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# Using MB-4 rock powder, poultry litter biochar, silicate and calcium carbonate to amend different soil types

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**Abstract**

The acids soils require lime materials to increase their pH and base saturation percentage. Soil acidity correction practice is restricted to limestone use. There is little information regarding the effects of others materials on soil amendment. This laboratory experiment was carried out to evaluate the effect of different materials on Ultisol, Oxisol and Entisol pH, as corrective material to amend acidity of acid soils, compared to common application of calcium carbonate and steel slag. Therefore, an experiment was conducted in laboratory, involving soils incubation treatments for 100 days. The treatments consisted of four corrective agents: rock powder, MB-4, poultry litter biochars, silicate and calcium carbonate, evaluated by the base saturation method, with correction levels from 40 to 80% for Ultisol and Entisol and from 20 to 80% for Oxisol and in three replicates. After the incubation period the soil samples were chemically analyzed. The results of this study confirmed the effectiveness of poultry litter biochar, MB-4, silicate and calcium carbonate for improving the chemical properties of Ultisol, Oxisol and Entisol. The results indicated that the improvements of soil characteristics are changed with variations in the amount of corrective agents added to the soil and time of incubation.The results showed that pH increased significantly with increasing application rates of correcting agents, reflecting the fact that the liming potential increased with increasing application rates of corrective materials. The sequence order of greater efficiency in the neutralization of the acidity of the soil was calcium carbonate > silicate > MB-4 >biochar.

**Keywords:** Residue industrial, Base saturation, Organic wastes, pH.

## Introduction

Acidic soils, having a high concentration of hydrogen ions and / or aluminum in the soil, promote the appearance of toxic metals such as Aluminum (Al) to plants and cause a reduction in nutrient availability to the soil and consequently low production yields. Therefore, the correction of soil acidity (liming) is considered as one of the practices that significantly contributes to the increase of efficiency of fertilizers and agricultural productivity. In Brazil, the most common material is being used for the acidity correction is limestone, whose components are the carbonates of calcium and/or magnesium which reacts with hydrogen soil release water and carbon dioxide and aluminum in the form of hydroxide.

Many other materials have been tested and used for the same purpose, but with very wide efficiency. Among these materials, steel slag, abundant sources of silicates, originated from iron ore, which is processed from the reaction between lime and silica ($SiO_2$) at high temperatures (Malavolta et al., 1981), have shown promising as corrective soil acidity (Chaves and Farias, 2008). The effect of slag on the soil reaction, is probably due to the neutralization of protons ($H^+$) by silicate anion ($SiO_3^{-2}$), present in the soil due to the solubilization of this product (Alcarde, 1992). In addition to this slag, the MB-4, a rock dust from grinding of silicate rock, has been used as a soil improver. This material is a mixture of two rocks, the biotitaxisto and serpentinite in the ratio of 1:1, having magnesium silicate composition, together with calcium and iron phosphate, potash and sulfur and several micronutrients, such as copper, zinc, manganese and cobalt (MIBASA, 2007).

The use of rock powders in soil is antique; however, a recent increase in the use of these materials in agriculture has been observed in several studies that evaluate their effects on soil (Camargo et al., 2012). According to Miyasaka et al. (2004), MB-4 is efficient recovery, soil improver and rejuvenating to possess a wide variety of chemicals, providing essential nutrients to plants. However, these authors did not comment about the soil acidity neutralization. Unlike that, according to Borges et al. (2003) the use of this material in the soil could theoretically replace the lime in the soil correction due to its chemical composition. The same way, Pontes et al. (2005) observed that the MB-4 increased the pH of the soil under *Coriandrum sativum* cultivated. However, this result is questionable since the release of silicon-MB-4 for soil is very low (Pereira et al., 2003). The Biochar, a carbon-rich compound, produced by the slow

**Table 1**. Chemical characterization of soil samples used for the tests.

| Attributes Chemical | Ultisol | Oxisol | Entisol |
|---|---|---|---|
| Calcium ($cmol_c\ kg^{-1}$) | 2.02 | 2.06 | 0.78 |
| Magnesium ($cmol_c\ kg^{-1}$) | 1.46 | 1.60 | 1.19 |
| Sodium ($cmol_c\ kg^{-1}$) | 0.09 | 0.09 | 0.08 |
| Potassium ($cmol_c\ kg^{-1}$) | 0.14 | 0.07 | 0.14 |
| Sum of bases ($cmol_c\ kg^{-1}$) | 3.71 | 3.85 | 2.19 |
| Hydrogen ($cmol_c\ kg^{-1}$) | 6.36 | 11.97 | 2.72 |
| Aluminum ($cmol_c\ kg^{-1}$) | 0.40 | 0.40 | 0.20 |
| CTC ($cmol_c\ kg^{-1}$) | 10.07 | 16.22 | 5.11 |
| Organic matter ($g\ kg^{-1}$) | 11.90 | 31.50 | 9.60 |
| Comparable phosphorus ($mg\ kg^{-1}$) | 3.20 | 2.60 | 11.40 |
| pH $H_2O$ (1:2.5) | 5.12 | 5.14 | 5.30 |
| V% | 36.84 | 23.74 | 42.85 |

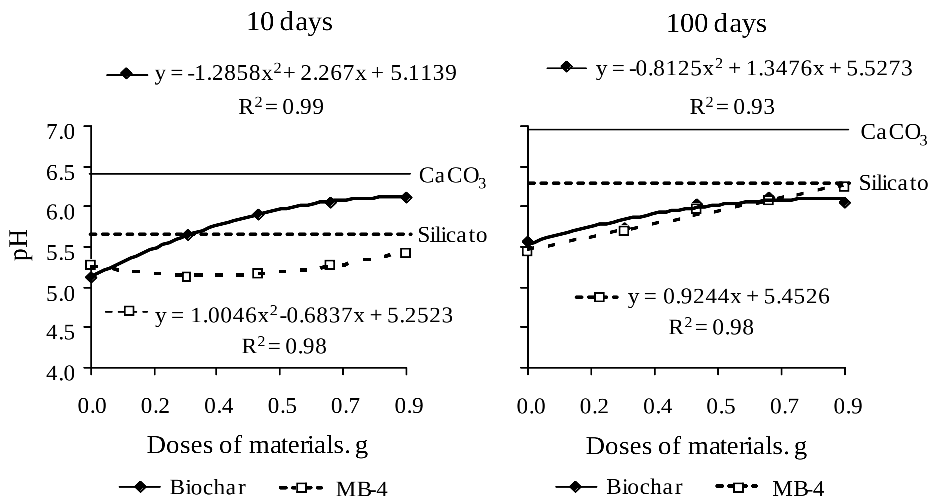


**Fig 1.** pH values due to the split of doses in material at 10 and 100 days of incubation.

thermo-chemical pyrolysis of biomass materials has been applied to the soil as an amendment agent. The biochar can improve the physical and chemical properties (Lehmannet al., 2006) of soil, reduce leaching of N, neutralize soil acidity, reduce the amount of extractable aluminum, and other benefits (Asai et al., 2009). Organic wastes, such as livestock manures, sewage sludge, crop residues and composts are converted to biochars. The production of biochar from animal waste has higher nutritional value regarding the biochar produced from vegetable waste. Poultry litter is of special interest for the production of biochar in Brazil due to the high production generated by year which reportedly is around 6.8 million $m^3$ (Corrêa and Miele, 2011). Accrding to Sanvong and Suppadit (2013) the poultry litter biochar can be effectively used as a fertilizer and soil conditioner. The results regarding the soil acidity neutralization through the application of MB-4 as well as poultry litter biochar in soil are few. Therefore, the aim of this study was to evaluate the effect of these products, as the corrective agents of pH in acid soils, comparing to the calcium carbonate and steel slag.

**Results and Discussion**

The analyses of variance of pH values of samples Ultisolare presented in Table 3. The results indicate that there is a significant effect of different materials, biochar and MB-4, on soil pH levels on 10 and 70 days after incubation, respectively, at 1% and 5% level of probability,. The doses of these materials had a significant effect on soil pH in all incubation periods ($p \leq 0.01$). However, the interaction of materials and doses was significant for soil pH level only to 10 and 100 days incubation. According to Lopes et al. (2014), the interaction of soil and rock powder, ie, basalt powder was significant for pH levels. At 10 and 70 days of incubation, soil pH values that received biochar were upper and lower than the those soil received MB-4, respectively. In the other incubation periods, the pH values were similar although higher values observed with biochar (Table 4).

The low effect of MB-4 on the soil reaction, is probably due to very low release of silicon-MB-4, i.e., the low neutralization of protons ($H^+$) by silicate anion ($SiO_3^{-2}$), which present in the soil from the solubilization of this product. According Pereira (2003), the soluble Si content in $Na_2CO_3$ + $NH_4NO_3$ is only 0.45%, which is characterized by the low reaction on the soil.

In all periods of incubation pH values of Ultisol treated with biochar and MB-4 increased as a function of increasing doses of these materials. Silva et al. (2012) observed increased soil pH as a function of increasing doses of ultramafic rock. However, this is contrary to what was observed by Lopes et al. (2014) that evaluated the basalt powder. Even though, values of biochar and MB-4 were lower than the values of the soil pH incubated with calcium carbonate and silicate. The data obtained with the calcium carbonate and the silicate, especially with the last dose, calculated for to 80% of base saturation, were used as reference to evaluate biochar and MB-4 behavior.

The purposes of applying calcium carbonate and silicate in the soil were similar in correcting soil acidity. In general, application of calcium carbonate can improve the soil's pH (Table 4). Comparison of pH values of the reference material (additional M) with biochar and MB-4, shows that these treatments have lower values, even double quantities and doses of them are applied (Table 4).

According to the split shown in Table 5, it is observed that the behavior of the soil pH values with biochar and MB-4

**Table 2**. Quantity of materials used to achieve different soil base saturation percentages.

| SOIL | Base saturation percentages | Quantity of materials used (g) to 0.3 kg of soil | | | |
|---|---|---|---|---|---|
| | | Calcium carbonate | Silicate | Biochar | MB-4 |
| | 20 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 40 | 0.335 | 0.519 | 0.670 | 0.670 |
| Oxisol | 50 | 0.540 | 0.839 | 1.080 | 1.080 |
| | 60 | 0.745 | 1.159 | 1.490 | 1.490 |
| | 70 | 0.955 | 1.478 | 1.910 | 1.910 |
| | 80 | 1.160 | 1.798 | 2.320 | 2.320 |
| | 40 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 50 | 0.133 | 0.207 | 0.267 | 0.267 |
| Ultisol | 60 | 0.234 | 0.364 | 0.469 | 0.469 |
| | 70 | 0.336 | 0.521 | 0.672 | 0.672 |
| | 80 | 0.437 | 0.678 | 0.875 | 0.875 |
| | 40 | 0.0 | 0.0 | 0.0 | 0.0 |
| Entisol | 50 | 0.036 | 0.056 | 0.072 | 0.072 |
| | 60 | 0.087 | 0.135 | 0.175 | 0.175 |
| | 70 | 0.138 | 0.214 | 0.276 | 0.276 |
| | 80 | 0.189 | 0.292 | 0.377 | 0.377 |

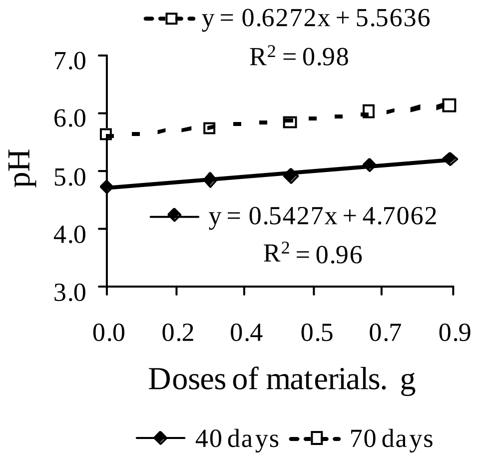


**Fig 2**. pH values due to the effect of the material isolated at 40 and 70 days incubation.

varied with the concentration in the soil and at different times, which at 10 days of incubation were fitted with second degree polynomial equations and at 100 days of incubation. The data of biochar were fitted with second degree polynomial equation and of MB-4 was fitted to the linear equation (Fig. 1).

There was no significant interaction between material and doses for the period from 40 to 70 days of incubation. Fig. 2 the pH linear behavior in relation doses is presented. The analyses of variance of pH values of Oxisol are presented in Table 6. The results indicate that there was a significant effect of different materials (M), biochar and MB-4, and doses on soil pH levels on 10, 40, 70 and 100 days incubation ($p \leq 0.01$). The interaction of materials and doses was significant for soil pH levels. According to Jien and Wang (2013), the biochar (made from the waste wood of white lead trees) application in a highly weathered soil increased the soil pH. In the same way, there was a significant difference between calcium carbonate and silicate (additional M) and between M with additional Mat at 1% level of probability.

According to the data presented in Table 7, except for the 10 days of incubation, the larger soil pH values were achieved with MB-4 application, contrary to what was observed in the Ultisol. Even then, after applying biochar and MB-4 to the soils and incubating for 100 d, the amended soils had a significantly higher soil pH than the control samples (5.12).

In all incubation periods the pH values increased as a function of higher doses of corrective agents corroborating with Jien and Wang (2013). As occurred in Ultisol, calcium carbonate had better neutralizing effect on soil acidity than silicate, but these two were better than the biochar and MB-4 in increasing the soil pH (Table 7).

According to the split shown in Table 8, it is observed that the behavior of the soil pH values with biochar and MB-4 varied with their concentration in the soil and at different times. The behaviors of these data are shown in Fig. 3.

Soil pH values with biochar and MB-4 treatments increased as a function of higher doses. However, it did not reach to silicate and calcium carbonate values, used as reference (Fig 3). The analyses of variance of pH values of samples Entisol are presented in Table 9. Except for pH values observed in relation to the materials (M) at 10 days of incubation, the results indicate that there was a significant effect of different

**Table 3.** Analysis of variance of pH Ultisol on different day's incubation depending on the materials, biochar and MB-4, and dosages of these materials, comparison of these values with additional materials, carbonate and silicate, as reference.

| Source of variation | DF | Mean Square | | | |
|---|---|---|---|---|---|
| | | 10 | 40 | 70 | 100 |
| Materials (M) | 1 | 1.31** | 0.001ns | 0.06* | 0.002ns |
| Doses (D) | 4 | 0.22** | 0.143** | 0.18** | 0.291** |
| Linear | 1 | 0.876** | 0.559** | 0.731** | 1.095** |
| Quadratic | 1 | 0.009ns | 0.010ns | 0.001ns | 0.060** |
| Deviation | 2 | 0.001ns | 0.002ns | 0.002ns | 0.005ns |
| M x D | 4 | 0.139** | 0.019ns | 0.011ns | 0.0152* |
| Doses in biochar | 1 | 0.11**Q | - | - | 0.04**Q |
| Doses in MB-4 | 1 | 0.069**Q | - | - | 0.803**L |
| M x additional M | 1 | 0.89** | 2.35** | 2.24** | 1.67** |
| $CaCO_3$xSilicate | 1 | 0.56** | 0.25** | 0.062* | 0.360** |
| Treatments | 11 | 4.22** | 0.296** | 0.287** | 0.297** |
| CV (%) | | 1.69 | 3.19 | 1.57 | 0.94 |
| General mean | | 5.75 | 5.3 | 6.15 | 6.15 |

Significant at 0.05 (*) and at 0.01 (**) of probability; (ns) not significant; DF: degree of freedom; CV: Coefficient of variation; additional M = additional materials ($CaCO_3$and Silicate)

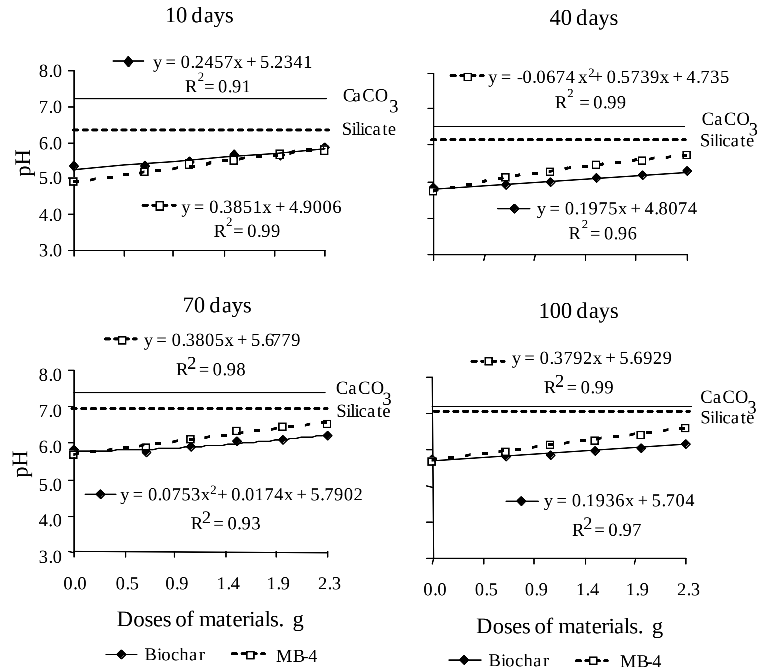


**Fig 3**. pH values due to the split of doses in material from 10 to 100 days of incubation in Oxisol.

materials (M), biochar and MB-4, and doses on soil pH levels on 10, 40, 70 and 100 days after incubation (p≤0.01). The interaction of materials and doses were significant on soil pH level (p≤0.01 and 0.05). In the same way there was a significant difference between calcium carbonate and silicate (additional M) however, only with 10 days of incubation and between M with additional M (p≤0.01).

Soil pH values were increased over the incubation time after biochar and MB-4 treatments and as a function of increasing doses (Table 10). The highest values were observed with the application of MB-4, since this material has more ions responsible for the neutralization of soil acidity than biochar. The difference between the pH values of experimental units that received calcium carbonate and silicate was small (Table 10), showing that these two corrective agents have similar effects on soil acidity neutralization corroborating with Souza and Chaves, (2015) that compared the neutralizing effect of limestone and silicate in Ultisol and Oxisol.

In all incubation periods, soil pH values with additional material (calcium carbonate and silicate) were higher from soil pH values with material (biochar and MB-4).

The behavior of data (Table 11) on interaction of biochar and MB-4 for doses at different incubation periods is shown in Fig 4. In addition to the soil pH variation as a function of corrective agents, the sum of bases also varied. The sum of bases ranged from 3.90 to 7.19 $cmol_c\ kg^{-1}$; 3.64 to 4.35 $cmol_c\ kg^{-1}$and 2.03 to 2.53 $cmol_c\ kg^{-1}$, after increasing doses of biochar in Oxisol, Ultisol and Entisol, respectively. Practically, the aluminum level did not change when the hydrogen level decreased. So, the cation exchange capacity (CEC) decreased contrary to what was observed by Jien and Wang (2013). Consequently, the base saturation percentage reflects the increase in bases in all soils and decreased potential soil acidity (Table 12). It is important to note that the greatest contribution to the sum of the bases was created with sodium and potassium elements. The variation of

**Table 4.** Comparison of pH values between corrective agents and between doses observed at different times of incubation.

| Source | Incubation days | | | |
|---|---|---|---|---|
| | 10 | 40 | 70 | 100 |
| Materials (M) | | | | |
| Biochar | 5.76 a | 4.96 a | 5.79 b | 5.90 a |
| MB-4 | 5.25 b | 4.95 a | 5.91 a | 5.88 a |
| Doses | | | | |
| 0 | 5.18 | 4.74 | 5.59 | 5.50 |
| 0.267 | 5.37 | 4.84 | 5.71 | 5.72 |
| 0.469 | 5.55 | 4.90 | 5.82 | 5.98 |
| 0.672 | 5.64 | 5.08 | 6.01 | 6.08 |
| 0.875 | 5.78 | 5.21 | 6.12 | 6.15 |
| Additional Material | | | | |
| $CaCO_3$ | 6.40a | 6.05a | 6.80a | 6.90a |
| Silicate | 5.65b | 5.55a | 6.55b | 6.30b |
| M xAdditional M | | | | |
| Materials | 5.51b | 4.96b | 5.85b | 5.89b |
| Additional M | 6.03a | 5.80a | 6.68a | 6.60a |

Different lowercase letters in the same column represent significantly different means (Tukey's test $p \leq 0.05$).

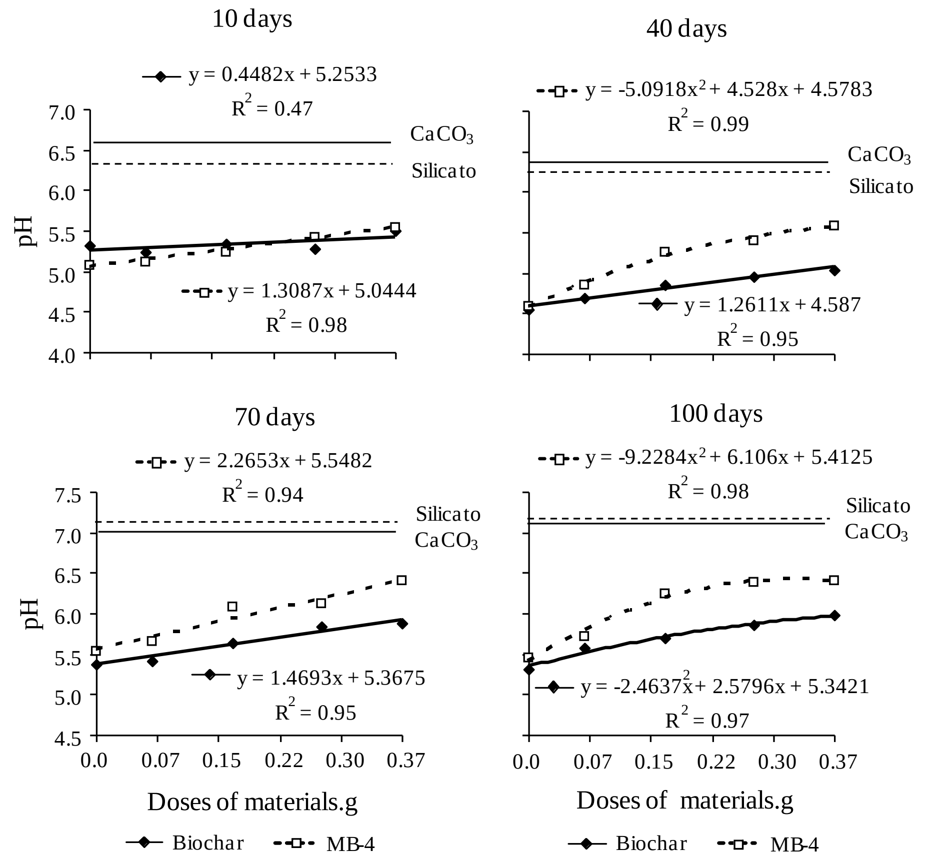


**Fig 4.** pH values due to the split of doses in material from 10 to 100 days of incubation in Entisol.

calcium and magnesium level was very small (data not presented).

According to Glaser et al. (2002) the increase in the amount of exchangeable cations is proportional to the amount of added biochar, because higher amounts of added biochar to the soil increase the ash content cations in soil solution. This enters rapidly to the equilibrium with the adsorption surface of the colloids by electrostatic forces.

The application of different types of biochar triggers variable results regarding the availability of nutrients in the soil, growth and crop yields. This research used biochar from poultry litter which probably resulted in the ashes with higher levels of potassium the sodium. After increasing doses of MB-4 in Oxisol, Ultisol and Entisol, the sum of bases ranged from 3.88 to 6.99cmol$_c$ kg$^{-1}$; 3.56 to 4.91 cmol$_c$ kg$^{-1}$ and 2.10 to 2.53 cmol$_c$ kg$^{-1}$, respectively. Unlike the biochar, in this case, the elements such as calcium and magnesium were predominant in soil without practically varying the levels of sodium and potassium corroborating with Lopes et al. (2014). Likewise, the sum of bases were increased, the CEC decreased and consequently, the base saturation percentage increased (Table 12). Table 12 shows that the MB-4 application in soils, practically was better than biochar.

**Table 5.** Split the interaction between materials and doses in time of incubation.

| Material | Dose (g) | | | | |
|---|---|---|---|---|---|
| | 0 | 0.267 | 0.469 | 0.672 | 0.875 |
| | | | 10 Days | | |
| Biochar | 5.11 a | 5.64 a | 5.90 a | 6.04 a | 6.12 a |
| MB-4 | 5.25 a | 5.10 b | 5.20 b | 5.25 b | 5.45 b |
| | | | 100 Days | | |
| Biochar | 5.56 a | 5.74 a | 6.02 a | 6.12 a | 6.05 b |
| MB-4 | 5.45 a | 5.70 a | 5.95 a | 6.05 a | 6.25 a |

Different lowercase letters in the same column represent significantly different means (Tukey's test p≤ 0.05).

**Table 6.** Analysis of variance of pH Oxisol on different days of incubation depending on the materials, biochar and MB-4, and dosages of these materials. Comparison of these values with additional materials, carbonate and silicate, as reference (Control).

| Source of variation | DF | Mean Square | | | |
|---|---|---|---|---|---|
| | | 10 | 40 | 70 | 100 |
| Materials (M) | 1 | 0.15** | 0.37** | 0.190** | 0.28** |
| Doses (D) | 5 | 0.28** | 0.26** | 0.245** | 0.23** |
| Linear | 1 | 1.410** | 1.3278** | 1.188** | 1.1743** |
| Quadratic | 1 | 0.002ns | 0.0007ns | 0.002ns | 0.0010ns |
| Deviation | 3 | 0.003ns | 0.0015ns | 0.012* | 0.0004ns |
| M x D | 5 | 0.0203* | 0.0394** | 0.0292** | 0.0262** |
| Doses in biochar | 1 | 0.427**L | 0.27**L | 0.02*Q | 0.269**L |
| Doses in MB-4 | 1 | 1.05**L | 0.016*Q | 1.04**L | 1.027**L |
| M x additional M | 1 | 5.52** | 4.70** | 3.77** | 3.77** |
| $CaCO_3$xSilicate | 1 | 0.6480** | 0.1482** | 0.1600** | 0.0121* |
| Treatments | 13 | 0.604** | 0.519** | 0.423** | 0.41** |
| CV (%) | | 1.45 | 1.00 | 0.82 | 0.73 |
| General mean | | 6.04 | 5.67 | 6.51 | 6.41 |

Significant at 0.05 (*) and at 0.01 (**) of probability; (ns) not significant; DF: degree of freedom; CV: Coefficient of variation; additional M = additional materials ($CaCO_3$ and Silicate).

**Table 7.** Comparison of pH values between corrective agents and between doses observed at different times of incubation.

| Source | Incubation days | | | |
|---|---|---|---|---|
| | 10 | 40 | 70 | 100 |
| Materials (M) | | | | |
| Biochar | 5.54 a | 5.05b | 5.98 b | 5.95b |
| MB-4 | 5.38 b | 5.31 a | 6.15 a | 6.16 a |
| Doses | | | | |
| 0 | 5.09 | 4.79 | 5.75 | 5.71 |
| 0.67 | 5.25 | 5.00 | 5.82 | 5.87 |
| 1.08 | 5.40 | 5.13 | 6.00 | 6.01 |
| 1.49 | 5.56 | 5.28 | 6.18 | 6.12 |
| 1.91 | 5.64 | 5.36 | 6.27 | 6.23 |
| 2.32 | 5.82 | 5.51 | 6.36 | 6.37 |
| Addicional Material | | | | |
| $CaCO_3$ | 7.14a | 6.55a | 7.32a | 7.16a |
| Silicate | 6.33b | 6.16a | 6.92b | 7.05b |
| M xAddicional M | | | | |
| Materials | 5.46b | 5.18b | 6.07b | 6.06b |
| Addicional M | 6.73a | 6.35a | 7.12a | 7.11a |

Different lowercase letters in the same column represent significantly different means (Tukey's test p≤ 0.05).

**Table 8.** Split the interaction between materials and doses in time of incubation.

| Material | Dose (g) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 0.67 | 1.08 | 1.49 | 1.91 | 2.32 |
| | | | 10 Days | | | |
| Biochar | 5.31 a | 5.32 a | 5.46 a | 5.63 a | 5.65 a | 5.87 a |
| MB-4 | 4.87 b | 5.17 a | 5.35 a | 5.49 a | 5.63 a | 5.77 a |
| | | | 40 Days | | | |
| Biochar | 4.85 a | 4.90 b | 5.00 b | 5.10 b | 5.17 b | 5.30 b |
| MB-4 | 4.73 b | 5.10 a | 5.27 a | 5.46 a | 5.55 a | 5.72 a |
| | | | 70 Days | | | |
| Biochar | 5.82 a | 5.76 b | 5.90 b | 6.04 b | 6.11 b | 6.21 b |
| MB-4 | 5.68 b | 5.88 a | 6.10 a | 6.32 a | 6.42 a | 6.51 a |
| | | | 100 Days | | | |
| Biochar | 5.74 a | 5.81 b | 5.88 b | 5.99 b | 6.07 b | 6.18 b |
| MB-4 | 5.68 a | 5.94 a | 6.14 a | 6.26 a | 6.40 a | 6.57 a |

Different lowercase letters in the same column represent significantly different means (Tukey's test p≤ 0.05).

**Table 9**. Analysis of variance of pH Entisolon different days incubation depending on the materials, biochar and MB-4, and dosages of these materials. Comparison of these values with additional materials, carbonate and silicate, as reference (Control).

| Source of variation | DF | Mean Square | | | |
|---|---|---|---|---|---|
| | | 10 | 40 | 70 | 100 |
| Materials (M) | 1 | 0.016ns | 0.505** | 0.52** | 0.63** |
| Doses (D) | 4 | 0.078** | 0.369** | 0.33** | 0.46** |
| Linear | 1 | 0.288** | 1.407** | 1.316** | 1.708** |
| Quadratic | 1 | 0.016ns | 0.060* | 0.011ns | 0.146** |
| Deviation | 2 | 0.004ns | 0.004ns | 0.014* | 0.002ns |
| M x D | 4 | 0.0225* | 0.0426** | 0.023** | 0.0435** |
| Doses in biochar | 1 | 0.036*L | 0.308**L | 0.403**L | 0.013**Q |
| Doses in MB-4 | 1 | 0.32**L | 0.05*Q | 0.975**L | 0.1812**Q |
| M x additional M | 1 | 4.80** | 6.32** | 5.41** | 5.21** |
| $CaCO_3$xSilicate | 1 | 0.0441* | 0.0090ns | 0.008ns | 0.0012ns |
| Treatments | 11 | 0.478** | 0.77** | 0.673** | 0.71** |
| CV (%) | | 1.32 | 1.47 | 0.92 | 0.46 |
| General mean | | 5.85 | 5.47 | 6.25 | 6.21 |

Significant at 0.05 (*) and at 0.01 (**) of probability; (ns) not significant; DF: degree of freedom; CV: Coefficient of variation; additional M = additional materials ($CaCO_3$ and Silicate).

**Table 10**. Comparison of pH values between corrective agents and between doses observed at different times of incubation.

| Source | Incubation days | | | |
|---|---|---|---|---|
| | 10 | 40 | 70 | 100 |
| Materials (M) | | | | |
| Biochar | 5.34 a | 4.82 b | 5.63 b | 5.68 b |
| MB-4 | 5.28 a | 5.13 a | 5.96 a | 6.04 a |
| Doses | | | | |
| 0 | 5.19 | 4.56 | 5.45 | 5.38 |
| 0.072 | 5.18 | 4.77 | 5.53 | 5.64 |
| 0.1748 | 5.29 | 5.05 | 5.86 | 5.97 |
| 0.276 | 5.35 | 5.17 | 5.98 | 6.11 |
| 0.3774 | 5.52 | 5.30 | 6.14 | 6.19 |
| Additional Material | | | | |
| $CaCO_3$ | 6.62 a | 6.40 a | 7.03 a | 7.10 a |
| Silicate | 6.41 b | 6.31 a | 7.12 a | 7.13 a |
| M xAddicional M | | | | |
| Materials | 5.31 b | 4.98 b | 5.80 b | 5.86 b |
| Additional M | 6.51 a | 6.35 a | 7.07 a | 7.11 a |

Different lowercase letters in the same column represent significantly different means (Tukey's test p≤ 0.05).

**Table 11.** Split the interaction between materials and doses in time of incubation.

| Material | Dose (g) | | | | |
|---|---|---|---|---|---|
| | 0 | 0.072 | 0.1748 | 0.276 | 0.3774 |
| | | | 10 Days | | |
| Biochar | 5.31 a | 5.24 a | 5.34 a | 5.28 a | 5.50 a |
| MB-4 | 5.07 b | 5.12 a | 5.24 a | 5.42 a | 5.55 a |
| | | | 40 Days | | |
| Biochar | 4.54 a | 4.69 a | 4.86 b | 4.95 b | 5.03 b |
| MB-4 | 4.58 a | 4.85 a | 5.25 a | 5.40 a | 5.58 a |
| | | | 70 Days | | |
| Biochar | 5.38 b | 5.42 b | 5.64 b | 5.84 b | 5.88 b |
| MB-4 | 5.53 a | 5.65 a | 6.08 a | 6.12 a | 6.40 a |
| | | | 100 Days | | |
| Biochar | 5.31 b | 5.57 b | 5.69 b | 5.85 b | 5.98 b |
| MB-4 | 5.45 a | 5.71 a | 6.25 a | 6.38 a | 6.40 a |

Different lowercase letters in the same column represent significantly different means (Tukey's test p≤ 0.05).

**Table 12**. Base saturation percentage after 100 days of incubation with calcium carbonate, silicate, biochar and MB-4 in Oxisol, Ultisol and Entisol.

| SOIL | Quantity of materials used (g) to 0.3 kg of soil | Base saturation percentage - after 100 days of incubation, % | |
|---|---|---|---|
| | | Biochar | MB-4 |
| | 0.0 | 22.30 | 20.89 |
| | 0.670 | 33.37 | 40.79 |
| Oxisol | 1.080 | 40.93 | 43.39 |
| | 1.490 | 41.55 | 50.46 |
| | 1.910 | 44.50 | 52.58 |
| | 2.320 | 46.71 | 55.77 |
| | 0.0 | 33.79 | 31.36 |
| | 0.267 | 39.76 | 43.54 |
| Ultisol | 0.469 | 44.48 | 44.14 |
| | 0.672 | 46.00 | 55.44 |
| | 0.875 | 51.35 | 57.49 |
| | 0.0 | 40.05 | 33.73 |
| Entisol | 0.072 | 41.10 | 42.76 |
| | 0.175 | 46.65 | 50.95 |
| | 0.276 | 48.97 | 52.56 |
| | 0.377 | 52.62 | 59.34 |
| | | Calcium carbonate | Silicate |
| Oxisol | 80 | 100.00 | 100.00 |
| Ultisol | 80 | 84.14 | 73.04 |
| Entisol | 80 | 100.00 | 100.00 |

However, in relation to the data corresponding to calcium carbonate and silicate, it is observed that the quantities applied biochar and MB-4 (twice the amounts of calcium carbonate) not reached the desirable base exchangeable percentages. Probably, if the amounts used of these materials were higher, we could achieve higher exchangeable base percentages.

## Materials and Methods

### *Soils and experimental site*

The experiment was carried in Irrigation and Salinity Laboratory of the Department of Agricultural Engineering, UFCG, from February 2 until April 13, 2015, using the incubation method in pots for 100 days.

To evaluate the behavior of different materials on soil pH and properties and to understand how they neutralize the acidity of the soil, samples of Ultisol, Oxisol and Entisol were collected in the municipalities Campina Grande, Areia and LagoaSeca, respectively, in State of Paraiba, Brazil, whose chemical characteristics according to the methodology of Embrapa (1997) are in Table 1.

### *Composition of corrective agents*

The corrective agents to be tested were produced by Agro silicon Hascos Minerals with 35% of Calcium; 6% of Magnesium; 10.535% of silicon and 64.6% PRNT named in this research as silicate; calcium carbonate PA given with PRNT 100%; poultry litter biochar with pH ($H_2O$) = 10.1; N = 42.31 g $kg^{-1}$; P = 32.56 g $kg^{-1}$; $K^+$ = 48.56 g $kg^{-1}$; $Ca^{2+}$ = 57.75 g $kg^{-1}$; $Mg^{2+}$ = 12.40 g $kg^{-1}$; Na = 14.37 g $kg^{-1}$; Fe = 137 g $kg^{-1}$; Cu = 812 g $kg^{-1}$; Zn = 700 g $kg^{-1}$; Mn = 862 g $kg^{-1}$ and MB-4 rock powder produced by MIBASA with the following composition 39.7% of $SiO_2$; 7.1% of $Al_2O_3$; 6.9% of $Fe_2O_3$; 5.9% of CaO; 17.8% of MgO; 1.5% of $Na_2O$; 0.8% of $K_2O$; 0.075% of $P_2O_5$; 0.2% of S.

### *Treatments and doses*

Treatments for Ultisol and Entisol consisted of five increasing doses of these materials corresponding to the quantities necessary to increase the saturation of soil around bases 40, 50, 60, 70 and 80%. For the Oxisol we used six doses to raise the base saturation around 20, 40, 40, 50, 70 and 80%. The amount of calcium carbonate to achieve the treatments were calculated based on 100% PRNT; in the case of silicate were also calculated based on the quantities PRNT 64.6%, however, it is not known PRNT biochar and 4-MB, so it was decided to use twice the quantities calculated based on the carbonate calcium (Table 2).

### *Incubation condition and time after treatments*

Incubation experiments were conducted to evaluate the effects of biochar on the chemical properties of soils. Three hundred grams samples of the study soils were placed in plastic pots (experimental units) and then mixed with biochar according to the treatments. Soil and biochar were mixed thoroughly, and then wetted with deionized water to approximately 60% water content (i.e., the field water capacity of the soil). The incubated pots were placed in a room at 28 °C and weighed every 5 d to maintain constant moisture content. All treatments were carried out in triplicate. The incubation time was 100 d in total, and soils were analyzed at 10 d, 40 d, 70 d and 100 d to determine their chemical properties.

### *Statistical analysis*

The results were analyzed statistically through the analyses of variance (ANOVA) described by Ferreira (2009), using the SAEG software Euclides (1997). Multi-comparison tests were carried out using Tukey's test at 5% and 1% probability.

## Conclusions

The results of this study confirmed the effectiveness of poultry litter biochar, MB-4, silicate and calcium carbonate for improvement of chemical properties of Ultisol, Oxisol and Entisol. The results indicated that the improvements in soil characteristics varied with variations in the amount of corrective agents added to the soil and in time of incubation. The results showed that pH increased significantly with increasing application rates of correcting agents, reflecting the fact that the liming potential increased with increasing application rates of these materials. The sequence of greater efficiency in the neutralization of the acidity of the soil = calcium carbonate > silicate > MB-4 >biochar.

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