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Improving available phosphorus in acidic soil using biochar

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Understanding of phosphorus (P) retention and release mechanisms provides crucial information for the effective management of phosphorus to enhance crop production and sustain soil. In acidic soil, available phosphorus is fixed by aluminum and iron. To overcome this problem, soils are limed to fix aluminum and iron. But this practice is not economical for small scale farmers and also it is not environmentally friendly. This study was conducted to improve phosphorus availability using biochar produced from coffee husk and corn cob to fix aluminum and iron instead of phosphorus. Acidic soil samples were mixed with biochar applied at the rates of 0, 5, 10 and 15 t ha^{-1} and incubated in laboratory for 2 months at ambient temperature. The results showed significant effects ($p<0.01$) on selected soil chemical properties by increasing soil pH and reduced exchangeable acidity, exchangeable aluminum, and exchangeable iron in a way that enhanced the availability of phosphorus. Due to the incorporation of biochar the available P level increased to a level ranging 3.64±0.34 - 23.21±0.07 mg/kg after an incubation period of 2 months and it increased by 84.3% available phosphorus when coffee husk biochar produced at 500°C temperature was applied at a rate of 15t/ha. Moreover, further field researches are needed to evaluate the effect of biochar on availability, the fate and uptake of available P in soil.

Key words: Fixation, biochar, feedstock, acidic soil, pyrolysis temperature.

INTRODUCTION

Phosphorus is an essential macronutrient for plants next to nitrogen. Understanding of phosphorus (P) retention and release mechanisms provides crucial information for the effective management of phosphorus to enhance crop production and sustain soil. Phosphorus undergoes several geo-chemical processes in soil such as solubilization, complexation, adsorption, and precipitation that determine its mobility and fate. These chemical processes are a complex function of several soil properties including, Al and Fe oxide form and content, the amount and form of silicate clays, and $CaCO_3$ content. The impact of these properties on P retention and release

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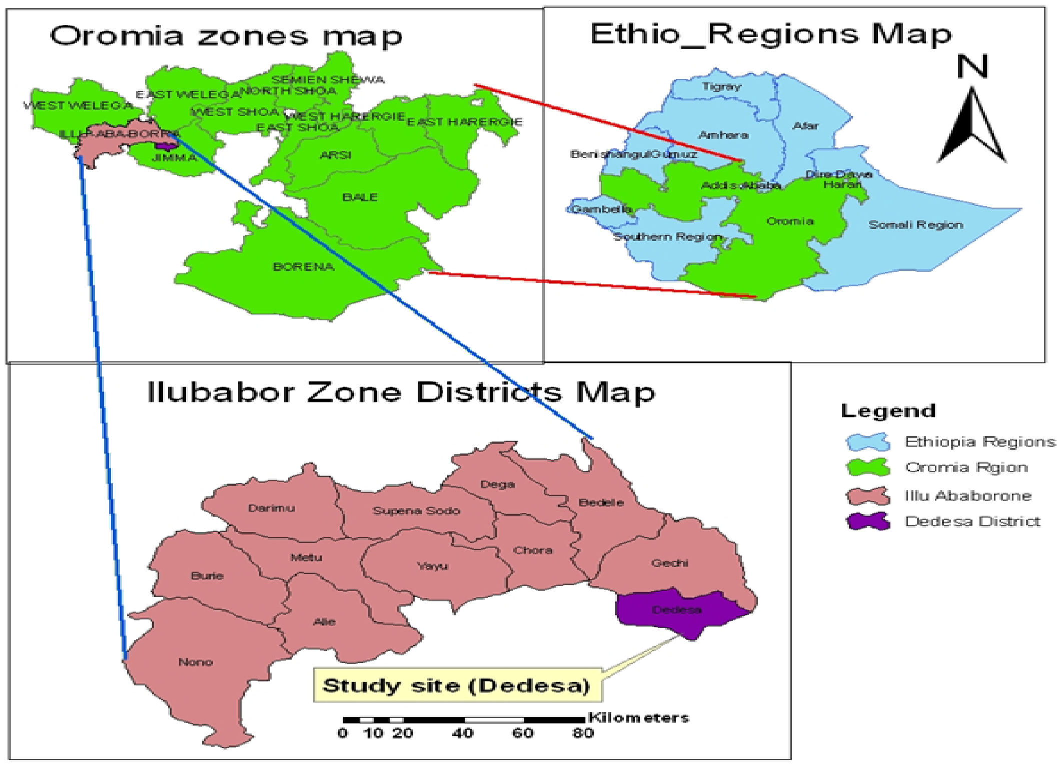

Figure 1. Map of the study area.

depends on soil acidity or alkalinity. The recovery of phosphorus by plants from applied fertilizer is limited in acidic soils due to P fixation. In acidic soils, the P is fixed by high-energy sorption surfaces such as oxides and hydroxides of Fe and Al by formation of insoluble Fe and Al phosphates by ligand exchange and precipitation reactions (Ohno and Amirbahman, 2010). The availability of P is influenced by soil organic matter, pH, and exchangeable and soluble Al and Fe. Phosphorus is generally available to crops at soil pH of 6 to 7. When the soil pH is less than 6, P deficiency increases in most crops. Conventionally, large amounts of lime and inorganic P fertilizers such as phosphate rocks and Triple Superphosphate (TSP) are used to saturate Al and Fe ions. This approach has not been successful because it is not economical for small scale farmers. The practice is also not environmentally friendly. Because, over liming precipitates P ions with Ca as calcium phosphate, whereas excessive use of P fertilizers causes eutrophication. Although there exist some information on P sorption and fixation using organic matter, there is a lack of information on the use of biochar to reduce P fixation. This is because biochar has high affinity for Al and Fe. Their affinity enables long term chelation of Al and Fe by biochar instead of P. Hence P will become readily and timely available for efficient crop use (Ohno et al., 2007).Therefore; the objective of this study was to improve available phosphorus by using biochar produced from the pyrolysis of coffee husk and corn cob at different charring temperature on acidic soil.

MATERIALS AND METHODS

Description of the soil sampling area

Soil sample was collected from Dedesa, Southwest Ethiopia. The site is located between 7°50’-8°10’ N latitude and 36°30’E to 36°45’ E longitude. The altitude of the area is about 2260 m above sea level. The mean annual minimum and maximum temperatures are 13 and 28°C, respectively and the mean minimum and maximum annual rainfalls are 1800 and 2200 mm respectively. The soil of the study area is dominated by Nitosol (World Reference Base, 2006) (Figure 1).

Preparation of biochar

Biochar of coffee husk and corn cob were prepared in Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) by using a pyrolysis unit at two different temperatures (350 and 500°C) and 3 h of residence time. The resulting biochar materials were grounded and sieved through a 0.25 mm -mesh sieve.

Soil sampling, preparation and incubated with biochar

The top 0 to 30 cm soil samples were collected by using auger. The collected soil samples were air-dried, crushed by using mortar and pestle and then passed through a 2 mm -mesh sieve. The effect of different levels of the biochar produced from different feedstock and different temperatures on available phosphorous was examined through a laboratory incubation experiment. Two hundred fifty grams of air-dried soil (<2 mm) were weighed in different beakers and biochar was added at rates of 0, 5, 10 and 15 t/ha which is equivalent to 0, 1.366, 2.732 and 4.098, g/kg respectively and thoroughly homogenized. The moisture content of the soil-biochar mixture was maintained at field capacity throughout the incubation period, by adding distilled water whenever necessary. Three replicates of each treatment were prepared, randomly placed and incubated in the laboratory at ambient temperature for 2 months. At the end of two months, samples (≈50 g) were removed from all the treatments and analyzed for pH, OC, OM, TN and other parameters were also analyzed as per the standard methods. But available P was analyzed by following successive weeks of incubation.

Physicochemical properties of biochar materials

The surface area of biochar was estimated according to Sears's method for silica-based materials (Sears, 1956). This can be obtained by agitating 1.5 g of each of the produced biochar in 100 ml of diluted hydrochloric acid (pH 3). Then a 30 g of sodium chloride was added with stirring and the volume was made up to 150 ml with deionized water. The solution was titrated with 0.10M NaOH and the volume, V, needed to raise the pH from 4 to 9 was then recorded. S (m2/g) = 32V-25, where V is the volume of sodium hydroxide require raising the pH of the sample from 4 to 9 and S is the surface area. pH and electrical conductivity (EC) were measured in distilled water at 1:10 biochar to water mass ratio after shaking for 30 min (ASTM, 2009). Biochar organic carbon content was determined by the Walkley-Black method and total nitrogen (TN) by the Kjeldahl method as cited in Chintala et al., 2013. Available phosphorous (P) was determined by using the Olsen extraction method (Shaheen et al., 2009). Total exchangeable bases were determined after leaching the biochar with ammonium acetate. Concentrations of Ca and Mg in the leachate were determined by atomic absorption spectrometer. K and Na were determined by flame photometer. Cation exchange capacity was determined at soil pH 7 after displacement by using 1N ammonium acetate method, and then estimated titrimetrically by distillation of ammonium that was displaced by sodium (Gaskin et al., 2008).

Physicochemical properties of soil sample and the soil-biochar mixture

The particle size distribution (texture), of the soil sample was determined by the Boycouos hydrometric method after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexametaphosphate $(NaPO3)_6$. Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights.The pH of the soil and soil-biochar mixture was determined in water suspension at 1:2.5 soil/soil-biochar: liquid ratio (w/v) potentiometrically using a glass-calomel combination electrode (Van Reeuwijk, 1992). Electrical conductivity (EC) was measured from a 1:5 (w/v) soil to water ratio after a one hour equilibration time as described by (ASTM, 2009). The Walkley and Black (1934) wet digestion method was used to determine carbon content and, percent OM was obtained by multiplying percent soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon. Total N was analyzed using the Kjeldahl method by oxidizing the OM in (0.1N H2SO4) as described in Black (1965). Cation exchange capacity and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by (1N NH4OAc) at pH 7. Ex. Fe was determining by AAS after extracting by DTPA solution.

Exchangeable Ca and Mg in the extracts were analyzed using atomic absorption spectrometer (AAS), while Na and K were analyzed by flame photometer (Rowell, 1994). Cation exchange capacity was there after estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution (Chapman, 1965). Exchangeable acidity was determined by titration method after 1N KCl solution at pH 7 used to leach exchangeable hydrogen and aluminum ion from soil sample. Available P was determined by using 1M HCl and 1M NH_4F solutions as an extractant by Bray II method (Van Reewijk, 1992). Total P was determining by spectrophotometer after digested by concentrated sulfuric acid. The sample-extractant mixtures were shaken for 30 min on a horizontal shaker (Shaheen et al., 2009), then centrifuged for 10 min at 1500 rpm and filtered by using Whatman no. 42 filter paper. The clear supernatant solutions were collected and analyzed using spectrophotometer at 882 nm.BDL=below detection level, CEC: Cation exchange capacity, CHB350: Coffee husk biochar produced at 350°C, CHB500: Coffee husk biochar at 500°C, CCB350: Corn cob biochar at 350°C, CCB500: Corn cob biochar at 500°C. Selected physicochemical properties of the studied soil and biochar are shown in Table 1. In the Table it indicates that the soil is strongly acidic. This shows that, the soil might possibly be affected by Al toxicity, excessive levels of micronutrients such as Co, Cu, Fe, Mn, Zn and, deficiency of macronutrients such as Ca, K, Mg, S, N, P. The low EC value shows that the soil is non-saline which indicates that the total concentration of the major dissolved inorganic solutes (Na^+, Mg^{2+}, Ca^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3^-, NO_3^- and CO_3^{2-}) in the soil solution is low and this soil acidity can cause limited availability of macronutrients like P and micronutrients Mo which binds to iron and aluminum oxides in acidic soil (Brady and Weil, 2002).

As can be seen in the table, the coffee husk biochar was more alkaline and has higher base cation concentration relative to that of the corn cob biochar. The pH, EC, CEC, P, and base cation concentration were higher in the coffee husk biochar produced at 500 and 350°C followed by corn cob biochar produced at 500 and 350°C.The high pH values of coffee husk biochar may be due to hydrolysis undergone by carbonates and bicarbonates of base cations such as Ca, Mg, Na, and K, which were present in the feedstock's materials (Gaskin et al., 2008). The EC value of coffee husk biochar was found to be higher than that of corn cob biochar, indicating the existence of more water soluble salts in coffee husk biochar than in corn cob biochar. The CEC of coffee husk biochar was also found to be higher than that of corn cob biochar. This may be due to high negative charge potential of surface functional groups in coffee husk than in corn cob. In general, results of the characterization studies of the biochars are clear demonstrations of the significant difference in the composition of biochar produced from different feed-stocks even when they are pyrolyzed under the same temperature. This fact was also reported in a study carried out by Novak et al., 2009. Available P, organic carbon and total nitrogen were also found to be higher in coffee husk biochar than in that of corn cob biochar. The high carbon, organic matter, total nitrogen and total P content in coffee husk biochar might have enriched the soil with high organic matter.

Statistical data analysis

Data analysis was done using SAS version 9.2. Three way analysis of variance (ANOVA) namely two feedstock biochar materials, two different pyrolysis temperatures and four application rates were performed to see the significance of differences in the effects of the various soil parameters and among each treatment, using the General Linear Model (GLM) procedure of SAS 9.2. Means separation was done using Least Significant Difference (LSD) after the treatments were found significant at p<0.05.

Table 1. Selected physicochemical properties of the studied soil and biochar produced from coffee husk and corn cob at 350°C and 500°C (Mean ±SD)

Parameters	Soil	CHB350	CHB500	CCB350	CCB500
Bulk density (gm/cm^3)	1.22 ± 0.03				
Specific surface area(m2/g)	-	14.07±0.02	26.2±0.01	4.46±0.05	18.14±0.04
pH-H_2O (1:2.5)	5.08 ± 0.06	9.62 ± .06	11.04 ±0.02	8.154 ± .01	9.44 ± 0.03
Exch. Acidity	4.5± 0.1	BDL	BDL	BDL	BDL
EC (mS/cm) (1:5)	0.03 ± 0.00	4.29 ± 0.03	6.44 ± 0.13	0.891 ± 0.23	1.81 ± 0.24
Exch. Ca (me/100g)	8.08 ± 1.32	50.48 ± 0.68	61.48 ± 0.81	37.38 ± 0.56	48.36 ± 0.06
Exch. Mg (me/100g)	1.20 ± 0.2	6.71 ± 0.11	8.21 ± 0.06	4.93 ± 0.04	6.43 ± 0.06
Exch. K (me/100g)	0.8 ± 0.02	1.96 ± 0.27	2.77 ± 0.43	1.711 ± 0.26	2.16 ± 0.14
Exch. Na (me/100g)	0.02 ± 0.00	3.43 ± 0.02	5.15 ± 0.11	0.71 ± 0.18	1.45 ± 0.19
Exch. Fe	35.54± 1.12	BDL	BDL	BDL	BDL
Exch. Al	795.00± 0.23	BDL	BDL	BDL	BDL
CEC (me/100g)	24.36 ± 1.7	64.75 ± 0.76	79.23 ± 0.33	47.52 ± 0.66	62.03 ± 0.80
Organic Carbon (%)	3.97 ± 0.23	16.45 ± 1.96	26.91 ± 7.22	13.98 ± 2.45	20.57 ± 1.40
Organic Matter (%)	6.85 ± 0.39	28.35 ± 3.38	46.39 ± 12.45	24.09 ± 4.23	35.46 ± 2.41
Nitrogen (%)	0.34 ± 0.02	1.42 ± 0.17	2.32 ± 0.62	1.2 ± 0.21	1.77 ± 0.12
Total P	16.2± 0.14	105.25±2.12	149.12±3.45	91.92±1.32	116.22±2.56
Available P (mg /kg)	4.52 ± 0.09	9.79 ± 1.34	13.87 ± 2.16	8.55 ± 1.31	10.81 ± 2.41
Texture	Clay loam				
%Sand	29.33 ± 4.16				
%Clay	30.67 ± 4.16				
%Silt	40.00 ± 0.00				

RESULTS AND DISCUSSION

Effect of biochar application on soil pH, exchangeable acidity, exchangeable aluminum and exchangeable iron

The biochar application significantly affects soil pH compared with the control pH (Table 2). The increase in soil pH was due to the rapid proton (H^+) exchange between the soil and the biochar (Tang et al., 1999). The reduction in exchangeable acidity, exchangeable Al, and exchangeable Fe relates to the increase in soil pH. Increase in pH resulted in the precipitation of exchangeable and soluble Al and Fe as insoluble Al and Fe hydroxides, thus reducing the concentrations of Al and Fe in the soil solution and also exchangeable acidity (Ritchie, 1994). The increase in the pH of the soil due to the application of biochar was generally attributed to an increase in ash content, because ash residues are generally dominated by carbonates of alkali and alkaline earth metals, phosphates and small amounts of organic and inorganic N (Arocena and Opio, 2003). A study by Khanna et al., 1994, has also revealed that the increase in soil pH due to the application of biochar could be because of the high surface area and porous nature of biochar that subsequently increase the CEC of the soil. But, with an increase in incubation period the pH of the soil-biochar mixture nearly constant and this could be due to buffering capacity of the soil.

Effect of biochar application on OC, OM and TN

The application of different rates of biochar on the acidic soil significantly ($P < 0.01$) increased the mean soil organic carbon (OC), organic matter (OM), total nitrogen (TN) and total phosphorous content (Table 3). The untreated acidic soil had 3.97 ± 0.23% OC and 6.85 ± 0.39% OM level before treatment, however, due to the incorporation of biochar the OC level increased to a level ranging 3.8 ± 0.29 - 5.79% and 6.56 ± 0.51%- 9.98 ± 0.07% OM in the first month of incubation period and it increased by 34.37% OC and 34.3% OM. In the control however, the level of OC and OM were found to decrease after an incubation period of 2 months. At the end of the incubation period the control had an OC level of 3.6 ± 0.29 and 6.56 ± 0.21% OM, whereas the soil amended with the biochar had levels ranging 3.6 ± 0.29 to 6.69 ± 0.04% OC and 6.56 ± 0.21 to 11.53 ± 0.41% OM which is increased by 45.6% OC and 43.1% OM. The highest OC and OM levels were recorded in the soil amended with 15t/ha of coffee husk biochar produced at 500°C temperature after 2 month incubation period. There were significant differences in the soil total nitrogen and total P after application of biochar. The highest increase was recorded in the soil amended with 15t/ha of coffee husk biochar produced at 500°C temperature. The observed increase in TN and total P could be due to some amount of decomposition which might have occurred when biochar is added to soil (Liang et al., 2006), which could

Table 2. Effect of biochar application on soil pH, exchangeable acidity, exchangeable aluminum and exchangeable iron.

Biochar materials	Rate of Biochar(t/ha)	pH	Exchangeable acidity	Exchangeable Al	Exchangeable Fe
		cmol (+)/kg			
Control	0	5.2±0.03^{d}	1.9± 0.1^{d}	795± 0.4^{d}	35.54± 0.1^{d}
CHB350	5	6.10±0.07^{abc}	1.22± 0.1^{bc}	530± 0.3^{b}	29.62± 0.02^{b}
	10	6.10±0.33^{abc}	1.19± 0.1^{bc}	373.5± 0.3^{c}	14.8± 0.02^{c}
	15	6.20±0.01^{ab}	1.15± 0.2^{bc}	186.75± 0.3^{e}	9.87± 0.02^{e}
CHB500	5	6.1±0.15^{abc}	0.16± 0.04^{e}	124.5± 0.01^{f}	17.64± 0.03^{f}
	10	6.3±0.10^{abc}	0.14± 0.04^{e}	62.25± 0.01^{g}	5.88± 0.03^{g}
	15	6.6±0.03^{a}	0.11± 0.04^{a}	20.75± 0.01^{a}	2.96± 0.03^{a}
CCB350	5	6.1±0.14^{bc}	1.34± 0.2^{bc}	560± 0.01^{b}	30.12± 0.12^{b}
	10	6.1±0.07^{abc}	1.25± 0.2^{bc}	395.5± 0.1^{bc}	20.08± 0.12^{ef}
	15	6.01±0.09^{c}	1.19± 0.2^{bc}	197.75± 0.1^{e}	15.02± 0.12^{e}
CCB500	5	6.01±0.19^{c}	0.37± 0.5^{c}	353.3± 0.2^{c}	21.09± 0.11^{ef}
	10	6.10±0.01^{abc}	0.29± 0.5^{ef}	176.6± 0.2^{ef}	10.54± 0.11^{e}
	15	6.14±0.02^{abc}	0.19± 0.5^{e}	58.88± 0.2^{g}	5.27± 0.11^{g}
Pv<0.05		<.0001	<.0001	<.0001	<.0001
LSD		0.3821	0.271	0.1911	0.1932

LSD: least significant difference, CHB350: Coffee husk biochar at 350°C, CHB500: Coffee husk biochar at 500°C, CCB350: Corn cob biochar at 350°C, CCB500: Corn cob biochar at at 500°C.

Table 3. The effect of biochar application on the soil OC, OM, TN and Total-P.

Biochar materials	Rate of biochar (t/ha)	%OC	%OM	%TN	Total-P
Control	0	3.64 ± 0.29^{g}	6.56 ± 0.21^{g}	0.32 ± 0.03^{g}	96.5 ± 1.3^{e}
CHB350	5	6.14 ± 0.06^{cd}	10.58 ± 0.37^{cd}	0.53 ± 0.016^{cd}	136.2 ± 2.6^{e}
	10	6.11 ± 0.04^{cd}	10.53 ± 0.37^{cd}	0.53 ± 0.0^{cd}	271.6 ± 3.25^{d}
	15	6.18 ± 0.06^{cb}	10.65 ± 0.37^{cb}	0.53 ± 0.01^{cb}	550 ± 4.32^{b}
CHB500	5	6.28 ± 0.08^{cb}	10.82 ± 0.38^{cb}	0.54 ± 0.01^{cb}	139.2 ± 3.2^{e}
	10	6.45 ± 0.08^{ab}	11.12 ± 0.39^{ab}	0.56 ± 0.08^{ab}	555 ± 4.50^{b}
	15	6.69 ± 0.04^{a}	11.53 ± 0.41^{a}	0.58 ± 0.0^{a}	615 ± 4.70^{a}
CCB350	5	5.58 ± 0.12^{f}	9.63 ± 0.33^{f}	0.48 ± 0.01^{f}	134.6 ± 3.3^{e}
	10	5.79 ± 0.06^{ef}	9.99 ± 0.35^{ef}	0.49 ± 0.01^{ef}	350 ± 3.60^{f}
	15	5.86 ± 0.04d^{ef}	10.1 ± 0.35^{def}	0.51 ± 0.0^{def}	449.5 ± 3.50^{g}
CCB500	5	5.98 ± 0.05^{cde}	10.32 ± 0.36^{cde}	0.52 ± 0.0^{cde}	136.2 ± 2.6^{e}
	10	5.98 ± 0.05^{cde}	10.32 ± 0.36^{cde}	0.52 ± 0.0^{cde}	365 ± 4.52^{cf}
	15	6.07 ± 0.04^{cde}	10.46 ± 0.37^{cde}	0.52 ± 0.0^{cde}	469 ± 4.55^{g}
Pv<0.05		<.0001	<.0001	<.0001	<.0001
LSD		0.30	0.52	0.026	0.76

OC, Organic carbon, OM, Organic matter; TN, Total nitrogen; LSD, least significant difference.

induce net immobilization of inorganic N and organic P already present in the soil solution.

Effect of biochar application on CEC and exchangeable cations

The effect of biochar addition on CEC and the contents of exchangeable cations in the acidic soil are presented in Table 4. As shown in the Table, CEC and exchangeable cations were found to increase upon amendment of the acidic soil with coffee husk and corn cob biochar. Statistical assessment of the significance of the observed increases was carried out using ANOVA and, both increases were found to be significant ($P < 0.01$). The untreated acidic soil had 24 me/100 g level before treatment, however, due to the incorporation of biochar the CEC level increased to a level ranging 24.95 ± 1.05-38.46 ± 1.07 me/100 g after 2 months of incubation

Table 4. The effect of Biochar application on CEC and exchangeable cations

Biochar materials	Rate of biochar (t/ha)	CEC (me/100 g)	Ca (cmol (+)/kg)	Mg (cmol (+)/kg)	K(cmol (+)/kg)	Na (cmol (+)/kg
Control	0	24.95 ± 1.05[e]	12.57 ± 0.82[e]	1.3 ± 0.11[e]	0.85 ± 0.04[g]	0.05 ± 0.0[bc]
CHB350	5	34.55 ± 1.09[bcd]	26.94 ± 0.85[bcd]	3.58 ± 0.11[bcd]	1.46 ± 0.03[efg]	0.05 ± 0.0[bc]
	10	35.46 ± 1.07[bcd]	27.65 ± 0.84[bcd]	3.68 ± 0.11[bcd]	1.55 ± 0.03[edf]	0.05 ± 0.0[bc]
	15	35.69 ± 1.09[abcd]	27.83 ± 0.85[abcd]	3.7 ± 0.11[abcd]	1.99 ± 0.15[bcde]	0.07 ± 0.0[abc]
CHB500	5	36.03 ± 1.03[abcd]	28.1 ± 0.80[abcd]	3.73 ± 0.10[abcd]	2.15 ± 0.19[bcd]	0.05 ± 0.01[bc]
	10	37.31 ± 0.86[ab]	29.09 ± 0.67[ab]	3.87 ± 0.09[ab]	2.96± 0.09[a]	0.06 ± 0.0[abc]
	15	38.46 ± 1.07[a]	29.99 ± 0.84[a]	3.98 ± 0.11[a]	3.01 ± 0.04[a]	0.09 ± 0.0[a]
CCB350	5	33.33 ± 0.52[d]	25.98 ± 0.40[d]	3.45 ± 0.05[d]	1.25 ± 0.22[fg]	0.04 ± 0.01[c]
	10	34.37 ± 1.21[cd]	26.8 ± 0.95[cd]	3.56 ± 0.13[cd]	1.46 ± 0.04[efg]	0.05 ± 0.02[bc]
	15	35.27 ± 0.46[bcd]	27.5 ± 0.36[bcd]	3.66 ± 0.05[bcd]	1.72 ± 0.29[cdef]	0.08 ± 0.01[a]
CCB500	5	34.7 ± 0.46[bcd]	27.06 ± 0.36[bcd]	3.6 ± 0.05[bcd]	1.85 ± 0.34[bcdef]	0.05 ± 0.02[bc]
	10	35.03 ± 1.15[bcd]	27.32 ± 0.90[bcd]	3.63 ± 0.12[bcd]	2.23 ± 0.27[bc]	0.06 ± 0.01[abc]
	15	36.99 ± 0.70[abc]	28.84 ± 0.55[abc]	3.83 ± 0.07[abc]	2.5 ± 0.54[ab]	0.07 ± 0.01[ab]
Pv<0.05		<.0001	<.0001	<.0001	<.0001	<.0001
LSD		2.80	2.18	0.29	0.68	0.029

CEC, Cations exchange capacity; me, Milliequivalents; cmol, centimol; CHB350, coffee husk biochar at 350°C; CHB500, coffee husk biochar at 500°C; CCB350, corn cob biochar at 350°C; CCB500, corn cob biochar at 500°C; LSD, least significant difference.

period and it increased by 34.13% .The highest increase in CEC was recorded in the soil amended with coffee husk biochar produced at 500°C, applied at a rate of 15t/ha and this increased of CEC results the increment of basic cations. The observed increase in CEC due to the application of biochar could have resulted from the inherent characteristics of biochar feedstock. Biochar has high surface area, is highly porous, possesses organic materials of variable charge that have the potential to increase soil CEC and base saturation when added to soil (Glaser et al., 2002). Available evidences also suggest that, on a mass basis, the intrinsic CEC of biochar is consistently higher than that of whole soil, clays or soil organic matter (Sohi et al., 2009).

Therefore, it is quite logical that soil treated with biochar had a highest CEC than the corresponding soil. Studies by Agusalim et al. (2010) have also revealed the increase in soil CEC after the application of biochar. Application of CCB500 at a rate of 15 t/ha on the acidic soil was found to increase the levels of exchangeable Ca and Mg significantly (P < 0.01) from12.57 ± 0.82-29.99 ± 0.84 and 1.3 ± 0.11-3.98 ± 0.11 me/100 g respectively which is increased by 58.08% Ca and 67.3% Mg. Application of CHB500, on the other hand, increased the values of exchangeable K from 0.85 ± 0.04-3.01 ± 0.04 me/100 g and Na 0.05 ± 0.0-0.09 ± 0.0 me/100 g which is increased exchangeable K by 71.5 and 44.4% Na. The observed increase in exchangeable cations in the biochar treated soils might be attributed to the ash content of the biochar. The ash content of biochar helps for the immediate release of the concluded mineral nutrients like Ca, Mg, K and Na for crop use (Niemeyer et al., 2005). The increase in soil pH and CEC, that reduce the activity of Fe and Al, could also contribute for the highest values of available phosphorous in soils treated with biochar. Van Zwieten et al. (2010) also reported the increase in available phosphorous after the application of biochar.

Effect of biochar application on available phosphorous

The amount of available phosphorous in acidic soil was also significantly (P<0.01) increased by application of biochar (Figure 2). The untreated

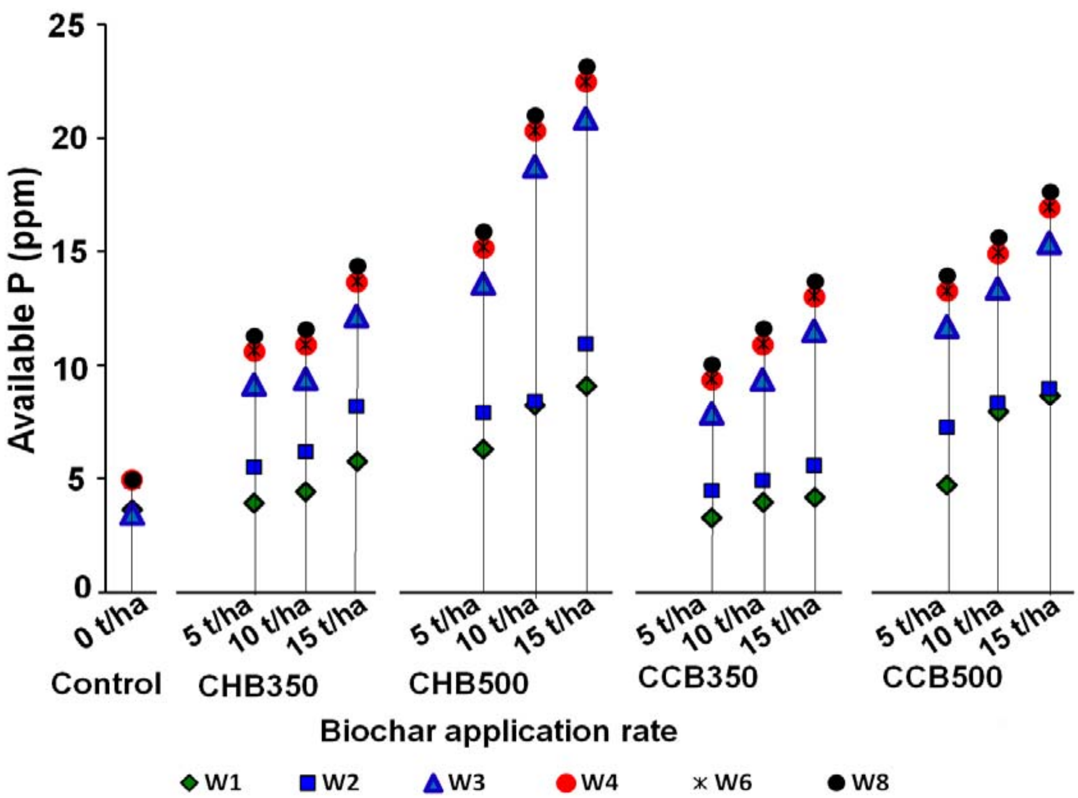

Figure 2. The effect of rate of application and incubation period of CHB350, CHBC500, CCB350 and CCB500, on soil available P

acidic soil had 3.64±0.34 mg/kg available phosphorus at first week (W1) of incubation period and 4.99±0.24 mg/kg after an incubation periods of two months. However, due to the incorporation of biochar the available P level increased to a level ranging 3.64±0.34 -23.21±0.07 mg/kg after an incubation period of 2 months and it increased by 84.3% available phosphorus. The highest values of available phosphorous recorded when coffee husk biochar produced at 500°C temperature was applied at a rate of 15 t/ha after two months of incubation periods and at pH values of 6.6. The observed increase in available phosphorus due to application of biochar could be due to the presence of phosphorous in the coffee husk and corn cob and the increase in the availability of P with time was because of microbially mediated mineralization of soil organic P to form inorganic P (Opala et al., 2012).

Significant differences were observed between soil available P and total levels of successive weeks of incubation of the biochar amended soil, that is, between available P levels of one week incubation and two weeks incubation, or between those of two weeks and three weeks of incubation period etc. (Figure 2). The biochar from both coffee husk and corn cob produced at 350°C and 500°C and applied at different levels on each treatment increased available P levels when compared with the control. The increase in available P with duration of incubation reported in this study is comparable to those reported by Laboski and Lamb (2003). The observed increase in available P with an increase in the duration of incubation was because of microbially mediated mineralization of soil organic P to form inorganic P.

Conclusion

The influence of coffee husk and corn cob biochar application on the level of available P of an acidic soil has been investigated. Findings of the study showed that, application of the biochar prepared from both feed stocks increased available P. The biochar application has also increased the pH and CEC of the soil. To enhance the bioavailability of P, alkaline biochars can be used on acidic soil and the finding of this study indicated that coffee husk residue biochar produced at 500°C highly increased available P as compared to corn cob reduced at the same temperatures. Corn cob residue biochar had the smallest effect on P availability but it could still improve soil quality parameters and increase available P. The effect of these biochar on soil P was in agreement with their characterization, suggesting that similar biochar evaluations might predict their effect on P availability and inform recommendations on biochar application to soils. Generally, in this study the application of both coffee husk and corn cob biochar produced at 350 and 500°C increases soil available P in all rating of application as compare to control (soil without application of biochar). Even though both feedstock biochar improved soil available P it is better to use coffee husk biochar produced at 500°C of pyrolyzing temperature applied at a rate of 15 t/ha. Moreover, further field researches are needed to evaluate the effect of biochar on the availability, fate and uptake of available p in soil.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Agusalim M, Wani HU, Syechfani MS (2010). Rice Husk Biochar for Rice Based Cropping System in Acid Soil: The Characteristics of Rice Husk Biochar and Its Influence on the Properties of Acid Sulfate Soils and Rice Growth in West Kalimantan. Indonesia. J. Agric. Sci. 2(1):39-47.

Arocena JM, Opio C (2003). Prescribed Fire- Induced Changes in Properties of Sub-Boreal Forest Soils. Geoderma. 113:1-16.

ASTM standard (2009). Standard test method for chemical analysis of wood charcoal. American Society for Testing and Materials (ASTM) International: Conshohocken, PA.

Black CA (1965). Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA. 1572 p.

Brady N, Weil R (2002). The Nature and Properties of Soils. 13thed.

Chapman H (1965). Cation Exchange Capacity. In: Black CA (Eds.) Methods of Soil Analysis.Agronomy, Madison, Wisconsin .Am. Soc. Agro. Inc. 9:891-901.

Chintala R, Mollinedo J, Schumacher TE, Malo DD, Julson JL (2013).Effect of Biochar on Chemical Properties of Acidic Soil, Arch. Agron. Soil Sci. 60(3):393-404.

Gaskin JW, Steiner C, Harris K, Das KC, Bibens B (2008). Effect of Low Temperature Pyrolysis Conditions on Biochars for Agricultural Use, Trans. ASABE. 51:2061-2069.

Glaser B, Lehmann J, Zech W (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal A review. Biol. Fertil. Soils 35:219-230.

Khanna PK, Raison RJ, Falkine RA (1994). Chemical properties of ash derived from Eucalyptuslitter and its effects on forest soils. For. Ecol. Manage. 66:107-125.

Laboski CAM, Lamb JA (2003). Changes in soil test phosphorus concentration after application of manure or fertilizer. Soil Sci. Soc. Am. J. 67(2):544-554.

Liang B, Lehmann J, Solomon D, Kinyangi J, Grossman J, O'Neill B, Skjemstad JO, Thesis J, Luizao FJ, Peterson J, Neves EG Black (2006). Carbon increases cation exchange capacity in soils. Soil Sci. Soc. Am. J. 70:1719-1730.

Niemeyer T, Niemeyer M, Mohamed A, Fottner S, Ha¨rdtle W (2005). Impact of prescribed burning on the nutrient balance of Heath Lands with particular reference to nitrogen and phosphorus. Appl. Veg. Sci. 8:183-192.

Novak JM, Busscher WJ, Laird DL, Ahmedna M, Watts DW, Niandou MAS (2009). Impact of biochar amendment on fertility of a southeastern Coastal Plain soil. Soil Sci. 174:105-112.

Ohno T, Amirbahman A (2010). Phosphorus availability in boreal forest soils: a geochemical and nutrient uptakemodeling approach. Geoderma. 155(2):46-54.

Ohno T, Fernandez JI, Hiradate S, and Sherman J F (2007). Effects of soil acidification and forest type on water soluble soil organic matter properties. Geoderma 140(2):176-187.

Opala PA, Okalebo JR, Othieno CO (2012). Effects of organic and inorganic materials on soil acidity and phosphorus availability in a soil incubation study. ISRN Agronomy, 20 Article ID597216. 10 p.

Ritchie GSP (1994). Role of dissolution and precipitation of minerals in controlling soluble aluminium in acidic soils,"Adv. Agron. 53:47-83

Rowell DL (1994). Soil science: Methods & Applications. Addison Wesley Longman Singapore Publishers (Pte) Ltd., England, UK. 350.

Scheuner ET, Makeschin F, Wells ED, Carter PQ (2004). Short-term impacts of arvesting and burning disturbances on physical and chemical characteristics of forest soils in western Newfoundland, Canada. European J. Forest Res. 123(4):321-330.

Sears G (1956). Determination of specific surface area of colloidal silica by titration with sodium hydroxide. Anal. Chem. 28(12):1981-1983.

Shaheen SM, Tsadilas CD, Eskridge KM (2009). Effect if Common Ions on Phosphorus Sorption and availability in Greek Alfisols with Different pH, Soil Sci. 174:21-26.

Sohi S, Lopez-Capel E, Krull E, Bol R (2009). Biochar, climate change and soil: A review to guide future research. CSIRO Land and Water Science Report.

Tang C, Sparling GP, McLay CDA, Raphael C (1999). "Effect of short-term legume residue decomposition on soil acidity,"Aust. J. Soil Res. 37(3):561-573.

Van Reewijk LP (1992). Procedures for Soil Analysis (3rd Ed.). International Soil Refrence Center (ISRIC), Wageningen, the Netherlands.

Van Zwieten L, Kimber S, Morris S, Chan KY, Downie A, Rust J, Joseph S, Cowie A (2010). Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant Soil. 327:235-246.

Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.

World Reference Base (2006). A Framework for International Classification, Correlation and Communication. Food and Agriculture Organization of the United Nations, Rome.