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Wood Ash in *Canavalia ensiformis* L. Cultivation on Highly Weathered Soil in Brazil

Edna Maria Bonfim-Silva[1*], Marcel Thomas Job Pereira[1], Julyane Vieira Fontenelli[1], Janaína M. Gonçalves Carvalho[1], Alessana Franciele Schlichting[1] and Tonny José Araújo da Silva[1]

[1]Department of Agricultural and Environmental Engineering, Institute of Agricultural Sciences and Technology, Federal University of Mato Grosso, Rondonópolis, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. The authors EMBS and TJAS conceived the idea, designed the experiment and edited the manuscript. The authors MTJP, JVF and JMGC conducted the experiment, statistical data analysis, interpretation of results and preparation of first draft of the manuscript. The author AFS interpretation of results and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The aim of study was to avaliate the productive and structural features of *Canavalia ensiformis* L. resulting from the wood ash acting as a soil corrective and fertilizer in the Oxisol. The experiment was performed in a greenhouse, from April to July 2012, in the Municipality of Rondonópolis, State of Mato Grosso, Brazil. The experiment, with Oxisol, use as of six wood ash doses (0.0, 3.0, 6.0, 9.0, 12.0 and 15.0 g dm^{-3}). Harvesting of the *Canavalia ensiformis* L. was done 60 days post germination, in plastic pots of 4 dm^{-3} capacity, to which the wood ash doses had been administered 20 days prior to planting. At the time of flowering, the following measurements were recorded, plant height, indirect chlorophyll index of leaf, stem diameter, leaf number count, soil pH, dry mass of shoot, dry mass of root, numbers and dry mass of the Rhizobia-rich root nodules. The findings were then submitted to the analysis of variance and regression test, up to p=0.05 significance. The wood ash acted as a corrective and induced a pH increase, enhancing the soil chemistry. Influencing the

**Corresponding author: E-mail: edna.bonfim.silva@gmail.com, embonfim@hotmail.com;*

number of leaves, dry mass of leaves and nodules. The other variables analyzed, which were adjusted to the quadratic regression model, demonstrated improved results when 9 to 12 g dm^{-3} of wood ash per pot were added.

Keywords: Cover crop; soil correction; vegetal residue.

1. INTRODUCTION

Responsibility for the environment and energy insecurity have kindled a great need for alternative renewable energy resources, among which biomass burning (trunks, forest and agricultural residues) used in power plants ranks high as an economically viable energy source [1], and which generates wood ash.

The burning of waste wood in the process of power production produces wood ash as an industrial residue. Wood ash has been found to be a viable alternative in agricultural soils as it contains substantial quantities of plant nutrients. Wood ash thus becomes a good source of essential plant nutrients like Ca, K, Mg and P [2] and exerts a corrective influence on acidic soils [3].

The predominant requirements for crop cultivation in acidic soils include soil correction and macronutrient availability, particularly with reference to the first crop. The soil acidity as one of the principal limiting factors for agricultural production [4]. South America hosts roughly 1,180.3 x 106 ha of acidic soils. As nitrogen occurs only in traces in wood ash, it must necessarily be added to the system, in a more sustainable manner, by incorporating green manure into the soil during crop cultivation.

Green manure added to the soil gets incorporated and decomposed, and mineralization and nitrification occur with the release of nitrogen (mineral; NH_4-N; NO_3-N) for the next crop [5]. The C / N ratio of the green manure is a reflection of its worth as a nitrogen fertilizer [6]. When the green manure shows a C / N ratio of 8 it implies a high soil nitrogen mineralization; however, when the C / N ratio equals 12, it reflects the value of the Franco-sandy loam and loamy clay soils [5]. The C / N ratio of 14.9 for Jack bean (*Canavalia ensiformis* L.), which when used as green manure, affected the soil microbial action and soil nitrogen availability [7].

The need to identify alternatives for wood ash disposal was high, the aim of study was to avaliate the productive and structural features of *Canavalia ensiformis* L. resulting from the wood ash acting as a soil corrective and fertilizer in the Oxisol.

2. MATERIALS AND METHODS

The experiment was performed in a greenhouse in the Municipality of Rondonópolis, State of Mato Grosso, Brazil, at the co-ordinates of 16º 28' 15' 'S and 54º 38' 05 '', at an altitude of 227 m. The region displayed the Aw climate pattern according to the Köppen classification, with 27°C average temperature and 62% mean humidity, as maintained in the greenhouse during the experiment.

The completely randomized experimental design was used, the wood ash was applied at rate of 0.0, 3.0, 6.0, 9.0, 12.0 and 15.0 g dm^{-3}, and six replications in total, amounting to a total of 36 experimental units.

The experimental units involved plastic containers of 4 dm^{-3} soil capacity. The Dystrophic Oxisol (Table 1) taken from the region of the first crop was used. It had been collected prior from the 0-20 cm soil layer and sieved through a 2 mm mesh. The wood ash (Table 2) applied was taken from the burning of the *Eucalyptus* sp. used in the energy generation of the industries in that area.

Table 1. Chemical and granulometric characteristics of the Oxisol in the 0-20 cm depth

pH	P	K	Ca	Mg	H	Al	SB	CTC	V	O.M.	Sand	Silt	Clay
($CaCl_2$)	-(mg dm^{-3})-		------------($Cmol_c$ dm^{-3})--------------						(%)	(g dm^{-3})	--------(g kg^{-1})--------		
4.1	2.4	28	0.3	0.2	4.2	1.1	0.6	5.9	9.8	22.7	549	84	367

Calcium Chloride ($CaCl_2$), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Hydrogen (H), Aluminum (Al), Sum of Bases (SB), Cation Exchange Capacity (CTC), Base Saturation (V) and Organic Matter (O.M)

Table 2. Chemical composition of wood ash

pH	P_2O_5	K_2O	Ca	Mg	S	B	Fe	Mn	Zn
($CaCl_2$)	---%---								
10.4	2.88	4.00	2.31	1.22	0.26	0.02	2.52	0.03	0.01

The wood ash was mixed with the soil and incubated for 30 days. The soil was watered and the moisture content was kept at 60% of the maximum water retention capacity. Measurements were taken every day using the gravimetric method [8]. After the incubation period five seeds *Canavalia ensiformis* L. was sown in the pot at 0.025 m depth. On the 10th days after planting only one plant per experimental unit was left.

Cultivation of the *Canavalia ensiformis* L. plant until it flowered (at 60 days post germination). At this point in time, the following parameters were determined: indirect chlorophyll index, soil pH, plant height, leaf number, stem diameter and the dry mass of shoot, root and nodules. The plant height was measured from the ground level to the point of insertion of the last leaf. Using calipers, the stem diameter was measured at 1 cm from the ground level. Indirect evaluation of the chlorophyll index in the leaves and the Falker indices were confirmed using the ClorofiLOG model CFL 1030 apparatus. Using 0.01M $CaCl_2$ solution in 10 cm^3 of soil, the pH was calculated.

Once the measurements were recorded, cutting of the plants was done at the ground level and the dry mass of the aerial plant parts determined; the roots were then washed and their dry mass was assessed. The root nodules (Rhizobia) present in the plant roots were counted and their dry mass was recorded. The material was placed in an oven under forced air circulation at ± 65°C until constant mass was attained and after weighing in an analytical balance, the dry mass was determined.

The findings were submitted to the analysis of variance and regression test, up to p = .05 probability. Employing the SISVAR statistical program [9].

3. RESULTS AND DISCUSSION

The indirect chlorophyll index in the leaf, the Falker index, revealed its highest value (51) for the wood ash dose of 9.53 g dm^{-3}, demonstrating that the plant nutrition, with respect to the nitrogen absorption, was greater at that dose (Fig. 1). The best nutrition for the Jack bean was at 60 days after planting, when the SPAD index, taken on the Minolta apparatus, registered a value of 55 [10].

The Falker index directly correlates with the nitrogen content in the leaf (r = 0.843), at a value of 51, and roughly indicates a 50 g kg^{-1} nitrogen content in the leaf [11]. It is noteworthy that the nitrogen nutrition in the Jack bean under these experimental conditions was possible essentially through the biological fixation of nitrogen because there was no provision of a nitrogen source.

The soil pH revealed statistical differences 60 days post wood ash application, the highest value (pH 5.38) reached in the dose of wood ash of 13.90 g dm^{-3} (Fig. 2). The wood ash used signifies the calcium, potassium and phosphorus levels, so that the pH rise can be ascribed largely to the release of calcium and potassium carbonates present in the soil, through the application of the wood ash. The escalation in the soil pH post ash application [12].

It occurred in the soil pH due to the application of up to 12 t ha^{-1} of wood ash; the application of 10 t ha^{-1} of wood ash caused the pH to rise to 7.6, whereas in the treatment lacking the addition of the vegetable ash, the pH remained at 6.4 [13].

With respect to the plant height the bean showed (Fig. 3) that the wood ash dose of 10.72 g dm^{-3} induced the greatest height (61.36 cm). This increase was most likely the effect of the wood ash which had enriched the soil and enhanced its chemical properties [14,15]. Besides, the utilization of organic fertilizers like plant ash can aid in optimizing the plant growth, thereby minimizing the production costs [16].

With reference to the number of leaves, an increase of 51.63% compared with the control was recorded in response to the higher dose of wood ash applied (Fig. 4). This rise may be attributed to the nutrients that constitute the wood ash (Table 2), which induced the increase in leaf number.

The highest production in the *Crotalaria juncea* crop, (an increase of 62.52% when compared with the control) occurred in response to the application of wood ash dose of 10.99 g dm^{-3} [17]. Thus, it is evident that the wood ash enhances plant development because leaf expansion is an accurate indicator for the estimation of the vegetative growth in legumes.

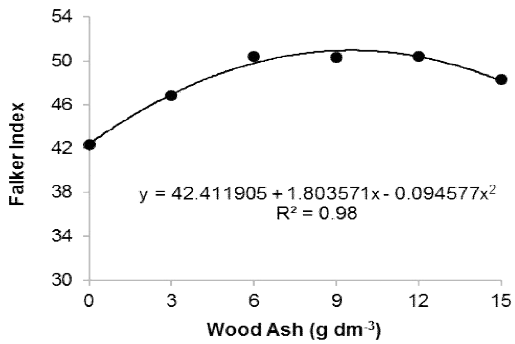

Fig. 1. Falker Index in *Canavalia ensiformis* L. as function of plant wood ash doses

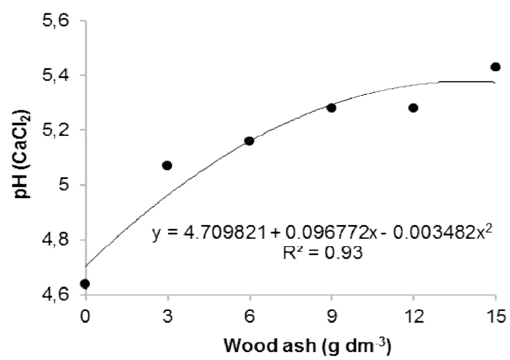

Fig. 2. Soil pH of the soil as function of plant wood ash doses

The wood ash application also influenced stem diameter, with the largest stem diameter (5.48 cm) recommended by the application of the 10.97 g dm^{-3} (Fig. 5). The wood ash supplements when added to the soil produced increased stem diameter in *Crotalaria juncea* [18]. Plants possessing larger stem diameter show improved balance in shoot growth [18].

The maximum yield (26.93 g) of dry mass of the shoot was recorded for the wood ash dose of 11.94 g dm^{-3}, registering a increase of 66.06% in comparison with the control (Fig. 6). The applied ash conditioned the soil, which, in turn, stimulated the development of the plant.

In their study on the biomass production of Jack bean (*Canavalia ensiformis* L.), during the reforestation conduced in the State of Pará, Brazil, the addition of the dry plant material of Jack bean revealed a high nutrient cycling potential in the soil [19].

On assessing the root dry mass, the wood ash doses were found to induce a substantial rise in the yield of the dry mass of the roots, the highest output being observed for the wood ash dose of 9.2 g dm^{-3}, demonstrating an increase of 54.5% hen compared with the control treatment (Fig. 7).

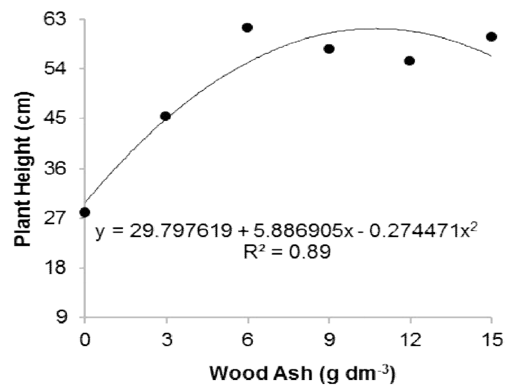

Fig. 3. Height of the *Canavalia ensiformis* L. plants as function of plant wood ash doses

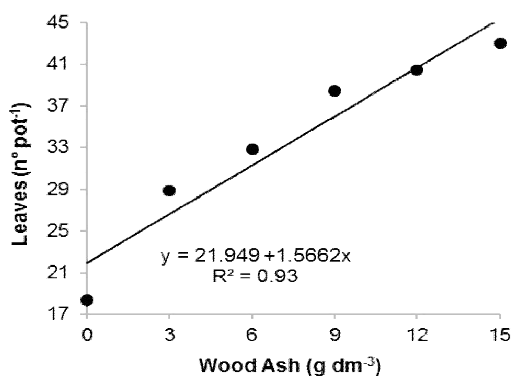

Fig. 4. Number of *Canavalia ensiformis* L. pot as function of plant wood ash doses

The ash could ensure a good supply of Ca and Mg, as well as decrease the Al content present in the soil, thus minimizing the toxicity and raising the concentration of nutrients available to the plants [20].

The wood ash doses were noted to influence the number and dry mass of the nodules (Fig. 8A and 8B). The wood ash applied induced the increase of 64.33 and 93.24% in the number and dry mass of the nodules, respectively, in the final dose supplied when compared with the control.

As the wood ash used contains high phosphorus concentrations (Table 2), it influences the nitrogenase enzyme activity due to the high-energy expenditure, stimulated by the natural biological nitrogen fixation that occurs in legumes.

The application of up to 8 t ha^{-1} the wood ash in the forest, reported no influence of the addition of the ash on the total microbial biomass in the mineral and organic soil layers. While the authors suggested that the low dose exerts some effect, the temperature, which hovered between -14.5 and -19.0°C during the course of the experiment, may have also affected this finding [21].

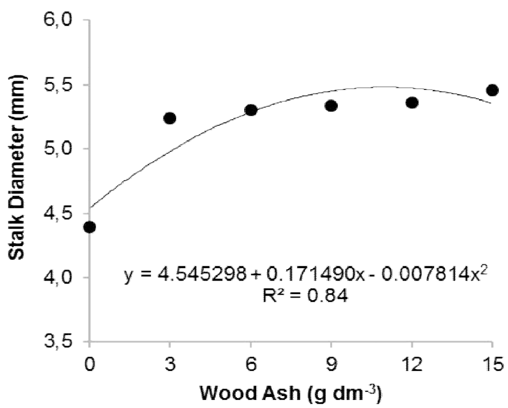

Fig. 5. Stem diameter of *Canavalia ensiformis* L. plants as function of plant wood ash doses

Occurs a linear rise in nodule production resulting from the increasing doses of the phosphorus added in *Trifolium subterraneum* L. cv. Woogenellup. Therefore, the ash used was seen to increase the number and the dry mass of the nodules in the bean cultivated [22].

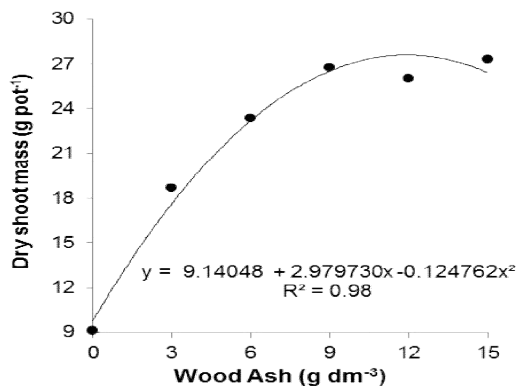

Fig. 6. Dry mass of the aerial part of *Canavalia ensiformis* L. as function of plant wood ash doses

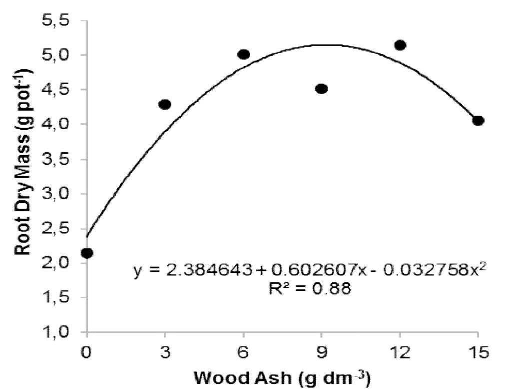

Fig. 7. Dry root mass of the *Canavalia ensiformis* L. as function of plant wood ash doses

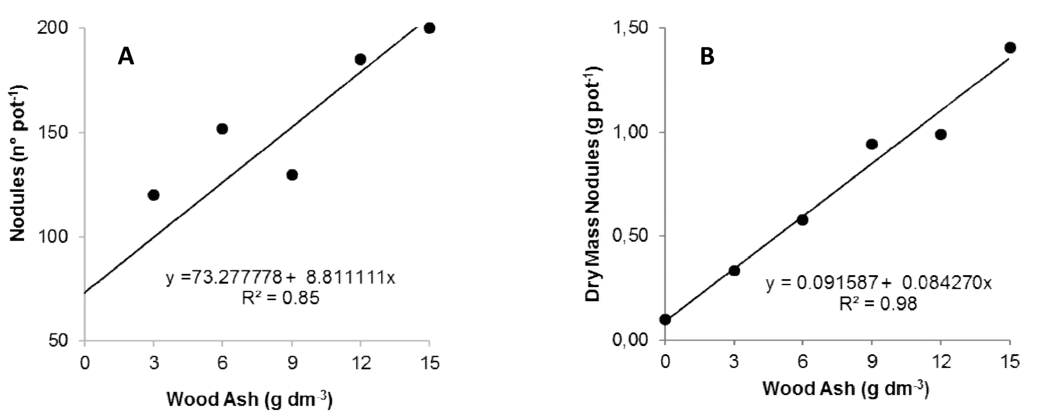

Fig. 8. Number of nodules (A) and dry mass of nodules (B) of *Canavalia ensiformis* L. as function of plant wood ash doses

The *Canavalia ensiformis* L. revealed the best chemical quality of the residue, showing higher N, P and Ca residues, which are essential for green manuring [23].

4. CONCLUSION

The wood ash increases the pH of the soil improving the chemical quality of the soil. Wood ash effective alternatives like soil correction and fertilizers especially for the first culture of *Canavalia ensiformis* L.

The vegetal ash added in a 15 g dm^{-3} dose increases the production of the greatest number of leaves and nodules, as well as dry mass of the nodules. The indirect chlorophyll index, plant height, soil pH and stem diameter revealed the best results when 9 to 12 g dm^{-3} doses of wood ash were used.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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