Growth and development of cowpea under wood ash doses and liming

Crescimento e desenvolvimento do feijão caupi sob doses de cinza de madeira e calagem

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ABSTRACT

Wood ash is a source of nutrients for plants and can be an option to correct and fertilize the soil, thus contributing to the increase of productivity and decreasing the costs in agricultural production by the use of mineral and organic fertilizers. Thus, the objective of this study was to evaluate the effects of combinations of wood ash doses and the absence and presence of liming on the growth and development of cowpea [Vigna unguiculata (L.) Walp.] cultivated in Oxisol. The experiment was conducted in a greenhouse at the Federal University of Mato...
Grosso, Campus of Rondonópolis. The experimental design was in a randomized block, arranged in a factorial scheme 6 x 2, with four replications. The treatments consisted of six doses of wood ash (0; 9; 18; 27; 36; and 45 g dm$^{-3}$) subjected to two conditions (without liming and with 60% liming of base saturation) in pots of 1.5 dm$^3$. Cowpea was positively influenced by the use of wood ash as fertilizer and concealer, contributing to the growth and development of cowpea, obtaining better results in the dose intervals between 36 g dm$^{-3}$ and 45 g dm$^{-3}$.

**Keywords:** Vigna unguiculata; disposal of solid waste; alternative concealer, soil pH.

**RESUMO**

A cinza de madeira é uma fonte de nutrientes para as plantas, podendo ser uma opção para corrigir e adubar o solo, contribuindo assim para o aumento da produtividade e diminuindo os custos na produção agrícola pelo uso dos adubos minerais e orgânicos. Assim, objetivou-se avaliar os efeitos das combinações de doses de cinza vegetal e da ausência e presença de calagem no solo no crescimento e desenvolvimento do feijão-caupi [Vigna unguiculata (L.) Walp.] cultivado em Latossolo Vermelho. O experimento foi conduzido em casa de vegetação na Universidade Federal de Mato Grosso, Campus de Rondonópolis. O delineamento experimental utilizado foi em bloco casualizado, arranjados em esquema fatorial 6 x 2, com quatro repetições. Os tratamentos consistiram em seis doses de cinza vegetal (0; 9; 18; 27; 36; e 45 g dm$^{-3}$) submetidos às duas condições (sem calagem e com calagem 60% da saturação por bases) em vasos de 1,5 dm$^3$. O feijão-caupi foi influenciado positivamente com a utilização de cinza vegetal como adubo e corretivo, contribuindo para o crescimento e desenvolvimento do feijão-caupi, obtendo melhores resultados nos intervalos de doses entre 36 g dm$^{-3}$ e 45 g dm$^{-3}$.

**Palavras-chave:** Vigna unguiculata; destinação de resíduo sólido; corretivo alternativo, pH do solo.

1 INTRODUCTION

Cowpea is produced mainly in the Northeast region that has the largest planted area, however the Midwest region presents the highest productivity, in which the state of Mato Grosso has a value of 1094 kg ha$^{-1}$ (CONAB, 2019). The production areas are in a Cerrado region with soils that have low natural fertility and high soil acidity, the costs with correction and fertilization contribute to the increase in production expenditures. These soils contain a high concentration of aluminum and manganese, and it is necessary to perform the liming to increase the agricultural production (SANTOS et al., 2018; SPERATTI et al., 2018).

Wood ash is an alternative for use as corrective and fertilizer (JOHANSEN et al., 2019). Provides increased nutrients (HUOTARI et al., 2015; IQBAL; LEWANDOWSKI, 2016), water retention capacity (BÄR et al., 2018; THOMAZ, 2018), soil pH (CRUZ-PAREDES et al., 2017; FÜZESI; HEIL; KOVÁCS, 2015) and enhances nitrogen fertilization (BRAIS; BÉLANGER; GUILLEMETTE, 2015) contributing to optimizing crop productivity (CRUZ-PAREDES et al., 2017; KINDTLER et al., 2019).
The complete burning of vegetable biomass has as residue the wood ash, which has a solid texture of grayish color (COELHO; COSTA, 2007), this material is chemically composed of bases (calcium carbonate and magnesium) capable of neutralizing soil acidity and reducing the aluminum content present in the soil (BRAIS; BÉLANGER; GUILLEMETTE, 2015). Thus, the use of wood ash is a low-cost alternative for the fertilization of crops in soils with high acidity (BONFIM-SILVA et al., 2011a).

However, it is necessary that the user has knowledge of the area of soil science for the correct recommendation of the doses of wood ash according to the soil classes, it is important to know the chemical composition of this residue that suffers variation in agreement with its origin (BONFIM-SILVA; SCHLICHTING; SILVA, 2019; PUGLIESE et al., 2014), and the appropriate dose for each culture avoiding lack or nutritional toxicity.

Studies of the application of wood ash in agricultural acidic soils have contributed positively to the development in various crops, such as grass (KINDTLER et al., 2019), wheat (OCHECOVA; TLUSTOS; SZAKOVA, 2014), in forests (PUGLIESE et al., 2014), corn (NDUBUISI; DEBORAH, 2010) and in flowers (BÄR et al., 2018; PEREIRA et al., 2016).

The objective of this study was to evaluate the effects of combinations of wood ash doses with the absence and presence of liming on the soil in the growth and development of cowpea (*Vigna unguiculata* (L.) Walp) cultivated in a Oxisol.

2 MATERIAL AND METHODS

The experiment was conducted in a greenhouse of the Institute of Agrarian and Technological Sciences (ICAT) of the Federal University of Mato Grosso (UFMT), Campus Rondonópolis – MT. The greenhouse is located in the north-south direction, with total area of 450 m² and cover of transparent plastic of 200 microns, located geographically at Latitude 16 ° 27 ' South, longitude 54 ° 34 ' West and altitude of 284 m.

The experimental design was in randomized blocks, arranged in a factorial scheme 6 x 2, with four replications totaling 48 experimental plots. The treatments consisted of six doses of wood ash (0; 9; 18; 27; 36; and 45 g dm⁻³), under two distinct conditions: no liming (Control) and liming at 60% of base saturation. Lime application was performed using 2.745 g pot⁻¹.

The experimental plots consisted of plastic pots with a capacity of 1.5 dm³ of soil. The wood ash used was derived from the activity of the ceramic sector and analyzed as fertilizer. The results of the analysis of plant ash as organic material are shown in Table 1.
Table 1. Chemical composition of wood ash analysed as corrective and fertilizer

|     | pH | N  | P_2O_5 | K_2O | Ca  | Mg  | SO_4 | Zn  | Mo  | Fe  | Mn  | B   | Si   |
|-----|----|----|--------|------|-----|-----|------|-----|-----|-----|-----|-----|-----|
| CaCl_2 | 10.7 | 0.31 | 0.96   | 3.47 | 3.30 | 2.10 | 0.20 | 0.01 | 0.05 | 1.03 | 0.04 | 0.01 | 27.44 |

N-Nitrogen; P_2O_5-Phosphorus in neutral ammonium citrate and water (NAC + water); K_2O-Potassium; Ca-Calcium; Mg-Magnesium; Na-Sodium; SO_4-Sulphur; Zn-Total Zinc; Cu-Total Copper; Mn-Total Manganese; B-Total Boron; Si-Silicon; Fe-Iron.

The soil used in the experiment was classified as dystrophic Oxisol (SANTOS et al., 2018) collected in the layer of 0.0-0.20 m depth, under Cerrado vegetation with no history of use for agricultural crops. The soil was sifted into a 4-mm mesh opening to fill the pots and a soil sample was sieved in a 2-mm mesh opening for the chemical and granulometric characterization according to Donagema et al., (2011).

The physicochemical characteristics in the depth of 0.0-0.20 m were as follows: organic matter- 28.7 g dm^{-3}; pH in CaCl_2- 4.2; K- 29 mg dm^{-3}; P (Mehlich-1)- 1.10 mg dm^{-3}; Al- 0.50 cmol_c dm^{-3}; H + Al- 6.30 cmol_c dm^{-3}; Ca^{2+}- 1.6 cmol_c dm^{-3}; Mg^{2+}- 0.30 cmol_c dm^{-3}; Clay- 549g kg^{-1}; Silte- 84 g kg^{-1}; and sand- 367 g kg^{-1}.

Lime and wood ash were incubated in the soil, with moisture at 60% of the maximum water retention capacity in the soil for a period of 21 days (BONFIM-SILVA et al., 2011c). After the incubation period, the cowpea (Vigna unguiculata (L.) Walp.) sowing was performed at an approximate depth of 2.5 cm, with 8 seeds per pot. At 7 and 14 days after sowing, the thinning was performed leaving the three most vigorous plants. The irrigation was performed by the gravimetric method, maintaining soil moisture at 60% of the maximum water retention capacity (SILVA-BONFIM et al., 2003).

The growth and development assessments of cowpea plants occurred at 15, 30 and 45 days after emergence (DAE), in which they were evaluated: plant height, number of leaves, chlorophyll index (SPAD) and stem diameter. At 48 days after sowing, the dry mass of the aerial part, leaf area index, root dry mass, root volume, number of nodules, dry mass of nodules and soil pH were evaluated.

The determination of the height of the plants occurred with the aid of a graduated ruler, measured from the soil to the last leaf, thus obtaining the average of the plants per pot. The number of leaves was determined by manually counting all existing leaves in each pot. The stem diameter was measured with the aid of a digital caliper. The chlorophyll index (SPAD) was determined using the Minolta SPAD-502 Plus chlorophilometer apparatus, where the reading was performed in 4 leaves per pot, with the mean SPAD reading. At 48 days after
sowing, the aerial part was cut and the roots were washed. A soil sample was removed from each pot to perform the pH reading.

Leaf area index was determined with bench leaf area meter LI-3100C. The volume of the roots was measured with the aid of a 1000 ml test, using a volume of 300 ml of water as a reference. Subsequently, the removal and counting of the root nodules were performed with the aid of a clamp. The fresh mass of the part area, the roots, and the nodules were taken to the forced air circulation, at 65 °C, for 72h, until constant mass, to subsequently be weighed and evaluated.

The experimental data were subjected to analysis of variance (P > 0.05) with the results compared by regression analysis of the quantitative variables (P > 0.10) and the F test (P > 0.05) for the qualitative variables. In the data analysis, the R Statistical 3.4.4® free software was used (R CORE TEAM, 2019). Parametric statistical analysis was implemented using functions available in the packages ExpDes.pt (FERREIRA; CAVALCANTI; NOGUEIRA, 2018) and ggpmisc (APHALO, 2016). The construction of the graphs was carried out by the package ggplot2 (WICKHAM et al., 2018).

3 RESULTS AND DISCUSSION

3.1 PLANT HEIGHT

For plant height variable there was interaction between the doses of wood ash and the presence or absence of limestone, at 15 (Figure 1A), 30 (Figure 1B) and 45 (Figure 1C) days after emergence. In the evaluation at 15 and 30 days after cowpea emergence there was adjustment to the linear regression model with the best performance at 45 g dm$^{-3}$ of wood ash, the values observed in the unfolding of the doses with limestone were 19.46 and 26.79 cm and in unfolding were 22.83 and 26.83 cm, respectively in relation to the evaluations. The plants height at 45 days after emergence varied significantly with the doses of wood ash, with adjustment to the quadratic regression model. The maximum plant heights of 26.29 and 24.85 cm were observed in the doses 45 and 40.41 g dm$^{-3}$ of wood ash, respectively for the presence and absence of limestone.

These results corroborate those observed by (BONFIM-SILVA et al., 2011b), when they verified an increase in plant height of marandu grass (*Brachiaria brizantha*) in response to different doses of wood ash incorporated into the soil. This is because the concentrations of the wood ash significantly influence the growth of the plants, favoring the reduction of the
Increment in height both in the absence and in excess, a fact that proves the importance of balance in the quantity of ash for plant metabolism (DALLAGO, 2000).

It was observed that in the presence of limestone at 30 days after emergence there was a better performance in relation to the plants height (23.46 cm), when compared to the treatment with the absence of limestone (20.95 cm) (Figure 1B), this occurs due to the lime increase the pH of the soil, which causes greater nutrient availability for plants.

Figure 1. Plant height of cowpea, as a function on the wood ash doses in the presence and absence of limestone in three assessments 15 (A), 30 (B) and 45 (C) days after emergence-DAE.
3.2 STEM DIAMETER AND NUMBER OF LEAVES

The stem diameter and the number of leaves at 30 and 45 days after emergence (Figure 2) were significantly influenced in isolation by the wood ash doses applied, with adjustment to the linear and quadratic regression models (Figure 2A). It was observed that the doses of 45 g dm$^{-3}$ of wood ash were responsible for the highest stem diameters (3.23 and 3.46 mm), respectively, at 30 and 45 days after emergence (Figure 2A), and also by the larger numbers of leaves (8.07 and 13.50 leaves pot$^{-1}$) of Cowpea plants, respectively, at 30 and 45 days after emergence (Figure 2B). For the evaluation at 15 days after emergence there was no significant effect for the variables stem diameter and number of leaves.

![Figure 2. Stem diameter (A) and number of leaves (B) of Cowpea, as a function of the wood ash doses in the presence and absence of limestone in two assessments 30 and 45 days after emergence-DAE.](image)

The plants cultivated with higher availability of wood ash showed a larger stem diameter, as well as in the results found by Bonfim-Silva et al., (2013), that verified the increase in the stem diameter of cowpea in response to the use of wood ash as fertilizer, with
an increment of 23.57% when compared to the dose of 15 g dm$^{-3}$ to treatment without wood ash.

The results observed in the present study corroborate the results found by Bezerra, Bonfim-Silva and Silva (2014), that working with wood ash in the cultivation of marandu grass in the Cerrado Oxisol, obtained the highest number of leaves in the treatment submitted to wood ash, which confirms the importance of the use of wood ash as soil fertilizer.

The wood ash is rich in macronutrients, which contributes to the increase of plant production. When the low availability of nutrients in the soil occurs, the development of the plant is reduced, causing lower emission and growth of the leaves, decreasing the uptake of solar radiation, and consequently the lower production of photoassimilates (BONFIM-SILVA et al., 2011d).

Thus, the increase in stem diameter and number of cowpea leaves evidence the importance of this residue in the nutrient supply to plants, significantly increasing the development of the crop.

3.3 CHLOROPHYLL INDEX AND LEAF AREA

For the chlorophyll index at 30 days after emergence, a significant isolated effect was observed for the wood ash doses applied to the soil. The fertilization with wood ash influenced the chlorophyll index of cowpea leaves adjusting to the linear regression model (Figure 3), verifying that the dose of 45 g dm$^{-3}$ was responsible for the highest chlorophyll index (59.4).

![Figure 3. Chlorophyll index (SPAD) as a function of the wood ash doses in the presence and absence of limestone in the evaluation at 30 days after emergence-DAE.]
In the evaluation at 45 days after the emergence of Cowpea, there was interaction between the factors for the chlorophyll index (Figure 4), adjusting to the linear regression model with the highest indexes (49.07 and 48.28) found in the dose of 45 g dm\(^{-3}\) of wood ash in unfolding of the doses for the presence and absence of limestone, respectively.

![Figure 4](image)

**Figure 4.** Chlorophyll index (SPAD) as a function of the wood ash doses in the presence and absence of limestone in the evaluation at 45 days after emergence-DAE.

The wood ash provided a linear increase in the chlorophyll index (SPAD reading) in the two assessments performed. The SPAD reading is directly related to the chlorophyll index and the nitrogen nutrition of the plant (NEVES et al., 2005). Nitrogen is a constituent part of the chlorophyll molecule and the nutrient requirement by the plant can be indirectly determined by the chlorophyll content (ARGENTA; SILVA; BORTOLINI, 2001; MALAVOLTA, 2006). Therefore, it can be inferred from the chlorophyll content by the SPAD reading, an improvement in the absorption of nitrogen by the plants in the treatments where the wood ash doses were applied (BONFIM-SILVA; SANTOS; SILVA, 2015).

For the leaf area, a significant effect was observed for the interaction of the wood ash doses both in the presence and in the absence of limestone, adjusting to the linear regression model (Figure 5), with the highest values for leaf area of Cowpea plants (881 and 806.4 cm\(^2\)) at a dose of 45 g dm\(^{-3}\) of wood ash, respectively.

Arshad et al. (2019) evaluating the effects of wood ash levels on the growth of cowpea seedlings, concluded that Cowpea has a high cultivation potential in the presence of wood ash at least 20% concentration, which validates the results found in this work in relation to the potential use of wood ash for this crop.
3.4 DRY MASS OF THE AERIAL PART, ROOT DRY MASS, ROOT VOLUME AND SOIL pH

A significant isolated effect was observed for the wood ash doses for the variables dry mass of the aerial part, dry mass of the root, root volume and soil pH (Figure 6).

For soil pH, there was a significant effect only for the wood ash doses, regardless of the presence or absence of limestone (Figure 6D). The soil pH increased from 1.49 in the soil control to 6.99 in the highest wood ash dose, thus demonstrating the potential of the wood ash in neutralizing the soil acidity, without the correction with limestone, confirming that the wood ash was efficient as soil concealer. The increase in soil pH due to wood ash occurred at the appropriate interval for most crops (BONFIM-SILVA; SCHLICHTING; SILVA, 2019; KINDTLER et al., 2019).

The capacity of wood ash as concealer is due to the alkalinity and presence of carbonates of K, Ca and Mg (SIRIKARE et al., 2015), demonstrated by the same pattern of increase in shoot dry mass (Figure 6A) and root dry mass (Figure 6B) and root volume (Figure 6C). This pattern of increase in biomass may be due to wood ash containing essential macronutrients, such as K and P (CRUZ-PAREDES et al., 2017) and N mineralization in soil due to wood ash (VESTERGÅRD et al., 2018).
The results obtained in this study corroborate those found by Kindtler et al., (2019) that observed an increase in soil pH whose values increased from 3.83 to 8.00 by the application of 30 t ha$^{-1}$ of eucalyptus wood ash. For Bonfim-Silva et al., (2015) this increase of pH in the soil can be attributed to the release of potassium carbonate by the reaction of the wood ash in the soil. According to Natale et al., (2012) when the soil is under conditions of acidity, liming promotes the neutralization of Al$^{3+}$, the elevation of pH and the supply of Ca and Mg, allowing a better development in plant growth.

Bonfim-Silva et al., (2019) compared the use of lime applied to base saturation levels and the use of wood ash doses to correct the acidity of an Oxisol cultivated with Cowpea. They verified that at 40 days after sowing, the pH values were within the range considered ideal for the soil (pH of 5 to 7), with better results for base saturation of 80% and for the application of
the wood ash dose of 32g dm\(^{-3}\). This study corroborates this work in proving that the use of wood ash has a high potential for soil correction.

### 3.5 NUMBER AND DRY MASS OF NODULES

There was a significant interaction between the factors for the number of nodules, adjusting to the quadratic regression model (Figure 7). The highest production occurred in the doses of 34.74 and 45 g dm\(^{-3}\) of wood ash, producing 343.39 and 215.8 nodules, in the presence and absence of limestone incorporated into the soil, respectively. There was also an increase in the dry mass of nodule from 0 to 36.5 g dm\(^{-3}\) of wood ash, where the maximum value of 0.34 g was obtained, in the presence of limestone incorporated into the soil. In the absence of limestone incorporated, the increase in the nodule dry mass was 0 to 35.5 g dm\(^{-3}\) of wood ash, producing a maximum value of 0.20 g.

Gregory (2006) observed that the growth and distribution of roots are influenced by the way the nutrients are available in the soil and its quantity. Thus, calcium, potassium and phosphorus that are the main nutrients incorporated into the soil by means of wood ash, directly influence the growth and development of plant roots, which are important factors for the formation of nodules.

Bonfim-Silva; Santos; Vilela, (2013) observed an increase in dry mass production of black mucuna nodules (\textit{Stizolobium aterrimum}) with an increment of 43.92% in the dose of 15 g dm\(^{-3}\), when compared to the treatment that did not receive fertilization.

Nutrient deficiency, especially when referring to potassium and phosphorus may limit the nodulation of leguminous plants such as cowpea, compromising nitrogen fixation. Phosphorus is responsible for the transfer of adenosine triphosphate, and potassium by supplying plant photosynthates to the nitrifying bacteria both assisting in nodulation (NKAA; NWOKEOCHA; IHUOMA, 2014). Thus, it is worth mentioning the importance of wood ash as fertilizer, because it assists indirectly in the process of nodulation, because it has a relatively high quantity of both potassium and phosphorus, when compared to the concentrations of other nutrients (BONFIM-SILVA; SANTOS; VILELA, 2013).
With the result of the present study, we can infer that the increase in the number of nodules with the wood ash doses indicates that the use of this residue in the fertilization of cowpea favors the activity in the rhizosphere with nitrogen fixation by the plants.

4 CONCLUSIONS

Cowpea responds positively to the fertilization with wood ash, presenting better growth, development and production in the dose intervals between 35 g dm$^{-3}$ and 45 g dm$^{-3}$.

Wood ash responded as soil acidity concealer, presenting similar and better conditions in growth, development and production variables.

Wood ash acting as fertilizer in cowpea cultivation favors activity in the rhizosphere in soil corrected with limestone.
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