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RESEARCH ARTICLE Agricultural Reviews, Volume Issue : ()

Soil Physical and Chemical Properties as Affected by Bio-, Organic and Inorganic NPSB Fertilizers and Lime in Assosa Zone, Western Ethiopia

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10.18805/ag.A-663

ABSTRACT

Background: Soil acidity, low soil nutrient status and low nitrogen fixing inoculants as a result of poor soil fertility management practices are the major constraints in soybean production in Assosa Zone, particularly in Assosa and Bambassi districts. Hence, this experiment was conducted to evaluate the effect of bio-, organic and inorganic NPSB fertilizers and lime on soil physico- chemical properties.

Methods: During the period 2019-2020 factorial combinations of two bio-fertilizer inoculants [without bio-fertilizer (B1) and SB12 plus MAR1495 bio-fertilizer at their recommended rates of 500 g ha^{-1} (B2); two organic fertilizers without fresh cattle manure (M1) and fresh cattle manure at 10 t ha^{-1} (M2); two lime rates without lime (L1) and lime at 5 t ha^{-1} (L2); two inorganic NPSB fertilizers NPSB at 9.5-23-3.5-0.05 (F1) and NPSB at 19-46-7-0.1 (F2) at their recommended rates for soybean] were laid out in a randomized complete block design with three replications. Bulk density, pH, total nitrogen, available phosphorus, organic carbon and cation exchange capacity were collected and analyzed using SAS software version 9.1.3 and significant mean differences were separated using Duncan's Multiple Range Test (DMRT).

Result: Bulk density, pH, total nitrogen, available phosphorus, organic carbon and cation exchange capacity were highly affected ($P<0.01$) by the interactions of bio-, organic and inorganic fertilizers and lime. Finally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved the bulk density, pH, total nitrogen, available phosphorus, organic carbon and cation exchange capacity at both districts.

Key words: Fertilizer, Manure, Soil acidity, Soil fertility, Soil properties.

INTRODUCTION

Soil acidity, low soil nutrient status and low nitrogen fixing inoculants are the major constraints in soybean production in Western Ethiopia particularly in Assosa and Bambassi districts of Assosa Zone (Ayoola, 2010). The major factors which resulted in soil acidity, low soil nutrient status and low nitrogen fixing inoculants in Western Ethiopia particularly in Assosa and Bambassi districts are poor soil fertility management practices such as absolute use of inorganic fertilizers and continuous cropping (AsARC, 2017).

According to Assosa Agricultural Research Center (2017), most of the soils in Assosa and Bambassi districts are acidic with pH ranging from 5.2-6.0. Soil acidity in both districts affected legume-*Rhizobium* symbiosis (decreases legume nodulation) and availability of nutrients like N, P, S and B. Hence, poor growth and yield reduction occur as a result of inadequate nutrition (Tisdall, 1993). According to Zelleke *et al.* (2010), *Bradyrhizobium japonicum* strains found in the soil was very low in Assosa and Bambassi districts. Assosa agricultural research center (2017) has also reported that there were poor soil management practices in Assosa and Bambassi districts as a result nutrient deficiencies have been observed. According to Asgelil (2000) most agricultural soils of the Western Ethiopia were deficient in nitrogen, phosphorus, sulphur and boron nutrients.

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How to cite this article: Abeje, A., Alemayehu, G. and Feyisa, T. (2023). Soil Physical and Chemical Properties as Affected by Bio-, Organic and Inorganic NPSB Fertilizers and Lime in Assosa Zone, Western Ethiopia. Agricultural Review. DOI: 10.18805/ag.A-663.

Submitted: 31-05-2021 **Accepted:** 24-11-2023 **Online:** 04-01-2024

According to Khaliq *et al.* (2015), degradation of soil as a result of repeated application of inorganic fertilizers to the farm land has been observed in Western Ethiopia. These problems make farmers not to meet soybean nutrient demand over large area. It is therefore justifiable to introduce integrated application of soil amendments such as bio-, organic and inorganic fertilizers and lime in Assosa and Bambassi districts, Assosa zone, Western Ethiopia (Zinaw *et al.*, 2013).

Kumar and Shivay (2010) revealed that integrated use of biofertilizers, organic fertilizers, inorganic fertilizers and lime significantly improved the available N and P and K contents compared to sole application of inorganic fertilizers. Tolanur and Badanur (2003) reported that available N, P and K contents increased significantly with the application of biofertilizers combination with inorganic fertilizers, organic fertilizers and lime over inorganic fertilizers alone. According to Harleen (2016) the significant increase in available nitrogen was observed in treatments having combined application of biofertilizer, inorganic fertilizer, organic fertilizer and lime.

According to Kassa *et al*. (2014), the combined application of fresh cattle manure with biofertilizer, inorganic fertilizer and lime increased the amount of available phosphorus in soil, as it helps in sustaining higher population of several bacteria and fungi, which are capable of solubilizing soil phosphorus. Courtney and Mullen (2008) reported that combined application of biofertilizer, organic fertilizer, inorganic fertilizer and lime improved soil physical (bulk density, stabilization of soil structure and aggregate formation) properties, soil chemical (pH, base saturation, salinity and CEC) and biological properties.

Li *et al.* (2017) also reported that the integrated use of organic manure and inorganic fertilizers along with biofertilizers and lime is a promising approach in preserving soil microbial communities and activities, which will ultimately show positive impacts on different soil physicochemical properties and crop production. Thus, this experiment was carried out to investigate the integrated application of bio-, organic and inorganic NPSB fertilizers and lime on soil physico-chemical properties in Assosa and Bambassi districts, Assosa Zone, Western Ethiopia.

MATERIALS AND METHODS

Descriptions of the experimental sites

The experiment was carried out for two years (2019-2020) during the main rainy season in Assosa and Bambassi districts, Assosa Zone, Western Ethiopia. Geographically, Assosa is located at 10°02′05″N latitude and 34°34′09″E longitude at an elevation of 1570 meter above sea level, while Bambassi is located at 9°23′22″N latitude and 34°00′ 12″W longitude at an elevation of 1470 meter above sea level. Both experimental sites are characterized by hot humid agro-ecology having mono-modal rainfall distribution pattern, which starts at the end of April and extends to mid-November, with maximum rainfall received in June, to October. In 2019 and 2020 cropping season, the mean annual rainfall at Assosa was 1221.7 mm and 1235.4 mm, respectively (Fig 2), while was 1209.1 mm and 1226.2 mm at Bambassi, respectively (Fig 3). In addition, the minimum and maximum temperatures of Assosa in 2019 cropping season were 16.5°C and 27.5°C and in 2020 were 16.7°C and 27.9°C, (Fig 2). Whereas, the minimum and maximum temperatures of Bambassi in 2019 were 17.2°C and 28.9°C, while in 2020 were 17.4°C and 29.7°C (Fig 3). The dominant soil type and soil textural of both experimental sites was Nitisols and clay, respectively. The soil pH at Assosa was 5.32 and 5.50 at Bambassi (Table 1). Sorghum, maize, haricot bean and soybean are the dominant crops grown at both study sites (BGBOARD, 2017).

Experimental treatments and design

Factorial combinations of four biofertilizer inoculants [without biofertilizer (B1), *SB12* biofertilizer at the recommended rate of 500 g ha^{-1} (B2), *MAR1495* biofertilizer at the recommended rate of 500 g ha^{-1} (B3) and *SB12* plus *MAR1495* biofertilizers at their recommended rates (B4); two organic fertilizers without fresh cattle manure (M1) and fresh cattle manure at 10 t ha^{-1} (M2); two lime rates without lime (L1) and lime at 5 t ha^{-1} (L2); two inorganic NPSB fertilizers NPSB at 9.5-23-3.5-0.05 (F1) and NPSB at 19-46-7-0.1 (F2) at their recommended rates for soybean] were laid out in randomized complete block design (RCBD) with three replications. The recommended rates of N, P_2O_5, S and B are 19 kg ha^{-1}, 46 kg ha^{-1}, 7 kg ha^{-1} and 0.1 kg ha^{-1},

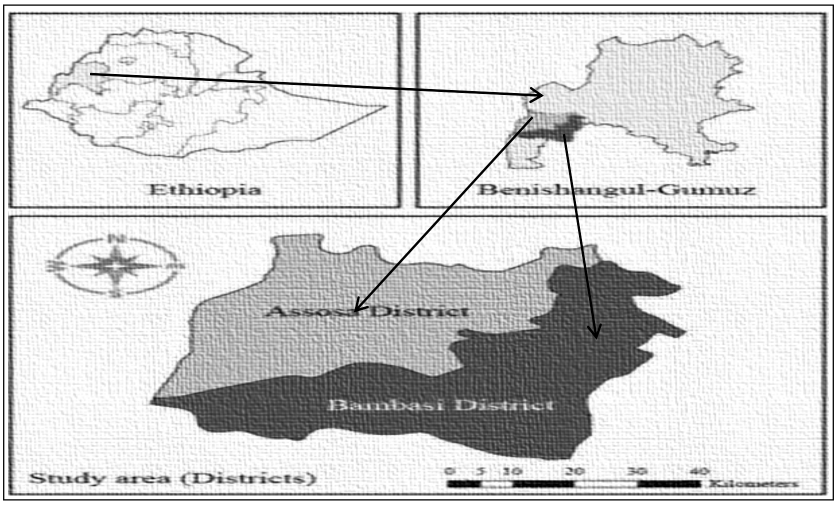

Fig 1: Location map of Assosa and Bambassi districts.

respectively for soybean in the study areas. The sources of NPSB were 100kg NPS (19 % N, 46% P_2O_5 and 7% S), 17.4 kg TSP (46% P_2O_5) and 1 kg Borax (0.1% B). Improved soybean variety ‘‘Gishama” was used as a planting material. There were 48 experimental plots having the gross plot size of 3 m × 2 m (6 m^2) and the net plot size of 2.4 m × 1.9 m (4.56 m^2). Within the net plot, there were five planting rows. The spacing between rows was 60 cm, while the spacing between plants was 5cm. Adjacent plots and blocks were separated by 0.5 and 1 m, respectively.

Experimental procedures

Prior to sowing, the land was finely ploughed and harrowed manually. Seeds were inoculated prior to drilling with inoculum of *SB12* and *MAR1495* at 500 g ha^{-1} and 500 g ha^{-1}, respectively for all treatments except the control. With regards to inoculation procedures, initially, 125 gram of sugar was applied to 1.25 liters of water and was heated for 15 minutes. Consequently, 500 gram of *SB12* and 500 gram of *MAR1495* were added and mixed in to the above sugar suspension to form slurry. Then, the recommended rate of seed (80 kg ha^{-1}) was added to the above slurry and mixed by hand. Finally, the inoculated seed was dried in a shade on a plastic sheet for 15 minutes and was sown on furrow within 24 hours (Somasegaran and Hoben, 1994). Inorganic fertilizers were applied as per the treatments. As per the recommendation, fresh cattle manure was prepared and applied 21 days before sowing. Again, as per the recommendation, lime (CaCO3) was broad casted and thoroughly mixed with the soil manually by hand 21 days

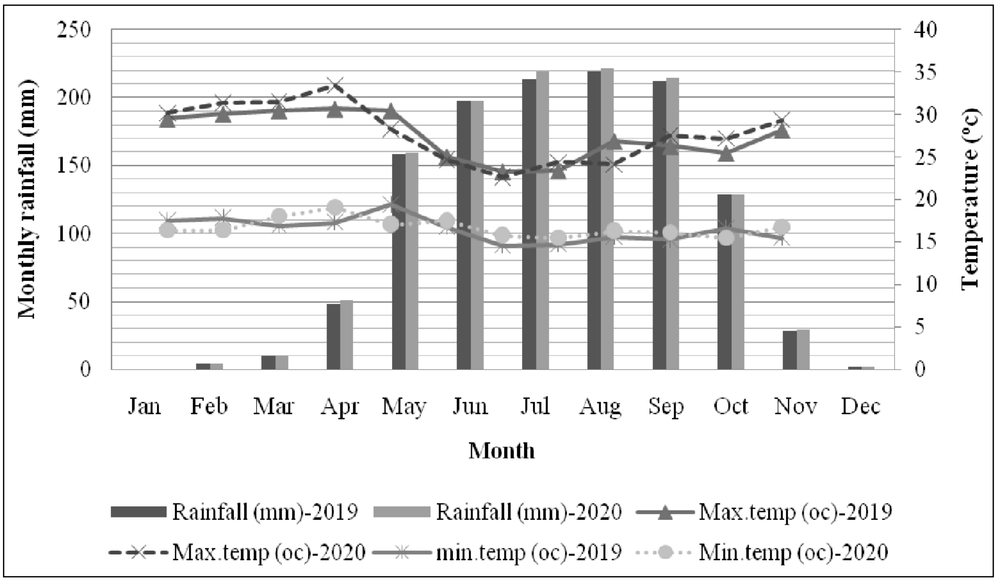

Fig 2: Average monthly rainfall and temperature distribution during 2019 and 2020 experimental years in Assosa.

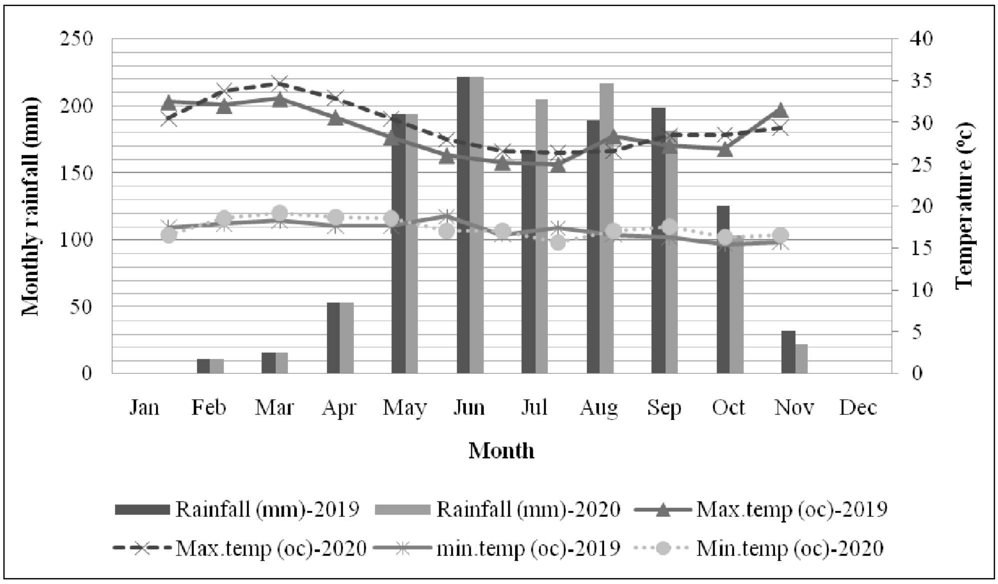

Fig 3: Average monthly rainfall and temperature distribution during 2019 and 2020 experimental years in Bambassi.

before sowing. Soon after seeding, the furrows were covered by soils. Besides, all other agronomic practices for soybean crop were done as per the recommendation. Finally, the data were collected following the appropriate procedures.

Soil sampling and analysis

Soil samples were collected at plow depth of 0-20 cm before sowing (one composite) and after harvesting of the crop (from each plot) for the analysis of major soil parameters. Disturbed soil samples of 1kg were collected using augur for the determination of most soil parameters while undisturbed soil samples were collected using core sampler to determine soil bulk density. Soil samples of 1 kg were collected from 12 spots of the experimental land in a block and thoroughly mixed to form a composite sample. Samples were then air dried and passed through 0.5 mm mesh sieve and packaged for laboratory analyses (Okalebo *et al*., 2002). Soil texture was analyzed by the Bouyoucos hydrometer method following the procedure described by Bouyoucos (1962) while bulk density was determined using the core method (Black, 1965). Soil pH was measured using a digital pH meter in a 1:2.5 soil-water suspension. Soil organic carbon content (OC) was determined by wet digestion method (Walkley and Black, 1934). Determination of total N was done using Kjeldahl digestion method (Black, 1965). Available P was analyzed by the Olsen method using a mixture solution of HCl and NH_4F solution spectrophotometer (Olsen and Sommers, 1982). Exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by 1.0 *M* ammonium acetate (NH4OAc) extract at pH 7.0 and Cations Exchange Capacity (CEC) was determined using Titration method.

Fresh cattle manure sampling and analysis

Before application of fresh cattle manure to the experimental plots, sample of 1 kg fresh cattle manure were collected from the source and stored in plastic bags. Then, it was air dried and ground to pass through a 2mm sieve and packaged for laboratory analyses. Then after, pH, total N, available P, organic carbon and cation exchange capacity in the fresh cattle manure were determined according to methods described by Okalebo *et al*. (2002).

Data analysis

The data were further subjected to analysis of variance (ANOVA) using SAS version 9.1.3 (SAS, 2002). For parameters whose ANOVA results showed significant differences between treatments, mean separation was done using DMRT at 1% or 5% level of probability.

RESULTS AND DISCUSSION

Initial soil physico-chemical properties of the experimental sites

Based on soil analysis result, the texture of soil was clay with more than 50% clay content at both locations (Table 1). The bulk densities of the experimental sites were 1.16, 1.23 g cm^{-3} and 1.19 g cm^{-3} for Assosa, Bambassi and combined over locations, respectively and it is in the suitable range for agricultural practices. The pH of soil was 5.32, 5.50 and 5.41 for Assosa, Bambassi and combined over locations, respectively and was all strongly acidic in nature at both locations (Table 1). In soils having a pH of the aforementioned range phosphorus fixation is a serious problem and useful microorganisms including nitrogen fixing rhizobia couldn't also survive for they need a soil pH above 5.5. At Assosa, total nitrogen (0.20%), available P (6.80 ppm), organic carbon (2.80%) and effective cation exchange capacity (22.05cmol (+) kg^{-1}) were medium, low, high and moderate, respectively for effective crop growth. Likewise, at Bambassi, total nitrogen (0.49%), available P (5.49 PPM), organic carbon (3.30%) and cation exchange capacity (25.61cmol (+) kg^{-1}) were high, low, very high and very high, respectively for effective crop growth.

Table 1: Initial soil physico-chemical properties of the experimental sites.

Soil properties	Assosa	Rating	Bambassi	Rating	COS	Rating
Physical properties						
Bulk density (g cm^{-3})	1.16	Low*	1.23	Low*	1.19	Low*
Particle size distribution						
Sand (%)	24.00		21.33		22.66	
Clay (%)	53.00		52.34		52.67	
Silt (%)	23.00		26.33		24.66	
Textural class	Clay		Clay		Clay	
Chemical properties						
pH (H_2O)	5.32	Strongly acidic*	5.50	Strongly acidic*	5.41	Strongly acidic*
Total nitrogen (%)	0.20	Medium	*0.49	High	*0.34	High*
Available P (ppm)	6.80	Low*	5.49	Low*	6.14	Low*
Organic carbon (%)	2.80	High*	3.30	Very high*	3.05	High*
CEC (meq 100 g $soil^{-1}$)	22.05	Moderate*	25.61	Very high*	23.83	Moderate*

Where, * shows Hazelton and Murphy (2007); CEC= Cation exchange capacity; P= Phosphorus; ppm= Part per million; pH= Power of hydrogen; COS= Combined over sites.

The mean results combined over locations showed that total nitrogen (0.34%), available P (6.14 ppm), organic carbon (3.05%) and cation exchange capacity (23.83 cmol (+) kg^{-1}) of soil were high, low, high and moderate, respectively for effective crop growth. This implies that the experimental soil apparently contains low to very high levels of soil quality parameters initially to support plant growth (Table 1). This is in agreement with standardizations of Hazelton and Murphy (2007) who categorized a soil with pH (5.41) as strongly acidic. Organic carbon with 3.05% of the soil and 0.34% nitrogen were considered as high in standards. Similarly, 6.14 ppm phosphorus was categorized as low and the cation exchange capacity (23.83 cmol (+) kg^{-1} of soil) of the soil was moderate with low level of soil bulk density (1.19 g cm^{-3}) (Hazelton and Murphy, 2007).

Chemical composition of fresh cattle manure

The nutrient concentration recorded from fresh cattle manure were 8.50% organic carbon, 14.67% organic matter, 0.92% total nitrogen, 63.00ppm available phosphorus, (45.15 cmol (+) kg^{-1}) cation exchange capacity and the pH 7.90 (Table 2). Based on the values recorded, the pH of fresh cattle manure was moderately alkaline. In addition, the recorded value of total nitrogen, available phosphorus, organic carbon and the cation exchange capacity of fresh cattle manure was very high according to the rating of Hazelton and Murphy (2007).

Effect of bio-, organic and inorganic NPSB fertilizers and lime on soil physico-chemical properties after two years experiment

Bulk density

Analysis of variance showed that application of biofertilizer and inorganic fertilizer were not affected (P>0.05) bulk density at both locations (Table 3). Unlike to the effect of biofertilizer and inorganic fertilizer, organic fertilizer was highly (P<0.01) affected bulk density at both locations (Table 3). Thus, application of 10t/ha fresh cattie manure gave the maximum bulk density of 1.17g/cm^3 and 1.24g/cm^3 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum bulk density of 1.15 g/cm^3 and 1.22 g/cm^3 was recorded from the control at Assosa and Bambassi, respectively.

The result indicated that application of 10t/ha fresh cattie manure to the soil improved the bulk density of the soil. This may be attributed to that application of fresh cattle manure resulted in high soil organic matter increases. The high soil organic matter generally increased the aggregate stability and total porosity, reduced soil compactness (improved the bulk density) and changed the pore-size distribution of the soil. This result is in line with the finding of Candemir, F. and Gulser, C. (2011) reported that soil organic matter lowered soil compaction, which results in an improved total soil porosity and permeability and because of that, soil bulk density was improved. Yazdanpanah *et al*. (2016) have also reported that the different soil physical properties, especially those related to soil hydraulic properties, can be improved by incorporating sufficient amounts of organic manure, which help to improve bulk density and surface crusting and increase aggregate stability, porosity and microbial activity. Meng *et al*. (2019) results also showed that manure applications decreased the bulk density and increased the total porosity of the soil. Dhaliwal *et al*. (2019) who also reported that treatment of the soil with organic products such as manure release bacterial gums and polysaccharides that aid in binding soil particles together, thus increasing aggregation and decreasing the bulk density.

Similar to the effect of organic fertilizer, lime was highly (P<0.01) affected bulk density at both locations (Table 3). Thus, application of 5t/ha lime gave the highest bulk density of 1.17 g/cm^3 and 1.24 g/cm^3 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum bulk density of 1.16 g/cm^3 and 1.23 g/cm^3 was recorded from un-limed soil at Assosa and Bambassi, respectively. The result implies that application of 5t/ha lime to the soil improved the bulk density of the soil. This might be due to liming played a significant role in reducing soil acidity. The reduction in soil acidity might contribute for survival of microorganisms. The microorganisms which are survived and found in soil might involve in decomposition process and that aid in binding soil particles together, thus increasing aggregation and decreasing the bulk density. This result is in agreement with the finding of Crawford *et al*. (2008) who reported that more than increasing soil pH; increased availability of P, Mo and B and more favorable conditions for microbial mediated reactions such as N2 fixation and nitrification and in some cases improved soil physical properties particularly soil structure and bulk density.

In addition, the interaction effect of biofertilizer, organic fertilizer, lime and inorganic fertilizers was highly (P<0.01)

Table 2: Chemical composition of fresh cattle manure.

Chemical properties	Value	Rating
pH (H_2O)	7. 90	Moderately alkaline*
Total nitrogen (%)	0. 92	Very high*
Available P (ppm)	63.00	Very high*
Organic carbon (%)	8.50	Very high*
CEC (meq 100 g $soil^{-1}$)	45.15	Very high*

Where, *shows Hazelton and Murphy (2007); CEC= Cation exchange capacity; P= Phosphorus; ppm= Part per million; pH= Power of hydrogen.

Table 3: Main effects of bio-, organic and inorganic NPSB fertilizers, and lime on soil physico-chemical properties after two years experiment at both locations in Assosa Zone, Western Ethiopia

Biofertilizer	Assosa						Bambassi					
	BD	pH	TN	AVP	OC	CEC	BD	pH	TN	AVP	OC	CEC
B1	1.16^{a}	5.31^{a}	0.20^{b}	6.74^{a}	2.76^{a}	21.87^{a}	1.23^{a}	5.48^{a}	0.48^{b}	5.47^{a}	3.28^{a}	25.42^{a}
B2	1.16^{a}	5.31^{a}	0.29^{a}	6.75^{a}	2.76^{a}	22.11^{a}	1.23^{a}	5.48^{a}	0.58^{a}	5.47^{a}	3.28^{a}	25.66
Sig. difference	ns	ns	**	ns	ns	ns	ns	ns	**	ns	ns	ns
Organic fertilizer												
M1	1.16^{b}	5.22^{b}	0.20^{b}	6.35^{b}	2.55^{b}	21.37^{b}	1.22^{b}	5.42^{b}	0.49^{b}	5.18^{b}	3.07^{b}	24.91^{b}
M2	1.17^{a}	5.39^{a}	0.28^{a}	7.14^{a}	2.98^{a}	22.85^{a}	1.24^{a}	5.54^{a}	0.57^{a}	5.76^{a}	3.50^{a}	26.40^{a}
Sig. difference	**	**	**	**	**	**	**	**	**	**	**	**
Lime												
L1	1.16^{b}	5.22^{b}	0.20^{b}	6.43^{b}	2.69^{a}	21.78^{b}	1.23^{b}	5.41^{b}	0.49^{b}	5.24^{b}	3.21^{a}	25.33^{b}
L2	1.17^{a}	5.39^{a}	0.28^{a}	7.06^{a}	2.84^{a}	22.44^{a}	1.24^{a}	5.54^{a}	0.57^{a}	5.70^{a}	3.36^{a}	25.99^{a}
Sig. difference	**	**	**	**	ns	**	**	**	**	**	ns	**
Inorganic fertilizer												
F1	1.16^{a}	5.30^{a}	0.23^{b}	6.60^{b}	2.76^{a}	22.04^{a}	1.23^{a}	5.48^{a}	0.52^{b}	5.37^{b}	3.28^{a}	25.58^{a}
F2	1.16^{a}	5.31^{a}	0.26^{a}	6.89^{a}	2.77^{a}	22.18^{a}	1.23^{a}	5.48^{a}	0.55^{a}	5.57^{a}	3.29^{a}	25.73^{a}
Sig. difference	ns	ns	**	**	ns	ns	ns	ns	**	**	ns	ns
SE (d) ±	0.003	0.02	0.01	0.19	0.07	0.16	0.003	0.02	0.01	0.13	0.07	0.16
CV (%)	1.73	2.29	17.78	12.50	12.47	5.08	1.68	2.21	12.29	10.53	9.80	4.37

Means within a column followed by the same letter(s) are not significantly different; B1= Without biofertilizer, B2 = SB12+MAR1495 biofertilizers; M1= Without fresh cattle manure; M2= Fresh cattle manure at 10 t ha^{-1}; L1= Without lime; L2= Lime at 5t/ha; F1= NPSB at 9.5-23-3.5-0.05, F2 = NPSB at 19-46-7-0.1; BD= Bulk density; pH= Power of hydrogen; TN= Total nitrogen; AVP= Available phosphorus; OC= Organic carbon; CEC= Cation exchange capacity; ** = highly significant at $P<0.01$; ns = not significant at $P>0.05$; SE=standard error; CV= Coefficient of variation.

Table 4: Interaction effects of bio-fertilizer, organic manure and inorganic NPSB fertilizer and lime on soil physico-chemical properties after two years experiment at both locations in Assosa Zone, Western Ethiopia.

Treatment combination				Assosa						Bambassi					
Biofertilizer	Organic manure	Lime	inorganic fertilizer	BD	PH	TN	AVP	OC	CEC	BD	PH	TN	AVP	OC	CEC
B1	M1	L1	F1	1.14^{g}	5.09^{h}	0.15^{l}	5.57^{h}	2.54^{f}	21.40^{h}	1.21^{g}	5.29^{d}	0.44^{l}	4.79^{h}	3.06^{f}	24.91^{f}
			E2	1.15^{f}	5.10^{g}	0.17^{k}	6.18^{g}	2.55^{e}	21.37^{g}	1.22^{f}	5.30^{d}	0.46^{k}	5.00^{g}	3.07^{e}	24.92^{g}
		L2	F1	1.15^{e}	5.36^{d}	0.18^{j}	6.76^{f}	2.55^{e}	21.36^{f}	1.22^{e}	5.54^{c}	0.47^{j}	5.42^{f}	3.07^{e}	24.91^{f}
			F2	1.15^{d}	5.34^{e}	0.21^{g}	6.91^{e}	2.55^{e}	21.37^{e}	1.22^{d}	5.54^{c}	0.50^{g}	5.52^{e}	3.07^{e}	24.92^{e}
	M2	L1	F1	1.17^{c}	5.33^{f}	0.19^{i}	6.93^{d}	2.83^{d}	22.12^{d}	1.24^{c}	5.53^{b}	0.48^{i}	5.55^{d}	3.35^{d}	25.66^{d}
			F2	1.17^{b}	5.37^{c}	0.20^{h}	7.04^{c}	2.84^{c}	22.24^{c}	1.24^{b}	5.53^{b}	0.49^{h}	5.64^{c}	3.36^{c}	25.79^{c}
		L2	F1	1.18^{a}	5.42^{b}	0.22^{f}	7.14^{b}	3.11^{b}	23.30^{b}	1.25^{a}	5.55^{a}	0.51^{f}	5.74^{b}	3.63^{b}	26.85
			F2	1.18^{a}	5.44^{a}	0.23^{e}	7.44^{a}	3.15^{a}	23.75^{a}	1.25^{a}	5.55^{a}	0.52^{e}	6.11^{a}	3.67^{a}	27.30^{a}
B2	M1	L1	F1	1.14^{g}	5.09^{h}	0.22^{f}	5.57^{h}	2.54^{f}	21.40^{h}	1.21^{g}	5.29^{d}	0.52^{e}	4.79^{h}	3.06^{f}	24.91^{f}
			F2	1.15^{f}	5.10^{g}	0.24^{d}	6.18^{g}	2.55^{e}	21.37^{g}	1.22^{f}	5.30^{d}	0.53^{d}	5.00^{g}	3.07^{e}	24.92^{g}
		L2	F1	1.15^{e}	5.36^{d}	0.24^{d}	6.76^{f}	2.55^{e}	21.36^{f}	1.22^{e}	5.54^{c}	0.53^{d}	5.42^{f}	3.07^{e}	24.91^{f}
			F2	1.15^{d}	5.34^{e}	0.25^{c}	6.91^{e}	2.55^{e}	21.37^{e}	1.22^{d}	5.54^{c}	0.54^{c}	5.52^{e}	3.07^{e}	24.92^{e}
	M2	L1	F1	1.17^{c}	5.33^{f}	0.24^{d}	6.93^{d}	2.83^{d}	22.12^{d}	1.24^{c}	5.53^{b}	0.53^{d}	5.55^{d}	3.35^{d}	25.66
			F2	1.17^{b}	5.37^{c}	0.25^{c}	7.04^{c}	2.84^{c}	22.24^{c}	1.24^{b}	5.53^{b}	0.54^{c}	5.64^{c}	3.36^{c}	25.79^{c}
		L2	F1	1.18^{a}	5.42^{b}	0.36^{b}	7.15^{b}	3.10^{b}	23.30^{b}	1.25^{a}	5.55^{a}	0.65^{b}	5.74^{b}	3.61^{b}	26.85^{b}
			F2	1.18^{a}	5.45^{a}	0.55^{a}	7.47^{a}	3.15^{a}	23.75^{a}	1.25^{a}	5.56^{a}	0.84^{a}	6.13^{a}	3.67^{a}	27.30^{a}
			Sig.difference	**	**	**	**	**	**	**	**	**	**	**	**
			SE (d) ±	0.003	0.02	0.01	0.19	0.07	0.16	0.003	0.02	0.01	0.13	0.07	0.16
			CV (%)	1.73	2.29	17.78	12.50	12.47	5.08	1.68	2.21	12.29	10.53	9.80	4.37

Means within a column followed by the same letter(s) are not significantly different; B1=without biofertilizer, B2 = SB12+MAR1495 biofertilizers; M1= without fresh cattle manure; M2 = fresh cattle manure at 10 t ha $^{-1}$; L1= without lime; L2 = Lime at 5t/ha; F1= NPSB at 9.5-23-3.5-0.05, F2 = NPSB at 19-46-7-0.1; BD= bulk density; PH= power of hydrogen; TN= total nitrogen; AVP= available phosphorus; OC= organic carbon; CEC= cation exchange capacity; ** = highly significant at $P<0.01$; SE=standard error; CV=coefficient of variation.

affected bulk density at both locations (Table 4). Thus, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 gave the maximum bulk density of 1.18g/cm^3 and 1.25g/cm^3 at Assosa and Bambassi, respectively. However, the interaction of un-inoculated, without fresh cattie manure, without lime and NPSB at 9.5-23-3.5-0.05 and the interaction of SB12+MAR1495, without fresh cattie manure, without lime and NPSB at 9.5-23-3.5-0.05 gave the minimum bulk density of 1.14g/cm^3 and 1.21g/cm^3 at Assosa and Bambassi, respectively. Moreover, bulk density (1.25g/cm^3) recorded at Bambassi is greater than that of Assosa. This might be due to the variation in initial soil conditions (Table 1).

Generally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved the bulk density of the soil as compared to sole application of biofertilizer, organic fertilizer, inorganic fertilizer and lime at both locations. This might be due to the availability of balanced nutrients obtained from both combined sources. The balanced nutrients obtained from both combined sources might have the contribution in enhancing the formation and stabilization of soil aggregates. The formation of soil aggregates increase soil porosity and hence lowered soil compaction or bulk density. This result is in line with Zhang *et al*. (2014) who reported that combined application of soil amendments enhance the stability of soil aggregation and has a positive significant effect on a range of soil physical properties and functions, which results in an improved total soil porosity and permeability and because of that, lowered soil compaction or soil bulk density. This result is also in agreement with the finding of Courtney and Mullen (2008) reported that combined application of biofertilizers, organic fertilizers, inorganic fertilizers and lime improved soil physical (bulk density, stabilization of soil structure and aggregate formation) properties, soil chemical (pH, base saturation, salinity and CEC) and biological properties.

PH

Analysis of variance showed that application of biofertilizer and inorganic fertilizer were not affected ($P>0.05$) pH at both locations (Table 3). Unlike to the effect of biofertilizer and inorganic fertilizer, organic fertilizer was highly ($P<0.01$) affected pH at both locations (Table 3). Thus, application of 10t/ha fresh cattie manure gave the maximum pH of 5.39 and 5.54 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum pH of 5.22 and 5.42 was recorded from the control at Assosa and Bambassi, respectively.

The result implies that application of 10t/ha fresh cattie manure to the soil improved the pH of the soil. The increase in the pH as a function of fresh cattle manure application might be attributed the presence of organic matter in the manure. The addition of organic matter to the soil through manure might have release the cations such as calcium and magnesium during decomposition and resulted in increasing of soil pH. This result is in agreement with Butterly *et al.* (2013) who reported that the addition of cations such as Ca and Mg through decomposition of organic matter neutralizes H+ ions and increase the pH of the soil. The result also in line with the finding of Whalen *et al*. (2000) who also reported that the increase in the pH as a function of manure application has been attributed to the calcium carbonate and bicarbonate found in manure. Suryantini (2007) reported that adding organic matter into soil for one season was generally changes the soil pH from acidic to around neutral. Similar finding was reported by Evelyn *et al.* (2004), that the application of organic matter increased soil pH from 5.0 to 6.5 after 90 days of application. Albiach *et al.* (2000) also reported that organic manures act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients turnover and many other changes related to physical, chemical and biological parameters of the soil.

Similar to the effect of organic fertilizer, lime was highly ($P<0.01$) affected pH at both locations (Table 3). Thus, application of 5t/ha lime gave the highest pH of 5.39 and 5.54 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum pH of 5.22 and 5.41 was recorded from un-limed soil at Assosa and Bambassi, respectively. The result implies that application of 5t/ha lime to the soil improved the pH of the soil. This might be due to liming played a significant role in increasing the pH by displacement of H+, Fe2+, Al3+ and Mn4+ ions from soil adsorption site and subsequent neutralization of H+ and precipitation of Fe, Al, Mn as hydroxides. This could be attributed to lime supplies significant amounts of Ca and Mg. As a result, Ca and Mg displaces H+, Fe2+, Al3+ and Mn4+ ions from soil adsorption site and hence increased pH. This result is in line with the findings of Onwonga *et al*. (2010) who reported that application of lime tends to raise the soil pH by displacement of H+, Fe2+, Al3+ and Mn4+ ions from soil adsorption site and subsequent neutralization of H+ and precipitation of Fe, Al, Mn as hydroxides.

In addition, the interaction effect of biofertilizer, organic fertilizer, lime and inorganic fertilizers was highly ($P<0.01$) affected pH at both locations (Table 4). Thus, the interaction of SB12+MAR1495, 10t/ha FCM, 5t/ha lime and NPSB at 19-46-7-0.1 gave the maximum pH of 5.45 and 5.56 at Assosa and Bambassi, respectively. However, the interaction of un-inoculated, without FCM, without lime and NPSB at 9.5-23-3.5-0.05 gave the minimum pH of pH of 5.09 and 5.29 at Assosa and Bambassi, respectively. Moreover, the pH (5.56) recorded at Bambassi is greater than that of Assosa. This might be due to the variation in initial soil conditions (Table 1).

Generally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved the pH of the soil as compared to sole application of biofertilizer, organic fertilizer, inorganic fertilizer and lime at both locations. This might be due to the availability of higher calcium and magnesium obtained from both combined sources. The presence of higher calcium and magnesium displaces H+, Fe2+, Al3+ and Mn4+ ions from soil adsorption site and hence increases soil pH. This result is in line with the findings of Onwonga *et al*. (2010) who reported that application of lime tends to raise the soil pH by displacement of H+, Fe2+, Al3+ and Mn4+ ions from soil adsorption site and subsequent neutralization of H+ and precipitation of Fe, Al, Mn as hydroxides. This result is also in agreement with the finding of Courtney and Mullen (2008) reported that combined application of biofertilizers, organic fertilizers, inorganic fertilizers and lime improved soil physical (bulk density, stabilization of soil structure and aggregate formation) properties, soil chemical (pH, base saturation, salinity and CEC) and biological properties.

Total nitrogen

Analysis of variance showed that application of biofertilizer to the soil through seed inoculation was highly (P<0.01) affected total nitrogen at both locations (Table 3). As a result, combined application of SB12 + MAR1495 strains gave the maximum total nitrogen of 0.29 and 0.58 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum total nitrogen of 0.20 and 0.49 was recorded from un-inoculated control at Assosa and Bambassi, respectively. The result implies that combined application of SB12+MAR1495 strains to the soil through seed inoculation improved the total nitrogen in the soil. The presence of maximum total nitrogen might be due to the addition of nitrogen to the soil through nitrogen fixation. This result is in agreement with the finding of Li *et al*. (2017) who reported that the microorganisms that are added to the soil by seed encapsulation have notable advantages for improving soil health and fertility through the promotion of biological nitrogen fixation, solubilization of insoluble phosphates, decomposition of organic matter, suppression of soil-borne pathogens, regulation of soil biological properties and strengthening of the microbial community structure, as well as preservation of the soil microbiota balance in a continuous crop cultivation cycle.

Similar to the effect of biofertilizer, organic fertilizer was highly (P<0.01) affected total nitrogen at both locations (Table 3). Thus, application of 10t/ha fresh cattie manure gave the maximum total nitrogen of 0.28 and 0.57 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum total nitrogen of 0.20 and 0.49 was recorded from the control at Assosa and Bambassi, respectively. The result implies that application of 10t/ha fresh cattie manure to the soil improved the total nitrogen in the soil. This might be due to application of fresh cattle manure releases micro and macro nutrients, particularly nitrogen and phosphorus during decomposition. This result is in agreement with the finding of Das *et al*. (2017) who reported that application of cattle manure stimulates soil microbial activities and their biomass, thereby enhancing the release of organic nutrients, such as nitrogen and phosphorus, in the soil. The result also in line with Lentz *et al*. (2012) who reported that after application of organic manure in to the soil, important micro and macro nutrients are released into the soil during decomposition.

Similar to the effect of biofertilizer and organic fertilizer, lime was highly (P<0.01) affected total nitrogen at both locations (Table 3). Thus, application of 5t/ha lime gave the highest total nitrogen of 0.28 and 0.57 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum total nitrogen of 0.20 and 0.49 was recorded from un-limed soil at Assosa and Bambassi, respectively. The result implies that application of 5t/ha lime to the soil improved the total nitrogen in the soil. This might be due to liming played a significant role in increasing the availability of nutrients by reducing soil acidity. This might be also due to liming creating favorable environmental condition for N-fixing bacteria's by reducing soil acidity as a result effective biological fixation might have occur. Because of the above two reasons, total nitrogen might be increased in the soil. This result is in line with the findings of Crawford *et al*. (2008) reported that more than increasing soil pH; increased availability of P, Mo and B and more favorable condition for microbial mediated reactions such as N2 fixation and nitrification.

Similar to the effect of biofertilizer, organic fertilizer and lime, inorganic fertilizer was highly (P<0.01) affected the total nitrogen at both locations (Table 3). Thus, application of NPSB at 19-46-7-0.1 fertilizer gave the maximum total nitrogen of 0.26 and 0.55 at Assosa and Bambassi, respectively, which was significantly higher than application of NPSB at 9.5-23-3.5-0.05 fertilizer. However, application of NPSB at 9.5-23-3.5-0.05 fertilizer gave the minimum total nitrogen of 0.23 and 0.52 at Assosa and Bambassi, respectively. The result further implies that application of NPSB at 19-46-7-0.1 fertilizer to the soil improved the total nitrogen in the soil. This might be due to the addition of nitrogen through application of NPSB at 19-46-7-0.1 fertilizer to the soil. This result is in line with the findings of Kibblewhite *et al*. (2008) who reported that application of inorganic fertilizers increased the total nitrogen in soil.

In addition, the interaction effect of biofertilizer, organic fertilizer, lime and inorganic fertilizers was highly (P<0.01) affected the total nitrogen at both locations (Table 4). Thus, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 gave the maximum total nitrogen of 0.55 and 0.84 at Assosa and Bambassi, respectively. However, the interaction of un-inoculated, without fresh cattie manure, without lime and NPSB at 9.5-23-3.5-0.05 gave the minimum total nitrogen of 0.15 and 0.44 at Assosa and Bambassi, respectively. Moreover, the total nitrogen (0.84) recorded at Bambassi is greater than that of Assosa. This might be due to the variation in initial soil conditions (Table 1).

Generally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved the total nitrogen in the soil as compared to sole application of biofertilizer, organic fertilizer, inorganic fertilizer and lime at both locations. This might be due to the availability of higher nitrogen obtained from both combined sources. This result is in agreement with the finding of Harleen (2016) who reported that the significant increase in total nitrogen was observed in treatments having combined application of biofertilizers, inorganic fertilizers, organic fertilizers and lime. Tolanur and Badanur (2003) also reported that available N, P and K contents increased significantly with the application of biofertilizers combination with inorganic fertilizers, organic fertilizers and lime over the inorganic fertilizers alone. Kumar and Shivay (2010) also revealed that integrated use of biofertilizers, organic fertilizers, inorganic fertilizers and lime significantly improved the available N and P and K contents compared to sole application of inorganic fertilizers.

Available phosphorus

Analysis of variance showed that application of biofertilizer to the soil through seed inoculation was not affected (P>0.05) available phosphorus at both locations (Table 3). Unlike to the effect of biofertilizer, organic fertilizer was highly (P<0.01) affected available phosphorus at both locations (Table 3). Thus, application of 10t/ha fresh cattie manure gave the maximum available phosphorus of 7.14 ppm and 5.76 ppm at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum available phosphorus of 6.35 ppm and 5.18 ppm was recorded from the control at Assosa and Bambassi, respectively.

The result indicated that application of 10t/ha fresh cattie manure to the soil improved available phosphorus in the soil. This might be due to application of fresh cattle manure releases micro and macro nutrients, particularly nitrogen and phosphorus during decomposition. Also, calcium and magnesium among macro nutrients again improves the acidic nature of the soil and make the phosphorus available in the soil. As a result, the phosphorus which was found initially in the soil; phosphorus which are released in to the soil during decomposition of organic matter; and phosphorus which was available in the soil due to calcium and magnesium resulted in increasing of available phosphorus in the soil. This result is in agreement with the finding of Das *et al*. (2017) who reported that application of cattle manure stimulates soil microbial activities and their biomass, thereby enhancing the release of organic nutrients, such as nitrogen and phosphorus, in the soil. The result also in line with Lentz *et al*. (2012) who reported that after application of organic manure in to the soil, important micro and macro nutrients are released into the soil during decomposition.

Similar to the effect of organic fertilizer, lime was highly (P<0.01) affected available phosphorus at both locations (Table 3). Thus, application of 5t/ha lime gave the highest available phosphorus of 7.06 ppm and 5.70 ppm at Assosa and Bambassi, respectively, which was significantly higher than un-limed soil. However, the minimum available phosphorus of 6.43 ppm and 5.24 ppm was recorded from un-limed soil at Assosa and Bambassi, respectively. The result implies that application of 5t/ha lime to the soil improved available phosphorus in the soil. This might be due to liming played a significant role in reducing soil acidity and therefore increased the availability of nutrients. This result is in line with the findings of Onwonga *et al*. (2010) who reported that application of lime tends to raise the soil pH by displacement of H+, Fe2+, Al3+ and Mn4+ ions from soil adsorption site and subsequent neutralization of H+ and precipitation of Fe, Al, Mn as hydroxides. Crawford *et al*. (2008) also reported that more than increasing soil pH; increased availability of P, Mo and B and more favorable conditions for microbial mediated reactions such as N2 fixation and nitrification and in some cases improved soil structure and ultimately increasing the growth attributes of soybean.

Similar to the effect of organic fertilizer and lime, inorganic fertilizer was highly (P<0.01) affected available phosphorus at both locations (Table 3). Thus, application of NPSB at 19-46-7-0.1 fertilizer gave the maximum available phosphorus of 6.89 ppm and 5.57 ppm at Assosa and Bambassi, respectively, which was significantly higher than application of NPSB at 9.5-23-3.5-0.05 fertilizer. However, application of NPSB at 9.5-23-3.5-0.05 fertilizer gave the minimum available phosphorus of 6.60 ppm and 5.37 ppm at Assosa and Bambassi, respectively. The result further implies that application of NPSB at 19-46-7-0.1 fertilizer to the soil improved available phosphorus in the soil. This might be due to the addition of phosphorus to the soil through application of NPSB at 19-46-7-0.1 fertilizer. This result is in line with the finding of Kibblewhite *et al*. (2008) who reported that application of inorganic fertilizers increased available phosphorus in soil.

In addition, the interaction of biofertilizer, organic fertilizer, lime and inorganic fertilizers was highly (P<0.01) affected available phosphorus at both locations (Table 4). Thus, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 gave the maximum available phosphorus of 7.47 ppm and 6.13 ppm at Assosa and Bambassi, respectively. However, the interaction of un-inoculated, without fresh cattie manure, without lime and NPSB at 9.5-23-3.5-0.05 gave the minimum available phosphorus of 6.07ppm and 4.79 ppm at Assosa and Bambassi, respectively. Moreover, available phosphorus (7.47 ppm) recorded at Assosa is greater than that of Bambassi. This might be due to the variation in initial soil conditions (Table 1).

Generally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved available phosphorus in the soil as compared to sole application of biofertilizer, organic fertilizer, inorganic fertilizer and lime at both locations. This might be due to the availability of higher phosphorus obtained from both combined sources. This result is in agreement with the finding of Kassa *et al*. (2014) who found that the combined application of fresh cattle manure with biofertilizers, inorganic fertilizers and lime increased the amount of available phosphorus in soil, as it helps in sustaining higher population of several bacteria and fungi, which are capable of solubilizing soil phosphorus. This result is also in line with the finding of Tolanur and Badanur (2003) who reported that available N, P and K contents increased significantly with the application of biofertilizers combination with inorganic fertilizers, organic fertilizers and lime over the inorganic fertilizers alone. Kumar and Shivay (2010) also revealed that integrated use of biofertilizers, organic fertilizers, inorganic fertilizers and lime significantly improved the available N and P and K contents compared to sole application of inorganic fertilizers.

Organic carbon

Analysis of variance showed that application of biofertilizer, inorganic fertilizer and lime were not affected ($P>0.05$) organic carbon at both locations (Table 3). Unlike to the main effects of biofertilizer, inorganic fertilizer and lime, the main effects of organic fertilizer was highly ($P<0.01$) affected organic carbon at both locations (Table 3). Thus, application of 10t/ha fresh cattie manure gave the maximum organic carbon of 2.98 and 3.50 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum organic carbon of 2.55 and 3.07 was recorded from the control at Assosa and Bambassi, respectively. The result implies that application of 10t/ha fresh cattie manure to the soil improved organic carbon in the soil. This might be due to the addition of organic matter to the soil through manure application. The higher organic matter applied, the higher organic carbon found in the soil. The presence of higher organic carbon might be also due to the slow mineralization of organic matter might increase the accumulation of organic carbon in the soil. This result is in agreement with the finding of Antil and Singh (2007) reported that the highest soil organic carbon value was obtained by applying cattle manure followed by poultry manure. The result is also in line with Blanchet *et al.* (2016) who found that with the application of organic manure, soil organic carbon significantly increased by 6.2%, compared with the application of inorganic fertilizer alone. Ozlu (2016) also reported that applying different soil enhancers, such as organic composts, plant residues, agricultural wastes and inorganic fertilizers is considered an effective way to enhance SOM and carbon concentration under different soil types and cropping systems.

In addition, the interaction of biofertilizer, organic fertilizer, lime and inorganic fertilizers was highly ($P<0.01$) affected organic carbon at both locations (Table 4). Thus, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 gave the maximum organic carbon of 3.15 and 3.67 at Assosa and Bambassi, respectively. However, the interaction of un-inoculated, without fresh cattie manure, without lime and NPSB at 9.5-23-3.5-0.05 gave the minimum organic carbon of 2.54 and 3.06 at Assosa and Bambassi, respectively.

Generally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved organic carbon in the soil as compared to sole application of biofertilizer, organic fertilizer, inorganic fertilizer and lime at both locations. The presence of higher organic carbon might be due to the synergetic effect of combined resources. This result is in agreement with the finding of Li *et al.* (2017) who reported that the integrated use of organic manure and inorganic fertilizers along with biofertilizers and lime is a promising approach in preserving soil microbial communities and activities, which will ultimately show positive impacts on different soil physico-chemical properties and crop production.

Cation exchange capacity

Analysis of variance showed that application of biofertilizer and inorganic fertilizer were not affected ($P>0.05$) cation exchange capacity at both locations (Table 3). Unlike to the main effects of biofertilizer and inorganic fertilizer, organic fertilizer was highly ($P<0.01$) affected cation exchange capacity at both locations (Table 3). Thus, application of 10t/ha fresh cattie manure gave the maximum cation exchange capacity of 22.85 and 26.40 at Assosa and Bambassi, respectively, which was significantly higher than control. However, the minimum cation exchange capacity of 21.37 and 24.91 was recorded from the control at Assosa and Bambassi, respectively. The result implies that application of 10t/ha fresh cattie manure to the soil improved cation exchange capacity in the soil. This might be due to application of cattle manure provides organic matter to the soil. As a result, the organic matter releases the cations such as calcium and magnesium in to the soil during decomposition, thus improved the cation exchange capacity of the soil. This result is in agreement with the finding of Das *et al*. (2017) who reported that application of cattle manure increases cation exchange capacity, which is a very important indicator for retaining nutrients and making them available to plants. This result is also similar with Miller *et al*. (2016) found that decomposition of organic matter increases the CEC due to an increase in the negatively charged sites on carboxyl and phenolic groups.

Similar to the main effect of organic fertilizer, lime was highly ($P<0.01$) affected cation exchange capacity at both locations (Table 3). Thus, application of 5t/ha lime gave the highest cation exchange capacity of 22.44 and 25.99 at Assosa and Bambassi, respectively, which was significantly higher than un-limed soil. However, the minimum cation exchange capacity of 21.78 and 25.33 was recorded from un-limed soil at Assosa and Bambassi, respectively.

The result indicated that application of 5t/ha lime to the soil improved cation exchange capacity in the soil. This might be due to liming the soil supplies significant amounts of exchangeable cations such as calcium and magnesium in to the soil. The presence of exchangeable cations in soil increases the cation exchange capacity of the soil. This result is in line with the findings of Graham *et al.* (2002) who reported that liming play a vital role in increasing the cation exchange capacity by supplying exchangeable cations to the soil.

In addition, the interaction effect of biofertilizer, organic fertilizer, lime and inorganic fertilizers was highly (P<0.01) affected cation exchange capacity at both locations (Table 4). Thus, the interaction of SB12+MAR1495, 10t/ha FCM, 5t/ha lime and NPSB at 19-46-7-0.1 gave the maximum cation exchange capacity of 23.75 and 27.30 at Assosa and Bambassi, respectively. However, the interaction of un-inoculated, without fresh cattie manure M, without lime and NPSB at 9.5-23-3.5-0.05 gave the minimum cation exchange capacity of 21.40 and 24.97 at Assosa and Bambassi, respectively. Moreover, the cation exchange capacity (27.30) recorded at Bambassi is greater than that of Assosa. This might be due to the variation in initial soil conditions (Table 1).

Generally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved cation exchange capacity in the soil as compared to sole application of biofertilizer, organic fertilizer, inorganic fertilizer and lime at both locations. This might be due to the availability of exchangeable cations obtained from both combined sources. This result is in agreement with the finding of Courtney and Mullen (2008) reported that combined application of bio-, organic and inorganic fertilizers and lime improved soil physical (bulk density, stabilization of soil structure and aggregate formation) properties, soil chemical (pH, base saturation, salinity and CEC) and biological properties. This result is also in line with the finding of Li *et al.* (2017) who reported that the integrated use of organic manure and inorganic fertilizers along with biofertilizers and lime is a promising approach in preserving soil microbial communities and activities, which will ultimately show positive impacts on different soil physico-chemical properties and crop production.

CONCLUSION

As a conclusion, from this experiment it was noted that bulk density was highly affected (P<0.01) by organic fertilizers, lime and the interactions of bio-organic and inorganic fertilizers and lime, while it was not affected (P>0.05) by both biofertilizer and inorganic fertilizer at both locations. pH was highly affected (P<0.01) by organic fertilizers, lime and the interactions of bio-, organic and inorganic fertilizers and lime, while it was not affected (P>0.05) by both biofertilizer and inorganic fertilizer at both locations. Total nitrogen was highly affected (P<0.01) by bio-, organic and inorganic fertilizers and lime and their interactions at both locations. Available phosphorous was highly affected (P<0.01) by organic fertilizers and inorganic fertilizers and lime and their interactions, while was not affected (P>0.05) by biofertilizers at both locations. Organic carbon was highly affected (P<0.01) by organic fertilizers and the interactions of bio-, organic and inorganic fertilizers and lime, while it was not affected (P>0.05) by biofertilizer, inorganic fertilizer and lime at both locations. Cation exchange capacity was highly affected (P<0.01) by organic fertilizers, lime and the interactions of bio-, organic and inorganic fertilizers and lime, while it was not affected (P>0.05) by both biofertilizer and inorganic fertilizer at both locations. The maximum bulk density, pH, total nitrogen, available phosphorus, organic carbon and CEC were recorded from combined use of SB12+MAR1495, application of 10t/ha fresh cattie manure, application of 5t/ha lime, application of NPSB at 19-46-7-0.1 fertilizer and the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1. Despite the individual role of bio-, organic and inorganic fertilizers and lime; their interaction effects has more pronounced effect in improving soil physico-chemical properties. Finally, the interaction of SB12+MAR1495, 10t/ha fresh cattie manure, 5t/ha lime and NPSB at 19-46-7-0.1 improved the bulk density, pH, total nitrogen, available phosphorus, organic carbon and CEC of the soil as compared to sole application of biofertilizer, organic fertilizer, inorganic fertilizer and lime at both districts and should be adopted appropriately to improve soil physico-chemical properties at both districts and similar agro-ecologies.

Conflict of interest

It is to declare that there are no conflicts of interest.

REFERENCES

Albiach, R., Canet, R., Pomares, F. and Ingelmo, F. (2000). Microbial biomass content and enzymatic activities after the application of organic amendments to horticultural soils. Bioresearch Technology. 75: 43-48.

Antil, R.S., Singh, M. (2007). Effects of organic manures and fertilizers on organic matter and nutrients status of the soil, Arch. Agron. Soil Sci. 53: 519-528.

Asgelil, D. (2000). Effect of fertilizer on the yield and nodulation pattern of faba bean on a Nitosol of Adet, North Western Ethiopia. Ethio. J. Nat. Res. 2: 237-244.

Assosa Agricultural Research Center (AsARC). (2017). Annual report, Assosa, Ethiopia.

Ayoola, O.T. (2010). Yield performance of crops and soil chemical changes under fertilizer treatments in a mixed cropping system. Afr .J. Biotechnol. 9(26): 4018-4021.

Benishangul Gumuz Beauro of Agriculture and Rural Development (BGBOARD). (2017). Annual Report, Assosa, Ethiopia.

Black, G.R. (1965). Bulk density. In: Methods of Analysis. [C.A. Black (ed.)]. Agronomy part I, No.9, American Society of Agronomy, Madison, Wisconsin. Pp: 374-399.

Blanchet, G., Gavazov, K., Bragazza, L., Sinaj, S. (2016). Responses of soil properties and crop yields to different inorganic and organic amendments in a Swiss conventional farming system. Agric. Ecosyst. Environ. 230: 116-126.

Bouyoucos, G.J. (1962). Hydrometer method improvement for making particle size analysis of soils. Agronomy Journal. 54: 464-4.

Butterly, C.R., Baldock, J.A., Tang, C. (2013). The contribution of crop residues to changes in soil pH under field conditions. Plant Soil. 366: 185-198.

Candemir, F., Gulser, C. (2011). Effects of different agricultural wastes on some soil quality indexes at clay and loamy sand fields. Commun. Soil Sci. Plant Anal. 42: 13-28.

Courtney, R.G., G.J. Mullen, (2008). Soil quality and barley growth as influenced by the land application of two compost types, Bioresour. Technol. 99: 2913-2918.

Crawford, Jr. T.W., Singh, U. and Breman, H. (2008). Solving problems related to soil acidity in Central Africa's Great Lakes Region. International Center for Soil Fertility and Agricultural Development (IFDC) - USA.

Das, S., Jeong, S.T., Das, S., Kim, P.J. (2017). Composted cattle manure increases microbial activity and soil fertility more than composted swine manure in a submerged rice paddy. Front. Microbiol. 8: 1702.

Dhaliwal, S.S., Naresh, R.K., Mandal, A., Walia, M.K., Gupta, R.K., Singh, R., Dhaliwal, M.K. (2019). Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems: A review. J. Plant Nutr. 42: 2873-2900.

Evelyn, S.K., Jan, O.S., Jeffrey, A.B. (2004). Functions of soil organic matter and the effect on soil properties. CSIRO Land and Water Report. pp: 129.

Graham, M.H., Haynes, R.J and Meyer, J.M. (2002). Changes in soil chemistry and aggregates stability induced by fertilizer application, burning and trash relation on a long-term sugarcane experiment in South Africa. European Journal of Soil Science 53: 589-598.

Harleen, K. (2016). Effect of bio-fertilizers and organic fertilizers on soil health, growth and yield of green pea (*pisum sativum* l.). Department of Microbiology College of Basic Sciences and Humanities ©Punjab Agricultural University Ludhiana -141004.

Hazelton, P. and Murphy, B. (2007). Interpreting Soil Test Results: What do all the numbers mean? 2nd Edition. CSIRO Publishing.

Kassa, M., Yebo, B., Habte, A. (2014). The response of Haricot bean (*Phaseolus vulgaris* L.) varieties to phosphorus levels on Nitosols at Wolayita Zone, Ethiopia. Am J Plant Nutr Fertil Technol. 4: 27-32.

Khaliq, A. and Abbasi, M.K. (2015). Soybean Response to single or mixed soil amendments in Kashmir, Pakistan. Agronomy Journal. 107(3): 887-895.

Kibblewhite, M.G., Ritz, K., Swift, M.J. (2008). Soil health in agricultural systems. Phil. Trans. R. Soc. B. Biol. Sci. 363: 685-701.

Kumar, V. and Shivay, Y.S. (2010). Integrated nutrient management: An ideal approach for enhancing agricultural production and productivity. Indian J. Fert. 6: 41-57.

Lentz, R.D., Ippolito, J.A. (2012). Biochar and manure affect calcareous soil and corn silage nutrient concentrations and uptake. J. Environ. Qual. 41: 1033-1043.

Li, R., Tao, R., Ling, N., Chu, G. (2017). Chemical, organic and biofertilizer management practices effect on soil physicochemical property and antagonistic bacteria abundance of a cotton field: Implications for soil biological quality. Soil Tillage Res. 167: 30-38.

Meng, Q., Ma, X., Zhang, J., Yu, Z. (2019). The long-term effects of cattle manure application to agricultural soils as a natural-based solution to combat salinization. Catena. 175: 193-202.

Miller, J., Beasley, B., Drury, C., Larney, F., Hao, X. (2016). Influence of long-term application of composted or stockpiled feedlot manure with straw or wood chips on soil cation exchange capacity. Compost. Sci. Util. 24: 54-60.

Okalebo, J.R., Gathua, K.W., Woomer, P.L. (2002). Laboratory Methods of Plant and Soil Analysis: A Working Manual, 2nd edn. TSBF-UNESCO, Nairobi.

Olsen, S.R. and Sommers, L.E. (1982). Phosphorus. in Methods of Soil Analysis. [A.L. Page (eds.)]. Part 2. Chemical and Microbiological Properties. Second Edition. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin USA. Pp: 403-430.

Onwonga, R.N., Lelei, J.J. and Mochoge, B.B. (2010). Mineral nitrogen and microbial biomass dynamics under different acid soil management practices for maize production. Journal of Agricultural Science. 2(1): 16. https://doi.org/10.5539/jas.v2n1p16.

Ozlu, E. (2016). Long-Term Impacts of Annual Cattle Manure and Fertilizer on Soil Quality under Corn-Soybean Rotation in Eastern South Dakota; South Dakota State University: Brookings, SD, USA.

Somasegaran, P. and Hoben, H.J. (1994). Handbook for Rhizobia: Methods in legume - Rhizobium technology. Springer-Verkag, New York, USA. P: 366.

Suryantini. 2007. The influence of type and dose of soil ameliorant on peanut productivity in marginal Alfisol. Agritek. 15: 1-6.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. (1993). Soil Acidity and Basicity. *In* Soil Fertility and Fertilizers. 5th ed. Macmillan Publ., New York. P: 364-404.

Tolanur, S.I. and Badanur, V.P. (2003). Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of *rabi* sorghum chickpea system and fertility of Vertisol. J. Indian Soc. Soil Sci. 51: 41-44.

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

Whalen, J.K., Chang, C., Clayton, G.W., Carefoot, J.P. (2000). Cattle manure amendments can increase the pH of acid soils. Soil Sci. Soc. Am. J. 64: 962-966.

Yazdanpanah, N., Mahmoodabadi, M., Cerda, A. (2016). The impact of organic amendments on soil hydrology, structure and microbial respiration in semiarid lands. Geoderma. 266: 58-65.

Zelleke, G., Agegnehu, G., Abera, D. and Rashid, S. (2010). Fertilizer and Soil Fertility Potential in Ethiopia: Constraints and Opportunities for Enhancing the System. Working Paper, International Food Policy Research institute.

Zhang, X., Wu, X., Zhang, S., Xing, Y., Wang, R., Liang, W. (2014). Organic amendment effects on aggregate-associated organic C, microbial biomass C and glomalin in agricultural soils. Catena. 123: 188-194.

Zinaw, D., Seltene, A., Addisu, G. (2013). Genetic variability and heritability of soybean (*Glycinemax* (L.) Merrill) genotypes in Pawe district, Metekel zone, Benishangul Gumuz regional state, northwestern Ethiopia. Wudpecker J. Agric. Res. 2(9): 240-245.