EFFECT OF BIOCHAR, FARMYARD MANURE AND NITROGEN FERTILIZER ON AVAILABILITY OF PLANT NUTRIENTS IN SINANA DISTRICT, SOUTH EASTERN OROMIA, ETHIOPIA

Abdurahman Husien[1], Nigussie Dechassa[2] and Bobe Bedadi[2]

[1]Sinana Agricultural Research Center, P.O. Box 208, Bale Robe, Ethiopia

[2]School of Plant Science, Haramaya University, P.O. Box 138 Dire Dawa, Ethiopia

[2]School of Natural Resource and Environmental Science, Haramaya University, P.O. Box 138 Dire Dawa, Ethiopia

ABSTRACT

Integrated soil fertility management could be a useful tool to maintain, preserving and improving soil fertility. Therefore, the experiment was conducted with the objective to investigate the influence of biochar, farmyard manure, and mineral nitrogen fertilizer on selected soil properties. The treatments consisted of two levels of farmyard manure (0 and 6 tons ha^{-1}), three levels of biochar (0, 5, and 10 tons ha^{-1}) and three levels of nitrogen (0, 23 and 46 kg N ha^{-1}). The results revealed that the interaction effects of biochar, farmyard manure, and mineral nitrogen fertilizer significantly influenced the soil properties of major contents of soil available potassium, phosphorus, and nitrate and ammonium ion after two months of treatments application. The interaction effect of biochar, farmyard manure and nitrogen levels and that of farmyard manure and nitrogen levels as well as farmyard manure and biochar levels on cation exchange capacity and total nitrogen were significant ($P < 0.05$). Generally, the availability of plant nutrients concentration in the soil solution after two months of farmyard manure and biochar application was higher than that of a post-harvest.

Key Words: Integrated, Chemical, Plant Nutrient and Organic Fertilizer

No: of Tables : 1 **No: of Figures 7** **No: of References: 33**

INTRODUCTION

Integrated soil fertility management could be a useful tool to maintain, preserving and improving soil fertility. The use of organic materials as fertilizers for crop production has received attention particularly recently for sustainable crop production (Yang *et al.*, 2007). However, the application of organic matter is constrained by lack of access to sufficient organic inputs, low nutrient content, high labor demand for preparation and transporting. Thus, the integration of organic and inorganic sources may improve and sustain crop yields without degrading soil fertility status. Additions of biochar to soil have shown definite increase in cation exchange capacity (CEC) and pH (Topoliantz *et al.*, 2002). Biochar application also improves the overall sorption capacity of soils (verheijen *et al.*, 2009), the increase in the availability of major plant nutrients due to application of biochar (Glaser *et al., 2002).*

Soil degradation and nutrient depletion have gradually increased and have become serious threats to agricultural productivity mainly due to a range of factors including soil erosion, acidity and nutrient depletion, lack of soil fertility replenishment, nutrient mining in Ethiopia. Likewise, many soils in the highlands of the country are poor in available plant nutrients and organic matter content. In addition to this previously, only nitrogen and phosphorus were considered to be the limiting nutrients in vertisols (Tekalign Mamo *et al.*, 1988 and 2002).

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 (Abayneh and Ashenafi, 2006). Therefore, it is generally accepted that improved soil conditions associated with manure and biochar application lead to changes in soil and nutrient availability. However, to date, no systematic study has been done to elucidate the effect of farmyard manure, biochar, and nitrogen fertilizer on available plant nutrient under agro-climatic conditions of Bale highland. Therefore, this study was undertaken to with the following objectives of investigate the effect of biochar, farmyard manure and nitrogen fertilizer rates on availability of plant nutrient.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted during 2015 main cropping season at Selka Kebele of Sinana district which is located in Bale zone of Oromia Regional State, southeastern Ethiopian highland 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 ^{0}C and the monthly values range between 19.39 ^{0}C in October and 22.85 ^{0}C in February. The mean annual minimum temperature is 9.67 ^{0}C and the monthly values range between 7.93 ^{0}C in December and 10.79 ^{0}C in May. The coldest month is December, whereas February is the hottest month (Figure 2).

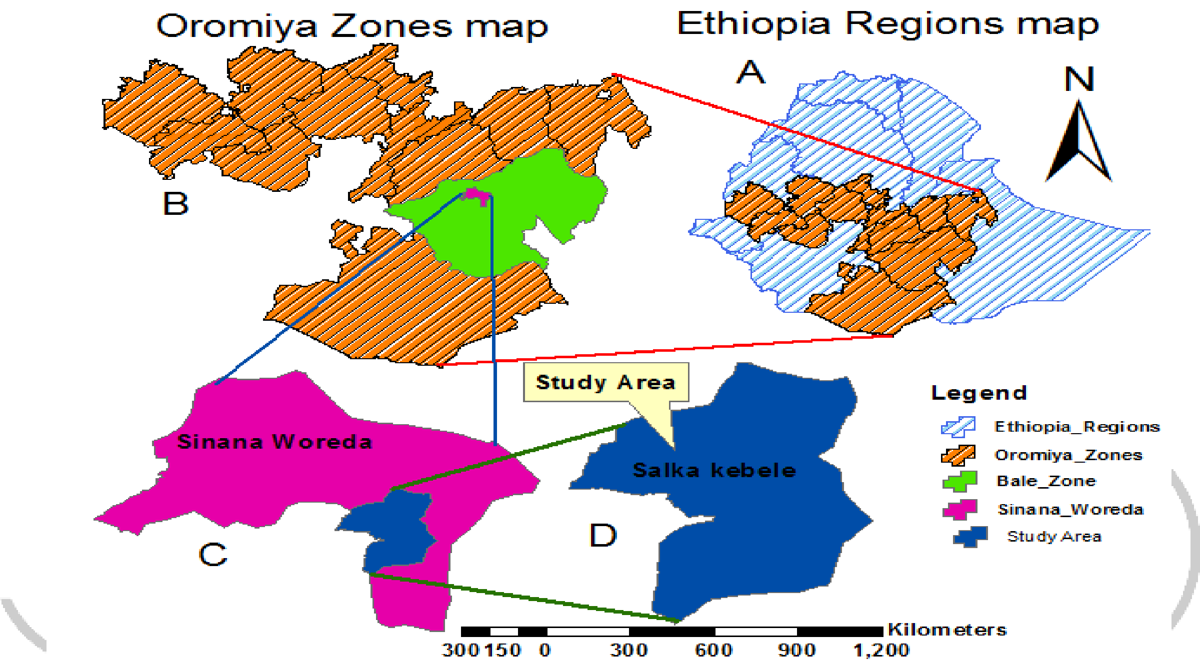

Figure 1. Maps of the study area

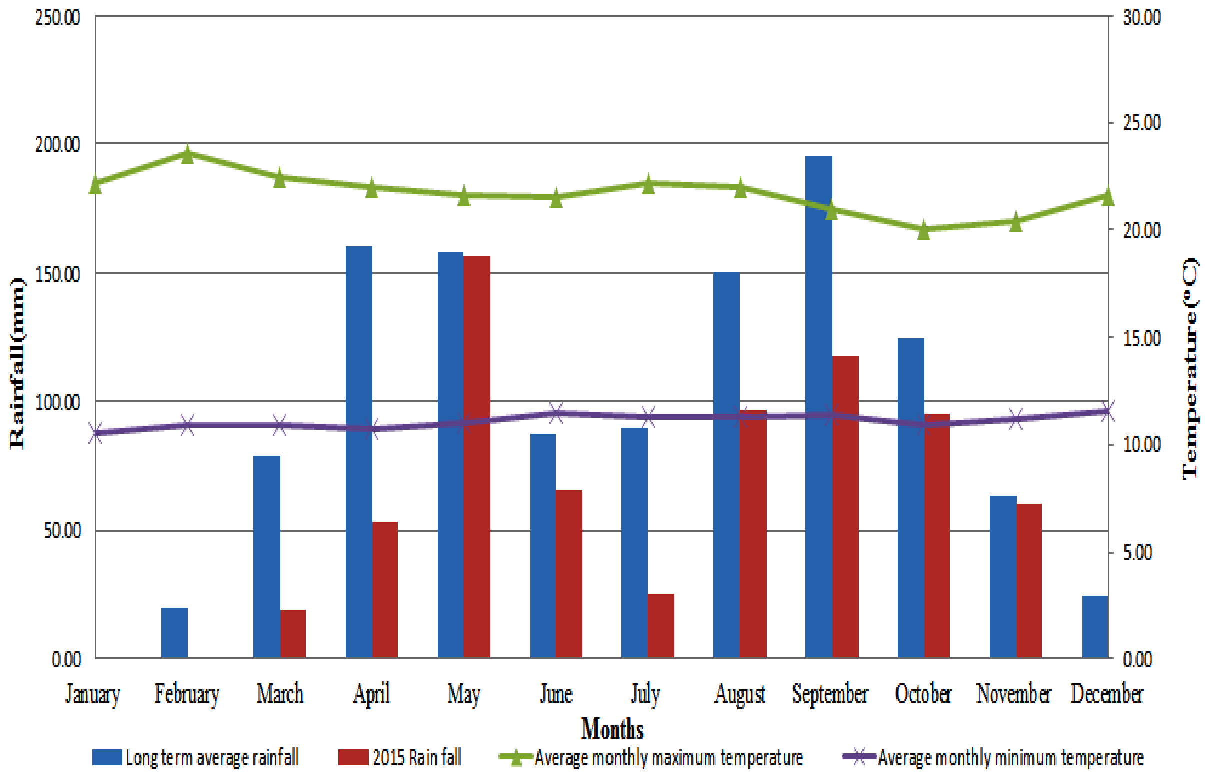

Figure 2. Monthly rainfall (2015), long term average rainfall, maximum and minimum monthly average temperature of Sinana Agricultural Research Center

Data Collection

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 two months of farmyard manure and biochar treatments application and after harvesting. 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.

Soil chemical analysis

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

Soil pH was potentiometrically measured in the supernatant suspension of 1:2.5 soils: water and Potassium Chloride solution ratio (Motsara and Roy, 2008). Soil organic carbon content of the soil was determined by potassium dichromate wet oxidation procedure (Walkley and Black, 1934). 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 (Motsara and Roy, 2008). Ratio of C: N 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 0.5 M sodium bicarbonate extraction procedures (Olsen *et al.,* 1954). Available potassium was determined by ammonium acetate extraction-flame photometry procedure (Lu, 1999). The cations exchange capacity of the soil (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc (Champman, 1965). Soil nitrate nitrogen and ammonium nitrogen ions were determined by steam distillation (ISO 7890-1) and (ISO 7150-1) respectively.

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. Separate samples were air-dried; ground using a pestle and mortar then it was 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 (Mehlich, 1984) using Atomic Absorption Spectroscopy and spectrophotometer and soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962).

Table 1. Soil chemical and physical properties of the experimental site before planting

Soil Chemical Properties	Results	Units
pH	6.64	-
Phosphorus	12.68	mg/kg soil
Potassium	2.65	$cmol_c$/kg soil
Calcium	25.47	$cmol_c$/kg soil
Magnesium	4.61	$cmol_c$/kg soil
Sodium	0.06	$cmol_c$/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
Cupper	4.51	mg/kg soil
Molybdenum	0.10	mg/kg soil
Total Nitrogen	0.18	%
Cation Exchange Capacity	53.93	$cmol_c$/kg soil
Aluminum	6.32	$cmol_c$/kg soil
Organic Matter	1.79	%
Soil Physical properties		
Soil texture (%)		
Clay	56	%
Silt	35	%
Sand	9	%
Soil textural class	Clay	Clayey

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

Description of Parameter	Biochar	Farmyard manure	Units
pH	9.81	8.67	-
Ammonium Ion	42.56	0.04	mg/kg soil
Nitrate Ion	2867.42	291.91	mg/kg soil
Phosphorus	141.39	5.84	mg/kg soil
Potassium	16.10	9.79	$cmol_c$/kg soil
Calcium	0.11	0.61	$cmol_c$/kg soil
Magnesium	0.04	0.18	$cmol_c$/kg soil
Sodium	0.12	0.10	$cmol_c$/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
Cupper	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	$cmol_c$/kg soil

Statistical data analysis

The effects of treatments on soil chemical properties, availability of plant nutrient after a month of planting or after two months of biochar and farmyard manure was subjected to analysis of variance (ANOVA) using general linear model (GLM) procedures of statistical analysis system of computer software (SAS, 2004. Version 9.1.2) 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.

RESULTS AND DISCUSSION

Post two Months Application of the Treatment

Soil reaction (H_2O and KCl), organic carbon and C: N ratio

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 ($P < 0.05$). As the results of main effect shows that soil pH changes slightly during two months after application of biochar and farmyard manure; thus, the effect of biochar levels (5 and 10 ton ha^{-1})

increase soil pH by 0.15 and 0.19 units, respectively. This study related to the finding of Masulili (2010) as the levels of biochar increase there was also increase in soil pH. Similarly, according to Mukherjee (2011) biochar may have buffering capacity towards pH changes.

The analysis of variance showed that none of the interaction effects were significant on soil organic carbon. However, the main effects of biochar as well as farmyard manure levels on soil organic carbon were highly significant ($P < 0.001$). As the main effect of farmyard manure and biochar results show that soil organic carbon changes slightly during two months after application of biochar and farmyard manure; this might be due the decomposition of biochar and farmyard manure in the soils with in short period of time. This study in line with that of Adesodun *et al*., (2005) who found that application of poultry manure to soil increased soil organic matter content.

The analysis of variance showed that the interaction effect of biochar, farmyard manure and Nitrogen levels on C:N ratio was non- significant; similarly, the interaction effect of farmyard manure and Nitrogen levels and that of farmyard manure and biochar level as well as biochar and Nitrogen levels on C:N ratio were non - significant. However, the main effect of farmyard manure levels on C: N ratio was highly significant ($P < 0.05$) (table 3). As the results of main effects show that the C: N ratio changes slightly during two months after application of farmyard manure; this might be due the shortage of decomposition time of treatment materials with the soils. This result in line with the Brady (1974) finding that organic matter addition to the soil, the C: N ratio subsequently settled to the constant soil ratio of about 10:1.Therefore, this depends on the material from which the organic matter was made.

Table 3. The main effects of farmyard manure, biochar and Nitrogen levels on soil pH, organic carbon, available phosphorus and C: N ratio after two months of application

FYM (ton ha^{-1})	pH: H_2O	pH: KCl	OC (%)	C:N ratio
0	6.93	5.97	1.26^{b}	7.56^{b}
6	6.90	5.94	1.42^{a}	8.79^{a}
$LSD_{(0.05)}$	NS	NS	0.05	0.64
Biochar (ton ha^{-1})				
0	6.80^{b}	5.87^{b}	1.21^{c}	8.06
5	6.95^{a}	5.98^{a}	1.34^{b}	7.85
10	6.99^{a}	6.01^{a}	1.48^{a}	8.61
$LSD_{(0.05)}$	0.04	0.04	0.07	NS
Nitrogen (kg N ha^{-1})				
0	6.93^{a}	5.97	1.30	8.52
23	6.94^{a}	5.96	1.34	7.96
46	6.88^{b}	5.93	1.37	8.05
$LSD_{(0.05)}$	0.04	NS	NS	NS
CV (%)	0.8	1.00	7.28	14.23

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, BC = Biochar, FYM = Farmyard manure, CV = Coefficient of variation, Least Significant differences, NS = not significant

Soil total nitrogen and cation exchange capacity

The analysis of variance showed that the interaction effect of biochar, farmyard manure and Nitrogen levels and that of farmyard manure and Nitrogen levels, biochar and Nitrogen levels as well as farmyard manure and biochar on soil total nitrogen were significant ($P < 0.05$)(Table 4). As the analyzed results of mean interaction show that the soil total Nitrogen changes with the changes in biochar and farmyard manure levels even though the changes was very small; this may be due to the nature of nitrogen in soils and intensive cultivation as well as less crop residue management may contribute significant roles for the low level of total nitrogen. This study was supported by Bishwoyog *et al.,* (2015) biochar addition to the hard setting soil resulted in significant increase total nitrogen. Similarly, the low total nitrogen may be associated with the low organic matter content, the loss of N due to the surface runoff, leaching, and crop removal (Fageria and Baligar, 2005). However, the total N content of a soil is directly associated with its OC content and its amount on cultivated soils is between 0.03% and 0.04% by weight (Tisdale *et al.,* 2002).

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 farmyard manure and biochar levels on cation exchange capacity were significant (P < 0.05). However, that of biochar and nitrogen levels was non-significant. The results of biochar and farmyard manure levels (5 ton ha^{-1} BC and 6 ton ha^{-1} FYM) and (10 ton ha^{-1} BC and 6 ton ha^{-1} FYM) on CEC was increased with the rate increments by 29.75 and 31.49% over the control treatment respectively. This results in line with finding of Chan *et al.*, 2008 and Masulili *et al.*, 2010; the increase in soil CEC with biochar application. The increase in CEC could have resulted from the inherent characteristics of the biochar, since biochar has high surface area that has exposed negative charges. Similarly, Glaser *et al.*, (2001) also discussed that after weathering, oxidation occurs that results in the formation of carboxylic groups on the edges of the aromatic carbon, which results in greater CEC.

Table 4. The interaction effect of farmyard manure, biochar and nitrogen levels on cation exchange capacity and total nitrogen after two months of application

FYM (ton ha^{-1})	Biochar (ton ha^{-1})	CEC (cmol$_c$ kg^{-1} soil)			Total Nitrogen (%)		
		Nitrogen (kg N ha^{-1})					
		0	23	46	0	23	46
0	0	39.07^{a}	49.60^{bc}	49.30^{b}	0.17^{bcde}	0.16^{abcd}	0.16^{bcd}
	5	51.00^{bcd}	55.50^{efg}	55.10^{efg}	0.15^{abc}	0.17^{bcde}	0.18^{cde}
	10	54.77^{efg}	57.57^{gh}	57.97^{gh}	0.17^{bcde}	0.16^{bcd}	0.18^{cde}
6	0	52.70^{cde}	53.43^{def}	53.10^{def}	0.13^{a}	0.17^{bcde}	0.13^{a}
	5	56.37^{fg}	57.50^{gh}	55.27^{efg}	0.17^{bcde}	0.17^{bcde}	0.18^{cde}
	10	57.03^{gh}	60.17^{hi}	61.57^{i}	0.15^{ab}	0.19^{de}	0.20^{e}
SE±			1.78			0.017	
LSD$_{(0.05)}$			2.96			0.027	
CV (%)			3.3			9.9	

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

Soil nitrate and ammonium ion

The analysis of variance show that the interaction effect of biochar, farmyard manure and nitrogen levels on soil available nitrate ion were highly significant (P < 0.001) (table 5); the soil available nitrate was affected by biochar, farmyard manure and nitrogen fertilizers over the control without linearity respectively. Therefore, interpretation of nitrate ion in the soil is determined by rainfall and level of stored water at sowing, time of sampling and depth over which the sample is taken. It is possible that some mineralization of organic matter occurred with addition of labile biochar; however, this would have been only a small contribution because of poor liability (Cross and Sohi, 2011).

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen level on soil available ammonium ion were highly significant (P < 0.001) (table 5). As the analyzed results of mean interactions show that the soil available ammonium ion was affected by the interaction of biochar, farmyard manure and nitrogen fertilizers over the control treatments respectively. But, the effect was not linearly. This finding was related to Lehmann *et al.*, (2006) suggested that biochar can absorb both ammonium and nitrate ion from the soil solution thus reducing solution inorganic nitrogen at least temporarily. Similarly Singh *et al.*, (2008) confirmed the role of organic manures in releasing nitrogen and improving nitrogen availability in soil. Generally, biochar efficiently adsorbs ammonia and acts as a binder for ammonium ion in soil, therefore having the potential to decrease ammonium ion volatilization from soil surface (Iyobe *et al.,* 2004).

Table 5. The interaction effect of farmyard manure, biochar and urea rate on soil available nitrate and ammonium ion

(ton ha^{-1})		Available nitrate in mg l^{-1}			Available ammonium ion in (mg l^{-1})		
		Nitrogen (kg N ha^{-1})			Nitrogen (kg N ha^{-1})		
FYM	Biochar	0	23	46	0	23	46
0	0	9.90d^{ef}	6.63^{a}	11.07^{efg}	11.73^{bcd}	14.40^{fg}	12.93^{def}
	5	6.63^{ab}	11.20^{efg}	9.40^{cdef}	11.80^{bcde}	16.77^{hi}	8.63^{a}
	10	11.53^{efg}	7.27b^{c}	11.10^{efg}	12.33^{bcde}	12.50^{cdef}	18.40^{ij}
6	0	4.97^{a}	12.53^{g}	13.27^{g}	10.47^{abc}	10.37^{ab}	8.90^{a}
	5	9.87^{def}	8.57^{bcd}	9.23^{cde}	15.40^{gh}	9.37^{a}	17.73^{ij}
	10	7.80^{bcd}	11.67^{fg}	10.97^{efg}	13.83^{efg}	9.13^{a}	19.10^{j}
SE±			1.23			1.11	
LSD$_{(0.05)}$			2.04			1.84	
CV (%)			12.70			8.50	

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

Soil available phosphorus

The analysis of variance showed that none of the interaction effects of the treatments were significant on soil available phosphorus. However, the main effects of farmyard manure levels as well as biochar levels on soil available phosphorus were highly significant (P < 0.001) and that of nitrogen level on soil available phosphorus was significant(P < 0.05). As the analyzed results of main effects show that the soil available phosphorus increase with the increase of biochar levels (5 and 10 ton ha^{-1}) by 16.26 and 30.16 % and farmyard manure levels (6 ton ha^{-1}) by 27.49 % over the control treatment respectively (Table 6). Therefore, from this point of view, the levels of biochar and farmyard manure affect soil available phosphorus two months after treatment application; this due to the increments' of soil reaction and mobility of soil phosphorus. This finding was related to Chan *et al.*, (2008) reported the increase in available phosphorus after the application of biochar. Similarly, the increase in available phosphorus with duration of incubation reported in this study is comparable to those reported by Lamb (2003) and also Glaser *et al*., (2002) who found increased plant-available phosphorus concentrations after biochar addition.

Table 6. The main effects of farmyard manure, biochar and nitrogen levels on soil available phosphorus

FYM (ton ha^{-1})	Soil available phosphorus (mg kg^{-1}soil)
0	12.66^{b}
6	17.46^{a}
$LSD_{(0.05)}$	1.54
Biochar (ton ha^{-1})	
0	12.46^{c}
5	14.88^{b}
10	17.84^{a}
$LSD_{(0.05)}$	1.89
Nitrogen (Kg N ha^{-1})	
0	16.64^{a}
23	12.99^{b}
46	15.54^{a}
$LSD_{(0.05)}$	1.89
CV (%)	18.51

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

Soil available potassium

The analysis of variance showed that the interaction effect of biochar, farmyard manure and nitrogen levels on soil available potassium was significant (P < 0.05) (table 7). Thus, with the increase of biochar and farmyard manure levels, the soil available potassium also increases; but, with the increases in the level of nitrogen the soil available potassium was not increase linearly. The interaction effect of biochar and farmyard manure (5 and 6 ton ha-1) and (10 and 6 ton ha-1) on soil available potassium were increased by 13.54 and 20.05 % over the control treatment, respectively. This study in line with the Bishwoyog *et al*., (2015) who observed that poultry manure biochar and sheep manure biochar have greatly increased the potassium content of the soil as compared to other biochar. Similarly, Ali *et al.,* (2015) also reported that effect of biochar application enhanced by 18.41 and FYM by 9.0% of soil potassium content over control treatment. Generally, the availability of plant nutrient concentration in the soil solution after two months of farmyard manure and biochar application were higher than that of a post-harvest, specially NPK which have been mostly required by plants; this might be due to moisture availability, reduction of

Table 7. The interaction effect of farmyard manure, biochar and nitrogen levels after two months of application on soil available Potassium availability

(ton ha^{-1})		Available Potassium (mg kg^{-1}soil)		
		Nitrogen (kg N ha^{-1})		
FYM	Biochar	0	23	46
0	0	165.88^{c}	151.14^{a}	158.32^{b}
	5	172.77^{d}	175.58^{de}	177.44^{de}
	10	193.62^{hi}	185.74^{fg}	188.47^{gh}
6	0	162.50^{bc}	178.37^{de}	176.05^{de}
	5	178.46^{de}	180.03^{ef}	191.00^{gh}
	10	198.17^{i}	198.09^{i}	197.77^{i}
SE±			3.757	
$LSD_{(0.05)}$			6.234	
CV (%)			2.1	

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, Least Significant differences, NS = not Significant

CONCLUSION

The availability of plant nutrients in the soil after two months of biochar and farmyard manure and that of Nitrogen fertilizer after one month application was highly influences the soil chemical properties. Likewise, the effects of the treatments on soil availability of plant nutrients increased in the soil solution; thus soil pH, organic carbon and soil available nitrate were slightly increased. Similarly, soil available potassium, cation exchange capacity and phosphorus were highly enhanced. Moreover, the availability of plant nutrient concentration in the soil solutions after two months of farmyard manure and biochar application were higher than that of a post-harvest, especially NPK. Generally recommendations for 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. The levels and application time of farmyard manure and biochar should be increased to increase the availability of plant nutrient by keeping inorganic fertilizer constant or decrease levels for the reduction of their environmental and economic impacts.

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 acknowledge

REFERENCES

Abayneh Esayas and Ashenafi Ali. (2006). Soils of Sinana Agricultural Research Center. Ethiopian Agricultural Research Institute. *National Soil Research Center, 43pp.*

Adesodun, Mbagwu and Oti. (2005). Distribution of carbon nitrogen and phosphorus in water stable aggregates of an organic waste amended Ultisol in southern Nigeria. *Bioresource Technol.* 96: 509-516.

Ali, Arif, Jan, Khan and Jones (2015). Integrated use of biochar: a tool for improving soil and wheat quality of degraded soil under wheat-maize cropping pattern. *Pak. J. Bot*., 47(1): 233-240.

Bishwoyog Bhattarai, Jasmine Neupane, Surya Prasad Dhakal, Jaya Nepal, Barsha Gnyawali, Ramsharan Timalsina and Ashmita Poudel (2015). Effect of Biochar from Different Origin on Physio-Chemical Properties of Soil and Yield of Garden Pea (*Pisum sativum* L.) at Paklihawa, Rupandehi, Nepal. *World Journal of Agricultural Research, Vol. 3, No. 4, 129-138*

Bouyoucos(1962). Hydrometer method improved for making particle size analyses of soils. *Agron. Jour.,* 54: 464-465.

Brady and Weil (2002). The nature and Properties of Soils. 13th Edition. New York, USA.

Brady(1974). the Nature and Properties of Soil. Macmillan Publishing Co. pp. 257-258, 268-269.

Champman (1965). Cation exchange capacity by ammonium saturation. In: black, C.A., L.E., Ensminger and F.E., Clark (Eds.). *Method of soil analysis American Society of Agronomy. Madison Wisconsin, USA. PP. 891-901.*

Chan, Van Zwieten, Meszaros, Downie and Joseph(2007). Using poultry litter biochars as soil amendments. Australia. *J. Soil Res. 46(5) 437-444*

Cross and Sohi(2011). The priming potential of biochar products in relation to labile carbon contents and soil organic matter status. Soil Biology & Biochemistry, **43**, 2127–2134.

Fageria and Baligar(2005). Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy,* 88:97–185

Glaser, Haumaier, Guggenberger and Zech(2001). The Terra Preta Phenomenon: A model for Sustainable agriculture in the humid tropics. Naturwissenschaften, 88, 37-41.

Glaser, Lehmann and Zech (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: A review. *Biology and Fertility of Soils*, **35**, 219–230.

Iyobe, Asada, Kawata and Oikawa (2004). Comparison of removal efficiencies for ammonia and amine gases between woody charcoal and activated carbon. J. Health Sci. 50: 148–153.

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

Laird, Fleming, Davis, Horton, Wang and Karlen (2010). Impact of biochar amendments on the quality of a typical mid-western agricultural soil. *Geoderma. 158:443-449.*

Lehmann J(2006). Bio-energy in the black. Frontiers in Ecology and the Environment 5: 381-387.

Lehmann, Silva, Rondon, Silva, Greenwood, Nehls, Steiner, and Glaser (2002). "Slash-and-Char: A Feasible Alternative for Soil Fertility Management in the Central Amazon?" *Paper No. 49, 17th World Congress of Soil Science, Thailand.*

u (1999). Analytical methods of soil and agricultural chemistry. *Chinese Agricultural Science and Technology Press, Beijing.*

Masulili, Utomo and Syechfani (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. *Journal of Agricultural Science, 2(1), 39-47.*

Mehlich(1984). Mehlich 3 Soil Test Extractant: A modification of Mehlich 2 extractant. *Communications in Soil Science and Plant Analysis, 15: 1409-1416*.

Motsara and Roy (2008). Guide to Laboratory Establishment for Plant Nutrient Analysis. Food and Agriculture Organization of the United Nations. Fertilizer and Plant Nutrition *Bulletin No. 19. Rome, Italy.*

Mukherjee A, Lal R (2013). Biochar Impacts on Soil Physical Properties and Greenhouse Gas Emissions Agronomy. *3:313-339.*

Olsen, Cole, Watanabe and Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA, Circ. 939.*

SAS Institute Inc (2004). SAS 9.1.2 Qualification Tools User's Guide, Cary, NC:

Singh AB, Saha JK, Gosh PK (2008). Effect of nutrient management practices on soybean (*Glycine max*)–chickpea (*Cicer arietinum*) cropping systems for improving seed yield, quality and soil biological health under rain fed condition. Indian J. Agric. Sci. 78(6): 485–489.

Tekalign Mamo, C. Richter and B. Heiligtag (2002). Phosphorus availability studies on ten Ethiopian Vertisols. *J. of Agri. and Rural Devt. in the Tropics and Subtropics*, 103 (2): 177–183

Tekalign Mamo, Haque I. and Kamara G. S., (1988). Follow one pattern P status of some Ethiopia highland Vertisols. PP. 232-249. In: Jutz, S.C., I. HaqueMdntirc (eds.) Soils in Sub-Saharan Africa, ILCA, Addis Ababa, Ethiopia.

Tisdale,S.L, Nelson W.L, Beaton D.J and Havlin J.L (2002). Soil Fertility and Fertilizer Macmillan Publishing Company.New York.633p.

Topoliantz, S., J.F. Ponge, D. Arrouays, S. Ballof, P. Lavelle (2002). Effect of organic manure and endogeic earthworm*Pontoscolex corethrurus* (Oligochaeta: Glossoscolecidae) on soil fertility andbean production, Biol. Fertil. Soils, 36: 313-319.

Verheijen, F.G.A., S. Jeffery, A.C. Bastos, M. Van Der Velde and I. Diafas (2009). Biochar Application to Soils - A Critical Scientific Review of Effects on Soil Properties, Processes and Functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg, pp: 149.

Walkley and Black (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.

Yang, Huffman, Jong, Kirkwood, MacDonald and Drury (2007). Residual soil nitrogen in soil landscapes of Canada as affected by land use practices and Agricultural policy scenarios. *Land Uses Policy,* 24: 89-99.