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Using Poultry Litter Biochar and Rock Dust MB-4 on Release Available Phosphorus to Soils

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Abstract

Highly weathered soils in areas from Brazil are acidic soils, typically characterized by poor fertility, particularly with low soil phosphorus level. This laboratory experiment was carried out to evaluate the influences of biochar, made from the poultry litter and MB-4, rock dust from grinding of silicate rocks in increasing the available soil phosphorus on Ultisol, Oxisol and Entisol. Thus, one experiment involving soils incubation was conducted in laboratory, during 100 days. The treatments consisted of rock powder, MB-4 and poultry litter, biochar, 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 three replicates. After the incubation period, the soil samples were analyzed in relation to available phosphorus in the soil. The results of this study confirmed that the biochar prepared from the poultry litter through slow pyrolysis was a potential source of phosphorus, particularly to weathered soils. Biochar released phosphorus into the soils. The biochar could be used in the improvement of available phosphorus for the three soils analyzed. During the incubation period, 100 days, the application of increasing doses of MB-4 in soils there was no improvement in the available soil phosphorus. MB-4 was not a source of phosphorus to the soil in a short term.

Keywords

Soil Amendment, Biochar, Poultry Litter, Phosphorus, Rock Dust

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1. Introduction

In tropical and subtropicas soils the total phosphorus levels are relatively high, but the bioavailable fraction is below the minimum requirements of commercial crops. Therefore, P is one of the nutrients whose scarcity most limits crop development. Besides, compared to other major nutrients, P is by far the least mobile and available to plants in most soil conditions.

Highly weathered soils in those areas from Brazil are acidic soils, typically characterized by poor fertility, particularly with low soil phosphorus level, *i.e.* deficiencies of phosphorus in soils, limiting the crop growth and reducing crop yield. The long-term cultivation of these soils due to plants' harvesting of the soil's valuable resources often results in poor fertility if fertilizers are not added to the soils. Phosphorus (P) may be immobilized and consequently the runoff loss risks are reduced if poultry litter (PL) is converted into biochar prior to land application [1].

Poultry litter (PL), a solid waste resulting from chicken rearing, is being explored as a feedstock for biofuels and industrial chemicals [2]. It has a high concentration of phosphorus and nitrogen, making it an ideal amendment to agricultural soils. However, through slow pyrolysis, a thermochemical conversion technology whereby organic materials are heated in the absence of oxygen, PL can be readily transformed into biochar. Biochar is the black solid, remaining after biomass pyrolysis. It is porous, enriched with recalcitrant organic carbon and sorptive for water and nutrients. Biochar has being explored for agricultural applications improving soil fertility for crop production by enhancing the retention of fertilizers [3] (Liang *et al.*, 2006) and encouraging the host of beneficial microorganism.

The quality of biochar varies with feedstock, production conditions, and even storage [4]. To assess the quality of biochar used in crop production, several properties should be measured: pH, volatile compound content, ash content, water holding capacity, bulk density, pore volume, and specific surface area [5]. However, for soil fertility enhancement, biochar should also be evaluated on plant-available nutrients, and nutrient release dynamics. Many studies have shown that biochar, in different soils, is a useful resource to improve the physicochemical properties of soil [6]-[8], effectively maintain soil organic matter SM levels, increase fertilizer-use efficiency and increase crop production, particularly for long-term cultivated soils in subtropical and tropical regions.

In addition, biochar has been used as a soil improver in a rock dust from grinding of silicate rocks called MB-4. This material is a mixture of two rocks, the biotitaxisto and serpentinite in the ratio of 1:1 having at its magnesium silicate composition, together with calcium and iron phosphate, potash and sulfur and several micronutrients, such as copper, zinc, manganese and cobalt [9]. According to the manufacturer, the application of this material in the soil is an option of small cost for improving soils with low fertility, as a source of nutrients for the plants, correction to acidity soils, reducing the toxic components of the plants. However, due to the low solubility of its constituent minerals, the release of nutrients of this material into the soil solution is slow which is difficult in the use of rock dust in the production of short cycle cultures, but providing nutrients for the plants is for a longer period than the conventional fertilizers [10].

According to [11], MB-4 was tested on various soils showing an efficient recovery, enhancer and rejuvenating to possess a wide variety of chemicals, providing essential nutrients to plants.

Assuming that phosphorus occurs in the chemical composition of biochar and MB-4, the objective of this study was to evaluate the influence of application of these materials in three different soils in increasing the soil phosphorus availability for crops.

2. Material and Methods

2.1. Location of the Experiment

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.

2.2. Soil Analysis

To evaluate the behavior of different materials in increasing the soil P availability for crops, samples of Ultisol, Oxisol and Entisol were collected in the municipalities Campina Grande, Areia and Lagoa Seca, respectively, in Paraiba State, Brazil, whose chemical characteristics according to the methodology of [12] are in **Table 1**. These soils were selected because they are those that predominate in the Paraíba State and are poor in phosphorus.

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

Attributes Chemical	Ultisol	Oxisol	Entisol
Calcium ($cmol \cdot kg^{-1}$)	2.02	2.06	0.78
Magnesium ($cmol \cdot kg^{-1}$)	1.46	1.60	1.19
Sodium ($cmol \cdot kg^{-1}$)	0.09	0.09	0.08
Potassium ($cmol \cdot kg^{-1}$)	0.14	0.07	0.14
Sum of bases ($cmol \cdot kg^{-1}$)	3.71	3.85	2.19
Hydrogen ($cmol \cdot kg^{-1}$)	6.36	11.97	2.72
Aluminum ($cmol \cdot kg^{-1}$)	0.40	0.40	0.20
CTC ($cmol \cdot kg^{-1}$)	10.07	16.22	5.11
Organic matter ($g \cdot kg^{-1}$)	11.90	31.50	9.60
Phosphorus available ($mg \cdot kg^{-1}$)	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

2.3. Biochar and MB-4 Analysis

The chemical characteristics of materials MB-4 rock powder produced by MIBASA and poultry litter biochar produced by SPPT Technological Research Ltda to be tested are presented in **Table 2**.

2.4. Experimental Design and Treatments

Three experiments were conducted independently using samples of Ultisol, Oxisol and Entisol. The experiments with Ultisol and Entisol were carried out in a completely randomized design in a factorial arrangement 2 × 5 (two materials: biochar and MR-4; five doses of such materials, according to **Table 3**) with three replicates; with samples of Oxisol was carried out in a completely randomized design in a factorial arrangement 2 × 6, with three replicates. Since it is not known RPTN biochar and 4-MB, then, for the treatments, it was decided to use twice the amount calculated based on carbonaceous calcium (RPTN 100%) to increase base saturation to 40%, 50%, 60%, 70% and 80% to samples of Ultisol and Entisol and to 20%, 40%, 50%, 60%, 70% and 80% to samples of Oxisol (**Table 3**).

2.5. Conduct of the Study

Incubation experiments were conducted to evaluate the effects of biochar and MB-4, in increasing the soil phosphorus availability for crops. Three hundred grams samples of the study soils were placed in plastic pots (experimental units) and then mixed with these materials according to the treatments. Soil and these materials 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. The soils samples were analyzed at 100 days after incubation to determine available phosphorus content of these samples. For this it used 10 ml soil sample added 100 ml of phosphorus extraction solution (H_2SO_4 0.025N + HCl 0.05N). The phosphorus was determined using photocolorimeter at a wavelength of 600 mµ.

2.6. Statistical Analysis

The results were submitted to variance analysis [13] with significance level determined by the test "F". The average for the materials, additional treatments and their interactions were compared by Tukey test at $p < 0.05$, while the effects of doses of MB-4 and biochar were assessed by regression analysis, adopting as a criterion for choosing of the mathematical model the magnitude significant regression coefficients to 5%, by t-test.

Table 2. Chemical characterization of corrective agents used for the tests.

Poultry litter biochar										
pH	N	P	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
-- $g \cdot kg^{-1}$ --										
10.1	42.31	32.56	48.56	57.75	12.40	14.37	137	812	700	863
MB-4										
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	S		
-- % --										
39.7	7.1	6.9	5.9	17.8	1.5	0.8	0.075	0.2		

Table 3. Quantity of materials used to achieve different soil base saturation percentages.

SOIL	Base saturation percentages	Quantity of materials used (g) to soil (kg)	
		Biochar	MB-4
Oxisol	20	0.0	0.0
	40	2.233	2.233
	50	3.600	3.600
	60	4.967	4.967
	70	6.367	6.367
	80	7.733	7.733
Ultisol	40	0.0	0.0
	50	0.890	0.890
	60	1.563	1.563
	70	2.240	2.240
	80	2.917	2.917
Entisol	40	0.0	0.0
	50	0.240	0.240
	60	0.583	0.583
	70	0.920	0.920
	80	1.257	1.257

3. Results and Discussion

The materials used biochar and MB-4, doses of these materials and the interaction between these variation factors showed significant effect on the 1% level of probability in relation to phosphorus available in the three soils. However, with the stock split, only the doses had a significant effect on interaction with biochar, *i.e.* there was no significant difference in rates on MB-4 (**Table 4**).

The results indicated that after applying biochar to the soils and incubating for 100 d, the concentrations of available phosphorus in the amended soils varied with variations in the amount of biochar, *i.e.* increased as function of applied doses corroborating [14] Chang *et al.* (2008). This increase in Oxisol and Ultisol varied quadratically and Entisol behavior was linear (**Figure 1**).

Morales (2010) [15] evaluating the effect of biochar (from elephant grass biomass, sawdust and straw cane

Table 4. Analysis of variance of available phosphorus in Oxisol, Ultisol and Entisol depending on the materials, biochar and MB-4, and dosages of these materials.

Source	DF	Oxisol	DF	Ultisol	Entisol
		Mean square		Mean square	
Material (M)	1	29.962**	1	23.11**	11.95**
Doses (D)	5	2.217**	4	1.92**	1.14**
Interaction M x D	5	2.218**	4	1.92**	1.16**
D within Biochar					
Linear regression	1	20.25**	1	14.46**	9.031**
Quadratic regression	1	0.83**	1	0.89**	0.023ns
D within MB-4					
Linear regression	1	0.27ns	1	0.00000ns	0.00007ns
Quadratic regression	1	0.27ns	1	0.00001ns	0.00091ns
Resídue	12	0.011	10	0.04	0.005
CV (%)		7.71		15.67	4.69
Mean		1.38		1.39	1.56

Significant at 0.05 (*) and at 0.01 (**) of probability; (ns) not significant; DF: degree of freedom; CV: Coefficient of variation.

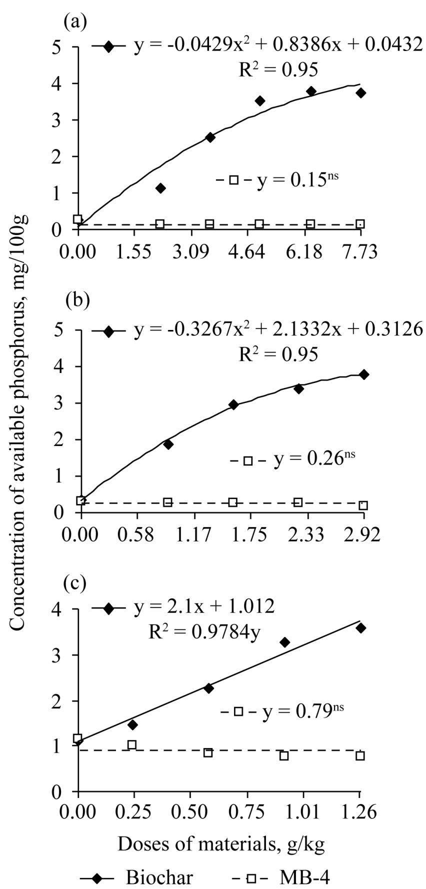

Figure 1. Concentration of available phosphorus as a function of biochar and MB-4 doses in Oxisol (a), Ultisol (b) and Entisol (c).

sugar) in the chemical characteristics of an Oxisol, noted that the addition of this material in the soil significantly increased the content of P around 39%, due to the high phosphorus content in biochar total present, 61% readily available. This nutrient can have a positive influence on soil fertility. Jien and Wang (2013) [16] evaluating the influences of biochar made from the waste wood of white lead trees (*Leucaena leucocephala* (Lam.) de Wit) on the physicochemical and biological properties of long-term cultivated, acidic Ultisol observed that that applying biochar improved these properties of the highly weathered soils.

The concentration of available phosphorus not increased as function of MB-4 doses, probably due to very low release of silicon-MB-4. According [17] phosphate and silicate are absorbed by the iron and aluminum oxides clay fraction, and thus can compete with each other for the same adsorption sites, ie, silicates can displace previously adsorbed phosphate, and vice versa, of the oxídicas surfaces. Bezerra *et al.* (2009) [18] evaluated the nutritional status of two varieties of sugarcane fertilized with MB-4, they observed an increase in phosphorus foliar. The authors attributed this increase as a function of competition between phosphate and silicate, as the MB-4 has in its composition 39.73% silica (SiO_2).

The element phosphorus (P) influences the better bird performance and the best cost/benefit. More recently, there is also concern about the excretion and environmental contamination, necessitating the need for better understanding of the sources used to adjust the levels of P in the diets [19]. Therefore, more and more have occurred to poultry litter processing in biorcarvão, which he has held various functions in the environment, both to prevent contamination of the same as to improve soil fertility for agricultural production [3]. If the phosphorus in poultry litter are high because the quality of chicken feed, phosphorus contents in the biochar also appear as high. This has been observed in this work, *i.e.* phosphorus content in the biochar were high.

Despite having incubated the same doses of biochar and MB-4, corresponding to each soil, amounts of phosphorus available from biochar were higher that from MB-4, *i.e.* biochar was more efficient in increasing phosphorus in soil, as seen in **Table 5**.

As [15] biochar produced from the carbonization separately biomass elephant grass, sawdust (various types of wood) and straw sugarcane, only presented the desorption of phosphorus to the soil. This seems what happened in our work since the concentration of available phosphorus in the soil increased as the doses applied biochar.

Release of phosphorus from poultry litter biochar in almost neutral soils is at a slower and steadier rate over a

Table 5. Concentration of available phosphorus (mg/100g) as a function of biochar and MB-4 doses in Oxisol, Ultisol and Entisol.

Material	Oxisol					
	Doses, g·kg^{-1}					
	0.000	2.233	3.600	4.967	6.367	7.733
Biochar	0.26a	1.15a	2.54a	3.52a	3.77a	3.76a
MB-4	0.27a	0.27b	0.26b	0.27b	0.26b	0.27b
	Ultisol					
	Doses					
	0.000	0.890	1.563	2.240	2.917	
Biochar	0.33a	1.87a	2.97a	3.38a	3.77a	
MB-4	0.31a	0.31b	0.31b	0.32b	0.31b	
	Entisol					
	Doses					
	0.000	0.240	0.583	0.920	1.257	
Biochar	0.92a	1.47a	2.27a	3.26a	3.57a	
MB-4	0.78a	0.80b	0.81b	0.78b	0.78b	

Values followed by the same letter within a column are not significantly different at $p < 0.05$ level based on F's test.

longer time period than from this material in soil acids which was observed by [1]. Because of this, many researchers show that the mixture of biochar in soil with organic matter (acid media) favors the release of chemical elements that composes the biochar. The soils pH in this study are very similar, but the organic matter values are different, 31.50, 11.90 and 9.6 g·kg^{-1} corresponding to Oxisol, Ultisol and Entisol, respectively. This probably affected the results of the phosphorus available (**Table 5**).

According [20] the use of rock dust (MB4) provided higher yields for bean (*Phaseolus vulgaris* L.). Santos *et al.* (2014) [10] evaluated the effect of MB-4 doses on the potato planting (*Solanum tuberosum*) observed that this rock dust has positive effects on components of production and productivity of the crop. Pinheiro *et al.* (2008) [21] testing the efficiency of MB-4 rock powder as corrective and fertilizer only observed that the values of pH, calcium and magnesium in the soil increased with the addition of MB-4 doses, while the potassium content was not affected. Nevertheless, our incubation experiments showed that MB-4 not improved the phosphorus available in soils. Practically the phosphorus available levels did not increase as a function of MB-4 doses (**Table 5**). Likewise several authors have shown that the MB-4 had no significant effect on the development of cultures. According to [22], for example, MB-4 doses, did not significantly influence the plant height and green matter yield of the aerial part of the cilantro (*Coriandrum sativum*) plant due to the small interval between the MB-4 applications and harvest, in addition to the slow availability of nutrients in soil. As [23] performed an experiment to test different combinations of the ingredient as fertilization, including MB-4, in sorghum, they noted that the MB-4 had no significant effect on the development of the plant.

4. Conclusions

The results of this study confirmed that the biochar prepared from the poultry litter through slow pyrolysis was a potential source of phosphorus, particularly to weathered soils.

Biochar released phosphorus into the soils.

The biochar could be used in the improvement of available phosphorus for the three soils analyzed.

During the incubation period, 100 days, the application of increasing doses of MB-4 in soils there was no improvement in the available soil phosphorus.

MB-4 was not a source of phosphorus to the soil in a short term.

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