

# Effect of Biochar, Farmyard Manure and Nitrogen Fertilizers on Soil Chemical Properties in Sinana District, South Eastern Oromia, Ethiopia

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## To cite this article:

Abdurahman Husien, Bobe Bedadi, Nigussie Dechassa. Effect of Biochar, Farmyard Manure and Nitrogen Fertilizers on Soil Chemical Properties in Sinana District, South Eastern Oromia, Ethiopia. *International Journal of Applied Agricultural Sciences*. Vol. 3, No. 6, 2017, pp. 148-153. doi: 10.11648/j.ijaas.20170306.12

**Received:** July 26, 2017; **Accepted:** August 7, 2017; **Published:** November 10, 2017

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**Abstract:** Integrated soil fertility management could be a useful tool to maintain and improving soil fertility. Therefore, the experiment was conducted with the objective of investigating the influence of biochar, farmyard manure, and mineral nitrogen fertilizer on soil chemical properties. *The disturbed soil samples were collected from five locations of each plot at optimum moisture conditions to a depth of 20 cm at the start of the experiment, after six months of farmyard manure and biochar treatments application.* The treatments consisted of two levels of farmyard manure (0 and 6 tons ha<sup>-1</sup>), three levels of biochar (0, 5, and 10 tons ha<sup>-1</sup>) and three levels of nitrogen (0, 23 and 46 kg N ha<sup>-1</sup>). The results revealed that the interaction effects of biochar, farmyard manure, and mineral nitrogen fertilizer significantly ( $P < 0.001$ ) influenced the soil chemical properties of major contents of soil available potassium, nitrate nitrogen and ammonium nitrogen after six months. Similarly, the analysis of variance showed that the interaction effect of biochar and farmyard manure levels significantly ( $P < 0.05$ ) influenced soil reaction (pH) and CEC. However, the interaction effect of biochar, farmyard manure and nitrogen levels and that of farmyard manure and biochar levels as well as biochar and nitrogen levels on soil available phosphorus were non-significant. Generally, the availability of plant nutrients concentration in the soil solution before treatments of farmyard manure and biochar application was lower than that of after six months. *Likewise, farmer should be advised to add small amount of mineral fertilizer to farmyard manure and biochar to improve soil properties and enhance soil productivity and quality.*

**Keywords:** Biochar, Farmyard Manure, Soil Solution, Chemical and Soil Reaction

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## 1. Introduction

Soil is the most important natural resources, because it is a primary medium for the growth of food and fodder. The use of organic materials as fertilizers for crop production has received attention particularly recently for sustainable crop production [1]. According to [2], many soils in the highlands of Ethiopia are poor in available plant nutrients and organic matter content. In addition to this previously, only nitrogen (N) and phosphorus (P) were considered to be the limiting nutrients in Vertisols of Ethiopia [3].

The application of farmyard manure (FYM) to soil has been practiced for many centuries and its application to soil have increased crop yield, improved soil fertility, increased soil organic matter, increased microbiological activities and improved soil structure for sustainable agriculture [4]. Likewise, biochar application has received a growing interest as a sustainable technology to improve highly weathered or degraded soils [5]. Similarly, According to [6], biochar application significantly increased soil carbon (C), phosphorus (P) and potassium (K) by 54.02, 61.39 and 18.41%, respectively.

The soils of Bale highlands including Sinana area are dominantly Vertisols, Cambisols and Phaeozems with poor

structure, low infiltration capacity and develop deep cracks in dry seasons [7]. Therefore, it is generally accepted that improved soil conditions associated with manure and biochar application lead to changes in soil physical and chemical properties. Therefore, this study was undertaken with the objectives of investigate the influence of biochar, farmyard manure and nitrogen fertilizer on soil chemical properties.

## 2. Materials and Methods

### 2.1. Description of the Study Area

The experiment was conducted during the 2015 main cropping season at Selka Kebele of Sinana district which is located in Bale zone of Oromia Regional State with the geographic coordinates of 07° 04' 248" N to 07° 04' 256" N and 040° 11' 137" E to 040° 11' 154" E at a distance of about 456 km Southeast of Addis Ababa and at an altitude of 2400 m above sea level (Figure 1). The area is characterized by

high altitude, sub humid climate with bimodal rainfall pattern, According to Sinana Agricultural Research Center Meteorology Station records from 1993 to 2015, the long-term precipitation ranges from 710.10 to 1566.30 mm with an annual average of 1149.72 mm. The area has bimodal rainfall pattern with the first rainy season start from March and taper off in July, while the second rains fall between August and December (Figure 2). The area receives rainfall of 320.05 to 861.39 mm during the first rainy season (March to July) and 353.38 to 867.90 mm during the main season (August to December). The mean annual maximum temperature is 20.96°C and the monthly values range between 19.39°C in October and 22.85°C in February. The mean annual minimum temperature is 9.67°C and the monthly values range between 7.93°C in December and 10.79°C in May. The coldest month is December whereas February is the hottest month (Figure 2).

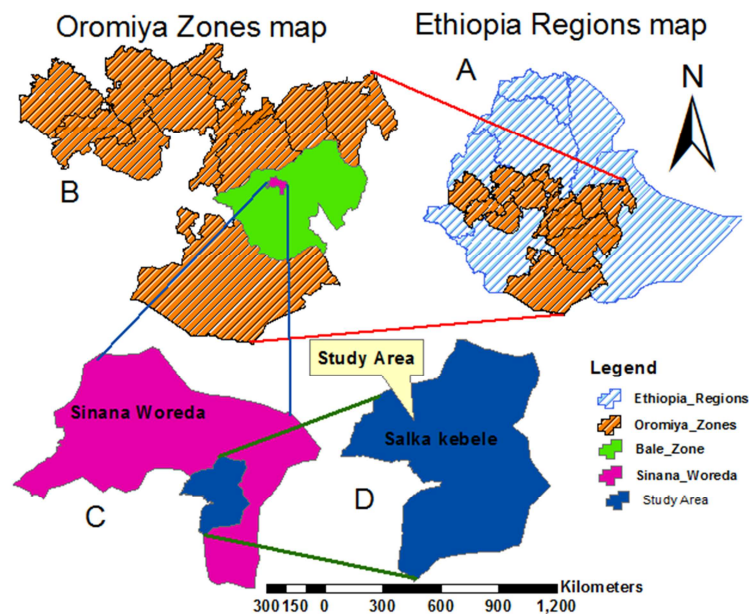


Figure 1. Maps of the study area.

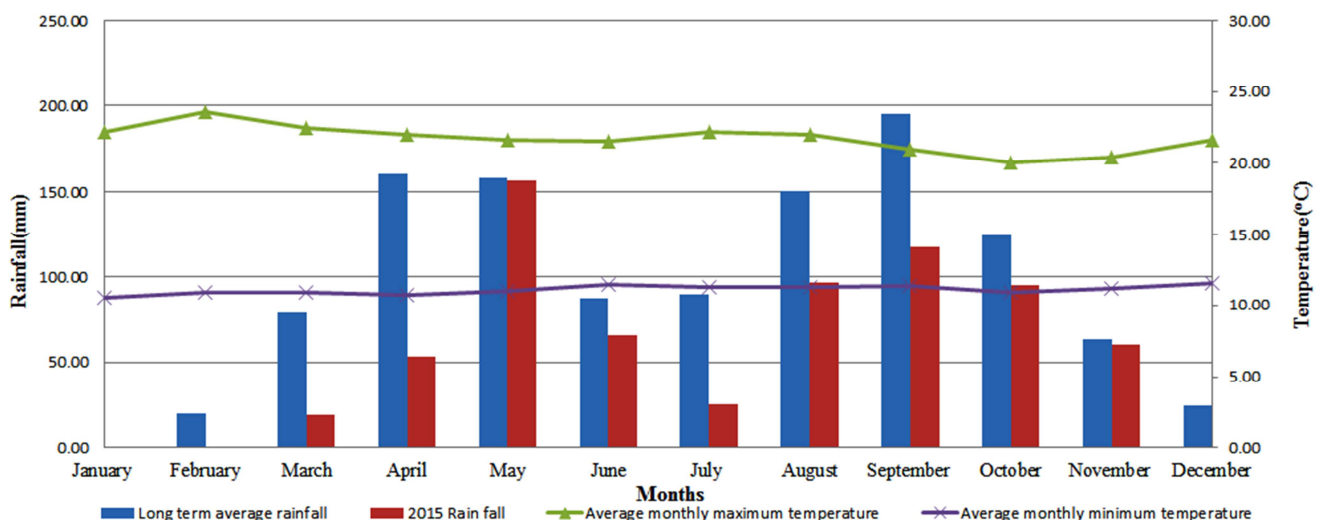


Figure 2. Monthly rainfall (2015), long term average rainfall, maximum and minimum monthly average temperature of Sinana Agricultural Research Center.

## 2.2. Data Collection

### 2.2.1. Soil Samples Collection and Preparation

Disturbed soil samples were collected from five locations of each plot at optimum moisture conditions to a depth of 20 cm using augur prior to the start of the experiment, after six months of farmyard manure and biochar treatments application. From these, composite samples of 1 kg soil were made for each plot. The samples were taken to the laboratory, air-dried, crushed, and sieved to pass through a 2 mm and 1 mm mesh.

### 2.2.2. Soil Sample Analysis

Laboratory analyses were conducted at Sinana Agricultural Research Center, Zeway Soil Agricultural Research Center and Horticoop Ethiopia for selected soil physico-chemical parameters following standard laboratory procedures.

### 2.2.3. Soil Chemical Analysis

Soil pH was potentiometrically measured in the supernatant suspension of 1:2.5 soils: water and potassium chloride solution ratio [8]. Soil organic carbon content of the soil was determined by potassium dichromate wet oxidation procedure [9]. Soil organic matter was calculated from soil organic carbon by multiplying with a coefficient of 1.724. Total nitrogen content of the soil was determined by wet digestion procedures of the Kjeldahl method [8]. C: N ratio was calculated from organic carbon and total nitrogen by dividing soil organic carbon with soil total nitrogen. The available phosphorus content of soils was determined by 0.5M sodium bicarbonate extraction procedures [10]. Available potassium (K) was determined by ammonium acetate extraction-flame photometry procedure [11]; The cations exchange capacity of the soil (CEC) was measured after saturating the soil with 1N ammonium acetate ( $\text{NH}_4\text{OAc}$ ) and displacing it with 1N  $\text{NaOAc}$  [12]; Soil nitrate nitrogen and ammonium nitrogen ions were determined by steam distillation (ISO 7890-1) and (ISO 7150-1) respectively.

**Table 1.** Soil chemical and physical properties of the experimental site before treatment application

Soil Chemical Properties	Results	Units
Soil Reaction(pH)	6.64	-
Phosphorus	12.68	mg/kg soil
Potassium	2.65	cmol <sub>c</sub> /kg soil
Calcium	25.47	cmol <sub>c</sub> /kg soil
Magnesium	4.61	cmol <sub>c</sub> /kg soil
Sodium	0.06	cmol <sub>c</sub> /kg soil
Sulfur	0.50	mg/kg soil
Iron	32.64	mg/kg soil
Manganese	221.67	mg/kg soil
Zinc	0.22	mg/kg soil
Boron	0.19	mg/kg soil
Copper	4.51	mg/kg soil
Molybdenum	0.10	mg/kg soil
Total Nitrogen	0.18	%
Cation Exchange Capacity	53.93	cmol <sub>c</sub> /kg soil
Aluminum	6.32	cmol <sub>c</sub> /kg soil
Organic Matter	1.79	%
Soil Physical properties		
Soil texture (%)		
Clay	56	%
Silt	35	%
Sand	9	%
Soil textural class	Clay	Clayey

### 2.2.4. Biochar, Farmyard Manure Chemical Composition and Pre Soil Analysis

A composite sample was made from the prepared treatment of biochar, farmyard manure and pretreatment application soil samples. A separate sample was air-dried; ground using a pestle and mortar and allowed to pass through a 2 mm and 1 mm sieve. The chemical analyses of the farmyard manure, biochar and pretreatment application soil samples were conducted using the Mehlich-III multi-nutrient extraction procedure [13] Using Atomic Absorption Spectroscopy and spectrophotometer

**Table 2.** Chemical compositions of farmyard manure and biochar applied as a treatment.

Description of Parameter	Biochar	Farmyard manure	Units
Soil Reaction	9.81	8.67	-
Ammonium	42.56	0.04	mg/kg soil
Nitrate	2867.42	291.91	mg/kg soil
Phosphorus	141.39	5.84	mg/kg soil
Potassium	16.10	9.79	cmol <sub>c</sub> /kg soil
Calcium	0.11	0.61	cmol <sub>c</sub> /kg soil
Magnesium	0.04	0.18	cmol <sub>c</sub> /kg soil
Sodium	0.12	0.10	cmol <sub>c</sub> /kg soil
Sulfur	415.28	19.90	mg/kg soil
Silicon	59.48	5.04	mg/kg soil
Iron	1.46	0.58	mg/kg soil
Manganese	0.09	0.06	mg/kg soil
Zinc	0.02	0.02	mg/kg soil
Boron	0.48	0.04	mg/kg soil
Copper	0.04	0.07	mg/kg soil
Molybdenum	0.31	0.02	mg/kg soil
Total Nitrogen	1.07	1.63	%
Cation Exchange Capacity	61.32	54.94	cmol <sub>c</sub> /kg soil

### 2.2.5. Statistical Data Analysis

The effects of treatments on soil chemical properties and the

collected data were subjected to analysis of variance (ANOVA) using general linear model (GLM) procedures of statistical

analysis system of computer software [14] and significantly differing means were separated using the Duncan's multiple range test (DMRT). Least significant difference (LSD) test was involved to compare among means separated by DMRT.

### 3. Results and Discussion

#### 3.1. Post-Harvest Soil Chemical Properties

Soil reaction (pH), organic carbon and available phosphorus

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen levels and that of farmyard manure and nitrogen levels as well as biochar and nitrogen levels on soil reaction were non-significant. However, that of farmyard manure and biochar on soil reaction was significant ( $P < 0.05$ ) (Table 3).

As the results of mean of main effects show that there was slight increase in soil reaction with the increase in biochar levels (0, 5 and 10 ton ha<sup>-1</sup>) from the control treatment 0.13 and 0.2 biochar levels respectively. This study in line with [15] finding application of charcoals from burned biomass had demonstrated well their ability to raise soil pH in previous.

The analysis of variance showed that none of the interaction effect of the treatments was significant on soil organic carbons. Likewise, the main effects of nitrogen levels on soil organic carbons were non-significant. However, that of biochar levels on soil organic carbons was highly significant ( $P < 0.001$ ) as well as farmyard manure levels on soil organic carbons was significant ( $P < 0.05$ ) (Table 3).

As the analyzed results shows that the soil organic carbon

increase with the increase of biochar (0, 5 and 10 ton ha<sup>-1</sup>) by 0.07 and 0.14% and farmyard manure rate (0 and 6 ton ha<sup>-1</sup>) by 0.08% over the control treatment respectively; this may be affected by the decomposing rate of organic material applied to the soils. In line with this finding of [16] who observed a remarkable increase in organic carbon and organic matter content of the soil after the application of biochar and attributed it to the fact that biochar is a recalcitrant organic material. Similarly, [17] also concluded that FYM application level of 30 and 60 Mg ha<sup>-1</sup> increased organic matter contents on both row and inter row tracks significantly.

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen levels and that of farmyard manure and biochar levels as well as biochar and nitrogen levels on soil available phosphorus were non-significant. However, that of farmyard manure and nitrogen levels on soil available phosphorus was significant ( $P < 0.05$ ).

As the analyzed results shows that the soil available phosphorus increase with the increase of biochar (0, 5 and 10 ton ha<sup>-1</sup>) by 35.44 and 43.29% and farmyard manure rate (0 and 6 ton ha<sup>-1</sup>) by 18.70% over the control respectively. Therefore from this point of view the levels of biochar affect soil available phosphorus than the levels of farmyard manure; this is due to the effects of biochar on soil reaction than farmyard manure which increases the mobility of phosphate in the soil solution. In line with this according to the study conducted by According to [18], the observed increase in available phosphorus due to application of biochar could be due to the presence of high phosphorous in the maize stalk.

**Table 3.** The main effect of biochar, farmyard manure and nitrogen levels on soil reaction, soil organic carbon (%) and available phosphorus after six months

FYM (ton ha <sup>-1</sup> )	pH: H <sub>2</sub> O	OC (%)	Ava. P (mg kg <sup>-1</sup> soil)
0	7.34	1.71 <sup>b</sup>	7.52 <sup>b</sup>
6	7.36	1.79 <sup>a</sup>	9.25 <sup>a</sup>
LSD <sub>(0.05)</sub>	NS	0.05	1.04
Biochar (ton ha <sup>-1</sup> )			
0	7.24 <sup>c</sup>	1.68 <sup>c</sup>	5.83 <sup>b</sup>
5	7.37 <sup>b</sup>	1.75 <sup>b</sup>	9.03 <sup>a</sup>
10	7.44 <sup>a</sup>	1.82 <sup>a</sup>	10.28 <sup>a</sup>
LSD <sub>(0.05)</sub>	0.04	0.06	1.27
Nitrogen (Kg N ha <sup>-1</sup> )			
0	7.35	1.73	8.08
23	7.35	1.74	8.11
46	7.36	1.78	8.96
LSD <sub>(0.05)</sub>	NS	NS	NS
CV (%)	0.85	4.72	22.41

Means followed by the same letter with in the same column of the respective treatment are not significantly different ( $P \leq 0.05$ ) according to Duncan's Multiple Range Test, FYM = Farmyard manure, CV = Coefficient of variation, LSD = Least Significant differences, NS = not Significant.

Soil total nitrogen, cation exchange capacity (CEC) and C: N ratio.

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen levels on soil total nitrogen were non-significant. However, that of farmyard manure and nitrogen level as well as biochar and nitrogen levels on soil total nitrogen was significant ( $P < 0.05$ ). Likewise, that of farmyard manure and biochar on soil total nitrogen was highly significant ( $P < 0.001$ ) (Table 4).

As the analyzed results revealed that the interaction mean of biochar and farmyard manure increases with the increase in the

biochar rates (0, 5 and 10 ton ha<sup>-1</sup>) by the 0 ton ha<sup>-1</sup> farmyard manure; however, the interaction mean between farmyard manure and biochar rates increments there was no regularity of mean interaction increment. Total nitrogen measures the total amount of nitrogen present in the soil, much of which is held in organic matter and is not immediately available to plants. It may be mineralized to be in available forms.

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen levels and that of

farmyard manure and nitrogen levels as well as biochar and nitrogen levels on cation exchange capacity (CEC) were non-significant. However, that of farmyard manure and biochar on cation exchange capacity (CEC) was significant ( $P < 0.05$ ) (Table 4).

As the mean interaction indicated that there was an increase in cation exchange capacity (CEC) with the increase in the rate of farmyard manure (0 and 6 ton ha<sup>-1</sup>) and biochar (0, 5 and 10 to ha<sup>-1</sup>) this shows that with the increase in the soil organic matter also increase in cation exchange capacity (CEC). This study in line with cation exchange capacities may increase over short time during aging as an increase in the CEC of aged biochar's compared to fresh ones due to generation of oxygenated surface functional groups by surface oxidation process has previously been reported [16].

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen levels on C: N ratio was non-significant. However, that of farmyard manure and

nitrogen levels as well as biochar and nitrogen levels on soil C: N ratio was significant ( $P < 0.05$ ). Likewise that of farmyard manure and biochar on C: N ratio was highly significant ( $P < 0.001$ ) (Table 4).

As the mean interaction results revealed that with increase rate of biochar there was a decrease of C: N Ratio with interaction of control farmyard manure, But the high value C: N Ratio was recorded with the of 6 ton ha<sup>-1</sup> farmyard manure and 5 ton ha<sup>-1</sup> biochar which was 13.28 and the lowest value was 10.81 with the mean interaction of 6 ton ha<sup>-1</sup> farmyard manure and 10 ton ha<sup>-1</sup> biochar. Similar findings according to [19] Increasing the biochar application levels increased the C: N ratio of the soil and appeared to reduce N uptake probably because of nitrogen immobilization. This might only be a short-term effect; once the more labile (volatile carbon component) of the biochar is degraded, then this should reduce immobilization. Therefore, the exclusive use of biochar in the absence of N fertilizer is not encouraged.

**Table 4.** The interaction effect of farmyard manure and biochar rate on cation exchange capacity, C: N ratio and soil total nitrogen after six months

CEC (cmolc kg <sup>-1</sup> )				C:N Ratio			TN (%)		
				Biochar (ton ha <sup>-1</sup> )					
FYM (ton ha <sup>-1</sup> )	0	5	10	0	5	10	0	5	10
0	48.88 <sup>a</sup>	53.62 <sup>b</sup>	55.92 <sup>cd</sup>	12.49 <sup>bc</sup>	11.47 <sup>ab</sup>	10.96 <sup>a</sup>	0.133 <sup>a</sup>	0.151 <sup>b</sup>	0.166 <sup>c</sup>
6	53.68 <sup>b</sup>	54.93 <sup>bc</sup>	57.54 <sup>d</sup>	11.03 <sup>a</sup>	13.28 <sup>c</sup>	10.81 <sup>a</sup>	0.160 <sup>bc</sup>	0.136 <sup>a</sup>	0.172 <sup>c</sup>
SE±		1.73			1.087			0.013	
LSD <sub>(0.05)</sub>		1.66			1.041			0.012	
CV (%)		3.2			9.3			8.2	

Means followed by the same letter with in the same column of the respective treatment are not significantly different ( $P \leq 0.05$ ) according to Duncan's Multiple Range Test, FYM = Farmyard manure, SE = Standard error, CV = Coefficient of variation, Least Significant differences, NS = not significant, CEC = Cation exchange capacity, TN = total nitrogen, C: N = Carbon to nitrogen.

### 3.2. Soil Available Potassium

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen levels on Soil Available Potassium were highly significant ( $P < 0.001$ ) (Table 5).

As the analyzed result of mean interaction revealed that the effect of biochar, farmyard manure and nitrogen levels on soil available potassium were increases with the levels of means interaction increase. Similarly, this study in line with [20] available potassium in soil increased with the application of organic manures which is due to solubilizing action of organic

acids produced during farmyard manure decomposition and its higher capacity to hold potassium in available form. Likewise, increase in exchangeable Potassium was recorded by the application of biochar [21].

Generally, the availability of plant nutrient concentration in the soil solution before application of treatments of farmyard manure and biochar were lower than that of after six months, specially NPK which have been mostly required by plants; this might be due to moisture availability, reduction of loss (volatilization and leaching) and the increments of soil organic matter.

**Table 5.** The interaction effect of farmyard manure, biochar and urea on soil available potassium after six months.

		Soil Available Potassium (mg kg <sup>-1</sup> soil)		
		Nitrogen (kg N ha <sup>-1</sup> )		
FYM (ton ha <sup>-1</sup> )	Biochar(ton ha <sup>-1</sup> )	0	23	46
0	0	147.50 <sup>ab</sup>	143.85 <sup>a</sup>	148.74 <sup>ab</sup>
	5	166.43 <sup>def</sup>	172.12 <sup>figh</sup>	161.30 <sup>cd</sup>
	10	177.90 <sup>i</sup>	173.97 <sup>ghi</sup>	167.31 <sup>ef</sup>
6	0	152.74 <sup>b</sup>	165.20 <sup>cde</sup>	160.09 <sup>c</sup>
	5	170.59 <sup>efg</sup>	168.23 <sup>ef</sup>	176.39 <sup>hi</sup>
	10	184.49 <sup>j</sup>	174.94 <sup>ghi</sup>	185.14 <sup>j</sup>
SE±			3.11	
LSD <sub>(0.05)</sub>			5.17	
CV (%)			1.90	

Means followed by the same letter with in the same column of the respective treatment are not significantly different ( $P \leq 0.05$ ) according to Duncan's Multiple Range Test, FYM = Farmyard manure, SE = Standard error, CV = Coefficient of variation, Least Significant differences, NS = not Significant.

## 4. Conclusion

The application of Biochar, Farmyard Manure and Nitrogen fertilizer on soil chemical properties after six months of treatments incorporation to the soils showed that none of the interaction effect of the treatments was significant on soil organic carbons. However, that of biochar levels on soil organic carbons was highly significant as well as farmyard manure levels on soil organic carbons was significantly enhanced. Accordingly, the interaction of biochar, farmyard manure and nitrogen levels and that of farmyard manure and biochar levels as well as biochar and nitrogen levels on soil available phosphorus were not increased. However, that of farmyard manure and nitrogen levels on soil available phosphorus was significantly increased. Generally, the interaction of biochar and farmyard manure on cation exchange capacity (CEC) was significant increased. However, as the results of mean of main effects show that there was slight increase in soil reaction with the increase in biochar levels. Recommendations; farmers are advised to add small amount of mineral fertilizer to farmyard manure and biochar to improve soil properties and enhance soil productivity and quality.

## Acknowledgements

The authors would like to thank all staffs of Soil Fertility Improvement and Soil and Water Conservation team of Sinana Agricultural Research Center, for their contribution towards implementation of the study, and Sinana Agricultural Research Centre for providing necessary logistic support in the course of the study. The generous financial assistance from Oromia Agricultural Research Institute is also gratefully acknowledged.

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