American-Eurasian J. Agric. & Environ. Sci., 16 (3): 442-448, 2016
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2016.16.3.12880

Interactive Effects of Biochar in Soil Related to Feedstock and Pyrolysis Temperature

[1]*Bayu Dume*, [2]*Dejene Ayele*, [1]*Alemayehu Regassa*, [3]*Gezahegn Barecha*

[1]Department of Natural Resource Management, College of Agriculture and Veterinary Medicine Jimma University, Jimma, Ethiopia
[2]Department of Chemistry, College of Natural Sciences, Wolkite University, Wolkite, Ethiopia
[3]Department of Horticulture and Plant Science, College of Agriculture and Veterinary Medicine Jimma University, Jimma, Ethiopia

Abstract: Biochar application to agricultural soil is a new management strategy for its potential role in soil quality improvements. The aim of this study was to evaluate the effects of biochar derived from coffee husk and corn cob produced at 350 and 500°C pyrolysis temperature on soil quality characteristics. The produced biochars were applied at rates of 0, 5, 10, 15t ha^{-1} and mixed with acidic soil then incubated in laboratory for three months at ambient temperature. The treatments were arranged in a completely randomized design with three replications. Results indicated a significant increase in soil pH, OM, OC, TN, available P, CEC and basic cations when compared with control. The highest values were recorded when CHB500 applied at a rate of 15 t ha^{-1}. In summary, the results of this study highlight biochars improved the quality of soil, with benefit to agriculture.

Key words: Soil amendment · Incubation · Aromaticity

INTRODUCTION

The thermal conversion of biomass carbon into a more recalcitrant form (black carbon which is biochar) through combustion under oxygen limited conditions, known as pyrolysis, has gained attention as a tool for soil amelioration in the recent years due to the identification of biochar as the key factor for the sustainable and highly fertile Terra preta soils [1]. Biomass-derived, biochar, has promising properties for improving soil quality due to its neutral to alkaline pH, high surface area, and high water holding capacity and can potentially increase the cation exchange capacity (CEC) of soils. Biochar additions to soil contributed to higher nutrient retention and availability, related to higher CEC, increased surface area, and direct nutrient additions [2].

The quality of biochar is largely controlled by the feedstock and production temperature and plays a major role for the extent of oxidation during ageing as shown in different incubation studies. The nature of feedstock and pyrolysis temperature affects the aromaticity of biochar and showed that woody biochar was less oxidized after incubation than biochar from corn residues due to higher aromaticity of the woody biochar. Besides the quality of feedstock, it was also shown that biochars produced at high temperatures were less oxidized after incubation than biochars produced at lower temperatures. This might be due to higher amounts of non-aromatic C and less ordered structures with a high quantity of reactive sites in low-temperature biochars making these more vulnerable for oxidation than biochars produced at higher temperature [3, 4]. The aim of this study was to evaluate the effects of biochar derived from coffee husk residues and corn cob produced at 350 and 500°C pyrolysis temperature on soil quality characteristics.

MATERIALS AND METHODS

Description of the Soil Sampling Area: Soil sample was collected from Dedesa area in Southwest Ethiopia. The soil of the study area is dominated by Nitosol [5]. The location is found between 7°50’-8°10’ N latitude and

Corresponding Author: Bayu Dume, Department of Natural Resource Management, College of Agriculture and Veterinary Medicine Jimma University, Jimma, Ethiopia, P.O.Box: 307, Mob: +251917829113, Fax: +251-047-1-11-09-34.

36°30'E -36°45' E longitude. The altitude of the area is about 2260 meter above sea level). The mean annual minimum and maximum temperatures are 13°C and 28°C respectively and the mean minimum and maximum annual rainfalls are 1800 and 2200 mm, respectively.

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

Soil Sampling and Preparation: The top 0 – 30 cm soil sample was collected by using auger. The collected soil samples were air-dried, crushed by using mortar and pestle and then passed through a 2 mm square-mesh sieve.

Laboratory Incubation of Soil with Biochar: The effect of different levels of the biochar produced from different feedstock and different temperatures on soil qualities was examined through a laboratory incubation experiment. One kilograms of air-dried soil (<2mm) 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, and 2.732, 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 three months. At the end of three months, samples (˜100 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 except available phosphorous that was analyzed by successive weeks.

Physicochemical properties of biochar materials. The surface area was estimated according to Sears's method for silica-based materials [6]. This can be obtained by agitating 1.5g of each of the produced sample in 100 ml of diluted hydrochloric acid (pH 3). Then a 30g of sodium chloride was added with stirring and the volume was made up to 150ml 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 (m^2/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 [7]. 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*. [8]. Available phosphorous (P) was determined by using the Olsen extraction method [9]. 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 [10].

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 [11] after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexametaphosphate $(NaPO_3)_6$. 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 [11]. 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 standard, [7]. The Walkley and Black [12] 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 H_2SO_4) as described in Black [13]. Cation exchange capacity and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by (1N NH_4OAc) 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 [14]. Cation exchange capacity was there after estimated titrimetrically by distillation of ammonium that was displaced by sodium from NaCl solution. 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 and exchangeable acidity was also determined by titration method. Available P was determined by using 1M HCl and 1M NH_4F solutions as an extractant by Bray II method for soils having pH values < 7 [11]. 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 [9], 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.

Statistical Analysis: Statistical analysis of the obtained data was done by using SAS version 9.2 and MS Excel. The treatments were arranged in a completely randomized design (CRD). Three way analysis of variance (ANOVA) namely two feedstock biochar, two different temperatures and three rating 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 $P<0.05$.

RESULTS AND DISCUSSION

Selected Physicochemical Properties of the Studied Soil: Results of the physicochemical properties of the studied soil shown in Table 1. The results are shown in the Table indicated that the soil is strongly acidic. As a results, 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 indicated 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 and micronutrients such as phosphorus which binds to iron and aluminum oxides in acidic soil [15].

Physicochemical Properties of Biochar: Results of physicochemical parameters of biochar are presented in Table 1. 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 also higher in the coffee husk biochar produced at 500°C and 350°C followed by corn cob biochar produced at 500°C 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 [10].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.

Table 1: Selected physicochemical properties of 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 (g/cm^3)	1.22±0.03				
Specific surface area(m^2/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	-	-	-	-
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	-	-	-	-
Exch. Al	795.00±0.23	-	-	-	-
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				

CEC: Cation exchange capacity, 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. SD: standard deviation

Table 2: Effects 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	6.11±0.07^{abc}	1.22±0.1^{bc}	530±0.3^{b}	29.62±0.02^{b}
	10	6.12±0.33^{abc}	1.19±0.1^{bc}	373.5±0.3^{c}	14.8±0.02^{c}
	15	6.21±0.01^{ab}	1.15±0.2^{bc}	186.75±0.3^{e}	9.87±0.02^{e}
CHB500	5	6.12±0.15^{abc}	0.16±0.04^{e}	124.5±0.01^{f}	17.64±0.03^{f}
	10	6.31±0.10^{abc}	0.14±0.04^{e}	62.25±0.01^{g}	5.88±0.03^{g}
	15	6.66±0.03^{a}	0.11±0.04^{a}	20.75±0.01^{a}	2.96±0.03^{a}
CCB350	5	6.10±0.14^{bc}	1.34±0.2^{bc}	560±0.01^{b}	30.12±0.12^{b}
	10	6.12±0.07^{abc}	1.25±0.2^{bc}	395.5±0.1^{bc}	20.08±0.12^{ef}
	15	6.02±0.09^{c}	1.19±0.2^{bc}	197.75±0.1^{e}	15.02±0.12^{e}
CCB500	5	6.02±0.19^{c}	0.37±0.5^{c}	353.3±0.2^{c}	21.09±0.11^{ef}
	10	6.12±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}
P-value		***	***	***	***

Means with the same letters are not significantly different ($p < 0.05$), ***significant at $P<0.01$

Table 3: The effect of biochar application on the soil OC, OM, TN and Total-P (Mean±SD)

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}
P-value		***	***	***	***

Means with different letters are significantly different ($p < 0.05$), ***significant at $P<0.01$

In general, results of the characterization studies of the biochars are clear demonstrations of the significant difference in the composition of biochars 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 J.M. Novak, et al. [16]. Available P, organic carbon and total nitrogen were also found to be higher in coffee husk biochar than in that of corn cob biochar.

Effect of Biochar Application on Soil pH, Exchangeable Acidity, Exchangeable Aluminum and Exchangeable Iron: Days of incubation significantly affected soil pH (Table 2). The biochar application significantly increased soil pH compared with the control. The increase in soil pH was due to the rapid proton (H^{+}) exchange between the soil and the biochar. 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 [17].

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 high carbon, organic matter, total nitrogen and total P content in coffee husk biochar might have enriched the soil with high organic matter. Addition of biochar has also resulted in marked changes in the TN and total phosphorus content of the soil. 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

Table 4: Effects of bochar application on CEC and exchangeable cations (Mean±SD)

Biochar Materials	Rate of Biochar(t/ha)	CEC (me/100 g)	Ca	Mg	K	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]
P-value		***	***	***	***	***

P could be due to some amount of decomposition which might have occurred when biochar is added to soil [18], which could 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. 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 [19]. Available evidences also suggested that, on a mass basis, the intrinsic CEC of biochar is consistently higher than that of whole soil, clays or soil organic matter [20]. Therefore, it is quite logical that soil treated with biochar had a highest CEC than the corresponding soil. Studies by Agusalim *et al*. [21], have also revealed the increase in soil CEC after the application of biochar. Application of CHB500 at a rate of 15t/ha on the acidic soil was found to increase the levels of exchangeable Ca and Mg significantly ($P<0.01$). 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 occluded mineral nutrients like Ca, Mg, K and Na for crop use [22].

Effects of Biochar Application on Available P Content: The amount of available phosphorous in acidic soil was also significantly ($P<0.01$) increased by applying biochar (Table 5).The untreated acidic soil had 3.64±0.34 mg/kg available phosphorus at first week 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 three 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 15t/ha after three months of incubation periods and at pH values of 6.66. 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[23]. 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. Chan *et al*. [24] also reported the increase in available phosphorous after the application of biochar. Significant differences were observed between soil available P and total levels of successive weeks of incubation of the biochar amended soil, i.e., between available P levels of two weeks incubation and four weeks incubation, or between those of two weeks and four weeks of incubation period etc. 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 total P and 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 Opala *et al*. [23].

Table 5: Effects of bochar application on available P (Mean±SD)

		P(ppm)					
		Incubation period(Weeks)					
Biochar materials	Rating (t/ha)	2	4	6	8	10	12
Control	0	3.64±0.34^{ef}	4.94±0.66^{e}	3.48±0.24^{e}	4.99±0.23^{e}	4.99±0.24^{e}	4.99±0.24^{e}
CHB350	5	3.92±0.17^{def}	5.54±0.31^{de}	9.15±0.20^{cde}	10.65±0.18^{cde}	10.65±0.18^{cde}	11.35±0.18^{cde}
	10	4.44±0.28^{def}	6.22±0.35^{cde}	9.41±0.06^{cde}	10.93±0.11^{cde}	10.93±0.12^{cde}	11.63±0.12^{cde}
	15	5.75±0.40^{cde}	8.21±2.05^{bc}	12.19±0.47^{bcd}	13.71±0.50^{bcd}	13.71±0.50^{bcd}	14.41±0.50^{bcd}
CHB500	5	6.29±1.06^{bcd}	7.94±0.46^{bc}	13.61±2.15^{bcd}	15.22±2.17^{bcd}	15.22±2.17^{bcd}	15.92±2.17^{bcd}
	10	8.22±1.03^{ab}	8.43±0.40^{b}	18.76±0.88^{ab}	20.36±0.85^{ab}	20.36±0.86^{ab}	21.06±0.86^{ab}
	15	9.09±2.19^{a}	11±1.18^{a}	20.91±0.02^{a}	22.51±0.06^{a}	22.51±0.07^{a}	23.21±0.07^{a}
CCB350	5	3.27±0.39^{f}	4.51±0.09^{e}	7.86±2.09^{de}	9.4±2.11d^{e}	9.4±2.12^{de}	10.1±2.12^{de}
	10	3.95±0.28^{def}	4.97±0.25^{e}	9.38±0.45^{cde}	10.95±0.42^{cde}	10.95±0.43^{cde}	11.65±0.43^{cde}
	15	4.19±0.52^{def}	5.62±0.37d^{e}	11.55±3.17^{cd}	13.06±3.21^{cd}	13.06±3.21^{cd}	13.76±3.21^{cd}
CCB500	5	4.73±0.41^{def}	7.29±0.15b^{cd}	11.72±3.32^{cd}	13.3±3.36^{cd}	13.3±3.37^{cd}	14±3.37^{cd}
	10	7.95±0.41^{abc}	8.37±0.43^{bc}	13.4±3.04^{bcd}	14.97±3.07bcd	14.97±3.07^{bcd}	15.67±3.07^{bcd}
	15	8.67±0.44^{ab}	9.02±0.04^{ab}	15.41±5.44^{abc}	16.98±5.44^{abc}	16.98±5.45^{abc}	17.68±5.45^{abc}
P-Value		***	***	***	***	***	***

Means with the same letters are not significantly different ($p < 0.05$), ***significant at $P < 0.01$

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 results of the study clearly showed that the physical and chemical properties of biochar varied as a function of feedstock selection and pyrolysis temperatures. Higher pyrolysis temperatures resulted in biochar with higher surface areas, pH, EC, OC, OM, TN, Av.P, CEC and basic cations. The findings of the study also showed that, application of biochar materials prepared from both feedstock improved physicochemical properties of acidic soil. The application of biochar has also increased the pH and CEC of the soil. Application of coffee husk residue biochar produced at 500°C and applied at the rate of 15 t ha^{-1} significantly improved physicochemical properties of soil as compared to corn cob produced at the same temperature and the same application rate. This study revealed several interesting aspects of the effects of pyrolysis temperature and feedstock types on biochar chemical properties and how these biochar materials influenced the physicochemical properties of acidic soil is convincing. Moreover, further field researches are needed to evaluate the interactive effects of biochar on physicochemical properties of acidic soil.

ACKNOWLEDGMENT

We would like to thank the Capacity building for Scaling up of evidence-based best practices in Agricultural Production in Ethiopia (CASCAPE) project, Jimma University College of Agriculture and Veterinary Medicine Jimma, Ethiopia, for funding this research.

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