International Journal of Applied Agricultural Sciences
2021; 7(6): 298-310
http://www.sciencepublishinggroup.com/j/ijaas
doi: 10.11648/j.ijaas.20210706.17
ISSN: 2469-7877 (Print); ISSN: 2469-7885 (Online)

Effect of Integrated Application of Compost and NPS Fertilizer on Selected Soil Physicochemical Properties and Yield of Barley (*Hordeum vulgare* L.) at Welmera, Ethiopia

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To cite this article:
Worku Ajema, Tesfaye Wakgari. Effect of Integrated Application of Compost and NPS Fertilizer on Selected Soil Physicochemical Properties and Yield of Barley (*Hordeum vulgare* L.) at Welmera, Ethiopia. *International Journal of Applied Agricultural Sciences*. Vol. 7, No. 6, 2021, pp. 298-310. doi: 10.11648/j.ijaas.20210706.17

Received: November 15, 2021; **Accepted**: December 11, 2021; **Published**: December 29, 2021

Abstract: Soil nutrient depletion under losing of soil organic matter content as a result of continuous cultivation and low input are among the major problems that constrain the sustainable productivity of yield of barley at Welmera district. Integrated application of compost and NPS fertilizers can be used to resolve this condition of soil. In this context, a study was conducted in 2019/2020 to determine the effect of combined use of compost and NPS blended fertilizer on soil physicochemical properties and yield of barley at Welmera district. In order to achieve this objective, field experiment was laid out in a randomized complete block design in a factorial arrangement and replicated three times. The results of this study showed that bulk density and total porosity of study area before planting were in acceptable range for barley crop production. The low content of soil organic carbon, total nitrogen, available phosphorus and available sulfur made the fertility status of the soils low. To improve this condition of soil conventional compost and NPS fertilizer were applied to study area soil and combined application of compost at (8 t ha^{-1}) and mineral NPS fertilizer at (150 kg ha^{-1}) gave yield of 5.96 t ha^{-1}. Therefore, based on the result of this study it can be concluded that low soil fertility status, which requires an urgent attention, is one of the major factors hampering the production and productivity of food barley at study area. However, the potential barley productivity of study area soil has not yet been exploited. Therefore, solving the soil fertility problems of the soils of study area through integrated application of compost and NPS fertilizer could be one option to reduce the yield gap seen between smallholder farmers and experimental fields. Hence, the current study recommends that in order to maintain soil fertility and sustain barley crop production combined application of compost at 8 t ha^{-1} and NPS fertilizer at 150 kg ha^{-1} can be the best alternative integrated soil fertility management option in place of the sole application of inorganic fertilizers for barley production at this area tentatively. Nevertheless, further studies at different locations for more than one cropping seasons should be considered to provide more conclusive recommendation for sustainable food barley production.

Keywords: Barley, Compost, Integrated Soil Fertility Management, NPS Fertilizer

1. Introduction

Soil fertility depletion is considered to be one of the major constraints of crop production in the highlands of Ethiopia [1]. The problem is more serious in the highlands of the country where the majority of the human and livestock population is concentrated [2]. The issue is further exacerbated by rapid population growth, which is rising by 2.6% per annum, and a small farm size (0.96 ha/household); these problems have intensified pressure on agricultural lands [3]. Beside this, a recent study showed that the average annual soil loss from agricultural land estimated to be 137 t ha^{-1} yr^{-1} for the Ethiopian highlands which is approximately an annual soil depth loss of 10 mm [4].

Moreover, most of Ethiopian soils, especially in the central highlands, are low in nutrient content due to the complete removal of crop residues from farm lands, low levels of fertilizer application, use of manure and crop residue as a source of fodder and fuel in place of soil fertility maintenance, lack of appropriate soil conservation practices and cropping systems [5]. Thus, most of the areas used for cereal crops production especially for barley, tef and wheat are low in soil fertility [6].

Commercial fertilizer is one of the most critical inputs that can bring about a rapid increase in agricultural production, which is the crucial for the study area. The total fertilizer use has generally increased for long years ago, but the amount and kind of fertilizer use in the country is low and only Urea and DAP are applied as sources of N and P fertilizers to crops by smallholder farmers in the highland of Ethiopia [7] including the study area. A recently acquired soil inventory data revealed that the deficiencies of most of nutrients such as, N, P and S are widespread in Ethiopian soils and similarly in study area [8]. To overcome this problem, Ethiopian Ministry of Agriculture has been recently introduced a new blended fertilizer (NPS) containing N, P, and S with the ratio of 19% N, 38% P_2O_5 and 7% S [9]. However, chemical fertilizers alone are unable to maintain and sustain long-term soil health and crop productivity [10] because they are unable to improve soil physicochemical properties and supply trace elements.

Many research findings have shown that the integrated soil fertility management can provide almost the highest barley yield benefits and improved soil fertility compared to fertilizers applied separately [11]. Similarly, Abedi *et al*. [12] and Getachew *et al*. [13] concluded that combined application of inorganic and organic fertilizers was better approach to increase barley yield than application of either inorganic or organic fertilizers alone. However, no more research conducted on combined application of compost with NPS mineral fertilizer for soil fertility enhancement as well as grain yield of food barley improvement on Nitisols of central highland. Hence, it is important to see the response of barley crop to these fertilizers in the area in order to tackle fertility depletion problem. This necessitated the initiation of this research project with the objective of assessing the effect of combined application of conventional compost and NPS blended fertilizers on selected soil physicochemical properties and yield of food barley at Welmera district.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Geographical Location and Area Coverage

The study was conducted at Holeta Agricultural Research Center (HARC), located at 30 km from Addis Ababa, within the Oromia National Regional State (ONRS) in 2019/2020 cropping season. Holeta Agricultural Research Center is located in the central highlands of Ethiopia, at latitude of 09° 01' 00"N to 9° 03' 30" North and longitude of 38° 30' 00" to 38° 32' 00" East. The total area of Welmera district was 66,247 ha, whereas the Holeta Agricultural Research Center is about 396 ha (HARC).

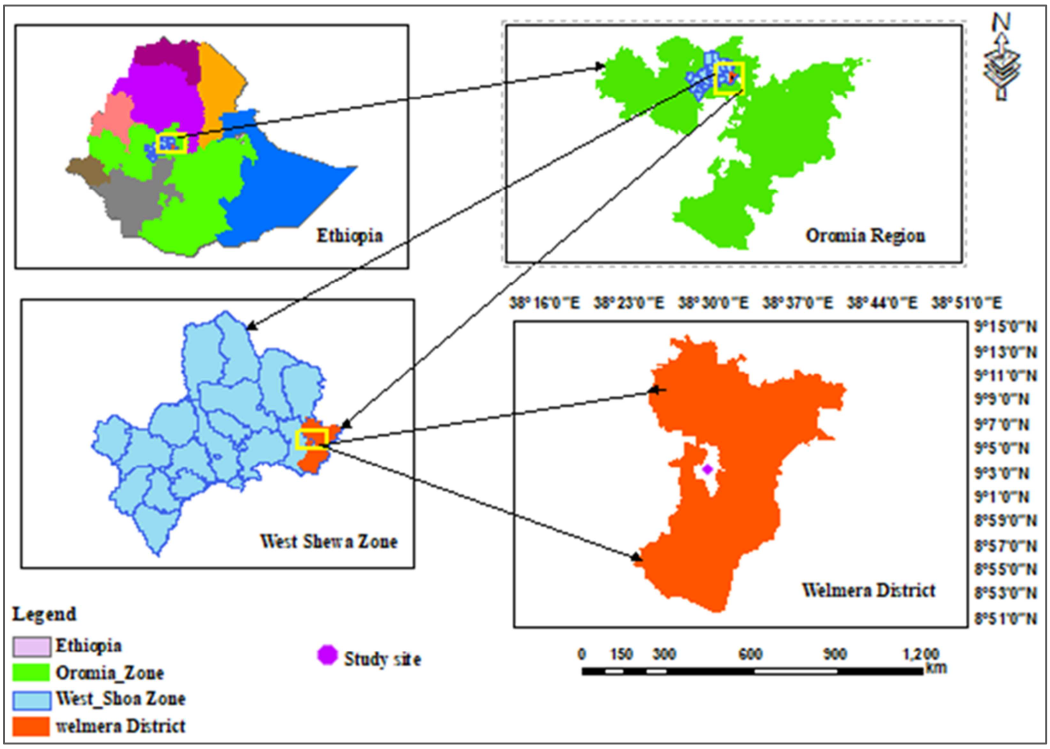

Figure 1. *Location map of the study area in Ethiopia.*

2.1.2. Climate and Topography

The annual rainfall of study area is 1044 mm and has unimodal rainfall pattern in which about 85% rain is received from

June to September. The minimum and maximum temperatures of the district are 6.1 and 22.2°C, respectively [14] (Figure 2). The mean relative humidity and altitude of the area were 62%, 2,400 m.a.s.l, respectively.

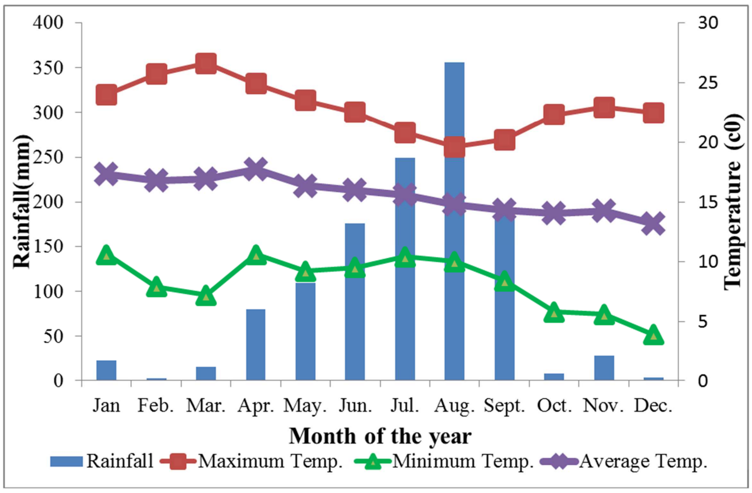

Figure 2. *Metrological data of the study area.*

2.1.3. Soil Types and Parent Materials

Welmera district is dominated by Eutric Nitisols and Vertisols soil types. Nitisols is deep, weel-drained, red soil with diffuse horizons boundaries and a sub-surface horizon with more than 30 percent clay and moderate to strong angular blocky structure and more productive than other red, tropical soils [15]. Vertisols are black to gray clay soils with high swelling and shrinking capacity. It is poorly drained when wet and cracking when dries. Soils of this area are originated from sedimentary rocks [16].

2.1.4. Population, Land Use and Farming System

According to CSA [17] the total population of Welmera district was 101,265 from this total population about 51,037 are males and 50,228 are females. The district covers 66,247 ha total area of landscape. From the total land coverage of the area about 54.5%, 15.26%, 12.2%, 11.02% and 7.02% are agricultural land, grazing land, residential area, forest land and others, respectively. The area is practiced by mixed farming system that combines crop production and animal husbandry. The dominant crops grown around the study area are wheat, barley, faba bean, maize, and tef. The major livestock reared are cattle, sheep, goat and horse. Agricultural production at the area (by farmers) is mainly depending on rainfall and oxen plough farming system [18].

2.2. Experimental Methods

2.2.1. Compost Materials and Compost Preparation Procedures

Compost was prepared in Holeta Agriculture Research Center (HARC). It was made from FYM, crop residues, household waste, ash, and weeds. The organic materials used for composting were collected depending on their availability in the study area. For a quick start of microbial activities, all sides of the walls of the composting pit were painted with semi-liquid mixture of dung, water, and animal urine. About 15 cm height layer of the mixed dry and green materials were put first and a mixture of different animal manure with about 5 cm height was added. Water was then sprinkled to wet the dry matter. Again dung slurry was spread. Lastly some fertile soil was added over the whole layer. This process was repeated four times to fill 1 m x 1.5 m x 1.5 m pit. Lastly, the heap was covered by a mixture of soil and dung and wide leaves were used as cover to protect the compost from sun and wind. The compost was turned ever two weeks and the moisture was again maintained. The compost was matured in a period of three months [19].

2.2.2. Treatments and Experimental Design

The treatments was laid out as randomized complete block design (RCBD) in a factorial arrangement replicated three times. The treatments consisted of four levels of conventional compost (0, 4, 8, 12 t ha^{-1}) and five levels of blended NPS fertilizers (0, 100, 150, 200 and 250 Kg ha^{-1}). The treatments consist of combination of recommended NPS fertilizer derived from local blanket recommendation of DAP (Di-ammonium phosphate) used by farmers, while, recommended conventional compost rate and standard check NP (60 Kg ha^{-1} N and 69 Kg ha^{-1} P_2O_5) were evaluated in this study [20].

2.2.3. Experimental Procedures and Field Management

The experimental field was prepared with tractor using mounted mould board plough and pulverized by disc harrow to break big soil clods into small sizes starting from May first week three times [21]. The field was leveled and divided into blocks and plots. The gross size of each plot was 2m x3m ($6m^2$) with the distance between adjacent plots and blocks were 0.5 m and 1 m apart, respectively. Totally the gross area of experimental site was 52 m x 11 m=572 m^2. Considering its slow nutrient releasing nature, conventional compost was applied to all plots on dry weight basis one month prior to planting of barley and thoroughly mixed in the upper 20 cm soil layer. The food barley variety (HB-1307) released in

2006 where used as a test crop.

The seed was drilled in rows using a manual raw marker in each plot uniformly at rate of 125 Kg ha^{-1}. Mineral NPS fertilizer as a source of 19% N, 38% P_2O_5 and 7% S was applied at time of planting. Urea fertilizer was applied to all plots uniformly (130 Kg ha^{-1}). Was applied in the row in split form; half at planting and the other half at tillering stage. Weeding was done by hand weeding twice at 33 and 55 days after sowing stages. All other agronomic practices have been applied properly as recommended for food barley production. Harvesting was done manually on December 07, 2019 from net plot areas (1.6 m x 2.2 m=3.52 m^2) which consisted of eleven rows and the outer most two rows on both sides of each plots with 20cm on both sides of each rows were considered as border plant, not used for data collection to avoid border effects. After harvesting the crop, threshing and winnowing was done; the yield was recorded and adjusted at 12.5% grain moisture content.

2.2.4. Soil Sampling and Laboratory Analysis

In order to determine soil physicochemical properties a composite and undisturbed soil samples (to a depth of 0-20cm) were collected from each replication of the test field prior to planting. The composite samples were collected in diagonal pattern from five spot of each block using auger and thoroughly mixed to produce composited representative samples before planting. After harvesting, soil samples were also collected from each experimental plot at similar depth. The composite sample was air dried, crushed and passed through 2 mm sieve for the determination of most of the soil fertility indicators except for total nitrogen and organic carbon in which 0.5 mm sieve is used. Following sample preparation, the selected soil physical and chemical properties was analyzed at HARC soil and plant analytical laboratory.

(i). Soil Physical Analysis

Soil particle size distribution was determined using hydrometer method [22]. After determining sand, silt, and clay separates; the soil was assigned to textural classes using the USDA soil textural triangle [23]. Bulk density was determined using the core method as described by Jamison *et al*. [24]. The average soil particle density (2.65 g cm^{-3}) was used for estimating total soil porosity using the method described by Rowell [25]. Soil water content was determined using gravimetric method following the procedures described by Reynolds [26].

(ii). Soil Chemical Properties

Soil pH was measured from soil suspension of 1:2.5 (weight/volume) soils to water ratio using a glass electrode attached to digital pH meter [27]. To determine organic carbon, wet digestion method following the procedure of Walkley and Black [28] was employed. Total nitrogen was determined using modified Kjeldahl method as described by Bremner and Mulvancy [29]. Available phosphorus was extracted by using the Bray II method [30]. The available P was determined by spectrophotometer following the procedures described by Murphy and Riley [31]. Available sulfur was determined using turbid metric method [32]. Cation exchange capacity (CEC) of the soil was determined by the method described by Black [33]. Exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH_4OAc) at pH 7.0. Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while Na and K were analyzed by flame photometer [34, 35]. Exchangeable acidity were determined from a neutral 1 N KCl extracted solution through titration with a standard NaOH solution based on the procedure described by Van Reeuwijk, [36]. Available Fe, Cu, Zn, and Mn were extracted by using DTPA method and the contents of each in the extract were determined by atomic absorption spectrophotometer [37].

2.2.5. Compost Laboratory Analysis

The compost sample was analyzed for pH, total N, available P, available S, Exchangeable bases (Ca, Mg, K and Na) and soil OC following the standard procedures. Soil pH was measured from suspension of 1:2.5 (weight/volume) soils to water ratio using a glass electrode attached to digital pH meter [38] (Ndegwa and Thompson, 2001). To determine organic carbon, wet digestion method following the procedure of Chapman and Pratt [39] was employed. Total Nitrogen content of compost was analyzed using modified Kjeldahl digestion, distillation and titration method as described by Nelson and Sommers [40]. Available phosphorus (P), available (S) and Exchangeable potassium (K) were determined by dry ashing method [41]. Exchangeable Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while Na was analyzed by flame photometer [42, 43].

2.3. Agronomic Data Collection

The grain yield (t ha^{-1}) was determined by harvesting and threshing the grain yield from net plot area and the grain yield of each treatment was adjusted to the standard moisture level by computing the conversion factor for each treatment to get the adjusted yield using the following formula described by Biru [44].

2.4. Data Analysis and Interpretation

All soil and agronomic data collected was subjected to the analysis of variance (ANOVA) by using statistical analysis software (SAS) version 9.0 (SAS, 2004). The mean values were compared and separated using Duncan's Multiple Range Test (DMRT) at 0.05 level of significant [45]. Correlation analysis was carried out using simple linear correlation coefficients between soil and grain yield of barley.

3. Results and Discussion

3.1. Selected Soil Physicochemical Properties of Experimental Site Before Planting

The laboratory results of the selected physicochemical properties of the soils sampled before sowing are presented in (Table 1). The results indicated that the soil has 68.75% clay, 22.5% silt and 8.75% sand, respectively, and might be classified as clay soil on the basis of USDA [46] textural soil classification system. The textural class of the soil indicates the degree of weathering as well as nutrient and water retaining capacity of the soil. According to Solomon [47] barley is best adapted to loams, silt, clay loams and clay soils. This indicates that the soil texture of study area is suitable for barley production.

The results of this study further showed that soil bulk density, total porosity and water content of the study site were 1.28g cm^{-3}, 51.7% and 16.30%, respectively (Table 1). According to Brady and Weil [48] critical value of bulk density for plant growth is 1.4 g cm^{-3}. In terms of this value experimentally determined bulk density value was by far below this critical value of bulk density. Moreover, the total porosity value was also in the ideal range for health root growth. This indicates that the porosity and bulk density values of the surface soil were in acceptable range for barley crop production.

The soil pH (4.68) of the experimental site was very strong acid on the basis of pH range proposed by Tekalign [49] which suggests the presence of substantial quantity of exchangeable H and Al ions in soil solution (Table 1). Barley can grow better under a wide range of soil pH varying from soil pH 5.5 to 8 [50] and any pH value out of this range will affect its growth. Thus, from the above result, the soil pH is out of suitable range for barley production. Under such condition of soil pH there is possibility of deficiency of most essential nutrients.

The organic carbon content (1.12%) and total nitrogen (0.11%) of the study site were categorized in low range as per rating by Berhanu [51]. Similarly, the available Phosphorus (4.90 ppm) and available sulfur (2.82 ppm) were categorized in very low range as per rating suggested by Ethiosis [52]. The low content of soil organic carbon, total nitrogen, available phosphorus and available sulfur in the study area indicates low fertility status of the soil. This could be due to continuous cultivation and lack of incorporation of enough organic materials to these soils. In line with this, Tesfaye and Sahlemedhin [53] also reported that organic matter content and nutrient supplying power of most cultivated soils in Ethiopia are low.

Exchangeable Ca, Mg, K, and Na were, respectively, 2.82 and 0.98, 1.98 and 0.01 (meq/100g) (Table 1). According to FAO [54] rating of these nutrient values exchangeable Ca and Mg were rated as low, exchangeable Na was rated as very low and exchangeable K was categorized as very high. Further, the result of this study showed that CEC of the experimental soil was 15.88 meq/100g (Table 1) and categorized in medium range as per rating suggested by Hazelton and Murphy [55]. The available micronutrients (Cu, Zn, Fe and Mn) before planting were 2.90, 12.04, 74.30 and 54.35, respectively (Table 1). According to Jones [56] rating classes available Zn, Fe and Mn were categorized in high class, while available Cu (2.90) was in medium categories.

Table 1. *Selected soil physicochemical properties of surface soils collected before planting.*

Physical properties									
Parameters	Clay (%)	Silt (%)	Sand (%)	Textural class	BD (gcm^{-3})	TP (%)	SMC (%)		
Mean values	68.75	22.5	8.75	Clay	1.28	51.7	16.30		
Chemical properties									
Parameters	pH (1:2.5H_2O)	OM (%)	TN (%)	Av. P (ppm)	Av. S (ppm)	Ex. K (meq/100g)	Ex.Ca (meq/100g)		Ex. Mg (meq/100g)
Mean values	4.68	2.01	0.11	4.90	2.82	1.98	2.82	0.98	
Parameters	Ex. Na (meq/100g)	CEC (meq/100g)		EA (Meq/100g)	Cu (ppm)		Zn (pmm)	Fe (pmm)	Mn (ppm)
Mean values	0.01	15.88		1.12	2.90		12.04	74.30	54.35

BD=Bulk Density; SMC=Soil moisture Content; TP=Total Porosity; OC=Organic Carbon; TN=Total Nitrogen; Av. P=Available Phosphorus; Av.S=Available Sulfur; Ex. K=Exchangeable Potassium Ex. Na=Exchangeable sodiumEx.Ca=Exchangeable Calcium; Ex. Mg=Exchangeable Magnesium; CEC=Cation Exchange Capacity; Ex, Ac=Exchangeable Acidity

Table 2. *Chemical composition of compost used for the experiment.*

Parameters	**PH**	**OC (%)**	**TN (%)**	**C/N**	**P (ppm)**	**S (ppm)**	**Exchangeable bases (cmol/kg)**				**CEC (cmol/kg)**
							Ca	**Mg**	**K**	**Na**	
Mean values	7.66	8.65	0.83	10.4	25.59	5.88	13.46	7.86	5.87	0.23	28.6

OC=Organic carbon; TN=Total nitrogen; C/N=Carbon to nitrogen ratio; CEC=Cat ion exchange capacity (meq/100g)

3.2. Chemical Composition of Compost

The pH value of compost used for this experiment was 7.66 and slightly alkaline in reaction. The organic carbon and total nitrogen contents of the compost was 8.65 and 0.83%, respectively, with resultant narrow C: N ratio of about 10.4. This indicates the compost applied to experimental field is well decomposed. Brady and Weil [57] recommended C: N ratio of compost to be below 20 before application to field. The concentration of phosphorus and sulfur was 25.59 and 5.88 ppm, respectively. The average concentration of basic cations (Ca, Mg, K and Na) was 13.46, 7.86, 5.87 and 0.23 meq/100g, respectively while the CEC was 28.6 meq/100 g (Table 2).

Table 3. *Main effect of compost and NPS blended on soil physical parameters.*

	Bulk density (g cm^{-3})	Total porosity (%)	Soil moisture content (%)
Compost (t ha^{-1})			
0	1.27^{a}	52.07^{d}	16.31^{d}
4	1.22^{b}	53.96^{c}	17.46^{c}
8	1.17^{b}	55.84^{b}	18.89^{b}
12	1.13^{c}	57.35^{a}	20.35^{a}
$CR_{0.05}$	0.04	1.50	1.05
$CV_{(\%)}$	3.1	10.48	2.79
NPS (Kg ha^{-1})			
0	1.28	51.69	16.28
100	1.28	51.69	16.32
150	1.28	51.69	16.34
200	1.27	52.07	16.35
250	1.27	52.07	16.37
RNP	1.28	51.69	16.35
$CR_{0.05}$	NS	NS	NS

Means followed by the same letter with in the same column of the respective treatment are not significantly different 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV=Coefficient of variation; CR=Critical Range

3.3. Effects of Compost and NPS Fertilizers on Selected Soil Physicochemical Properties After Harvesting

3.3.1. Effects of Compost and NPS Fertilizers on Selected Soil Physical Properties

(i). Bulk density (g cm^{-3})

Soil bulk density is the mass of a unit volume of soil and it is an important parameter in soil fertility studies. The analysis of variance showed that main effect of conventional compost was significantly ($p<0.05$) affected soil bulk density of the soil. However, main effect of NPS fertilizer and their interaction was not-significant ($p\geq0.05$) (Table 3). The lowest (1.13 g cm^{-3}) bulk density was recorded from 12 t ha^{-1} compost whereas the highest (1.27 g cm^{-3}) bulk density was recorded from the control plot (Table 3). The relatively decrease in bulk density after harvesting might be due to the bulk density decreasing effect of organic matter from compost which can be ensured by negative correlation (r=-0.70**) between bulk density and organic matter (Table 9). Reduced bulk density of soils with the increased compost doses has been recognized. Similarly, Tesfaye *et al*. [58] reported the bulk density decreasing effect of organic matter from compost source.

(ii). Total Porosity (%)

Total porosity was significantly ($P<0.05$) affected by compost, whereas, the main effect of NPS fertilizer and the interaction effect were not significantly ($P\geq0.05$) affected total porosity (Table 3). The highest total porosity (57.35%) was obtained from the plots treated by 12 t ha^{-1} compost and the lowest total porosity (52.07%) was recorded from the control treatment. The highest values of total porosity obtained for 12 t ha^{-1} compost could be explained in terms of the higher amount of organic matter contents and lower bulk density values of this treatment. This finding was supported by Tamado and Mitiku [59] who revealed that OM contributes for improving of soil structure and total porosity.

(iii). Soil Moisture Content (%)

Only main effect of compost was significantly ($P<0.05$) affected the moisture content of the soil (Table 3). The highest soil moisture content (20.35%) was obtained from the application of 12 t compost ha^{-1}. On the other hand, the lowest soil moisture content, 16.31%, was obtained from the control treatment (Table 3). The highest soil moisture content for plot treated by highest compost dose might be due to the presence of enrichment of soil with organic matter which has high surface area for better retention of moisture in the soil. In agreement with this, Aggelides and Londra [60] reported increase in water retention with increasing of compost rates.

Table 4. *Effect of compost on soil reaction (pH) and organic matter.*

Compost (t ha^{-1})	pH	OM (%)
0	4.71^{c}	2.06^{c}
4	5.06^{b}	2.32^{b}
8	5.42^{ab}	2.62^{b}
12	5.48^{a}	2.82^{a}
$CR_{0.05}$	0.07	0.08
$CV_{(\%)}$	1.54	3.67
NPS (Kg ha^{-1})		
0	5.12	2.21
100	5.15	2.24
150	5.17	2.36
200	5.18	2.37
250	5.21	2.4
RNP	5.17	2.36
$CR_{0.05}$	NS	NS

Means followed by the same letter with in the same column of the respective treatment are not significantly different 5% probability level (DMRT); OM=Organic matter; RNP=Recommended Nitrogen and Phosphorus; CV=Coefficient of variation; C=Critical Range

3.3.2. Effect of Compost and NPS Fertilizer on Selected Soil Chemical Properties

(i). Soil Reaction (pH)

Results of soil analysis after harvesting of barley revealed that the main effect of compost was significantly ($p<0.05$) affected soil pH. However, the main effect of blended NPS fertilizer and their interaction were not significantly ($p \geq 0.05$) affected soil pH (Table 4). The highest pH (5.48) was recorded in plots treated with 12 t. ha^{-1} and the lowest soil pH (4.71) value was measured in control plot treatments which was statistically par with 8 t ha^{-1} compost. The result revealed improvement in soil pH by 8.1%. The increase of soil pH of plots treated by compost when compared to the analytical results of control plots might be due to high pH value of the compost. This could be evident from the positive correlation (r=0.83**) discovered between pH and organic matter (Table 9). In agreement with this, Zhang *et al.* [61] reported that increase in soil pH was observed due to increase in application rate of compost.

(ii). Soil Organic Matter (%)

The main effect of compost was significantly ($p<0.05$) influenced soil organic matter. However, the sole blended NPS and their interaction were not significantly ($p \geq 0.05$) affected soil Organic matter in the soil (Table 4). The highest percentage of organic matter (2.82%) was recorded in plots treated with 12 t compost while the lowest value of organic matter (2.06%) was recorded from control plot. The organic matter content showed increment of 14.05% over the control. This increase of organic matter over the control might be due to enrichment of compost with organic matter. These results are consistent with that of Bouajila and Sana [62] who reported that the application of mature composts increased soil organic matter due to their higher level of stable carbon.

(iii). Total Nitrogen (%)

Total nitrogen was significantly ($P<0.05$) affected by the main effects of compost and NPS fertilizer. Likewise, the interaction effect of compost and NPS fertilizer were also significantly ($P<0.05$) affected total nitrogen (Table 5). Considering the whole treatment combinations, total nitrogen content ranged from 0.12 to 0.23%, the least value (0.12%) was recorded from control treatment and the highest value (0.23%) was obtained from combined application of 12 t ha^{-1} compost + 250 Kg ha^{-1} NPS fertilizer. The incorporation of high proportion of compost in combination with blended NPS fertilizer appreciably increased the total nitrogen above the control. Such relatively high total nitrogen contents of the plots treated with 12 t ha^{-1} compost and 250 Kg ha^{-1} NPS fertilizer could be related to the release of mineralized nitrogen from compost and N supplied to soil from the blended NPS fertilizer. This can be confirmed by positive correlation (r=0.73**) between total nitrogen and organic matter (Table 9). The result of this finding was in agreement with the findings of Abreha *et al*. [63] who reported that total N content was increased with increasing of doses of both organic and inorganic fertilizers.

Table 5. *Interaction effects of compost and NPS Fertilizer on total nitrogen content.*

Total Nitrogen (%)						
NPS Kg ha^{-1}						
Compost (t ha^{-1})	**0**	**100**	**150**	**200**	**250**	**RNP**
0	0.12^{k}	0.14^{j}	0.15^{h-j}	0.16^{g-h}	0.16^{g-h}	0
4	0.14^{j}	0.15^{h-j}	0.16^{g-h}	0.17^{d-g}	0.17^{d-g}	0
8	0.16^{g-h}	0.17^{d-g}	0.17^{d-g}	0.18^{b-d}	0.20^{b}	0
12	0.18^{b-d}	0.18^{b-d}	0.18^{b-d}	0.20^{b}	0.23^{a}	0
RNP	0.00	0.00	0.00	0.00	0.14^{e-g}	0.15^{h-j}
$CR_{0.05}$			0.018			
$CV_{(\%)}$			8.81			

Means followed by the same letter with in the same column of the respective treatment are not significantly different 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV=Coefficient of variation; CR=Critical Range

(iv). Available Phosphorus

The analysis of variance showed that the interaction effect of compost and NPS fertilizer was significantly ($p<0.05$) affected available phosphorus. Nevertheless, available phosphorus was not significantly ($p \geq 0.05$) affected by both main effect of compost and NPS fertilizer (Table 6). The rate at which the plant absorbs phosphate ions is determined by their concentration in the soil solutions. The available p in soil after harvesting ranges from 4.91 to 11.89 ppm. The maximum available phosphorus (11.89 ppm) was obtained from 12 t ha^{-1} compost + 250 Kg ha^{-1} NPS fertilizer and the lowest (4.91 ppm) was obtained from control treatment. This can be associated to positive correlation (r=0.81**) between available P and OM (Table 9). In all cases, available P concentration in the soil increased with the increase in the rate of amendments. The value of available P determined for 12 t ha^{-1} compost + 250 Kg ha^{-1} NPS fertilizer was above the critical range of P (8 mg kg^{-1}) for Ethiopian soils suggested by Tekalign and Haque [64].

Table 6. *Interaction effects of compost and NPS Fertilizer on available phosphorus.*

NPS (Kg ha^{-1})			**Phosphorus (ppm)**			
Compost (t ha^{-1})	**0**	**100**	**150**	**200**	**250**	**RNP**
0	4.91^{m}	6.34^{lm}	6.70^{k-m}	7.10^{j-m}	7.40^{i-l}	0.00
4	5.18^{lm}	8.41^{h-l}	9.49^{h-k}	9.59^{g-k}	10.10^{cd}	0.00
8	5.90^{k-m}	10.21^{f-i}	10.36^{f-h}	10.67^{e-g}	11.09^{c}	0.00

NPS (Kg ha^{-1})			Phosphorus (ppm)			
Compost (t ha^{-1})	**0**	**100**	**150**	**200**	**250**	**RNP**
12	6.50^{k-m}	11.20^{cd}	11.43^{c}	11.65^{b}	11.89^{a}	0.00
RNP	0.00	0.00	0.00	0.00	0.00	6.90^{j-m}
$CR_{0.05}$			0.25			
$CV_{(\%)}$			5.73			

Means followed by the same letter with in the same column of the respective treatment are not significantly different 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV=Coefficient of variation; CR=Critical Range

The highest available phosphorus obtained from the plots treated with 12 t ha^{-1} compost+250 Kg ha^{-1} NPS fertilizer might be due to relatively highest phosphorus released from compost and supplied from blended NPS fertilizer for this plot soils. This could be evident from the positive correlation (r=0.80**) discovered between phosphorus and organic matter (Table 9). Similar to this result, Tariku *et al*. [65] reported that the availability of available phosphorus was improved as cattle manure and NPS fertilizer were applied.

Table 7. *Interactioneffects of compost and NPS Fertilizer on available sulfur.*

NPS (Kg ha^{-1})			Sulfur (ppm)			
Compost (t ha^{-1})	**0**	**100**	**150**	**200**	**250**	**RNP**
0	2.34^{j}	2.66^{k}	2.77^{ij}	2.80^{ij}	3.38^{ij}	0.00
4	2.65^{ij}	2.73^{h-j}	2.85^{ih}	2.92^{gh}	3.42^{fg}	0.00
8	2.76^{fg}	3.08^{h}	3.66^{e}	4.57^{d}	4.66^{c}	0.00
12	2.91^{b}	3.42^{b}	3.84^{b}	4.67^{ab}	4.98^{a}	0.00
RNP	0.00	0.00	0.00	0.00	0.00	2.79^{j}
$CR_{0.05}$			0.30			
$CV_{(\%)}$			13.35			

Means followed by the same letter with in the same column of the respective treatment are not significantly different 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV=Coefficient of variation; CR=Critical Range

(v). Available Sulfur (ppm)

There was a variation among the treatments formed by using integrated applications of organic and inorganic fertilizers after harvesting barley. The available sulfur of experimental site after harvesting was significantly (P<0.05) affected by interaction effect of compost and NPS fertilizer (Table 7). But, the main effect of compost and NPS fertilizer was not significantly (p≥0.05) affected available sulfur. The highest (4.98 ppm) and the lowest (2.34 ppm) available sulfur were recorded from plots treated by 12 t ha^{-1} compost + 250 Kg ha^{-1} NPS and control, respectively. This result was statistically par with 12 t ha^{-1} compost and 200 Kg ha^{-1} NPSfertilizer.

Available sulfur concentration in the soil increased with the increase in doses of fertilizers. Such increase in available S might be due to the sulfur released from compost and supplied from NPS fertilizers. These findings are supported by Zhihui *et al.* [66] who reported that compost application increased sulfur contents of soils.

(vi) Exchangeable Acidity

The analysis of variance showed that the main effect of compost was significantly (p<0.05) affected exchangeable acidity of soil. But exchangeable acidity was not significantly (p≥0.05) affected by NPS fertilizer and their interaction (Table 8). The highest dose of compost (12 t ha^{-1}) reduced exchangeable acidity from 1.03 to 0.66 meq/100g. Thus, application of compost decreased the exchangeable acidity by 35.9%. The observed reduction in exchangeable acidity that occurred when compost was applied may have resulted from an increment of soil pH; which can be confirmed by negative correlation (r=-66**) between pH and exchangeable acidity (Table 9). In agreement to this, Guong *et al*. [67] suggested reduction of exchangeable acidity due to increase in doses of compost.

Table 8. *Main effect of compost and NPS fertilizer rate on exchangeable acidity, exchangeable cations and CEC.*

	K	Mg	Ca	Na	CEC	EA
	(meq/100g)	**(meq/100g)**	**(meq/100g)**	**(Meq/100g)**	**(meq/100g)**	**(meq/100g)**
Compost (t ha^{-1})						
0	2.01^{d}	1.00^{d}	2.98^{d}	0.011	16.59^{c}	1.03^{a}
4	2.36^{c}	2.24^{c}	4.79^{c}	0.012	18.12^{b}	0.87^{b}
8	2.57^{b}	3.07^{b}	5.42^{b}	0.014	19.07^{b}	0.74^{b}
12	2.79^{a}	3.86^{a}	6.12^{a}	0.017	20.11^{a}	0.66^{c}
$CR_{0.05}$	0.09	0.83	0.70	NS	0.97	0.03
$CV_{(\%)}$	4.85	2.79	2.36	7.97	5.48	3.73
NPS (Kg ha^{-1})						
0	1.98	0.98	3.81	0.013	18.21	1.07
100	1.95	2.45	3.84	0.013	18.23	0.96
150	1.97	2.56	3.87	0.013	18.33	0.96

	K	Mg	Ca	Na	CEC	EA
	(meq/100g)	(meq/100g)	(meq/100g)	(Meq/100g)	(meq/100g)	(meq/100g)
Compost (t ha^{-1})						
200	1.98	2.67	3.91	0.014	18.67	0.96
250	2.00	2.78	3.92	0.014	18.88	0.95
RNP	1.97	2.57	3.89	0.014	18.54	0.96
$CR_{(5\%)}$	NS	NS	NS	NS	NS	NS

Means followed by the same letter with in the same column of the respective treatment are not significantly different at 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; EA=Exchangeable Acidity; CEC=Cation Exchange Capacity; CV=Coefficient of variation; CR=Critical Range

(vii). Exchangeable Bases

The analysis of variance after harvesting of barley showed that only the main effect of compost was significantly ($p<0.05$) affected both monovalent and divalent exchangeable cations (K, Ca, and Mg) of soil. But exchangeable Na was not significantly ($p\geq0.05$) affected by any of the factors and their interaction (Table 8). Exchangeable Ca followed by Mg was the predominant cation in the exchange site. The lowest exchangeable bases K (2.01 meq/100g), Ca (2.98meq/100g), Mg (1.00meq/100g) were recorded from control plots. Whereas, the highest available K (2.79 meq/100g), Ca (6.12meq/100g), and Mg (4.86 meq/100g) were obtained from the plots treated with 12 t ha^{-1} compost. The increase in base cations over the control might be due to releasing of these cations to soils from compost and improvement of their availability through relatively increasing of pH. This finding was in line with the result of Tabitha *et al*. [68] who reported addition of organic manure of different rates increased the exchangeable bases (Ca Mg, K and Na) in soil.

(viii). Cation Exchange Capacity (CEC)

Cation exchange capacity is one of the most important parameters used in assessing soil fertility and capacity to retain nutrients against leaching. The analysis of variance for this study indicated that the main effect of compost was significantly ($p<0.05$) affect soil CEC and the effects of sole blended NPS and their interaction were not significantly ($p\geq0.05$) affected soil CEC (Table 8). The highest CEC (20.11 meq/100g) was obtained from the plot treated by 12 t ha^{-1} compost and the lowest (16.59 meq/100g) CEC value was recorded from the control. The increase in CEC of treated plots over the control plots might be attributed to the increase in soil organic matter content as a result of application of increasing doses of compost. This could be evident from significantly and positive correlation (r=0.77**) of cation exchange capacity with organic matter (Table 9). This result is in concurrence with several previous findings [69] (Belay, 2015) proved that compost amendment resulted in an increase of CEC.

Table 9. *Correlation analysis of selected soil physicochemical properties of the experimental site.*

	BD	SMC	TP	pH	OM	TN	P	S	CEC	K	Ca	Mg	EA
BD	1												
SMC	-0.81**	1											
TP	-0.77**	0.81**	1										
pH	-0.73**	0.75**	0.70**	1									
OC	-0.79**	0.80**	0.80**	0.83**	1								
OM	-0.79**	0.80**	0.80**	0.83**	0.73**								
TN	-0.85**	0.84**	0.75**	0.71**	0.80**	1							
P	-0.83**	0.83**	0.68**	0.76**	0.81**	0.85**	1						
S	-0.83**	0.72**	0.62**	0.80**	0.75**	0.69**	0.84**	1					
CEC	-0.68**	0.72**	0.61**	0.63**	0.77**	0.67**	0.74**	0.64**	1				
K	-0.80**	0.72**	0.70**	0.71**	0.85**	0.66**	0.76**	0.83**	0.73**	1			
Ca	-0.77**	0.70**	0.64**	0.84**	0.71**	0.65**	0.81**	0.84**	0.67**	0.77**	1		
Mg	-0.68**	0.60**	0.56**	0.67**	0.71**	0.59**	0.74**	0.80**	0.58**	0.73**	0.78**	1	
Ex.Ac	-0.66**	-0.55**	-0.49**	-0.72**	-0.67**	-0.5**	-0.718**	-0.75**	-0.55**	-0.68**	-0.83**	-0.59**	1
Cu	0.53**	-0.58**	-0.56**	-0.73**	-0.82**	-0.4**	-0.65**	-0.76**	-0.59**	-0.63**	-0.82**	-0.70**	-0.64**
Zn	0.74**	-0.68**	-0.66**	-0.86**	-0.87**	-0.6**	-0.78**	-0.89**	-0.68**	-0.80**	-0.91**	-0.78**	0.80**
Fe	0.72**	-0.69**	-0.66**	-0.82**	-0.90**	-0.6**	-0.79**	-0.83**	-0.69**	-0.76**	-0.90**	-0.71**	0.78**
Mn	0.73**	-0.67**	-0.70**	-0.79**	-0.93	-0.6	-0.72**	-0.81**	-0.72**	-0.78**	-0.87**	-0.76**	0.70**

BD=Bulk density; SMC=Soil moisture content, TP=Total porosity; OC=Organic carbon; TN=total nitrogen; EA=Exchangeable acidity; CEC=Cation exchange capacity;**=highly significant.

3.4. Effects of Compost and NPS Fertilizer on Yield of Barley

Analysis of variance indicated that grain yield of food barley was significantly ($P<0.05$) affected by the effects of compost and NPS fertilizer as well as by interaction effect of compost and NPS (Table 10). The highest Gain yield of barley 5.96 t ha^{-1} were obtained from the application of 8 t ha^{-1} compost and 150 Kg ha^{-1} NPS fertilizer followed by 5.74 t ha^{-1} and 5.70 t ha^{-1} which was obtained from plots treated by 8 t ha^{-1} with 200 Kg ha^{-1} NPS fertilizer and 8 t ha^{-1} with 250 Kg ha^{-1} NPS fertilizer, respectively. This indicates that the application of 8 t ha^{-1} compost and 150 Kg ha^{-1} NPS fertilizer can be taken as optimum for the maximum productivity of this crop in the study area and more than this rate might cause yield decreases which might be due to lodging effect.

The lowest grain yield (1.66 t h^{-1}) was recorded from control plots (Table 10). Combined application of 8 t ha^{-1} compost with 150 Kg ha^{-1} NPS fertilizer increased grain yield by 32.6% and 72.1% than current blanket fertilizer recommendation and the control plots, respectively.

Table 10. *Interaction effects of compost and NPS fertilizer rate on grain yield.*

NPS (Kg ha^{-1})	Grain Yield (t ha^{-1})					
Compost (t ha^{-1})	**0**	**100**	**150**	**200**	**250**	**RNP**
0	1.66^{j}	3.19^{g}	3.52^{fg}	$4.16^{e\text{-}g}$	4.54^{de}	0.00
4	2.23^{i}	3.92^{fg}	$4.22^{d\text{-}f}$	4.42^{de}	$4.71^{c\text{-}e}$	0.00
8	2.53^{gh}	$5.29^{c\text{-}e}$	5.96^{a}	5.74^{ab}	5.70^{ab}	0.00
12	2.72^{gh}	5.58^{b}	5.43^{bc}	$5.34^{b\text{-}d}$	$5.27^{c\text{-}e}$	0.00
RNP	0.00	0.00	0.00	0.00	0.00	$4.02^{e\text{-}g}$
$CR_{0.05}$			0.04			
$CV_{(\%)}$			6.18			

Means followed by the same letter with in the same column of the respective treatment are not significantly different (P≥0.05) according to Duncan's Multiple Range Test, RNP=Recommended Nitrogen and Phosphorus, CV=Coefficient of variation, CR=Critical Range

In barley grain yield owing to the combined use of compost Increase with NPS fertilizer might be due to synergistic nutrient interaction effects between the two nutrient sources in improving sustained availability of essential nutrients to plants, soil physical conditions, biological process in soil, to facilitate rate of photosynthesis and brought better crop growth led to improvement in soil organic matter and grain yield. This can be confirmed by significantly and positive correlation (r=0.64** 0.75**) of grain yield with soil organic matter.

In line with this result, Bationo *et al*. [70] reported that applications of different proportion of organic with inorganic fertilizer were increased grain yield. Similarly, Abay and Tesfaye [71] also reported that application of inorganic fertilizers with FYM gave a better yield of barley than the application of 100% inorganic fertilizers alone.

4. Conclusions and Recommendation

4.1. Conclusion

The results of this study showed that bulk density and total porosity of study area were in acceptable range for barley crop production. In contrary to this the pH of the experimental soil was out of suitable range for barley production in which there is possibility of deficiency of most essential nutrients. Continuous cultivation without incorporation of enough organic materials to soils made the soil low in the content of soil organic carbon, total nitrogen, available phosphorus and available S which indicates low fertility status of the soils of study area.

To improve this condition of soil conventional compost and NPS fertilizer were applied to study area soils; the result for sole application of compost to plots revealed that soil physicochemical parameters (total porosity, soil moisture content, soil pH, organic matter, and exchangeable acidity, K, Ca, Mg and CEC) were increased with increasing rates of applied compost. Likewise, plant height and spike length were positively influenced by NPS fertilizer applied to the experimental plots. With the same manner synergistic nutrient interaction effect sourced from compost and NPS fertilizer brought positive influence on soil chemical parameters (total nitrogen, available P and available S) and yield parameters (grain per spike, thousand grain yield, biomass yield, straw yield, and grain yield).

The combined use of compost and NPS fertilizer (8 t ha^{-1} compost + 150 Kg ha^{-1} NPS) was increased barley yield by 72.1% over control treatment, which is better improvement than at highest rate of sole application of NPS fertilizer (23.8%), compost (54.4%) and standard check or recommended NP (32.6%). The estimated average yields of barley crop for smallholder farmers at study area is 2.2 t ha^{-1}, which is much lower than the yield recorded under experimental plots of 6 t ha^{-1}. However, the experimental yield was 5.96 t ha^{-1} at combination of 8 t ha^{-1} compost and 150 NPS fertilizer Kg ha^{-1}.

From this finding one can conclude that low soil fertility status, which requires an urgent attention, is one of the major factors hampering the production and productivity of food barley in Welmera district. In resolving this situation, the use of combined application of compost along with NPS fertilizers was justified to improve soil organic matter and nutrient contents that are important in enhancing soil fertility status and in turn to increase barley crop yields. The result of combined application of compost with NPS fertilizer has given highest yield benefit than sole use of NPS fertilizer, control and recommended NP mineral fertilizer currently in used at the study area. Moreover, the potential barley productivity of study area soil has not yet been exploited. Therefore, solving the soil fertility problems of the soils of study area through integrated application of compost and NPS fertilizer could be one option to reduce the yield gap seen between smallholder farmers and experimental fields.

4.2. Recommendation

Based on the findings and conclusions of this study the following recommendations are given:

1) Soil management practices that can enhance soil fertility and increase soil pH are important for this area
2) Combined application of compost at 8 t ha^{-1} and NPS fertilizer at 150 Kg ha^{-1} can be the best alternative integrated soil fertility management option in place of the sole application of inorganic fertilizers for barley production at this area tentatively.
3) Nevertheless, further studies at different locations for more than one cropping seasons should be considered to provide more conclusive recommendation for sustainable food barley production.

Conflict of Interests

The authors declare that they have no competing interests.

Acknowledgements

The authors are grateful to Elfeta District Agricultural Office and Ambo University for facilitating for the implementation of the project.

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