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Influenced of Organic and Chemical Source Fertilizer on Soil Physicochemical Properties and Nutrient Concentration of Nitisol in Welmera District, Central Ethiopia

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Abstract: Sustaining soil fertility and enhancing food production on smallholder farms is a great challenge in High Lands of Ethiopia due to mining of nutrients as result of continuous cropping without adequate external addition of inputs. A study was therefore, conducted to investigate effects of vermicompost and nitrogen fertilizer combination on soil physicochemical properties at Holeta Agricultural Research Center on Nitisols in the central highlands of Ethiopia in the 2019 cropping season. The treatments were arranged in a factorial split split-plot combination with two wheat varieties (Danda'a and Wane) as main plot, four vermicompost levels (0, 2.5, 5 and 7.5 t. ha^{-1}) as sub plot plot and four N fertilizer levels (0, 23, 46, 69 kg N ha^{-1}) as sub- sub- plot with three replications. The results revealed that the main effect of vermicompost significantly ($P<0.05$) influenced and improved major soil physico-chemical properties; soil bulk density, total porosity, soil moisture content, soil organic carbon (SOC), cation exchange capacity (CEC), soil available P, available S, exchangeable K, Ca and Mg after five months of wheat harvesting. Similarly, soil reaction and total nitrogen (TN) significantly ($P< 0.05$) influenced by combination of vermicompost and nitrogen fertilizers. Exchangeable acidity and exchangeable Al as well as available soil micronutrients (Cu, Zn, Fe and Mn) were found decreased after harvesting of wheat. Similarly, soil reaction and total nitrogen (TN) significantly ($P< 0.05$) influenced by combination of vermicompost and nitrogen fertilizers. Therefore, we conclude that integrated use of vermompost with nitrogen fertilizer improve soil physicochemical properties and fertility status of nitisol soils.

Key words: Nitrogen Fertilizer · Vermicompost Amendment · Soil Physicochemical Properties · Soil Fertility Management

INTRODUCTION

Soil fertility depletion due to reduction of soil organic matter and loss of nutrients are among the major constraints to agricultural productivity in tropics [1, 2] including acidic soils of Ethiopian high lands [3, 4]. Most of the Ethiopian high land soils are acidic, infertile and, hence, cannot support sustainable crop production without external inputs such as inorganic and organic fertilizer. Moreover, continuous cropping and inadequate replacement of nutrients removed in harvested materials or lose through erosion and leaching have been the major causes of soil fertility decline. This is particularly evident in the intensively cultivated areas in central highlands of the country [5].

Soil fertility depletion and related low agricultural productivity are serious challenges in Ethiopia particularly in central high lands [6, 7]. Soil nutrient depletion due to inadequate soil management have gradually increased and become serious problems to crop productivity in the country due to the strong association that exists between soil properties, land scape and cultural practice [8]. Soil nutrient status assessment at national level by FAO [9] showed that the nutrient depletion rate of Ethiopian soil was -47 N, -7 P and -32 K kg ha^{-1}. These were about twice as much as the average depletion rates for Sub Saharan Africa -22 kg N, -2.5 kg P and -15 kg K ha^{-1} yr^{-1} and it indicates the severe magnitude of soil nutrient depletion in Ethiopia.

Shifting the use of chemical fertilizer to organic source or supplementing inorganic fertilizers is indispensable option in improving properties and fertility status of soil. Application of organic substances has been recognized as an effective means for maintaining soil

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fertility, structure and aggregation, increasing soil microbial diversity and populations, increasing the moisture-holding capacity of soils and subsequently improving crop yields [10, 11]. Maintaining an appropriate level of soil organic carbon and ensuring the efficiency of biological cycling of nutrients, is crucial to the success of soil fertility management and agricultural productivity [12, 13]. However, the use of organic input alone cannot meet high yielding improved varieties nutrient demand due to their low nutrient content and slow release [14, 15].

Integrated soil fertility management in which both organic and inorganic fertilizers are used simultaneously is the most effective way to maintain soil sustainability [16] and crop yield as compared to the use of inorganic fertilizers alone [17]. The uses of biologically synthesized fertilizers such as vermicompost have been recognized as an effective means for improving soil physicochemical properties and soil fertility [18]. Combined application of vermicompost and inorganic fertilizers results in significant difference in bulk density, pH, Organic carbon, available nitrogen and available phosphorus. It has also advantage of, improving moisture and nutrient holding capacity, structure and aggregate of soil and also can increase soil microbial populations [19]. Vermicompost application can continuously supply crop-nutrient demand thus enhance soil fertility and soil quality [20].

Application of vermicompost as organic manure in soil revealed positive result in organic carbon, nutrient status; cation exchange capacity, microbial activities, microbial biomass and enzymatic activities [21]. Therefore, the objective of this paper was to evaluate the effect of combined application of vermicompost and N-fertilizer on soil physicochemical properties and soil nutrient status of acidic nitisol condition of welmera district.

MATERIALS AND METHODS

Description of the Study Area: The experiment was conducted at Holeta Agricultural Research Center, which is located at a distance of 30 km from Addis Ababa within the Oromia National Regional State. Holeta Agricultural Research Center is found in Welmera district West Shewa Zone at latitude of 9°2' 30" to 9° 3' 19.43" North and longitude of 38° 28'15" to 38° 30' 25.43" East. Welmera district has about 66, 247 ha total area and the total area of land under cultivation at Holeta Agricultural Research Center is about396-hectare hectares.

Climate and Topography: The study area is characterized by mono-modal rainfall pattern with an average annual rainfall of 1067 mm (834 to 1300 mm). The rainfall distribution is high during the three summer months (June to August), which accounts for 85 percent of the annual rainfall. Average minimum and maximum temperatures are 6.2°C and 22.1°C, respectively. The mean relative humidity is 58.7% at Holeta Agricultural Research Center. Welmera district is situated at an altitude of 2, 400 m above sea level and characterized by plateau plains, which are moderately elevated and gentle sloping.

Parent Materials and Soil Types: The dominant soil types at Welmera district are Nitisol and Vertisols. Nitisol are the dominant soil type and characterized by well-drained soils with a deep clayey sub-surface horizon that have typical nutty, or polyhedric blocky peds with shiny faces [22]. Light Vertisol covers small portions of the district. These soils are predominantly derived from basic volcanic rocks by strong weathering, but they are far more fertile than most other red tropical soils.

Vermicompost Materials and Preparation Procedures: Vermicompost preparation was conducted at Holeta Agricultural Research center. A vermicomposting unit dimension of $1\times 1 \times 1$ m^3 was set up. The vermicompost was prepared from organic materials such as green plants, animal dung, pulse straw and leaves. The raw materials were put up in layers in the following sequence according to Suparno *et al.* [23]. A layer of crop residues (20 cm= 60%) were spread as bedding materials. A layer of animal dung (5-10 cm = 30%) was scattered over the bedding materials and then a layer of topsoil (2-4 cm= 10%) was spread over cattle dung. Then, species of earthworms (*Eisenia foetida)* were introduced. After inoculation of worms, well chopped castor leaf was spread over as feeding materials subsequently upon decomposition. On three-day interval, sprinkling of water was done to maintain 60-70% moisture content until 90% bio-wastes were decomposed. Maturity of the compost was judged visually by observing the formation of black-brown color and granular structure of the compost at the surface of the bin. Three months later, upon decomposition, the vermicompost was harvested. The harvesting was made by manual separation of castings from worms. The vermicompost obtained was shade dried, sieved and analyzed for nutrient contents using standard procedures in the laboratory.

Treatments and Experimental Design: The experiment was arranged in a factorial split- split-plot design with three replications. Two wheat varieties (Wane and Danda'a) as main plots, four vermicompost amendment levels (0, 2.5, 5 and 7.5 t. ha^{-1}) as sub-plot and four

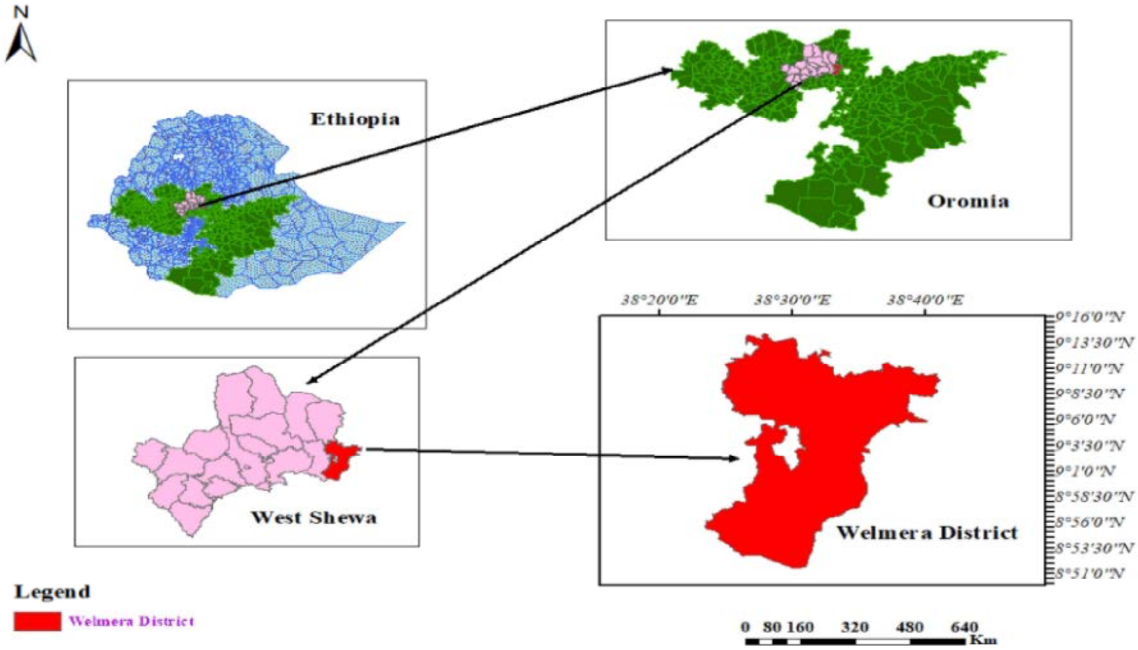

Fig. 1: Map of the Study Area

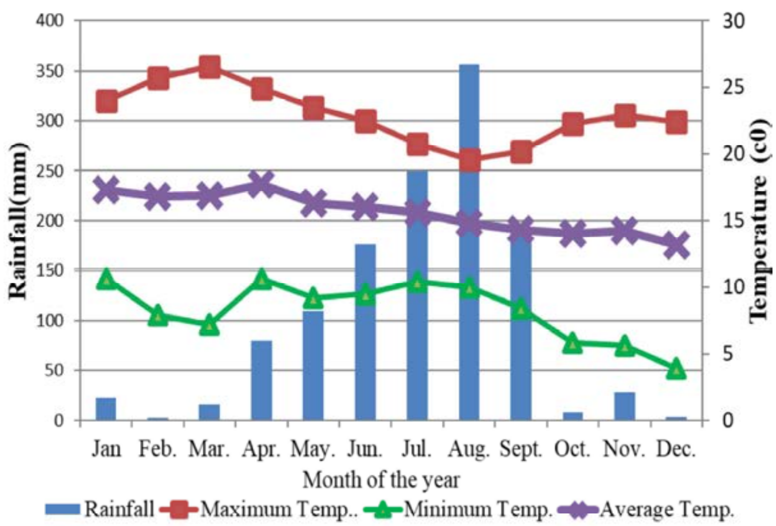

Fig. 2: Total rainfall and mean temperature of HARC center

N fertilizer (0, 23, 46 and 69 kg N ha^{-1}) as sub-sub-plots were used. Treatments were randomized in every block. The experiment had total treatment combination of 2 x 4 x 4 = 32 treatments.

Experimental Procedures and Field Management: The experiment was conducted at the experimental field of Holeta Agricultural Research Center. The experimental site was prepared for sowing using standard land preparation practices of the center; Tractor-mounted disk plowing and disk harrowing was carried out in May 2019. The area of main plots and sub plots were 9.5 m x 2.5 m and 2 m x 2.5 m respectively. The net plot size of the sub plot was 1.8 m * 2.3 m (4.14 m^2). Sowing was taken place at the end of June. At the time of sowing, the experimental plots were finely delineated manually using rakes and fork diggers and the planting rows were made using iron row markers adjusted in 20 cm row spacing. The vermicompost were applied manually and evenly to main plots during sowing and thoroughly mixed in the upper 15 cm of soil. To minimize losses and increase efficiency, all the levels of N were applied in the row as urea in two applications; half at planting and the other half at mid-tillering during light rainfall. Recommended phosphorus fertilizer (69 kg P ha^{-1}) was uniformly applied as triple super phosphate (TSP) to all plots at sowing in a band to the rows. Other relevant field trial management practices were uniformly applied with close supervision during the crop growth period.

Soil Sampling and Sample Analysis: Soil samples were taken both before and after planting from the experimental field. Disturbed (using auger) soil samples which were composited by thoroughly mixing and undisturbed (using core) one was also collected. Before planting, disturbed samples were randomly taken from five different spots across each block from a depth of 0-20 cm to make one composite sample. After harvesting, soil samples were collected from each plot at a depth of 0 - 20 cm. The collected soil samples were bagged, labeled and submitted to the Holeta Agricultural research laboratory. In the laboratory, sufficient amount of composite soil samples was air dried and ground to pass a 2-mm sieve except for organic carbon and total N in which 0.5 mm sieve was used. Then, soil samples were analyzed for physicochemical properties following standard laboratory procedures.

Physical Analysis: Particle size distribution was determined by the hydrometer method [24]. After determining sand, silt and clay separates; the soil was assigned to textural classes using the USDA soil textural triangle [25]. Bulk density was determined using the core method as described by Jamison *et al.* [26]. The average soil particle density (2.65 g cm^{-3}) was used for estimating total soil porosity [27]. Soil water content was determined using gravimetric method following the procedures described by Reynolds *et al.* [28].

Soil Chemical and Vermicompost Analysis: The pH of the soil was measured from suspension of 1:2.5 (weight/ volume) soil to water ratio using a glass electrode attached to digital pH meter [29]. Organic carbon content was determined using the Walkley and Black [30] wet digestion method. Total Nitrogen content was determined by the Kjeldahl digestion [31]. Available Phosphorus was extracted using Bray-II method [32]. The P extracted with this method was measured by spectrophotometer following the procedures described by Murphy and Riley [33]. Exchangeable acidity of the soil was determined by leaching-titration with 1N KCl as described by Van Reeuwijk [34]. Cation exchange capacity (CEC) and exchangeable bases were extracted by saturating the sample with 1N NH_4OA_c and CEC were determined using ammonium acetate method [35]. Exchangeable bases (K, Ca, Mg and Na) were extracted by saturating the sample with 1N NH_4OA_c; Calcium (Ca) and magnesium (Mg) were determined using Atomic Absorption Spectrophotometer (AAS) while potassium (K) and sodium by using a flame photometer [36]. Available micronutrients iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) contents of the soils were extracted by diethylene triaminepenta acetic acid (DTPA) method [37] and the contents of each in the extract were determined by atomic absorption spectrophotometer at soil and plant analysis laboratory of Holeta Agricultural Research Center. The chemical nutrient contents were analyzed following as methods used for soil analysis.

Statistical Analyses: All soil parameters were subjected to statistical analysis of variance using a generalized linear model (GLM) in R statistical software version 3.5.3 [38]. Significance of the treatments was tested using the agricolae package of R [39]. The means were compared using the lsmean package of R [40] with Duncan Multiple Range Test (DMRT) set at a 5% level of significance.

RESULTS AND DISCUSSION

Physicochemical Properties of Soils of the Experimental Sites Before Planting: The results of laboratory analysis for soil physical properties were presented in Table 1 for composited soil sample collected from (0-20 cm) before planting. The results indicated that soil texture was dominated by 68.8% clay followed by 20.8% silt and 11.3% sand. Dominance of clay soil content shows the opportunity of holding high water and nutrient for crop growth. However, such characteristics of soil may be prone to erosion unless properly managed [41].

The average bulk density of soil at the study site was 1.4 g cm^{-3}. Although the soil is in the range considered suitable for the normal growth of crops, it is susceptible and almost closer to threshold level as farming practice in the site undertaken by tractor. The mean total soil porosity percentage of the study area was 45.9 while the soil moisture content was 13.8 percent. The soil reaction of the experimental site was 4.74. Based on the rating of Tekalign [42], the soil reaction is rated as strongly acidic. FAO [43] reported that the preferable pH ranges for most crops and productive soils are between 4 and 8 range. Mengel and Kirkby [44] also reported optimum pH range of 4.1 to 7.4 for wheat production. Thus, the pH of the experimental soil was within the range for productive soils, however the soil required amendment to increase the availability of nutrients to reduce toxicity of other nutrients. Organic matter content of soil before planting

Table 1: Soil physico- chemical properties before treatment application

Sand	Silt	Clay	BD	TP	SM	pH	OC	TN	av. P	Ex. K	Ex. Ca	Ex. Mg	Ex. acidity	Ex. Al	CEC	S	Fe	Mn	Zn	Cu
11.3	20.8	68.8	1.4	45.9	13.8	4.7	2.1	0.1	6.3	2.3	5.5	3.0	1.1	0.8	15	2.1	90	75.2	0.84	2.6

BD = Bulk Density; TP =Total Porosity; SMC = Soil Moisture Content, pH=Power of Hydrogen, OC = Organic Carbon, TN = Total Nitrogen, av. P = available, Ex.=Exchangeable K, Ca, Mg, acidity, Al, CEC = Cation Exchange Capacity.

Table 2: Vermicompost chemical composition before treatment application

pH	OC	TN	av. P	Ex. K	Ex. Ca	Ex. Mg	Ex. Na	CEC	Fe	Mn	Cu	Zn
7.6	4.78	1.2	16.22	12.34	15.14	8.2	1.32	39.8	5	20.1	3.5	4.2

Power of Hydrogen, OC = Organic Carbon, TN = Total Nitrogen, av. P = available, Ex.=Exchangeable K, Ca, Mg, Na, acidity, Al, CEC = Cation Exchange Capacity.

Table 3: Main Effect of vermicompost and N- fertilizer on bulk density, total porosity and soil moisture content of soil

Vermicompost level	BD(g/cm)	SMC (%)	TP (%)
0	1.35[a]	13.01[d]	45.56[d]
2.5	1.24[b]	16.05[c]	50.97[c]
5	1.16[c]	18.07[b]	53.23[b]
7.5	1.11[d]	20.07[a]	55.16[a]
CD (5%)	0.026	0.34	1.08
CV (5%)	3.4	3.6	3.2
Nitrogen level			
0	1.34	14.68	49.23
23	1.32	15.09	50.09
45	1.30	15.58	51.96
69	1.28	15.85	52.14
CD (5%)	NS	NS	NS
CV (5%)	3	2.31	2.8
Significance level			
VC	**	**	**
N	NS	NS	NS

Means followed by the same letter within the same Colum is not significantly different (P = 0.05) according to Duncan's Multiple Range Test, VC = Vermicompost in ton per hector, CR = Critical Difference; N =Nitrogen in kg per hector; CV = Coefficient of variation, NS = non-significant, ** =highly significant

was 2.1 which can be classified in low range. The pH of vermicompost was 7.6 as indicated in Table 3. Based on the rating of Tekalign [45] and it was moderately alkaline. Soil organic carbon and total nitrogen content was 1.20 and 0.12 percent. This classified was in low range as suggested by Tekalign [46]. Soils that are tilled frequently like this site are usually low in organic matter content because tilling decreases residue particle size and increases the amount of air in the soil by increasing the rate of organic matter decomposition, thus decrease soil organic carbon content which adversely affect soil fertility unless organic source added timely.

Similarly; Available phosphorus in soil was 6.3. It was found in the medium range as suggested by Cottenie [47]. The soil has CEC of (15 meq/100g) which was classified in moderate range as rated by Landon [48]. According to FAO [49] rating, soil exchangeable potassium was high whereas exchangeable calcium and magnesium were classified under medium range while exchangeable sodium was in a very low range. Soil available copper and zinc were in a medium class while iron and manganese classified under high and very high range as suggested by Jone [50].

Effect of Vermicompost and Nitrogen Fertilizer on Soil Physical Properties

Bulk Density, Soil Moisture Content and Total Porosity: The analysis of variance indicated that the main effect of vermicompost had significantly affected soil bulk density, total porosity and soil moisture content ($P < 0.05$) Table 4. However, the main effect of nitrogen as well as the interaction effect of vermicompost and nitrogen fertilizer had not significantly ($P < 0.05$) influenced these parameters after harvesting.

Bulk density is an indicator of the amount of pore space available within individual soil layers or horizons, as it is inversely proportional to pore space. It is an important physical property which could affect the root developments of plants. The results of main effect of vermicompost indicated that application of different levels

Table 4: Interaction effect of vermicompost and N-fertilizer on soil reaction

	Soil pH			
VC	N-level			
	0	23	46	69
0	4.75[e]	4.67[e]	4.66[e]	4.65[e]
2.5	4.79[e]	4.78[e]	4.78[e]	4.79[e]
5	4.98[d]	5.02[d]	5.12[cd]	5.09[cd]
7.5	5.12[cd]	5.20[bd]	5.28[ab]	5.38[a]
CD (5%)			0.14	
CV (5%)			2.3	

Means followed by the same letter is not significantly different (P = 0.05) according to Duncan's Multiple Range Test, VC = Vermicompost in ton per hector, CD = Difference; N =Nitrogen in kg per hector; CV = Coefficient of variation

of vermicompost significantly ($P < 0.05$) influenced soil bulk density. Decreased in the rate of soil bulk density due to increment in application rate of vermicompost was higher. Accordingly, significant reduction in soil bulk density (1.35 to 1.11 g/cm^3) was observed in the treatment that received vermicompost at the rate of 7.5 t. ha^{-1} than control plot. The main reason for the reduction in the bulk density of the soil was due to the action of vermicompost addition caused a significant reduction of bulk density resulted from porous nature of vermicompost.

Different investigators suggested reduction in bulk density due to application of organic materials. According to Meena *et al*. [51] significant improvement in soil bulk density and other properties of soil by applying organic source with and without chemical fertilizer. Similarly, Ibrahim *et al.* [52] found that application of vermicompost after harvesting of crop significantly decreased soil bulk density and other physical properties. Maximum soil moisture content (18.07 percent) was obtained from plot that received higher rates of vermicompost (7.5 t. ha^{-1}) while the minimum value (12.01 percent) was observed from control plot. Improvement in soil water content might be attributed to enhancement in soil infiltration and retention by application of vermicompost. Soil moisture content and other physical properties were highly and positively affected due to application of vermicompost in separate [53]. Similar results have been reported by Lazcano and Dominguez [54] also indicated that soil moisture content significantly increased when vermicompost applied alone than together with chemical fertilizer.

Total porosity of soil after harvesting of wheat was observed increased as bulk density decreased. The data indicated that the porosity of soil increased from 45.56 to 55.16 percent while bulk density decreased from 1.35 to 1.11 gcm^{-3} in response to application of maximum vermicompost rate. Accordingly, maximum improvement in total porosity of the soil (55. 16 percent) was observed in plot that treated with vermicompost (7.5 t. ha^{-1}) followed by 5 t. ha^{-1} vermicompost rate compared to control. This was mainly due to high organic material content of vermicompost which creates aggregates of soil particles and increases the amount of rounded pore. It creates opportunity to allows water to move more rapidly around soil particles in clay soil. The present finding supported the results suggested by Singh *et al*. [55], Rao *et al*. [56] and Husen [57] who asserted overall porosity of soil increased with application of vermicompost. Azarmi *et al*. [58] also found that addition of vermicompost at higher rate significantly improved porosity of soil when compared with control plots.

Effect of Vermicompost and N-Fertilizer on Soil Chemical Properties After harvest Soil Reaction (pH): The analysis of variance indicated that the interaction effect of vermicompost and nitrogen level as well as the main effect of vermicompost levels on soil reaction were significant ($P < 0.05$ (Table 4). However, the main effect of nitrogen on soil reaction was not significant. After harvest of the crop, the pH value of the vermicompost treated acid soil have been raised towards the neutral as the level of the application increased compared to nitrogen fertilizer and control plot. Addition of the levels of vermicompost and nitrogen fertilizers interacted to increased soil pH of the study area. Maximum improvement in soil pH (5.38) was observed in plot that received vermicompost (7.5 t. ha^{-1}) along with nitrogen fertilizer (69 kg ha^{-1}) followed by application of vermicompost (7.5 t. ha^{-1}) with nitrogen fertilizer (46 kg ha^{-1}) respectively by about 11.71 and 10.04 percent compared to untreated plot. The lowest pH value was obtained from control plot.

The lowest value of pH observed in control plot may be due to depletion of basic cations in through runoff while the increment in the interaction mean has led the soil to neutralize due to the presence of vermicompost through, absorbing or binding acid forming ions in its humic substance, possibly due to formation of stable chelates with aluminum. This study in line with Gopinath *et al.* [59] and Girma [60] findings who observed improvement in soil pH after vermicompost amendment in combination with inorganic fertilizers. Combined application of organic and inorganic fertilizers results in significant difference in soil pH [61, 62]. Generally, the pH values observed in the plot with maximum level of treatment combination was within the ranges of moderately acidic soil reaction.

Table 5: Interaction Effect of vermicompost and N-fertilizer on total nitrogen of soil

	Total Nitrogen (%)			
VC	N-level			
	0	23	46	69
0	0.115^{h}	0.118^{h}	0.127^{g}	0.127^{g}
2.5	0.130^{g}	0.130^{g}	0.130^{g}	0.130^{g}
5	0.132^{g}	0.140^{f}	0.145f	0.157^{e}
7.5	0.197^{d}	0.212^{c}	0.227^{b}	0.240^{a}
CD (5%)			0.01	
CV (5%)			3.1	

Means followed by the same letter is not significantly different (P = 0.05) according to Duncan's Multiple Range Test, VC = Vermicompost in ton per hector, CD = Difference; N =Nitrogen in kg per hector; CV = Coefficient of variation

Soil Total Nitrogen (TN): The analysis of variance indicated that the main effect of vermicompost and nitrogen fertilizers as well as the interaction effect of vermicompost and nitrogen fertilizer on soil total nitrogen was highly significant ($P < 0.05$). The two-way interaction effect of vermicompost and nitrogen fertilizer significantly ($P < 0.05$) influenced total nitrogen in the soil (Table 5). Total nitrogen measures the total amount of nitrogen present in the soil, much of which is held in organic matter and is not immediately available to plants. It may be mineralized to be in available forms (NH_4^+ and NO_3^-). In this finding, application of vermicompost at the rate of (7.5 t. ha^{-1}) with nitrogen fertilizer at the rate of (69 kg ha^{-1}) followed by vermicompost (5 t. ha^{-1}) with nitrogen fertilizer (46 kgha^{-}1) respectively observed increased total soil nitrogen content by about 52.10 and 49.34 percent over the control plot.

According to ratings suggested by Berhanu [63], the soil total nitrogen was low with the control treatment and increase with the increase in vermicompost and nitrogen levels combination so the ratings change in to high range. Similarly, Kumar *et al.* [64] observed improvement in total nitrogen percentage by increasing the levels of vermicompost and nitrogen fertilizer application. Incorporated of vermicompost with other sources of inorganic nutrient source had a greater beneficial effect on soil total nitrogen and soil health as compared to chemical fertilizer and control plot [65].

Organic Matter, Cation Exchange Capacity, Available Soil Phosphorus and Sulfur: As shown in table 6, the main effect of vermicompost significantly ($P < 0.05$) affected soil organic matter, cation exchange capacity, available phosphorous and available sulfur. However, the main effect of nitrogen as well as the interaction effect of vermicompost and nitrogen fertilizer had not significantly ($P<0.05$) influenced organic matter, cation exchange capacity, available phosphorous and available sulfur of soil after harvesting. Increasing the rate of vermicompost significantly increased soil organic matter content Table 6. Maximum improvement in soil organic matter status was obtained from plot that received the highest rate of vermicompost (7.5 t. ha^{-1}) while the minimum value observed in control plot. The minimum value observed in untreated plot might be due to insufficient inputs of organic substrate and residue removal in harvested crop while improvement soil organic matter with increasing the levels of was due to addition of high organic matter source of vermicompost which considerably change soil organic matter status. Such significant enhancement in soil organic matter clearly shows improvement in fertility of the soil when amended with high organic source substances.

The present finding in agreement with Narasimha [66] and Kp *et al*. [67] who suggested that application of organic source could resulted in improvement in soil organic matter. Similarly, Ahmed *et al*. [68] and Mohammad *et al*.[69] observed significant improvement in SOC in plots treated with different sources of organic with chemical fertilizers than to control plot. For soil to be productive, it needs to have organic carbon content in the range of 1.8-3.0% to achieve a good soil structural condition and structural stability [70] which can be obtained by the presence of adequate organic matter in soil.

Application of vermicompost at the rate of 7.5 t. ha^{-1} increased CEC of soil by about 26.02 and 25.04 percent over the control plot. The lowest CEC values observed in the control plots could be attributed to the leaching of bases cations from the soil due to the high rainfall in the study area, which was not replenished since no fertilizer had provided to the plot. A high soil CEC allows the soil to retain a large amount of nutrients and at the same time, keep them available for the plants. Thus, vermicompost incorporation highly improved soil fertility by increasing soil organic matter and cation exchange capacity [71] and nutrient retention ability of soils which attributed to improvement in buffering capacity of a soil which increased with increases in soil organic matter and CEC content [72].

CEC increased soil fertility through greater nutrient availability, as nutrients are retained in the soil against leaching. Yadav [73] observed improvement in CEC and soil nutrient retention by increasing rates of vermicompost application. Similarly, Raizada [74] revealed that amendment of soil with organic manure significantly increased cation exchange capacity of soil after harvest [75].

Table 6: Main effect of vermicompost on OM, CEC, available P and S after harvest

VC- level	OM	CEC	av. P	av. S
0	2.13[d]	15.64[d]	6.26[d]	2.17[d]
2.5	2.77[c]	17.91[c]	7.12[c]	2.37[c]
5	3.36[b]	19.79[b]	9.08[b]	2.66[b]
7.5	4.05[a]	21.14[a]	10.23[a]	2.82[a]
$CD_{(5\%)}$	0.23	0.39	0.03	0.13
$CV_{(5\%)}$	7.7	3.4	5.8	3.6
N- level				
0	2.19	15.7	6.32	2.29
23	2.28	16.21	6.38	2.29
45	2.4	16.75	6.49	2.35
69	2.5	17.12	6.76	2.4
$CD_{(5\%)}$	NS	NS	NS	NS
$CV_{(5\%)}$	6.1	2.9	4.2	3
Significance				
VC	**	**	**	**
N	NS	NS	NS	NS

means followed by the same letter within the same Colum is not significantly different ($P < 0.05$) according to Duncan's Multiple Range Test, VC = Vermicompost in tone per hector, N= nitrogen OM= Organic Matter, CEC = Cation Exchange capacity, av. P=available phosphorus, av. S=available Sulfur, CV = Coefficient of variation, CD=Critical Differences, NS=on Significant, ** = significant at 0.05

Considerable soil available P improvement was observed under the maximum application of vermicompost (7.5 t. ha^{-1}). This improvement might be because vermicompost have the greatest ability to reduce the inorganic P sorption capacity of the soil beside converting non-labile P to labile P under acidic nature of soil. In acid soils, where P fixation is a major challenge, application of organic manure releases a range of organic acids that can form stable complexes with Al and Fe metals. This organo-metallic complex could block the P retention sites and as a result, the availability and use efficiency of P had been improved [76]. Addition of organic matter contributes to the desorption of phosphate and thus improved the available of P content in soil. Sudhakar *et al*. [77] and Arthur [78] also reported that increases in application of vermicompost level substantially increases the availability and efficiency of phosphorus in soil. Increment in the level of vermicompost application increased the status of sulfur. Accordingly, maximum improvement was observed when vermicompost applied at the rate of 7.5 t. ha^{-1}. The increased in the sulfur concentration in the soil were resulted from contribution of vermicompost which can supply and improve availability of the nutrient in the soil.

Exchangeable Cations (K, Ca, Mg, Na, Al and Acidity): The analysis of the present study indicated that the main effect of vermicompost and nitrogen fertilizer levels significantly ($P < 0.05$) affected soil exchangeable potassium, calcium and magnesium (Table 7). However, the main effect of nitrogen as well as the interaction effect of vermicompost and nitrogen were did not significantly influenced exchangeable potassium, calcium and magnesium. Similarly, exchangeable sodium was not significantly affected by the main effect of vermicompost and nitrogen fertilizer.

Improvement in soil exchangeable bases (K, Ca, Mg and Na) was observed due to application of vermicompost alone. Increment in application of vermicompost level had observed enhanced exchangeable (K, Ca, Mg and Na) after harvesting. In the present finding, vermicompost application at the rate of (7.5 t. ha^{-1}) observed increased soil exchangeable K by about 14.59 percent over the control plot. Similarly, enhancement in the status of soil exchangeable Ca, Mg and Na was obtained as a result of vermicompost level addition. Application of organic source to a low-fertility and acidic soil can improve concentrations of basic cations in soil solution. The present finding was in agreement with Kumar *et al.* [79] who found enhancement in exchangeable bases like K, Ca, Mg and Na status in soil with increment in vermicompost levels. Similarly, Azarmi *et al*. [80] also observed improvement in these exchangeable bases due to increment in the levels of vermicompost at the rates.

The main effect of vermicompost and nitrogen levels significantly ($P <0.05$) affected exchangeable Al and exchangeable acidity. Incorporation of vermicompost in soil contributed to enhancement of soil fertility and acidity. The present finding exhibited that Exchangeable aluminum was decreased by about 11.79, 14.62 and 26.08 percent while exchangeable acidity decreased by about 16.63, 17.71 and 24.73 percent respectively by application of 2.5, 5 and 7.5 t. ha^{-1} of vermicompost over control plot. However, the use of nitrogen fertilizer significantly ($P < 0.05$) increased soil exchangeable acidity. This might be due to the contributions of hydrogen ion by N fertilizers (urea) to the soil acidity.

Increasing in soil pH following application of vermicompost had attributed to the release of organic acids, which in turn resulted in decreasing in exchangeable Al and exchangeable acidity in the soil through chelation. This decreased might be ascribed to the increased in replacement of Al by Ca in the exchange site and by the subsequent precipitation of Al to Al $(OH)_3$, as the vermicompost had liming effect on soil. The finding was in agreement with Haynes and Molokobate [81] who reported application of organic residues decreased exchangeable acidity and aluminum.

Table 7: Interaction effect of vermicompost and N-fertilizer on K, Ca and Na of soils

VC	Ex. K	Ex. Ca	Ex. Mg	Ex. Na	Ex. Al	Ex. acidity
0	2.40d	5.25d	3.6[d]	0.015	0.602a	1.093a
2.5	2.45[c]	6.05[c]	4.45[c]	0.015	0.531b	0.872[b]
5	2.65[b]	6.74[b]	4.61[b]	0.014	0.514[b]	0.762[b]
7.5	2.81[a]	7.13[a]	4.78[a]	0.014	0.445[c]	0.597[c]
$CD_{(5\%)}$	0.035	0.23	0.14	NS	0.046	0.46
$CV_{(5\%)}$	2.2	5.9	5.2	16.9	8.4	9.2
N						
0	2.56	6.24	4.30	0.016	0.509	0.758a
23	2.58	6.26	4.37	0.015	0.52	0.774b
46	2.58	6.3	4.40	0.015	0.531	0.798c
69	2.59	6.37	4.42	0.016	0.532	0.828c
$CD_{(5\%)}$	NS	NS	NS	NS	NS	0.023
$CV_{(5\%)}$	1.8	2.8	0.123	5.4	5.4	5
Significance						
VC	**	**	**	NS	**	**
N	NS	NS	*	NS	NS	*

Means followed by the same letter within the same column are not significantly different (P < 0.05) according to Duncan's Multiple Range Test, VC = Vermicompost in ton per hector; CD = Critical Difference; CV = Coefficient of variation; Ex = Exchangeable; NS, * and **, = Non significant, significant at 0.05 and 0.01 respectively

Table 8: Main effect of vermicompost and nitrogen fertilizer on soil (Cu, Zn, Fe and Mn) content

VC-level	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)
0	2.60[a]	0.85	89.35[a]	64.64[a]
2.5	2.47[ab]	0.82	86.64[b]	57.89[b]
5	2.40[bc]	0.81	84.64[c]	56.53[b]
7.5	2.27[c]	0.79	82.71[d]	51.29[c]
$CD_{(5\%)}$	0.14	NS	0.9	3.9
$CV_{(5\%)}$	3.1	12.6	2.5	5.8
N-level				
0	2.409	0.83	86.06	58.09
23	2.442	0.82	85.81	57.79
46	2.443	0.81	85.77	57.42
69	2.437	0.81	85.69	57.05
$CD_{(5\%)}$	NS	NS	NS	NS
$CV_{(5\%)}$	2.7	12.3	3.5	4.3
Significant				
VC	**	NS	**	**
N	NS	NS	NS	NS

Means followed by the same letters within a column are not significantly different (P < 0.05) according to Duncan's Multiple Range Test; CD=Critical Difference; VC=Vermicompost; CV = Coefficient of variation, NS and ** Non-significant and significant at 0.01 respectively.

Micronutrients (Cu, Zn, Fe and Mn): The analysis of variance revealed that the main effect of nitrogen as well as interaction effect of vermicompost and nitrogen fertilizer did not significantly influence the status of available Cu, Zn, Fe and Mn in the soil. However, the main effect of vermicompost levels significant affected (P < 0.05) Cur, Fe and Mn while no significant change was observed on zinc status of the soil (Table 8).

Subsequent addition of vermicompost application levels significantly (P < 0.05) decreased copper availability in soil. Soil cupper status was decreased by about 5, 7.69 and 12.69 percent with the application of 2.5, 5 and 7.5 $tonha^{-1}$ of vermicompost relative to control plot respectively. Increases in soil pH due to application of vermicompost under acidic soil resulted in lower Cu mobility, solubility and availability as it formed strong bond with organic matter in the soil. Available Fe was decreased by about 3.03, 5.56 and 7.43 percent with the application of 2.5, 5 and 7.5 $tonha^{-1}$ of vermicompost over control plot respectively. Iron availability in soil largely depends on pH and redox-potential of soil. Increased in the pH of soil had led to decreased dissolution of Fe in the soil thus decreased Fe availability in soil.

Increased in oxidation potential changed the oxidation state of Fe from ferrous (Fe^{3+}) to ferric (Fe^{2+}) forms and, hence, decreased its solubility and availability in the soil. Similarly, soil available Mn was decreased by about 3.03, 5.56 and 7.43 percent respectively with the application of 2.5, 5 and 7.5 t. ha^{-1} of vermicompost over control plot. Because the status and forms by which Mn exist in the soil largely depends on soil pH and the oxidation reduction conditions in soil, which in turn influenced by application of organic source, improvement in soil pH substantially decreased the status of Mn in soil. Similar finding also reported by Ojha *et al*. [82] who indicated that decreased in soil acidity due to application of organic source had contributed to decline in Cu, Fe and Mn availability of acid soil.

CONCLUSIONS AND RECOMMENDATIONS

Integrated use of vermicompost and nitrogen fertilizer positively influenced soil physicochemical properties. Significant improvement in soil physical properties like bulk density, total porosity and soil moisture were observed due to combined application of vermicompost with chemical fertilizer. Similarly, significant improvement in soil pH, TN, OC, SOC, CEC and available P were found up on soil analysis after wheat harvest. Vermicompost Contributed considerable essential nutrients for example, soil macro nutrients (K, Ca, Mg and Na) and micronutrients (Fe, Cu, Mn and Zn). The present soil analysis indicated that soil micronutrient status decreased with increasing soil pH due to vermicompost amendment under acid condition. Based on the result of this finding, generally, it is advised to add small amount of mineral fertilizer to vermicompost to improve soil properties and enhance soil productivity and quality. The levels of vermicompost should be increased to maintain soil sustainability and increase availability of plant nutrient by decreasing levels of nitrogen fertilizer in order to reduce environmental impacts.

Conflict of Interest: The authors declare that they have no conflict of interests on the manuscript

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