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Correction of Acidity of a Brazilian Cerrado Oxisol with Limestone and Wood Ash on the Initial Growth of Cowpea

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Abstract

Among Brazilian soils orders, there are some of it classified as acid soils, which need correction to guarantee crop productivity. Currently, limestone is the most used soil corrective and wood ash has been a sustainable alternative to this process. Thus, the objective was to evaluate the effect of two correctives of soil acidity on an Oxisol collected in the Brazilian Cerrado area using limestone and wood ash and the effect of soil correction on initial growth of cowpea. Two greenhouse experiments were carried out: 1) with limestone, using base saturation levels (V%) of 0, 20, 40, 60 and 80; and 2) wood ash, with doses of 0, 8, 16, 24 and 32 $g\cdot dm^{-3}$, both in five randomized blocks. At 40 days after sowing, it was verified that pH values were within the range considered ideal for soil (pH of 5 to 7), according to the increase of base saturation levels and wood ash doses, but limestone provided faster results. Initial growth of cowpea was positively influenced by soil correction with use of both correctives. Wood ash and limestone increased soil pH to adequate values and resulted in better initial crop development.

Keywords

Vigna unguiculata, Solid Waste Disposal, Alternative Soil Corrective, Soil pH

1. Introduction

Among the diversity of soil orders existing between the various Brazilian regions, there are some that present calcium, magnesium and phosphorus deficiency. These soils are known as acid soils. These soils contain high concentration of aluminum and manganese, being necessary the use of liming to increase crop production [1] [2].

In relation to the correctives used in agricultural system limestone is the most applied, being extracted from rocks composed of calcite, a mineral that contains calcium carbonate. In the limestone application, the incorporation has to be very well done, in order to guarantee the maximum possible contact of corrective with soil so that the chemical reactions that will result in increase of soil pH occur [3] [4].

As a result of increase in the use of residues from industrial processes, wood ash has presented potential of use in agricultural environment as an alternative soil corrective and fertilizer [5], due to the high concentrations of calcium, potassium and magnesium. This contributes to reduction of environmental impact due to the accumulation of solid waste in disposal sites, besides increasing crop productivity [6]. In this sense, wood ash reduces the frequent dependence of chemical fertilizers, besides offering a better destination to the solid residue [7].

Wood ash has the potential to act as soil corrective and fertilizer, because it contains calcium carbonate and magnesium, which can act in reduction of aluminum content present in the soil. In addition, wood ash has other essential nutrients for plant development, such as phosphorus and potassium [8] [9]. For recommendation use of wood ash, it is necessary to know its source material, soil and culture, in order to avoid sub or overdoses that can harm the plant.

Oxisol (Red Latosol) can be characterized as a deep mineral soil, with high iron oxide (Fe_2O_3) content and low natural fertility [10] [11]. In the Brazilian Cerrado the Latosols stand out because they occupy almost half of the area, being common in flat reliefs and plateaus [11]. Latosols present good rainfall drainage, low cation exchange capacity and nutrient deficiency. Due to ease of being corrected with fertilizers and limestone, it is the most used soil for crop production in the cited biome, and the most common exploitation in the region is the annual crops production [12] [13] [14].

A culture that has shown response in Red Latosol in the Brazilian Cerrado is cowpea (*Vigna unguiculata* (L.) Walp.). This soil class presents good drainage and low fertility, presenting good results from the application of soil correctives and fertilizers [15] [16].

Thus, it is shown the current study relevance of soil correction with limestone and vegetal ash, both being alternative techniques that have shown efficiency. The objective of this study was to evaluate the effect of two correctives of acidity on an Oxisol collected in Brazilian Cerrado area with use of limestone and wood ash and the correction effect on initial development of cowpea.

2. Material and Methods

The experiments were carried out in a greenhouse at the Institute of Agricultural and Technological Sciences (ICAT) of the Federal University of Mato Grosso (UFMT), campus Rondonópolis, at an average altitude of 227 meters, in the coordinates 16˚28'S and 54˚38'W.

Two soil correction experiments were performed: 1) using limestone ($CaMg(CO_3)_2$), in which were used five base saturation levels (V%): 0, 20, 40, 60 and 80, with 80% PRNT (total relative neutralizing power); and 2) using five wood ash doses: 0.8, 16, 24 and 32 g·dm^{-3}.

The experimental design was in randomized blocks, with 5 replicates, totaling 25 experimental units for each experiment. Wood ash used came from ceramic industrial sector and it was analyzed as fertilizer (**Table 1**).

The soil used in the experiment was an Oxisol collected in the 0.0 - 0.20 m soil layer, under Cerrado vegetation in experimental area of Federal University of Mato Grosso (UFMT). Soil samples were sieved in a 4 mm mesh and chemical and granulometric analysis was performed (**Table 2**). Subsequently, the soil was added in pots of 1 dm^{-3}. Limestone and wood ash were incubated in the soil, with moisture at 60% of maximum water retention capacity in the soil for a 30-days period [17].

Sowing occurred at 40 days after correctives incubation in the soil, and nine seeds were added in each pot. At 10 days after sowing, thinning was done leaving three vigorous plants per pot. Soil moisture was maintained at 80% of the maximum soil water retention capacity by daily weighing of all experimental plots.

At 10, 20, 30 and 40 days of soil-correctives incubation, a pH analysis was done by collecting soil samples with a 10 cm^{-3} capacity metering pipe. Ten grams of soil were collected in each pot for the analyzes, which were performed in two ways: with 0.01 mol·L^{-1} of $CaCl_2$ solution and with distilled water. Each sample was placed in a 50 ml container. In one of the samples were added 25 ml of $CaCl_2$ solution and 25 ml of distilled water in the other one. Thereafter, each sample was shaken for 30 seconds and allowed to stand for 30 minutes for $CaCl_2$

Table 1. Chemical composition of wood ash used.

pH	N	P_2O_5	K_2O	Ca	Mg	Na	SO_4	Zn	Cu	Fe	Mn	B	Si
$CaCl_2$	g kg^{-1}												
10.7	3.1	9.6	34.7	33.0	21.0	0.1224	2.0	0.1	0.0	10.3	0.4	0.1	274.4

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

Table 2. Chemical and granulometric analysis of the Oxisol sample collected in the 0 - 0.20 m soil layer.

pH ($CaCl_2$)	P	K	S	Ca	Mg	Al	H+Al	SB	CTC	V	M
	mg·dm^{-3}					cmolc·dm^{-3}				%	
4.0	1.3	33.0	2.0	0.4	0.2	1.1	5.7	0.7	6.4	10.7	61.8
Zn	Mn	Cu	Fe	B				M.O.	Argila	Silte	Areia
	mg·dm^{-3}								g·kg^{-1}		
4.0	10.4	0.6	60.0	0.15				21.2	455	100	445

solution and for 60 minutes for the samples with distilled water. After resting period all solutions were agitated again and the readings were made with pH meter [18].

Cowpea plants were evaluated at 25 days after sowing. The following response variables were evaluated: plant height, measuring with graduated ruler the distance from soil surface to the last fully expanded leaf; SPAD reading, which was performed on five random leaves in each pot using a portable chlorophyll meter (SPAD-502-PLUS model); fresh and dry shoot mass; fresh and dry root mass; and root volume. For this, plants were cut close to the soil surface and the soil was sieved in a 4 mm sieve for root separation. The roots and shoot were weighed to determine fresh mass. Roots were placed in a graduated cylinder containing a known volume of water. In this way, root volume corresponded to the volume of displaced water. The samples were dried with a forced air circulation oven at 65˚C for 48 h to evaluate dry masses.

The results were submitted to analysis of variance and regression analysis with up to 10% probability, using SISVAR software v.5.6 [19].

3. Results and Discussion

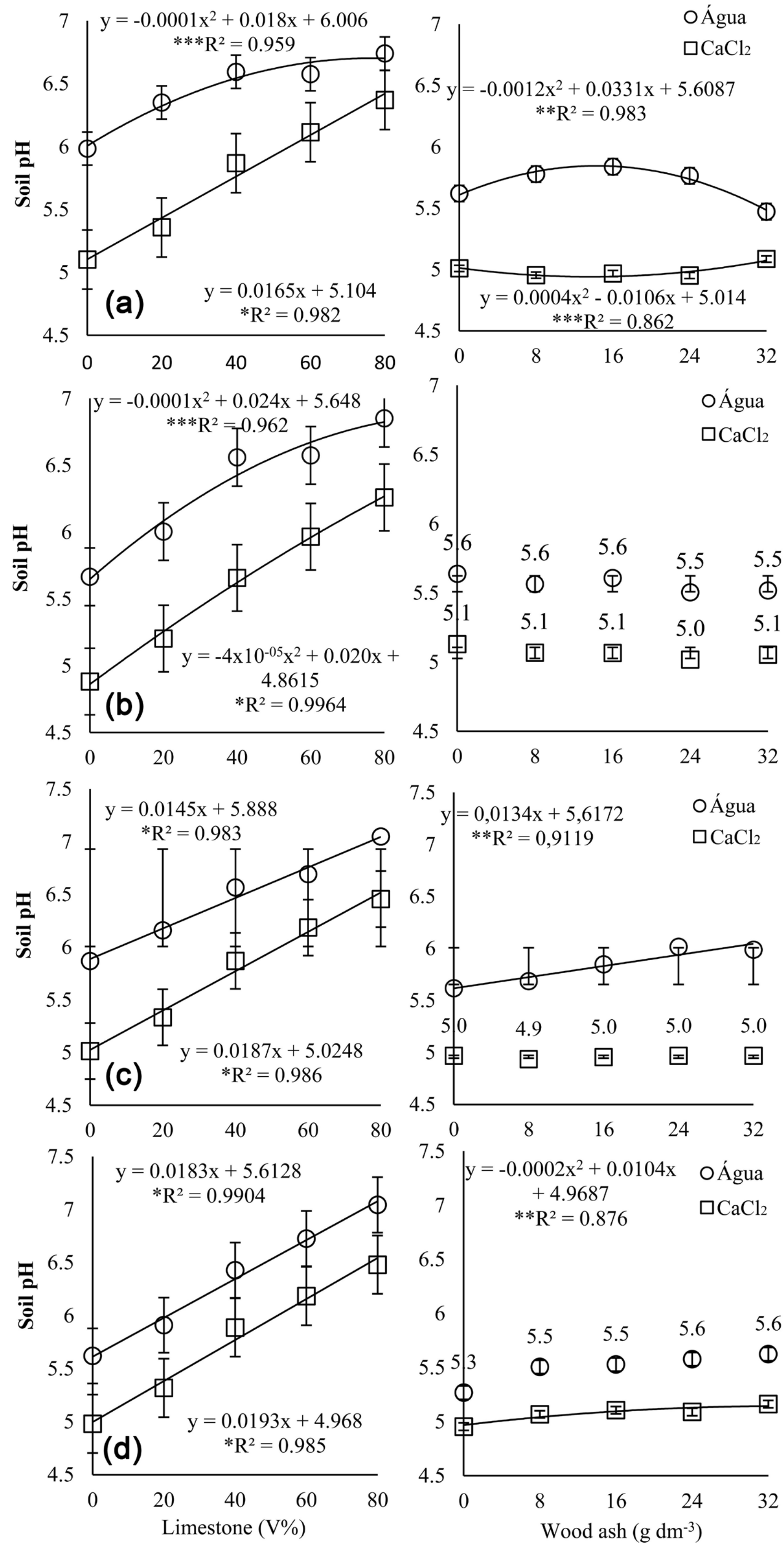
At 10 days after experiments beginning it was observed that soil pH values in distilled water and $CaCl_2$ solution, both using limestone and wood ash, were significantly influenced by applied doses.

The increase was 10.39% for limestone in distilled water and 24.06% for $CaCl_2$ solution, with soil pH adjusting to the quadratic and linear regression model, respectively, comparing in the highest base saturation dose (80%). Wood ash provided a 4.05% increase in soil pH using distilled water, adjusting to the quadratic regression model, with a maximum point at 14.32 $g \cdot dm^{-3}$ of wood ash and decreasing with dose increasing. For $CaCl_2$ solution, there was a decrease in soil pH value by 1.46% with the equation fitting to the quadratic model (**Figure 1(a)**).

Increasing soil pH provides greater nutrients availability. Studies have shown that increasing soil pH with liming results in a linear reduction of soil exchangeable Al^{3+} contents [20]. [21] reported that calcium carbonates ($CaCO_3$) and magnesium carbonate ($MgCO_3$) react with soil hydrogen releasing water and carbon dioxide. The aluminum is insolubilized in the hydroxide form.

At 10 days of incubation with wood ash, for both distilled water and $CaCl_2$ solution, an adequate pH value was not obtained for soil correction. [22] pointed out that this can be due to the fact that, in relation to limestone, the PRNT of wood ash are lower, which makes it less efficient in short term period. Wood ash presents particles larger than limestone, which may be beneficial for long-term soil correction and also for nutrient release to the plants [22].

At 20 days of incubation, considering the limestone base saturations, soil pH varied significantly (**Figure 1(b)**), both for distilled water and for $CaCl_2$ solution, with an increase of 17.98% and 37.46%, adjusting to the quadratic and linear regression model, respectively. However, according to [23], this result can be



* and **: significant at 0.1% and 1% of probability, respectively; Ns: not significant.

Figure 1. Soil pH under correction with limestone and wood ash at 10 (a); 0 (b); 30 (c); 40 (d) days of incubation.

attributed to increase in concentration of salts in the soil, since this increase reduces pH. On the other hand, values observed with application of wood ash did not present significant difference (**Figure 1(b)**).

With the 30-day period, it was possible observe that the limestone doses significantly influenced pH values, which adjustment to linear regression model and presented higher values for higher limestone doses, both for distilled water and $CaCl_2$ solution. Soil pH increased by 16.44% and 22.93%, respectively (**Figure 1(c)**).

The same was observed for soil pH in distilled water for wood ash, with equation adjusting to the linear model and an increase of 7.08%. However, when analyzing pH in $CaCl_2$ solution, there was no significant difference (**Figure 1(c)**). At 30 days of incubation, in relation to the 20 days, pH values with use of limestone continued to decrease. This result was also reported by [24], who observed that this decrease in pH values over time is slightly linked to the release of H^+ ions, as a consequence of organic matter mineralization in the soil. The environmental temperature, soil tillage and soil field capacity may have influenced these results [24].

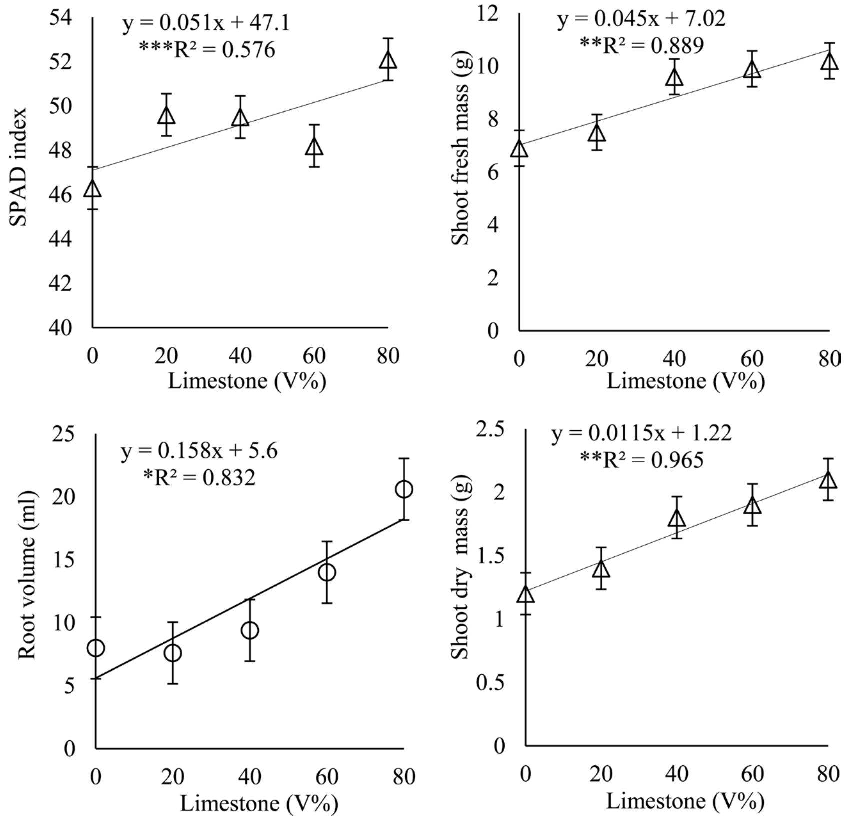
From the pH analyzes at 40 days, pH values were adjusted to the linear regression model, presenting a significant difference between limestone base saturations (**Figure 1(d)**). Increase in soil pH was 20.71% and 23.64% for distilled water and $CaCl_2$ solution, respectively. Regarding wood ash doses, soil pH values in distilled water did not present a significant statistical difference. However, soil pH in $CaCl_2$ solution presented significant effect, with the equation adjusting to the quadratic regression model, with increase by 3.42% in pH value (**Figure 1(d)**).

At 40 days after incubation, it was observed that both limestone and wood ash had values considered ideal for a corrected soil, as the doses increased. [24] reported that in soils with pH levels of 5.50 exchangeable aluminum are very low or inexistent. Depending on the soil the pH value can vary from 5 to 5.50, favoring nutrients availability to the plant.

Plant height under limestone and wood ash correction did not present significant difference, presenting an average of 24.24 and 23.04 cm, respectively. Limestone corrects soil, but it does not have nutrients for the plant, besides Ca and Mg, which may explain absence of significant difference in plant height. [25] observed that soybean cultivated under liming and phosphorus fertilization had no significant difference between applied limestone doses. [26] reported that application of limestone in corn crop did not cause significant difference in plant height.

In limestone experiment there was a significant difference. Dose applied was adjusted to linear regression model and there was an increase of 7.98% in SPAD reading with increasing doses (**Figure 2** and **Figure 3**). On the other hand, wood ash had no significant effect on the chlorophyll index and mean value for this response variable was 48.96.

According to [27], relative chlorophyll index is related to the nitrogen concentration present in leaves as a function of contribution of this nutrient in plant



* and **: significant at 0.1% and 1% of probability, respectively; Ns: not significant.

Figure 2. SPAD index, fresh and dry shoot mass and root volume of cowpea under limestone and wood ash soil correction at 25 days after sowing.

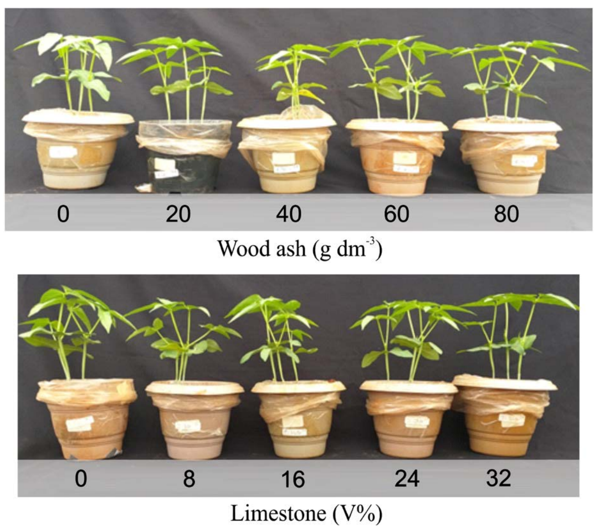


Figure 3. Growth of cowpea under limestone and wood ash soil correction at 25 days after sowing.

chloroplasts, conferring green coloration. Thus, it can be concluded that chlorophyll contents found in the work using SPAD index indicated an increase in nitrogen absorption by plants as the increase of applied limestone doses.

In relation to shoot fresh mass there was a significant difference for the experiment with limestone, with an increase of 47.82% in shoot fresh mass for highest limestone dose (V of 80%) (**Figure 2** and **Figure 3**). Unlike limestone, wood ash did not present significant result with applied doses, which can be explained by little time of plant development, since its evaluation was made only in the initial growth phase.

For shoot dry mass limestone showed significant difference and there was an increase in dry mass by 40.61% for the highest base saturation level (**Figure 2**). However, in the experiment performed with wood ash doses there was no significant difference. However, [28] in a study carried out with marandu grass, verified that wood ash doses provided greater shoot dry mass. The results of [28] corroborate with [29], who evaluated the xaraés and marandu grasses and verified that there was a isolated significant effect of forages with wood ash doses.

When analyzing fresh and dry root mass, there was effect of limestone in these response variables, with both equations adjusting to the linear regression model, with an increase by 65.13% in root fresh mass and 78.42% of root dry mass. The use of wood ash did not have a significant effect on the fresh and dry root mass (**Figure 2**).

Regarding the limestone, root dry mass production was significant with limestone application, corroborating with study by [25], where the application of limestone influenced root dry matter accumulation. [30] verified that the dolomitic limestone did not influence root dry matter, assuming that root system of "angelim-pedra" does not develop with limestone application to supply correction need or calcium and magnesium.

In the experiment with wood ash there was no significant effect to root dry mass production, this was demonstrated by [31] in his experiment, in which he explains that this probably occurs due to increase of saline concentration promoted by ashes. [32] reported that excessive use of wood ash can damage plant roots because they are excessively alkaline. But [28] in his study verified that use of wood ash in cultivation of marandu grass in Oxisol increased root dry mass production, confirming importance of wood ash to increase soil fertility. It is important, therefore, adopt adequate wood ash doses in agricultural activity. Both lack of soil nutrients and excess of wood ash can reduce crop yields.

When considering root volumes, it was observed that use of limestone provided significant difference, with the equation being adjusted to linear regression model, with increase in volume by 69.30%, with maximum base saturation (**Figure 2**). Regarding wood ash, data obtained did not present significant difference between doses applied in the experiment.

Root volume with limestone use varied significantly. [33] also verified a positive effect of liming on the root volume of cowpea at different limestone rates. This increase refers to length and root surface.

Wood ash did not have expected results with the experiment, and treatment with absence of this solid residue reached a root volume higher than other doses, being below only the application of 8 g·dm^{-3}. [34] reported that with nutrients supply plants develop producing a greater root length density, that is, a greater root amounts per explored soil volume. With evaluation done only at the beginning of cowpea development, results with use of wood ash were less expressive.

4. Conclusions

Limestone and wood ash applied to Oxisol, at the end of 40 days, increased soil pH, and in the limestone experiment reaction was faster than with wood ash.

Best results were provided for limestone with 80% of base saturation and for wood ash at 32 g·dm^{-3}.

Cowpea cultivated in corrected soil with limestone presented better conditions in all evaluated response variables in relation to wood ash.

Although the efficiency of wood ash as soil acidity corrective is proven, there is still a need for further studies with wood ash doses as corrective to calculate the most suitable doses for cowpea cultivation in Cerrado Oxisol.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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