured after extraction and quantification of these nutrients in leaves (leaves +1 and leaves +2) of the Marandu grass in the two experimental years, performing the average of the four forage cuts within each year.
For the nitrogen concentration in the leaves, the plants were submitted to sulfur digestion followed by distillation by the semi-micro-Kjeldahl method. To determine the concentration of phosphorus, potassium, calcium, magnesium, and sulfur, nitric-perchloric digestion was also performed. Phosphorus was quantified by metavanadate colorimetry, potassium by flame emission photometry, calcium by atomic absorption spectrophotometry, magnesium by thiazole yellow colorimetry and sulfur by barium sulfate turbidimetry (Malavolta et al., 1997).

Statistical analysis

The data were submitted to analysis of variance. The Tukey's test was applied for qualitative variables (incorporation management). The regression analysis was conducted for quantitative variables (doses of wood ash) ($p \leq 0.05$) using statistical program SISVAR (Ferreira, 2011).

Conclusion

The wood ash improved the nutritional quality of the recovering pasture. Wood ash doses between 9 and 12 t ha^{-1} present the highest concentration of nutrients in the plant.
The incorporation of the wood ash in the soil assisted in better availability of nutrients to Marandu grass. The

nutritive value of pasture depends on the quality of the applied wood ash as an alternative fertilizer.

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