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Effect of Compost and Blended NPS Fertilizers on Yield and Yield Components of Food Barley (*Hordeum Vulgare* L.) at Welmera District, Central Highland of Ethiopia

Worku Ajema[1, *], Tesfaye Wakgari[2, *], Girma Chala[3, *]

[1]Department of Soil Resources and Watershed Management, Oda Bultum University, Chiro, Ethiopia

[2]Department of Natural Resource Management, Ambo University, Ambo, Ethiopia

[3]Ethiopian Institute of Agricultural Research, Holeta Agricultural Research Center, Holeta, Ethiopia

Email address:

workuajema@gmail.com (W. Ajema)

[*]Corresponding author

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Abstract: Soil nutrient depletion under losing of soil organic matter consequently continuous cultivation and low input are among the major issues that oblige the sustainable productivity of the yield of barley at Welmera area. A study was, hence, lead to explore the impact of compost and NPS fertilizer combination on yield and yield components of food barley at Holeta Agricultural Research Center on Nitisols in the central highlands of Ethiopia in 2019/2020 cropping season. To achieve this objective, a field trial was arranged in a randomized complete block design in a factorial arrangement. The treatments consisted of four rates of compost (0, 4, 8, and 12 t/ha), five rates of blended NPS fertilizer (0, 100, 150, 200, and 250 kg/ha) and blanket recommended NP fertilizer (60 kg/ha N + 69 kg/ha P_2O_5) as standard check. Food barley (HB-1304 variety) was used as a test crop. The result revealed that 50% day to heading, 90% day to maturity, plant height, and spike length were positively influenced by NPS fertilizer applied to the experimental plots. On the contrary, synergistic nutrient interaction effect sourced from compost and NPS fertilizer brought positive influence on yield parameters (total number of tillers, effective tillers per plant, and grain per spike, thousand-grain yield, biomass yield, straw yield, grain yield, and harvest index). Moreover, the collective use of compost at (8 t/ha) and mineral NPS fertilizer at (150 kg/ha) has a better-improved yield of the barley crop. Likewise, the outcome of the economic analysis showed that the application of 8 t/ha compost and 150 kg/ha NPS fertilizer gave the highest economic benefit of 70528 Ethiopian birr ha^{-1} with the maximum marginal rate of return of 1504%. Hence, the current study recommends that to maintain soil fertility and sustain barley crop production combined use of 8 t/ha compost and 150 kg/ha NPS fertilizer was the best alternate integrated soil fertility management choice in the position of the sole application of inorganic fertilizers for barley production at this area reluctantly. Nevertheless, further studies at different locations for more than one cropping season ought to be considered to provide a more conclusive recommendation for sustainable food barley production.

Keywords: Barley, Compost, Nitosol, NPS Fertilizer

1. Introduction

Soil fertility depletion is well-thought-out to be one of the key limitations 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 small farm size (0.96 ha per household); these problems have intensified pressure on agricultural lands [3]. Besides this, the average annual soil loss from agricultural land is estimated to be 137 t/ha per year for the Ethiopian highlands, which is approximately an annual soil depth loss of 10 mm [4].

Besides, most Ethiopian soils, particularly in the central highlands, are low in nutrient content owing to the complete removal of crop remains from farmlands, low levels of fertilizer application, use of manure and crop residue as a source of silage and fuel in place of soil fertility conservation, absence of appropriate soil preservation practices and cropping schemes [5]. As a result, most of the areas used for cereal crops production especially for barley, tef, and wheat are low in soil productiveness [6].

Food barley (Hordeum Vulgare. L) is the most important staple food crop and accounts for 90% of all barley produced in Ethiopia [7]. It was covered an area of 951,993.16 ha with an average national yield of 2.2 t ha^{-1} in the country [8]. However, on experimental plots yield can go up to 6 t ha^{-1} [9] indicating a productivity gap of about 4 t/ha. Although there is considerable potential for increased barley production, numerous factors limit yields [10]. The most important abiotic stresses include low soil fertility, poor soil drainage, soil acidity, drought, and poor agronomic practices [11]. Soil fertility is the most limiting factor for barley production in the highlands of Ethiopia [12]. Thus, an external supply of inorganic and organic fertilizer inputs is necessary to increase the crop productivity of major food crops in Ethiopia [13].

Organic fertilizer materials, such as compost and farmyard manure (FYM) were stated that they can improve soil physical properties such as bulk density, porosity, water holding capacity, and chemical properties such as CEC, organic carbon, total nitrogen, available phosphorous, etc. [14]. Compost has been proposed as soil amendments to increase soil organic matter content as well as soil fertility. Compost addition to soil has also been shown to increase the yield of crops similarly to, or beyond the effects of mineral fertilizer application [15]. Hence, it acts as a mixed complete fertilizer [16]. Moreover, in Ethiopia, the normal sum of compost application for crops extended from 5-15 t/ha, depending on the accessibility of materials [17]. However, the application of organic matter is compelled by access to adequate organic inputs, low nutrient content, high labor demand for preparation and transporting [18]. This has led the farmers to use mineral fertilizers as they are easy to use and quick in response.

Commercial fertilizer is one of the most critical inputs that can bring about a rapid increase in agricultural production, which is 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 are low and only Urea and DAP are applied as sources of N and P fertilizers to crops by smallholder agriculturalists in the highland of Ethiopia [19] including the study area. A as of late procured soil stock information uncovered that the insufficiencies of most supplements such as N, P, and S are broad in Ethiopian soils and similarly in the study area [20]. To overcome this problem, the 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 [21]. However, chemical fertilizers alone are unable to maintain and sustain long-term soil health and crop productivity [22] because they are unable to improve soil physicochemical properties and supply trace elements.

Inadequate agronomic studies aligned with combined nutrient use request to investigation integrated nutrient management practices and recommend best practices to maximize the yield potential of crops such as barley [23]. Integrated use of organic and mineral fertilizers for tackling soil fertility depletion and sustainably increasing crop yields had paramount importance [18]. Integrated soil fertility management involving the judicious use of combinations of organic and inorganic resources is a feasible approach to overcome soil fertility constraints and contribute to high crop productivity [24] because they are unable to improve soil physicochemical properties and supply trace elements.

Many investigation have shown that integrated soil fertility management can provide almost the highest barley yield benefits and improved soil fertility compared to fertilizers applied separately [25, 26]. Similarly, [27] concluded that the combined application of inorganic and organic fertilizers was a better approach to increase barley yield than the application of either inorganic or organic fertilizers alone.

However, little has been done on the combined application of compost with NPS mineral fertilizer for soil fertility improvement as well as grain yield of food barley improvement on Nitisols of the central highland of Ethiopia. Hence, this paper tries to determine the combined effect of compost and mineral NPS fertilizer on yield and yield components of food barley at Welmera district, central highlands of Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Holeta Agricultural Research Center which is located at a distance of 29 km from Addis Ababa, within the Oromia National Regional State in 2019/2020 cropping season. It’s located at the latitude of 09° 01' 00"N to 9° 03' 30" North and longitude of 38° 30' 00" to 38° 32' 00" East.

2.2. Climate and Topography

The study area was categorized by a mono-modal rainfall pattern. The ten-year average annual rainfall recorded was 1067 mm (834 to 1300 mm). It was high during the three summer months (June to August), which accounts for 85 percent of the annual rainfall. The average minimum and maximum temperatures of the study area are 6.1°C and 22.2°C, respectively. Welmera district is found at an altitude of 2400 m above sea level and characterized by plateau plains, which are moderately elevated and gentle sloping. The mean relative humidity of the area was 62%.

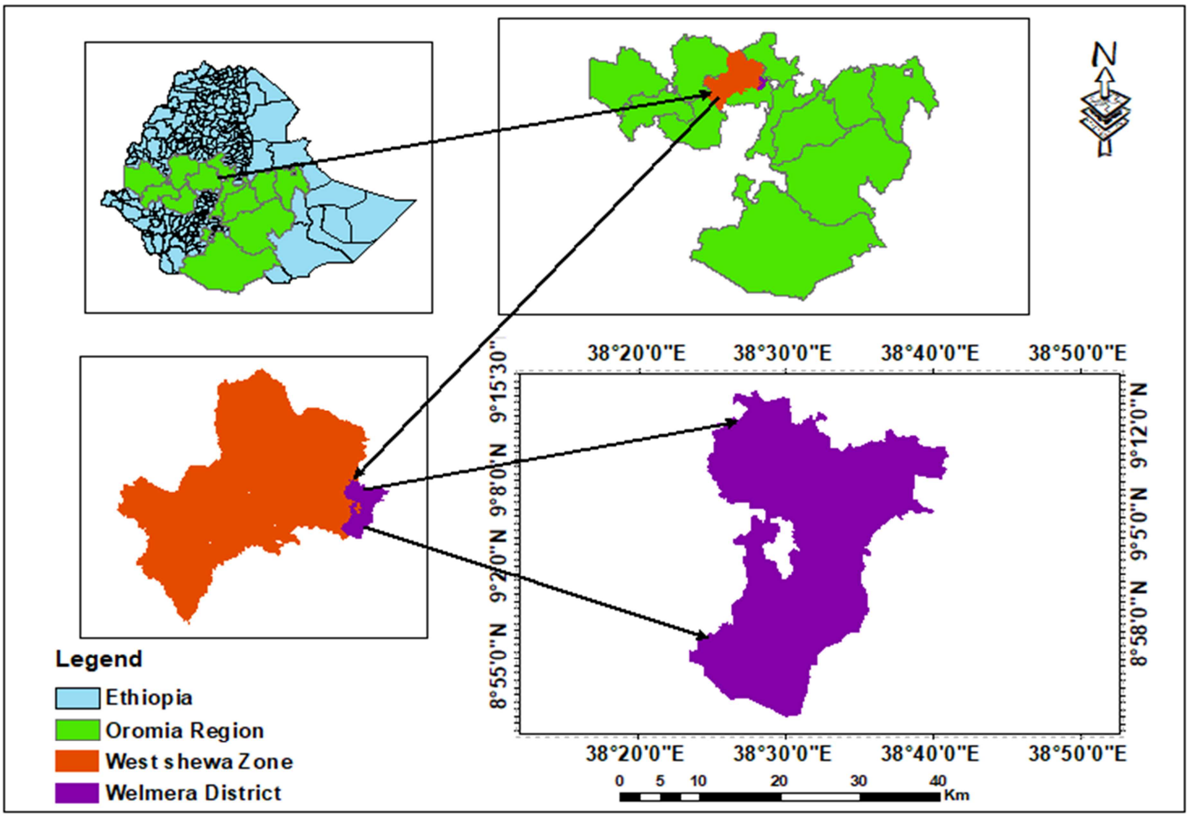

Figure 1. *Location map of the study area in Ethiopia.*

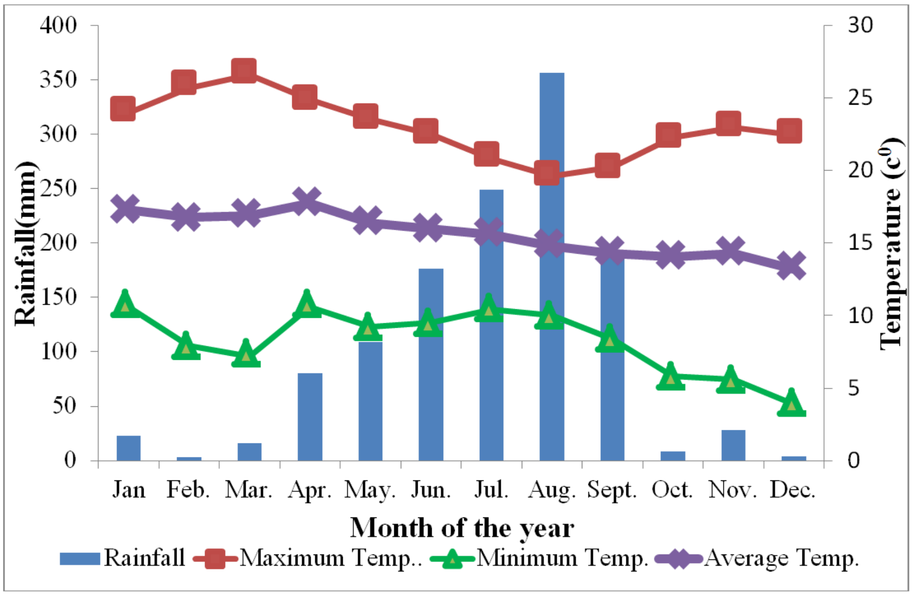

Figure 2. *Metrological data of the study area.*

2.3. Compost Preparation Procedures

Compost was prepared in Holeta Agriculture Research Center. It was made from FYM, crop residues, family squander, fiery debris, and weeds. The natural materials utilized for composting were collected depending on their accessibility within the considered range. For a speedy beginning of microbial exercises, all sides of the dividers of the composting pit were painted with a semi-liquid blend of dung, water, and animal urine. Around 15 cm stature layer of the blended dry and green materials were put, to begin with, and a blend of diverse animal excrement with approximately 5 cm tallness was included. Water was at that point sprinkled to dampen the dry matter. Again dung slurry was spread. In conclusion, a few fertile soils were included over the complete layer. This handle was rehashed four times to fill the 1 m x 1.5 m x 1.5 m pit. Finally, the pit was secured by a blend of soil and dung, and wide leaves were utilized as cover to ensure the compost from sun and wind. The compost was turned every two weeks and the dampness was once more kept up. The compost was matured in three months [28].

2.4. Treatments and Experimental Design

The treatments were 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, and 12 t/ha) and five levels of blended NPS fertilizers (0, 100, 150, 200, and 250 kg/ha). The treatments consist of a combination of recommended NPS fertilizer derived from a local blanket recommendation of DAP (Di-ammonium phosphate) used by farmers, while, recommended compost rate and standard check NP (60 kg/ha N and 69 kg/ha P_2O_5) were evaluated in this study [29, 30].

The experimental field was prepared with a tractor using a mounted moldboard plow and pulverized by disc harrow to break big soil clods into small sizes starting from May first week three times [14]. The field was leveled and divided into blocks and plots. The gross size of each plot was 2 m x 3 m (6 m^2) with the distance between adjacent plots and blocks being 0.5 m and 1 m apart, respectively. The gross area of the 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 a dry weight basis one month before planting of barley and thoroughly mixed in the upper 20 cm soil layer. The food barley variety (HB-1307) released in 2006 was used as a test crop. The seed was drilled in rows using a manual raw marker in each plot uniformly at the rate of 125 kg ha^{-1} [26]. Mineral NPS fertilizer as a source of 19% N, 38% P_2O_5, and 7% S was applied at the time of planting. Urea fertilizer was applied to all plots consistently (130 kg ha^{-1}) as per the recommendation by [18]. It 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 the 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 outermost two rows on both sides of each plot with 20 cm on both sides of each row were considered as a border plant, not used for data collection to avoid border effects. After harvesting the crop, threshing and winnowing were done; the yield was recorded and adjusted at 12.5% grain moisture content.

2.5. Soil Sampling and Laboratory Analysis

Soil samples were collected both before and after planting from the experimental field. Disturbed (using auger) soil samples which were composited thoroughly undisturbed (using core) one was also collected. Before planting, disturbed samples were randomly taken from six different sots across each block from a depth of 0-20 cm to make one composite sample. After harvesting of barley crop (five months later), 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. The composite sample was air-dried, crushed, and passed through a 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. Then, soil samples were analyzed for physicochemical properties following laboratory procedures.

Particle size distribution was determined using the Bouyoucos hydrometer method [31]. After determining sand, silt, and clay separates; the soil was assigned to textural classes using the USDA soil textural triangle [32]. Bulk density was determined using the core method as described by [33]. The average soil particle density (2.65 g cm-3) was used for estimating total soil porosity using the method described by [34]. Soil moisture content was determined using the gravimetric method following the procedures described by [35].

Soil pH was measured from soil suspension of 1:2.5 (weight/volume) soils to water ratio using a glass electrode attached to a digital pH meter [36]. Soil organic matter was determined by the [37] method. Total nitrogen was determined using the modified Kjeldahl method as described by [38]. Available phosphorus was extracted by using the Bray II method [39]. The available P was determined by spectrophotometer following the procedures described by [40]. Available sulfur was determined using the turbid metric method [41]. Cation exchange capacity (CEC) of the soil was determined by the method described by [42]. 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 a flame photometer [43]. Percent base saturation was calculated as the percentage of CEC occupied by base cations Ca, Mg, K, and Na [44]. Exchangeable acidity was determined from a neutral 1 N KCl extracted solution through titration with a standard NaOH solution based on the procedure described by [45]. Available Fe, Cu, Zn, and Mn were extracted by using the DTPA method, and the contents of each in the extract were determined by atomic absorption spectrophotometer [46].

2.6. 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 a digital pH meter [40]. Organic carbon was determined using the [41] method. The total Nitrogen content of compost was analyzed using modified Kjeldahl digestion, distillation, and titration method as described by [47]. Phosphorus (P), Sulfur (S), and potassium (K) were determined by the dry ashing method [48]. Ca and Mg in the extracts was analyzed using atomic absorption spectrophotometer, while Na was analyzed by a flame photometer [47, 38].

2.7. Agronomic Data Collection

Agronomic parameters were measured from the middle rows area per plot include Phenological parameters (days to 50% emergence, 50% heading, and days to 90% maturity), growth parameters (total number of tillers, number of effective tillers, and plant height), and yield and yield components (spike length, number of grains per spike, thousand seed weights, grain yield, straw yield, biomass yield, harvest index).

Days to 50% heading was determined by counting the number of days from sowing to the time when 50% of the plants started to head. Similarly, days to Physiological maturity was determined as the number of days from sowing to the time when the plants reached 90% maturity based on visual observation. It was visualized assessed by senescence of the leaves as well as frees threshing of grain from the glumes when pressed between the forefinger and thumb. Plant height was measured at physiological maturity from the ground level to the top of the spike excluding awns from five randomly selected plants from central rows each plot using a measuring tape. The total number of tillers and the Number of effective tillers was determined by counting the total and productive tillers from five plants in the middle portion of each plot at physiological maturity.

Spike length was determined by measuring the length of the spike from the node where the first spikelet emerges to the tip of the spike excluding the awns. The number of seeds per spike was counted using an electronic seed counter. Thousand-grain weights were measured by taking the mass of counted thousand kernels randomly taken from the total grains harvested from each experimental plot by using a sensitive electronic balance. Further, total above-ground biomass was taken after harvesting from the whole plant parts, including leaves, stems, and seeds from the net plot. Then dried up to the loss of the moisture content for two weeks in the open air and weighed and converted into t/ha. The grain yield (t/ha) was taken by harvesting and threshing the grain yield from the 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 [49].

$$\text{Conversion factor (C.F)} = \frac{100-y}{100-x} \quad (1)$$

Where Y is actual moisture content and X is the standard moisture content to which the yield is to be adjusted (for cereals the standard moisture content is 12.5%).

$$\text{Ad.GY= GY *C. F} \quad (2)$$

Where Ad.GY= adjusted grain yield, GY= actual grain yield of the plot for each, and C. F= Conversion factor.

Finally, yield per plot was converted to a per hectare basis and the yield was reported in t ha^{-1}.

Straw yield (t/ha) was determined by subtracting grain yield from total above-ground biomass. Moreover, harvest index (%) was calculated by the ratio of grain yield per plot to biological yield per plot and it was calculated by using the formula given by [50]:

$$\text{HI (\%)} = \text{GY/BY} \times 100 \quad (3)$$

Where GY = grain yield and AGBY= above-ground dry biomass yield.

2.8. 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 [51]. The mean values were compared and separated using Duncan's Multiple Range Test (DMRT) at 0.05 levels of significant [52]. Correlation analysis was carried out by calculating simple linear correlation coefficients between soil and plant parameters.

2.9. Partial Budget Analysis

To assess the costs and benefits associated with compost and NPS fertilizer treatments the partial budget technique as described by [53] was applied to the yield results. For the economic analysis, the prevailing market price for NPS, TSP, UREA, and Compost during planting time and prevailing market price for outputs (barley grain and straw yield) during harvesting time were considered.

The actual price of seed was used to convert the adjusted yield into gross yield benefits (15 ETB/kg) and adjusted straw yield benefit (0.60 ETB/kg), the cost of the fertilizer NPS, Urea, and TSP were 16, 13, and 35 ETB/kg respectively. The market price of compost was 1.00 ETB/kg. The other cost of inputs and production practices remains insignificant among treatments. Mean barley yield was computed as the average yield (kg/ha) of each treatment minus 10% of the yield (to estimate what can be expected for a farmers' field). Gross field benefit (GFB) per hectare was calculated as the product of grain yield of barley and straw yield time's market price of both mean adjusted grain yield and straw yield of barley. Field price of compost and NPS fertilizer were computed as the marketing price/kg and their transportation to the field. Field cost of compost and NPS fertilizer were computed as the product of the quantity of compost t ha^{-1} and NPS kg/ha fertilizer applied in each treatment and wage rate per day. Then, the total variable cost (TVC) was computed as the sum of all costs incurred. The net benefit (NB) ha^{-1} for each treatment was calculated as GFB minus TVC.

After the TVC and NB were calculated, potentially promising treatments were selected for further marginal rate of return (MRR) analysis by the dominant analysis procedure explained in [53]. The treatments were ranked from the lowest to highest TVC for % MRR analysis between pairs of treatments. The MRR between two treatments (say 1 and 2) was calculated as follows:

$$\text{MRR} = \frac{\text{change in NB(NB2−NB1)}}{\text{change in TVC(TVC2−TVC1)}} * 100 \quad (4)$$

3. Results and Discussion

3.1. Selected Soil Physicochemical Properties of Experimental Site Before Planting

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

Clay	Silt	Sand	BD	TP	SMC	pH	OM	TN	Av.P	Av.S	Ex.K	Ex.Ca	Ex.Mg	EA	CEC	PBS	Fe	Mn	Zn	Cu
68.75	22.5	8.75	1.28	51.7	16.3	4.68	2.01	0.11	4.9	2.82	1.98	2.82	0.98	1.12	15.88	35.9	74.3	54.4	12.04	2.9

BD= Bulk Density (g.cm3); SMC= Soil moisture Content (%); TP=Total Porosity (%); OM= Organic matter (%); TN= Total Nitrogen (%); Av. P=Available Phosphorus (ppm); Av.S=Available Sulfur (ppm); Ex. K=Exchangeable Potassium (ppm); Ex. Na=Exchangeable sodium (ppm); Ex.Ca=Exchangeable Calcium (ppm); Ex. Mg=Exchangeable Magnesium (ppm); CEC=Cation Exchange Capacity (meq/100g); Ex, Ac=Exchangeable Acidity (meq/100g).

3.2. Chemical Composition of Compost

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

Parameters	pH	OC	TN	C/N	P	S	Exchangeable bases				CEC
							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).

3.3. Effects of Compost and NPS Fertilizer on Yield and Yield Component of Food Barley

3.3.1. Effects of Compost and NPS Fertilizer on Phenological Parameters of Barley

(i). Day to 50% Emergence

The analysis of variance indicated that the main effects of compost, NPS fertilizer level, and their interaction were not significantly ($p \geq 0.05$) affected days to 50% emergence (Table 3).

Table 3. *Main effect of compost and NPS rate on Phenological parameters of barley.*

Compost (t/ha)	50%DE	50% DH	90%DPM
0	6.66	77.86	120.53
4	6.6	77.13	120.13
8	6.6	77.46	119.46
12	6.53	76.4	118.93
$CR_{0.05}$	NS	NS	NS
NPS (kg ha^{-1})			
0	6.83	79.75^{a}	127.83^{a}
100	6.75	77.16^{ab}	120.5^{ab}
150	6.58	76.41^{ab}	119.66^{ab}
200	6.41	75.75^{ab}	118.66^{b}
250	6.41	75.75^{b}	118.16^{b}
RNP	6.66	76.43^{ab}	119^{ab}
$CR_{0.05}$	NS	2.50	2.84
CV $_{(\%)}$	7.48	4.53	2.35

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT); 50% DE= 50% Day to Emergence; 50% DH= 50% Day to Heading; 90% DPM= 90% Day to Physiological Maturity; RNP=Recommended Nitrogen and Phosphorus; CV = Coefficient of variation; CR=Critical Range.

(ii). Day to 50% Heading

Blended NPS fertilizer was significantly ($p<0.05$) affected 50% day to heading. But it was not affected either by compost or their interaction (Table 3). Longer (77.86) days to 50% heading of barley was observed under control plots and the lowest (76.4) was recorded from 250 kg/ha fertilizer which was statistically at par with (100, 150, 200) Kg/ha NPS and RNP fertilizer. This indicates that days to heading were decreased with the increasing rate of NPS fertilizer. The hastened heading as a result highest rate of NPS could be due to the fact plots receiving the highest rates of nutrients encouraged for the early establishment, rapid growth and development promoted by nitrogen as explained by [54]. Lake Mekonnen *et al*. [55] and Ottman M. [56] also reported that an increase in fertilizer rates decreased time to heading.

(iii). Days to 90% Physiological Maturity

The main effect of NPS rates was significantly ($p<0.05$) affected the physiological maturity of barley (Table 3). However, application of compost and their interaction was not significantly ($p\geq0.05$) affected 90% physiological maturity of barley. Accordingly, the highest 127.83 days to maturity were obtained from the control plot and the minimum 118.16 days to maturity was recorded from 250 Kg/ha NPS fertilizer rate, it was statistically at par with (100, 200, 150) Kg/ha NPS and RNP fertilizer. There was a very short time for growth and development in the plots well supplied with nutrients. Early maturity in response to an increasing rate of NPS fertilizer may be attributed to the adequate nutrients supplied to soil from NPS fertilizer that may have led to quick maturity. The finding of this study was in agreement with the results of [57, 58] whose reported that NPS fertilizers have the potential to cause early flowering and maturity of the crop.

3.3.2. Effects of Compost and NPS on Growth Parameters of Barley

(i). Plant Height (cm)

The analysis of variance exposed that the main effects of NPS fertilizer were significantly ($P<0.05$) affected plant height. However, the main effect of compost and the two-factor interaction was not significantly ($p \geq 0.05$) affected plant height (Table 4). Significantly tallest (100.2 cm) mean plant height of barley was obtained from the application of 250 kg/ha NPS fertilizer and while the shortest 86.7cm plant height was recorded from the control plot. As the level of NPS fertilizer increase from 0 to 250 kg/ha, the plant height increases from 86.7 cm to 100.2 cm. This could be due to NPS fertilizer which has a great contribution to vigorous vegetative growth and development by promoting growth and photosynthetic activity. The result of this study is in contract with the result of [59, 60] whose reported that plant height was significantly influenced by different rates of NPS fertilizer.

(ii). Total Number of Tillers Per Plant

Tillers are an important component of barley yield because they have the potential to develop grain-bearing heads and the total number of tillers eventually developed will not all produce grain-bearing heads. The main effect of compost and NPS fertilizer rates, as well as their interaction, was highly significant ($p<0.05$) on the total number of tillers produced per plant (Table 4). The highest number of total tillers per plant (11.1) was produced at the plot that was treated with 12 t/ha and 250 kg/ha NPS fertilizer, which was exceeded by 246.8% over the minimum number of total tillers per plant (3.2) which was produced at the control plot.

Table 4. *Interaction effect of compost and NPS rate on the total number of tillers of barley.*

Treatments Compost t/ha	Total Number of Tillers					
	NPS kg/ha					
	0	100	150	200	250	RNP
0	3.2^{i}	3.9^{hi}	5.6^{fg}	5.8^{fg}	6.1^{ef}	
4	3.7^{hi}	5.2^{f-h}	5.9^{f}	6.5^{ef}	6.8^{ef}	
8	4.0^{hi}	8.5^{cd}	9.1^{bc}	9.5^{bc}	9.9^{a-c}	
12	4.3^{g-i}	7.6^{de}	9.5^{bc}	10.4^{ab}	11.1^{a}	
RNP						5.8^{fg}
$CR_{0.05}$			1.42			
$CV_{(\%)}$			12.71			

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT), RNP=Recommended Nitrogen and Phosphorus, CV = Coefficient of variation, Least Significant differences.

This indicates the easy availability of nutrients from inorganic fertilizers as compared to the gradual release of nutrients from organic fertilizer sources. This result was in agreement with the findings of [26, 61].

(iii). Number of Effective Tillers

The analysis of variance indicated that the main effects of compost, NPS fertilizer, and their interaction were highly and significantly ($p<0.05$) affected the number of effective tillers produced per plant (Table 5). Crop yields are generally dependent upon many yield contributing factors. Among these, numbers of effective tillers are the most important because the final economic yield of most of the cereals is determined by the number of fertile tillers as reported by [62].

Table 5. *Interaction effect of compost and NPS rate on the number of effective tillers of barley.*

Compost (t/ha)	Number of Effective Tillers					
	NPS (kg/ha)					
	0	100	150	200	250	RNP
0	2.6^{g}	2.9^{g}	4.6^{ef}	4.8^{ef}	4.8^{ef}	
4	3.0^{g}	3.1^{g}	4.2^{f}	4.8^{ef}	4.8^{ef}	
8	3.1^{g}	7.0^{b}	8.6^{a}	7.3^{b}	6.2^{c}	
12	3.1^{g}	5.9^{cd}	5.8^{cd}	5.7^{cd}	5.3^{de}	
RNP						4.1^{f}
$CR_{0.05}$			0.39			
$CV_{(\%)}$			8.64			

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV = Coefficient of variation; CR=Critical Range.

The maximum number of effective tillers per plant (8.6) was recorded from the plots treated by 8 t/ha compost with 150 kg/ha NPS fertilizer, while, the minimum effective number of tillers per plant (2.6) was obtained from the control plot. The attainment of the higher number of effective tillers might be due to the synergetic interaction effects of nutrients contributed by compost and NPS fertilizers. This is consistent with [22] who observed that the application of 5 t/ha farmyard manure along with 75% of recommended NP gave the highest number of productive tillers per square meter.

3.3.3. Effects of Compost and NPS on Yield and Yield Component of Barley

(i). Spike Length (cm)

The main effects of NPS fertilizer rate were significantly ($p<0.05$) affected spike length. However, the effect of compost and their interaction effect was not significantly ($p \geq 0.05$) affected spike length of food barley (Table 6). The longest spike length (7.61 cm) was obtained from the plot treated by 250 kg/ha NPS fertilizer rate which was statistically at par with (150, 200) kg/ha NPS and RNP.

Table 6. *The main effect of compost and NPS rate on plant height and spike length of barley.*

Compost t/ha	Plant Height	Spike Length
0	93.0	6.59
4	93.8	6.59
8	94.3	7.00
12	95.3	7.11
$CR_{0.05}$	NS	NS
NPS (kg/ha)		
0	86.7^{d}	5.45^{c}
100	91.4^{c}	6.54^{b}
150	94.2^{bc}	7.10^{ab}
200	96.6^{b}	7.40^{a}
250	100.2^{a}	7.61^{a}
RNP	95.1^{b}	7.20^{ab}
$CR_{0.05}$	3.2	0.70
$CV_{(\%)}$	3.3	9.3

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV = Coefficient of variation; CR=Critical Range.

While, the shortest (5.45 cm) spike length was recorded from control plots. The possible reason for the increase in spike length with an rise in NPS rate might be related to the availability of growth-limiting primary nutrients such as N and P insufficient amounts in the soils which in turn promotes vegetative growth. The result of this finding is in agreement with the finding by [26] which showed that application of inorganic fertilizer alone produced the tallest spike length of barley.

(ii). Number of Grain Per Spike

The number of kernels per spike was knowingly ($P<0.05$) affected by the main effect of compost, NPS fertilizer, and their interaction (Table 7). The highest number of grains per spike (57.20) was gained from the plots treated with 8 t/ha compost and 150 kg/ha NPS fertilizer which was statistically at par with 8t ha^{-1} compost with 100 NPS kg/ha and 8 t/ha compost with 200 kg/ha NPS fertilizer rate. In contrary to this the lowest total number of grains per spike (36.13) was obtained at the control plots.

Table 7. *Interaction effect of compost and NPS rate on the number of grain per spike of barley.*

Compost (t/ha)	Number of grain per spike					
	NPS (kg/ha)					
	0	100	150	200	250	RNP
0	36.13^{h}	38.40^{gh}	42.60^{fg}	45.53^{ef}	48.80^{b-e}	
4	37.27^{gh}	41.03^{f-h}	46.03^{d-f}	48.73^{b-e}	50.67^{b-e}	
8	37.63^{gh}	53.43^{ab}	57.20^{a}	54.67^{ab}	52.33^{b}	
12	38.67^{g-h}	51.53^{a-d}	49.67^{b-e}	49.17^{b-e}	46.63^{d-f}	
RNP						45.13^{ef}
$CR_{0.05}$			5.12			
CV (%)			6.71			

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT), RNP=Recommended Nitrogen and Phosphorus, CV = Coefficient of variation, CR=Critical Range.

The attainment of the highest value in the number of grains per spike might be due to the synergistic interaction effect of nutrients sourced from both compost and NPS fertilizer which was resulted in the greater number of grains per spike. Inconsistent with this result, [63] stated significant increases in the number of grains per spike by applying organic manures and inorganic fertilizer application. Sepat and Dhar [61] are also reported an increase in the number of grains per spike of barley due to the application of organic and inorganic fertilizers.

(iii). Thousand-grain Weight (g)

Thousand-grain weights are a function of grain size or grain density which is an important yield contributing parameter which indicates the superior in predicting the milling quality of grains as compared to test weight. The analysis of variance exhibited that thousand-grain weight was significantly ($p<0.05$) affected by the main and interaction effect of compost and NPS fertilizer (Table 8). Plots received 8 t/ha compost and 150 kg/ha NPS fertilizer showed significantly higher thousand-grain weight (49.5g) than control plots (34.9g) which is at par with other treatments. The lowest thousand-grain weight from the control plot could be due to shriveled seeds that have a small size which contributed to the less grain weight.

Table 8. *Interaction effect of compost and NPS on the thousand-grain weight of barley.*

Compost (t/ha)	Thousand-grain weight (g)					
	NPS (kg/ha)					
	0	100	150	200	250	RNP
0	34.9^{f}	42.5^{e}	44.8^{c-e}	45.9^{b-d}	47.1^{a-c}	
4	35.1^{f}	42.6^{e}	45.0^{b-e}	45.8^{b-d}	46.7^{a-d}	
8	35.2^{f}	47.0^{a-c}	49.5^{a}	48.0^{ab}	47.3^{a-c}	
12	35.3^{f}	46.6^{a-d}	47.1^{a-c}	44.6^{c-e}	44.3^{c-e}	
RNP						43.7^{de}
$CR_{0.05}$				0.2		
CV (%)				3.70		

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT), RNP=Recommended Nitrogen and Phosphorus, CV= Coefficient of variation, CR=Critical Range.

In contrary to this, the highest thousand-grain weight might be due to the synergistic interaction effect of nutrients from combined fertilizers for better growth and grain filling of the barley crop. Similar to this finding, [27] reported higher thousand-grain weights from the combined application of organic and inorganic fertilizers. Likewise, [64] also found that amendment of different organic sources with NP fertilizer significantly improved the thousand-grain weight of barley.

(iv). Total Biomass Yield (t/ha)

The above-ground dry biomass yield was highly and significantly ($p<0.05$) affected by the compost and NPS fertilizer and their interaction (Table 9). The maximum (15.66 t/ha) dry biomass of barley was attained from plots treated by 12 t/ha compost and 250 kg/ha NPS fertilizer and the lowest (5.14 t/ha) were obtained from control plots. With the increase of compost and NPS fertilizer rates, the total biological yield also improved.

Table 9. *Interaction effects of compost and NPS rate on total biomass yield of barley.*

Compost (t/ha)	Total biomass yield (t/ha)					
	NPS (kg/ha)					
	0	100	150	200	250	RNP
0	5.14^{k}	9.36^{hi}	9.49^{hi}	10.50^{f-h}	11.50^{ef}	
4	7.99^{j}	10.32^{g-i}	10.62^{fg}	11.50^{ef}	12.30^{de}	
8	8.12^{j}	12.53^{d}	13.57^{bc}	13.14^{cd}	14.23^{b}	
12	9.31^{gh}	13.24^{b-d}	14.14^{b}	14.26^{b}	15.66^{a}	
RNP						10.03^{g-j}
$CR_{0.05}$			1.10			
CV (%)			5.01			

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV = Coefficient of variation; CR=Critical Range.

This highest value in total above-ground dry biomass over the control and organic or inorganic fertilizer alone might be due to the good response of barley crop to synergistic interaction effect of nutrients supplied by compost and NPS fertilizers which are well observed through the synthesis of proteins, formation of new tissues and overall vegetative growth of barley crop. Moreover, an increase in plant height, spike length, number of seeds per spike, thousand-grain weights, and number of tillers could contribute to the significant increase of the total biomass yield of food barley. This could be evident from the significant and positive correlation of total biomass yield with plant height (r=0.73**, effective tillering r=0.86**, spike length r=0.81**, the number of grain per spike r=0.80** and thousand-grain weight r=0.78**) Table 10.

This result was in agreement with [26] who suggested that the dry biomass yield of barley was significantly affected by the application of integrated nutrient management. Likewise, [65] also reported that the use of combined application of organic and inorganic fertilizers increases dry biomass yield.

(v). Straw Yield (t/ha)

Analysis of variance showed that the straw yield of food barley was highly and significantly ($p<0.05$) affected by the main effects of compost and NPS fertilizer, and their interaction (Table 10). The highest mean straw yield (9.46 t/ha) was obtained from 12 t/ha compost and 250 kg/ha NPS fertilizer. It exceeds the lowest straw yield (3.51 t/ha) by 62.9% which was recorded from control plots. The increase in straw yield as a result of the interaction effect of compost and NPS fertilizer might be due to improvement in the crop biological yield which in turn increased straw yield.

This could be apparent from a significant and positive correlation (r=0.95**) between straw yield and total biomass yield (Table 13). In line with this finding, [66] reported that higher straw yield was obtained due to the combined application of integrated fertilizer sources. Similarly, [7] also reported that straw yield was increased with increasing organic and inorganic fertilizer rates.

Table 10. *Interaction effects of compost and NPS rate on straw yield of barley.*

Compost (t/ha)	Straw Yield (t/ha)					
	NPS (kg/ha)					
	0	100	150	200	250	RNP
0	3.51^{g}	5.00^{def}	5.10^{ef}	6.02^{ed}	6.94^{cd}	
4	4.13^{e-g}	5.28^{d}	5.43^{ef}	6.17^{ed}	6.95^{cd}	
8	4.24^{ef}	6.84^{c}	7.89^{bc}	8.24^{b}	7.32^{bc}	
12	5.00^{ed}	7.53^{bc}	8.39^{b}	8.36^{b}	9.46^{a}	
RNP						5.70^{ef}
$CR_{0.05}$			0.70			
CV $_{(\%)}$			9.06			

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT), RNP=Recommended Nitrogen and Phosphorus, CV = Coefficient of variation, CR=Critical Range.

(vi). Grain Yield (t/ha)

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 the interaction effect of compost and NPS application (Table 11). The highest Gain yield of barley 5.96 t/ha was obtained from the application of 8 t/ha compost and 150 kg/ha NPS fertilizer followed by 5.74 t/ha and 5.70 t/ha which was obtained from plots treated by 8 t/ha with 200 kg/ha NPS fertilizer and 8 t/ha with 250 kg/ha NPS fertilizer, respectively. This indicates that the application of 8 t/ha compost and 150 kg/ha 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 the lodging effect. The lowest grain yield (1.66 t/ha) was recorded from control plots (Table 11). The combined application of 8 t/ha compost with 150 kg/ha NPS fertilizer increased grain yield by 32.6% and 72.1% than the current blanket fertilizer recommendation and the control plots, respectively.

An increase in barley grain yield owing to the combined use of compost 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 the rate of photosynthesis and brought better crop growth led to improvement in soil organic matter, plant height, total tillers, effective tiller, spike length, thousand-grain weight, number of grain per spike, total biomass yield and in turn increased the final output grain yield. This can be confirmed by significantly and positive correlation (r= 0.64**, 0.71**, 0.75**, 0.67**, 0.78**, 0.72**, 0.91**, 0.75**) of grain yield with soil organic matter, plant height, effective tiller, spike length, thousand-grain weight, number of grain per spike, total biomass yield and straw yield, respectively (Table 13).

Table 11. *Interaction effects of compost and NPS rate on grain yield of barley.*

Compost (t ha^{-1})	Grain Yield (t/ha)					
	NPS (kg/ha)					
	0	100	150	200	250	RNP
0	1.66^{l}	3.19^{h}	3.52^{g}	4.16^{f}	4.54^{e}	
4	2.23^{k}	3.92^{g}	4.22^{f}	4.42^{e}	4.71^{d}	
8	2.53^{j}	5.29^{c}	5.96^{a}	5.74^{b}	5.70^{b}	
12	2.72^{i}	5.58^{bc}	5.43^{c}	5.34^{c}	5.27^{c}	
RNP						4.02^{g}
$CR_{0.05}$			0.15			
CV $_{(\%)}$			6.18			

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT), RNP=Recommended Nitrogen and Phosphorus, CV = Coefficient of variation, CR=Critical Range.

Table 12. *Interaction effect of compost and NPS rate on harvest index of barley.*

Compost (t/ha)	Harvest index (%)					
	NPS (kg/ha)					
	0	100	150	200	250	RNP
0	32.16^{d}	45.54^{ab}	46.22^{ab}	42.62^{a-c}	39.65^{c}	
4	39.64^{c}	48.82^{a}	48.85^{a}	46.28^{ab}	43.44^{a-c}	
8	40.74^{cd}	42.30^{bc}	39.73^{cd}	41.29^{bc}	44.40^{a-c}	
12	42.04^{bc}	43.13^{bc}	40.76^{cd}	41.92^{b-d}	45.51^{a-c}	
RNP						43.15^{bc}
$CR_{0.05}$			5.35			
CV $_{(\%)}$			7.33			

Means taken after by the same letter within the same column of the particular treatment are not considerably distinctive at 5% probability level (DMRT); RNP=Recommended Nitrogen and Phosphorus; CV = Coefficient of variation; CR=Critical Range.

In line with this result, [67, 68] reported that the application of different proportions of organic with inorganic fertilizer was increased grain yield. Similarly [27] also reported that application of inorganic fertilizers with FYM gave a better yield of barley than the application of 100% inorganic fertilizers alone. On the other hand, [22] reported that increasing organic and inorganic NP rates beyond the optimum requirement level of the crop did not increase the grain yield of barley.

(vii). Harvest Index (%)

Harvest index was calculated as the proportion of grain yield to the entire above-ground dry biomass yield. Analysis of variance showed that the harvest index of food barley was significantly ($p<0.05$) affected by the main effects of compost and NPS fertilizer and their interaction (Table 12). The highest Harvest index (48.85%) was obtained from plots treated by 4 t/ha compost with 150 kg/ha NPS fertilizer which is statistically par with the 48.82% harvest index that was obtained from the application of 4 t/ha and 100 kg/ha NPS fertilizer.

These two highest values exceed the lowest harvest index (32.16%), which was recorded from control plots, by 51.89 and 51.80%, respectively. This might be due to supplying of sufficient amount of available nutrients and an increase of nutrient use efficiency when compost and NPS fertilizer sources are applied. Similar to this result, [64] reported that a considerably greater mean harvest index of barley was obtained from the combined application of organic and inorganic fertilizer.

Table 13. *Correlation among phenology, growth, yield, and yield Parameter of food barley.*

	DH	DPM	PH	SL	ET	NGS	TGW	TAB	GY	SY	HI
DH	1										
DM	0.51**	1									
PH	-0.36*	-0.44^{NS}	1								
SL	-0.30*	0.18^{NS}	0.52**	1							
ET	-0.30*	-0.25*	0.69**	0.85**	1						
NGS	-0.35*	0.22^{NS}	0.71**	0.75**	0.86**	1					
TGW	-0.46**	-0.39**	0.68**	0.70**	0.71**	0.72**	1				
TAB	-0.36^{NS}	-0.33*	0.73**	0.81**	0.86**	0.80**	0.79**	1			
GY	-0.43**	-0.39*	0.71**	0.67*	0.75**	0.72**	0.78**	0.91**	1		
SY	0.27*	0.26*	0.66**	0.82**	0.84^{NS}	0.76**	0.79**	0.95**	0.75**	1	
HI	-0.33*	-0.28*	0.10^{NS}	-0.10^{NS}	-0.05**	-0.004^{NS}	0.19^{NS}	0.05^{NS}	0.45**	-0.22^{NS}	1

DH= Days to heading; DPM=Days physiological maturity; PH= Plant height; SL= Spike length; ET= Effective tillers; NGS= Number of grain per spikes; TGW= Thousand grain weight; TAB= Total above ground Biomass; SY= Straw yield;, HI=Harvest index; ** =highly significant differences; *= significant differences; NS= Non significant differences.

Table 14. *Marginal analysis of food barley as influenced by the compost and NPS fertilizer rate.*

Compost t/ha	NPS kg/ha	Ad.P	Ad.Y	Av.SY	Ad.SY	GB	TVC	NB	MRR
0	0	1660	1494	3150	2835	24111		24111	
0	100	3190	2871	4700	4230	45603	2859	42744	652
0	150	3520	3168	5800	5220	50652	3440	47212	768
0	200	4160	3744	7280	6552	60091	4048	56044	1454
0	250	4540	4086	7920	7128	65567	4603	60964	886
4	0	2230	2007	5560	5004	33107	5300	27807D	
-	RNP	4020	3618	5810	5229	57407	7090	50317	1258
4	100	3920	3528	5970	5373	56144	8159	47985D	
4	150	4220	3798	6570	5913	60518	8740	51778	652
4	200	4420	3978	7070	6363	63488	9348	54140	389
4	250	4710	4239	7980	7182	67894	9903	57991	693
8	0	2530	2277	6050	5445	37422	10600	26822D	
8	100	5290	4761	7090	6381	75244	13459	61785	1223
8	150	5960	5364	7610	6847	84568	14040	70528	1504
8	200	5740	5166	8110	7299	81869	14648	67222D	
8	250	5700	5130	8500	7650	81540	15203	66337D	
12	0	2720	2448	6220	5598	40079	15900	24179D	
12	100	5580	5022	7790	7011	79537	18759	60778	1280
12	150	5430	4887	8570	7713	77933	19340	58593D	
12	200	5340	4806	9240	8316	77080	19948	57132D	
12	250	5270	4743	10610	9549	76874	20503	56371D	

Where: NB= Net benefit; Av.GY= Average Grain yield (kg/ha); Ad.GY= Average grain yield (kg/ha); Av. SY= Average straw yield (kg/ha); Ad.SY= Adjusted straw yield; RNP: Recommended Nitrogen and Phosphorous; GFB: Gross field benefit (ETB); TVC: Total Variable Cost (ETB); NB: Net benefit (ETB); MRR%: Marginal rate of return: D= Dominated; ETB: Ethiopian Birr.

3.4. Partial Budget Analysis

The outcome of the economic analysis showed that the highest 70528 per hectare ETB net benefit with the minimal rate of return 1504% was accomplished by application of 8 t/ha compost with 150 kg/ha NPS fertilizer rate economically was greater and profitable than the rest of the treatments (Table 14). This suggestion is bolstered by [53] which expressed that farmers ought to be willing to alter from one treatment to another if the minimal rate of return of that change is more prominent than the least worthy rate of return. The dominated treatments (control) were rejected from further economic analysis. Thus, the mixture of 8 t/ha compost and 150 kg/ha NPS fertilizer was economically practicable for the production of food barley in the Welmera district area and other regions with comparable agro-ecological conditions.

4. Conclusions and Recommendations

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

To improve this condition of soil conventional compost and NPS fertilizer were applied to study area soils;

The combined use of compost and NPS fertilizer (8 t/ha) compost + 150 kg/ha NPS) was increased barley yield by 72.1% over control treatment, which is a better improvement than at the highest rate of sole application of NPS fertilizer (23.8%), compost (54.4%) and standard check or recommended NP (32.6%).

From this finding, one can conclude that low soil fertility status, which requires urgent attention, is one of the major causes hindering the production and productivity of food barley at Welmera district. In resolving this situation, the use of combined application of compost along with NPS fertilizers was justified to increase soil organic substance and nutrient contents that are important in improving soil richness status and in turn to raise 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 use at the study area. Moreover, the potential barley productivity of study area soil has not yet been exploited. Hence, solving the soil fertility problems of the soils of the study area through the integrated application of compost and NPS fertilizer might be one option to reduce the yield gap seen between smallholder farmers and experimental fields. Nevertheless, further studies at different locations for more than one cropping season should be considered to provide more conclusive recommendations for sustainable food barley production.

Conflict of Interest

All the authors do not have any possible conflicts of interest.

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