

Effect of Incubation Study of Coffee Husk on the Amendment of Chemical Properties on Acid Soil

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Abstract: Pot experiment incubation study was carried out to investigate the influence of biochar and lime on selected soil chemical properties of Nitisol loam soil with characteristic of high Phosphorus fixation and acidity. The treatments included (control, 10 t h⁻¹ coffee husk biochar (CHB), 20 t h⁻¹ CHB, lime and 10 t h⁻¹ CHB +50% lime). These were employed in Randomized Complete Block Design with three replications. The studied soil were collected and subjected to analysis of variance and treatment means were compared at the 0.05 probability level using list significant difference test. The results showed that soil pH increased from 4.89 to 6.68 by applying 20 t h⁻¹ CHB biochar at the same times the exchangeable acidity and acid cation are reduced significantly and. Moreover, liming significantly ($P \leq 0.05$) increased Cation Exchange Capacity (CEC) and available Phosphorus. This study stresses the importance of long-term lime experiments on major crops in order to investigate the residual effects and reduce lime costs.

Keywords: Incubation, coffee husk biochar, lime, soil acidity,

1. INTRODUCTION

Soil acidification is one of a natural process, which can be enhanced either by the activity of humans or in general living things. An example of man-made activity is Industrial and mining activities can lead to soil acidification through acid drains resulting primarily from pyrite oxidation and from acid precipitation caused by the emission of sulfur (SO_x) and nitrogen (NO_x) gases. The role of chemistry in this area that stay unaffected by industrial pollution, soil acidification is mainly caused by the release of H⁺ ions during the transformation and cycling of C, N and S in managed ecosystems. Soil acidification is not only detriment and also can use itself in several ways: increase of soil acidity or decrease of pH, decrease of base saturation and unbalanced availability of elements in the root environment, or decrease of the acid neutralizing capacity (ANC) of the soil [1].

It is one of the major limiting factors to crop productivity in the major part of highland area of Ethiopia since excessive rainfall coupled with that removes appreciable amounts of exchangeable basic ions like calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) from the surface of soil [2]. As you know Soil acidity and P fixation in the highlands are among the major challenges affecting agricultural productivity and food security (Agegnehu *et al.*, 2015, 2016, 2019).

Fortunately, such problems can be tackled by the application of appropriate fertilizer, addition of lime and biochar as soil improvements. Agricultural liming material is the most common soil management practices whose addition to agricultural soil in moderate amounts may be beneficial as plant nutrients, minimize soil acidification. The beneficial effects of liming soil are neutralization of exchangeable Al, increase Ca, Mg, P and Mo availability, stimulate microbiological activity in soil; improve physical structure of soil by clumping together or flocculation, clay in to more stable aggregates. In the same manner like agricultural lime recent studies have suggested that the soil amended with biochar can potentially enhance plant physiological processes [3,4, 5]. The term biochar refers to the carbonaceous product obtained by thermal decomposition of plant or animal residue in an oxygen-limited environment and when applied to soil as an amendment [6]. It is not only to maintain soil acidity but also to enhance soil fertility and nutrients for plant uptake, enrich plant growth and yield [7].

Know a day limestone material is relatively expensive and unaffordable to the Ethiopian farmers; the supply has limited in Ethiopia, and also can only amend exchangeable calcium, magnesium, and phosphorus. Due to this, researchers have recently started using biochar as an alternative soil amendment mechanism. Once to adjust the pyrolysis machine and demonstrate the technology for producer the material locally available, cheaper, environmentally friend compared to limestone and fertilizer. So, the potential of biochar as a soil nutrient amendment, soil acid management in agricultural fields is a recently recognized and yet it is underutilized technology. Therefore, the aims of this study explored the effects of biochar and combination of biochar with lime to soil physicochemical properties and acid saturation under greenhouse condition.

2. MATERIALS AND METHODS

2.1. Soil sampling

Bulk Soil sample Known pH level or below 5 were collected from on station of Holetta agricultural research center. Soil sample (0–20 cm depth) at five points in zigzag pattern was collected using an auger, core samplers were used for bulk density sampling separately from the place of soil pH below 5. Coffee husk biochar was collected from Jimma University College of Agriculture and Veterinary Medicine and used for Incubation experiment studies. Before applying soil amendment some collected soil and biochar sample were transferred to plastic trays and break up the large clods to speed up drying for initial laboratory analysis. The sample was air-dried, crushed with mortar and pestle and passed through a 2 mm opening stainless steel sieve [8] and laboratory analysis was done.

2.2 Soil physico-chemical Analysis

All analytical measurement was performed in Agricultural Research Laboratory and also all the chemicals used were of analytical reagent grade. Distilled water was used for all dilutions throughout the study. For each Laboratory analysis use three Replication .bulky density were determined by using oven dry method while soil texture was analyzed by hydrometer after soil soaked by calgon solution and Soil organic carbon content was determined by the method of [9] and organic matter was estimated from the organic carbon content by multiplying the latter by 1.724 factors. Total N was determined using the micro-Kjeldahl digestion, distillation and titration procedure as described by Bremner and Mulvaney [10]. Soils available P was extracted by the Bray-II method [11] were quantified using spectrophotometer (wave length of 880 m) calorimetrically using the mixture of ammonium molybdate, sulphuric acid and potassium antimony tartrate as an indicator. To determine the cation exchange capacity (CEC), the soil samples were first leached with 1M NH₄OAC, and excess NH₄OAC washed with ethanol and the adsorbed ammonium was replaced by sodium [12]. The CEC was then measured titrimetrically by distillation of ammonia that was displaced by Na following the micro- Kjeldahl procedure. Total exchangeable acidity was determined by saturating the soil samples with 1M KCl solution and titrating with 0.02M H₂SO₄ as described by Rowell [13]. From the same extract, exchangeable Al in the soil was titrating with a standard dispersed by mechanical stirrer.

2.3. Laboratory incubation experimental setup

The air dried soil sample was used in the laboratory incubation experiments and 3 kg of soil was filled in plastic pots. The treatments were includes at the rate of control without biochar, 10 t h⁻¹ CHB, 20 t h⁻¹ CHB, lime and 50% lime +10 t h⁻¹CHB thoroughly mixed with soil. During the incubation period, the pots were employed in a greenhouse experiment in a randomized complete block design (RCBD). By adding distilled water in to the mixture of soil –biochar maintained at field capacity throughout the incubation period .The treatments were incubated for 60 days and soil pH, Exg-acidity and Excg.Al⁺³ were analyzed within 15 days interval and other important physico-chemical properties analyzed at the end of 60 days by removing the sample from each treatments since the target of study to observed which treatment at which time neutralized.

3. RESULTS

Table1. Physico-chemical properties of studied soil and coffee husk biochar before incubation (mean ± SD)

Element	Unit	soil	Biochar
BD	g cm ⁻³	1.02	
pH	Soil (H ₂ O 1:2.5) biochar (1:5)	4.89	11.05
EC	dS m ⁻¹	0.069	5.697
Exch acidity	cmol _c kg ⁻¹	3.24	-
Exch Al ⁺³	cmol _c kg ⁻¹	2.094	-
CEC	cmol _c kg ⁻¹	19.68 ± 0.11	65.89±0.183
OC	%	2.28	17.29
TN	%	0.11	0.62
available p	Ppm	7	1109
Clay	%	72.5	
Silt	%	17.5	
Sand	%	10	

Table1. Treatment effect of coffee husk biochar on soil pH (mean ± SD)

Treatment	Incubation period				
	0	15	30	45	60
control	4.890 ±0.02	4.97±0.02	5.11±0.08	5.18±0.02	5.18±0.09
CHB(10 t h ⁻¹)	5.13±0.03	5.26±0.02	5.47±0.03	5.75±0.03	5.89±0.1
CHB(20 t h ⁻¹)	5.33±0.01	5.75±0.01	6.13±0.06	6.48±0.01	6.68±0.02
Lime	5.05±0.02	5.19±0.09	5.37±0.06	5.44±0.01	5.77±0.06
CHB (10 t h ⁻¹)+50% lime	5.21±0.02	5.35±0.01	5.68±0.02	5.88±0.1	5.94±0.01
LSD(0.05)	0.24	0.11	0.3	0.22	0.25
CV (%)	2.4	4	2.5	2.6	3

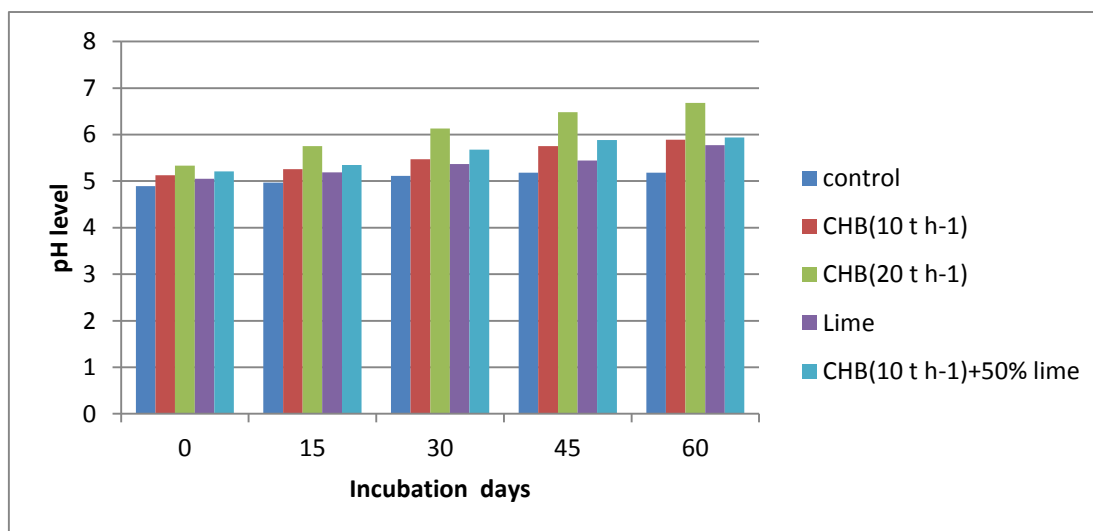


Figure1. Effect of coffee husk biochar on soil pH

Table2. Treatment effect of coffee husk biochar on Exch.acidity (mean ± SD)

Treatment	Incubation period				
	0	15	30	45	60
control	3.24±0.01	3.22±0.02	3.2±0.04	3.21±0.05	3.22±0.02
CHB10 t h-	2.92±0.05	2.45±0.01	1.95±0.05	0.74±0.02	0.22±0.03
CHB20 t h-	2.82±0.07	1.19±0.09	-	-	-
Lime	3.01±0.01	2.55±0.01	2.04±0.07	1.12±0.01	0.68±0.05
CHB t h-+50% lime	2.85±0.01	2.53±0.03	0.72±0.03	0.18±0.01	-
LSD (0.05)	0.7	0.09	1.21	2.8	3.53
CV (%)	4.36	1.36	2.32	3.21	2.48

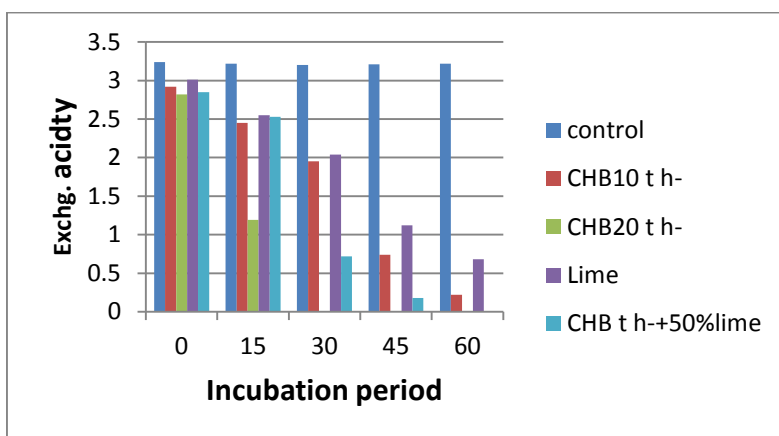


Figure2. Effect of coffee husk biochar on Exch.acidity

Table3. Treatment effect of coffee husk biochar on Exch.Al³⁺ (mean ± SD)

Treatment	Incubation period				
	0	15	30	45	60
control	2.12±0.01	2.1±0.06	2.0±0.02	2.0±0.02	2.12±0.05
CHB10 t h-	1.85±0.03	1.6±0.01	1.25±0.04	0.33±0.05	0.09±0.05
CHB20 t h-	1.63±0.02	0.76±0.03	-	-	-
Lime	1.97±0.02	1.56±0.04	1.22±0.05	0.43±0.04	0.24±0.03
	1.75±0.08	1.32±0.04	0.21±0.06	0.18±0.04	-
LSD (0.05)	0.8	0.75	1.3	2.14	2.35
CV (%)	1.21	2.18	2.82	1.6	1.53

Table4. Treatment effect of coffee husk biochar on Exch. H⁺ (mean ± SD)

treatment	Incubation period				
	0	15	30	45	60
control	1.12±0.04	1.12±0.05	1.2±0.01	1.21±0.02	1.1±0.02
CHB(10 t h ⁻¹)	1.07±0.01	0.85±0.03	0.7±0.09	0.41±0.03	0.13±0.05
CHB (20 t h ⁻¹)	1.19±0.03	0.43±0.03	-	-	-
Lime	1.04±0.02	0.99±0.01	0.82±0.1	0.69±0.09	0.44±0.04
CHB (10 t h ⁻¹ + 50 % lime)	1.1±0.01	1.21±0.01	0.51±0.02	-	-
LSD(0.05)	0.07	1.2	1.5	1.33	1.32
CV (%)	2.5	4.35	2.2	3,4	0.89

Table5. Effect of coffee husk biochar on some selected physico-chemical properties of amended soil

Treatment	% OC	% OM	TN (%)	P(ppm)	CEC(Cmol/kg)
Con	2.76 ± 0.01 ^c	4.75 ± 0.01 ^c	0.11 ± 0.0a	7.48 ± 0.75 ^e	19.65 ± 0.197 ^d
CHB (10 t h ⁻¹)	3.9 ± 0.002 ^b	6.72 ± 0.003 ^b	0.11 ± 0.003 ^a	9.48 ± 0.199 ^c	32.89 ± 1.00 ^c
CHB (20 t h ⁻¹)	5.04 ± 0.002 ^a	8.7 ± 0.11 ^a	0.11 ± 0.006 ^a	13.564 ± 0.32 ^a	41.56 ± 0.9 ^a
Lime	2.78 ± 0.009 ^c	5.28 ± 0.016 ^c	0.113 ± 0.005 ^a	8.822 ± 0.096 ^d	34.2 ± 0.08 ^c
CHB (10 t h ⁻¹) + 50% lime	3.89 ± 0.06 ^b	6.71 ± 0.096 ^b	0.113 ± 0.008 ^a	10.944 ± 0.49 ^b	38.9 ± 0.05 ^b
LSD (0.05)	0.12	0.12	NS	0.471	0.562
CV (%)	0.3	4.83	4.11	3.266	2.23

%OC, soil organic carbon; %OM, soil organic matter; TN, soil total nitrogen; P, soil available phosphorus; CEC, cation exchange capacity; LSD., least significant difference; CV, the coefficient of Variation. Within columns means followed by the same letter are not significantly different at P = 0.05.

4. DISCUSSIONS

4.1 Selected physico-chemical properties of studied soil and biochar produced from coffee husk before incubation

The initial status of soil physico- chemical properties were shown in table 1. The mean value of soil texture were found to be clay about (72.5%), silt (17.5%) and sand (10%) due to this result indicated the soil texture categorized under clay content(14). In this study, the mean value of soil bulk density was found to be 1.02 g/cm³ and its low shown in Table 1. This is due to high clay contents of soil and Density that occupy small volume [15]. In this finding, the mean value of the initial soil pH was categorized under strong acidic (pH 4.89) [16] similarly from the table 1 the value of Exch.acidity and acid cations (Al³⁺ and H⁺) were categorized under toxic level [17]. The other properties of soil status of organic carbon, total nitrogen, CEC and available phosphors were very low as shown in table 1 this is due to the fixation of those elements expected in acid soil. The biochar results indicated that as used for the amendment of soil has strong alkaline (pH, 11.05). High electrical conductivity value (5.693 ± 0.13 dS/m) and CEC of 65.89 ± 0.183 Cmol (+) kg⁻¹ was observed in biochar. No detectable exchangeable acidity and exchangeable aluminum were observed in the biochar sample. In this study, the biochar carbon content was (17. 29%) and the values of available K (243 cmol (+) kg⁻¹), P (1109 ppm) is approximately similar with the report of our finding with which is observed by [18]

4.2 Effect of coffee husk Biochar and lime on selected Soil physico-chemical properties

The changes in soil pH due to addition of treatments during 60 days of incubation period are presented in Table 2 and Figure 1. Soil pH known as potential of hydrogen is a specific that describes the relative acidity or alkalinity of the soil. pH is defined as the negative (-) log or base 10 value of the concentration of hydrogen ions [19,20]. Soil pH influences some soil parameters (soil quality) that affect plant growth and yield; these include soil bacteria, nutrient leaching, nutrient availability, toxic elements and soil structure [21]. Our findings indicate that application of all amendments except control has showed significantly positive effect since; initially the soil pH was 4.89 due to the addition of treatment the pH was found increase at all days of incubation. Increase both incubation period and the rate of application of biochar alone and combined together with lime correspondingly increases the soil pH. From this the highest value obtained in 20t h⁻¹CHB at the end of Incubation period. From the graph 1 observing from 0 up to 45 incubation periods the application of lime enhanced the pH value slowly as compared to 10 t h⁻¹ CHB alone. When 10 th⁻¹ CHB with 50% lime increased significantly the pH value next to 20 t h CHB. This positive effect of treatment and incubation time it may be due to Lime materials is very slowly soluble in water, if the material easily soluble to facilitates speed of reaction between lime and water and carbon dioxide in soil to yield bicarbonate (HCO₃⁻), which is able to take H⁺ and Al³⁺ (acid-forming cations) out of solution, thereby raising the soil pH. Correspondingly this amendment not only pH change can also amend Exch.acidity and acid cations (Al³⁺ and H⁺) as show figure 2, table 3, 4, 5. Exchangeable acidity is the combination of H⁺ and Al³⁺ ions reserved or fixed on soil colloid after the active acidity is measured [22]. When the exchangeable acidity of the soil is high with a resultant low pH, it affects the soil condition and many processes in the soil. In an acidic condition, aluminum fixes phosphorus causing its deficiency in plants roots [23], the bioavailability of iron, aluminum, or manganese can be very high and may reach toxic levels at lower pH [24]. In other wards both pH and exchangeable acidity negative relationship as soil pH increased to reduce acid cations. This result indicated that drastic change due to the process of acid neutralization reaction takes place between soil surface and soil amendments When addition of coffee husk biochar alone and combined with lime they form strong bonds known as chelates with aluminum and this gives rise to the reduction of the solubility of aluminum and soil acidity.. Our finding agrees to [18] who reported days of incubation significantly affected soil pH.

There is no much significant change was observed between lime and control on the value of organic carbon (2.76, 2.78) respectively (table 6) similarly between 10 t h⁻¹ CHB and 10 t h CHB + 50 % lime also no significant change on OC content at the last incubation days (3.9 and 3.89) respectively. Whereas significant difference was observed at 20 t h CHB (5.04) and this significant change due to the addition of biochar could result from the presence of a high amount of organic matter.

Availability of Phosphorous is significantly affected by soil acidity. The phosphorous concentration is found to be increased after application of treatments at 60 day incubation period (Table 6). This is due to either the nature of existence of phosphorous in soil or due to the presence of concentration of

phosphorous in the biochar. The existence of P is extremely limited by soil pH. At $\text{pH} < 5.5$ P is fixed by Al^{+3} and Fe^{+3} in the form of AlPO_4 and FePO_4 , while at $\text{pH} > 5.5$ it exists in the form of $\text{Ca}_3(\text{PO}_4)_2$. On the other hand, there is a high competition between acid cations such as Al^{+3} , Fe^{+3} and basic cations such as Na^+ , K^+ , Ca^{+2} and Mg^{+2} to be bonded to PO_4^{-3} during this time phosphorus could not be absorbed by plant roots [25]. Phosphorus is the primary nutrient for all plants and uptake in the form of PO_4^{-3} . In this study the concentration of phosphorus was found between the range of 7.48- 13.56 in all treatment and at the last day of incubation. High value was observed in the application of 20 t h^{-1} of CHB (Table 6).

Cation exchange sites are found primarily on clay minerals and organic matter (OM) surfaces. Soil OM will develop a greater CEC at near-neutral pH than under acidic conditions (pH-dependent CEC) in other words both CEC and pH positive correlations as pH rise with CEC increase. In our study the content of CEC indicate that highly significant change at all treatment after 60 days incubation period than the control as shown in Table 6. Significantly higher soil CEC contents were obtained from 20 t h^{-1} CHB, 10 t h^{-1} CHB + 50 % lime, and recommended lime than 10 t h^{-1} CHB alone (41.56, 38.9, and 34.2) respectively. The positive effect of the application of biochar and lime indicated that might be due to the high surface area of biochar could increase cation exchange capacity and enhance the ability of soils to retain and supply nutrients and improved soil conditions such as soil pH and reduction of exchangeable acidity which in turn increased the exchange sites of the soil respectively.

5. CONCLUSIONS

Application of biochar alone and combined with lime resulted in positive effect on soil chemical properties. In highly acidic soils it may serve as a soil amendment by increasing the soil pH, P availability, CEC and SOC in a sustainable manner. From all treatment plant nutrient (soil chemical) property highly significant result obtained at applying 20 t h^{-1} CHB and next 10 t h^{-1} CHB

After 60 days greenhouse incubation of biochar alone and combined with lime attain the target pH 6.68 and decrease in both exchangeable acidity and Al to undetectable cmol/Kg . During application of treatment, soil pH increases slightly in the first incubation period and fastly increases the last two months due to a slight decrease in the strengths of acidity as liming period increases. So, the farmer must be to give incubation period after applying the treatment of acid soil management before show his/her seeds. This is due to the reaction between materials and soil acidity is time dependent reaction. Therefore this is particular importance as it indicates the value of biochar as alternative amendments to ameliorate acid soil management for small-scale farmers who cannot afford to regularly purchase lime and mineral fertilizers.

Generally, all the result of soil nutrient obtained with the acceptable analytical methods which were evaluated by analytical method validation and quality control parameters such as precision accuracy, reliability by measurements of replication, method blank, spike recovery was taken

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