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The Ameliorative Effects of Organic and Inorganic Fertilizers on Yield and Yield Components of Barley and Soil Properties on Nitisols of Central Ethiopian Highlands

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ይህ የመስክ ሙከራ በኦሮሚያ ክልል ወልመራ፤ አዳአ በርጋ እና ኤጄሬ ወረዳ በአርሶ አደር ማሳዎች ላይ ለሶስት ተከታታይ ዓመታት (ከ2015 – 2017 እ.ኤ. አ.) የተከናወነ ሲሆን ዋና ዓላማዉም የተፈጥሮ እና ሰው ሰራሽ ማዳበሪያዎችን በምግብ ገብስ ዕድገትና ምርት እንዲሁም የአፈር ኬሚካላዊ ባህሪ ላይ ያላቸዉን ተፅዕኖ ለመገምገም ነበር፡፡ ይህንንም ለማጥናት የፍግ፤ ቀልዘ-ትል (ቨርሚኮምፖስት)፤ ቀልዝ (ኮምፖስት)፤ ናይትሮጅን ማዳበሪያ (ዩሪያ)፣ ፎስፎረስ ማዳበሪያ (ዳፕ) እና የነሱን ቅልቅሎች በRCB ዲዛይንና በሦስት ድግግሞሽ ተሞክሯል፡፡ ዉጤቱ እንደሚያሳየዉ የምግብ ገብስ ምርት እና የአፈር ኬሚካላዊ ባህርይ በተፈጥሮና ሰው ሰራሽ ማዳበሪያ መጠቀም አመርቂ ለዉጥ አሳይቷል፡፡ በመሆኑም 3.8 ቶን ቨርሚኮምፖስት እና 30 ኪ.ግ ናይትሮጅን እንዲሁም 34.5 ኪ.ግ ፎስፌት በሄ/ር በመጠቀም 4277 ኪ.ግ የምግብ ገብስ ምርት እና 9557.8 ኪ.ግ ጠቅላላ ምርት (ባዮማስ) በሄ/ር ተገኝቷል፡፡ በመቀጠልም 60 ኪ.ግ ናይትሮጅን እና 69 ኪ.ግ ፎስፌት በመጠቀም 3911 ኪ.ግ የምግብ ገብስ ምርት እና 9937 ኪ.ግ ጠቅላላ ምርት በሄክታር ተገኝቷል፡፡ በሌላ በኩል የተፈጥሮ ማዳበሪያዎችን በመጠቀም የአፈር ካርቦናዊ ቁስ ፣ የጠቅላላ የናይትሮጅን እና የፎስፈረስ ይዘት እንዲሁም የአፈር pH መጠን የተወሰነ ለውጥ ሊያሳይ ችሏል፡፡ ይህ በእንዲህ እንዳለ 3.8 ቶን በሄ/ር ቨርሚኮምፖስት እና 30 ኪ.ግ ናይትሮጅን እንዲሁም 34.5 ኪ.ግ ፎስፌት በሄ/ር አደባልቆ መጠቀም ከፍተኛ የሆነ ትርፍ ያለዉና አዋጭ የማዳበሪያ አጠቃቀም መሆኑ ተረጋግጧል፡፡

Abstract

A field experiment was conducted for three consecutive cropping seasons (2015-2017) on farmers' fields in Welmera, Ada'a Berga and Ejere district of Oromiya Regional State. The objectives of this study were to evaluate the influence of organic and inorganic fertilizers on growth and yield of barley and soil chemical properties. The treatments included eleven selected combinations of organic and inorganic nutrient sources, including farmyard manure (FYM), vermicompost, compost, nitrogen (N), phosphorus (P) and boron (B). The design was randomized complete block with three replications. Results showed that barley yield and yield components, and soil chemical properties were significantly affected by the application of organic and inorganic fertilizer sources. The highest barley grain yield of 4277 kg ha^{-1} was obtained from the applications of half doses of vermicompost (3.8 t ha^{-1}) based on the recommended N equivalent and half doses of the recommended N and P fertilizers (30 kg N ha^{-1} N and 34.5 P_2O_5 kg ha^{-1}), followed by 3911 kg ha^{-1} due to the application of the full recommended inorganic N and P fertilizers (60 kg N ha^{-1} and 69 kg P ha^{-1}). The highest biomass yield of 9937 kg/ha was obtained from the applications of the full recommended N and P rates (60 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}). Application of organic fertilizer significantly improved soil organic carbon from 1.26 % to 1.56%, N from 0.14% to 0.23% and phosphorous from 7.84 mg kg^{-1} to

12.59 mg kg^{-1}. The result also showed that the highest marginal rate of return was obtained from the application of 50% vermicompost based on N equivalent) + 50% N and P, which is economically the most feasible alternative on Nitisols of central Ethiopian highlands.

Keywords: Barley, compost, farmyard manure, Nitisols, nitrogen, phosphorus, vermicompost

Introduction

Barley (*Hordeum vulgare L.*) is one of the main cereal crops produced in the World. It ranks fourth in the world in production after wheat, maize and rice (FAO, 2013). Global barley production is estimated about 141.7 million tons (USDA, 2017). Globally, European Union, Russia, Canada, USA and Argentina are the top five largest world barley producers where, European Union produces the greatest quantities of barley with an estimated production of 20.5 million tons followed by the Russian federations with a production of about 8 million tons, whereas barley production in Canada, USA and Argentina was estimated 7.3, 3.1 and 2.8 million tons, respectively (UDSA, 2017). In the African continent, Morocco, Ethiopia, Algeria, Tunisia and south Africa were the top five largest barley producers for the year 2016 with estimated production of approximately 2.1,1.85, 1.3, 0.5 million and 0.307 million tons, respectively. More than half of barley area coverage is in the developing countries (FAO, 2016).

Ethiopia is the second largest producer of barley in Africa next to Morocco, accounting for about 26% of the total barley production in Ethiopia (Shahidur *et al*., 2015). It is the fifth important cereal crop next to *tef*, maize, sorghum and wheat, with the total area coverage of 0.952 million ha and total annual production of about 2.05 million tons in the main cropping season, with the mean barley yield of 2.16 t ha^{-1} (CSA, 2018). In 2017/18, the number of smallholder farmers growing barley was 3.5 million, of which 1.30 million holders were from Oromia, with a total area coverage of 0.451 million ha and a mean yield of 2.41 t ha-1 (CSA, 2018).

Barley is a major staple food in some areas of North Africa and the near Middle East, in the highlands of Central Asia, in the Horn of Africa, in the Andean countries and in the Baltic States (Grando and Macpherson, 2005). In Ethiopia, barely is a dependable source of food in the highlands as it is produced during the main and short rainy seasons as well as under residual moisture/moisture stress areas or eroded lands (Melle *et al.*, 2015). Its grain is used for the preparation of different foodstuffs, such as *injera, kolo* and local drinks (Mulatu, 2011). Yosef *et al*. (2011) reported that barley straw is a good source of animal feed, especially during the dry season and it is also a useful material for thatching roofs of houses and for use as beddings.

In addition to its significant share in the annual grain production of cereals, barley has a number of advantages that testify to its role in food security (Grando and Macpherson, 2005). Despite, the importance of barley and its many useful characteristics, there are several factors affecting its production and productivity. The most important factors that reduce yield of barley in Ethiopia are poor soil fertility, low soil pH and soil acidity, water logging, drought, frost, poor crop management practices (Agegnehu *et al*., 2011), use of low yielding cultivars, weed competition, diseases and insects (Mulatu, 2011), and limited availability of the very few improved cultivars released and supplied to farmers (Lakew, 2008). Poor soil fertility and use of low yielding cultivars are among the most important constraints that threaten barley production in Ethiopia (Agegnehu *et al*., 2011). Assefa *et al*. (2017) reported that, soils in the highlands of Ethiopia usually have low levels of essential plant nutrients, especially low availability of nitrogen and it is the major constraint to cereal crop production. Studies indicated that the integrated application of inorganic and organic nutrient sources significantly improved the yield of crops (Agegnehu *et al*., 2006; Agegnehu and Amede, 2017; Girma and Gebreyes, 2017). The objectives of this study were to: 1) determine the effect of the combined application of organic and inorganic fertilizers on growth and yield of barley, and 2) evaluate their influence on soil chemical properties.

Materials and Methods

Experimental site

The experiment was conducted in Welmera, Ada'a Berga, and Ejere districts of West Shewa Zone of Oromia National Regional State for three consecutive cropping seasons (2015 -2017). The experiment site is located at 09^0 03′ N latitude and 38^0 30′ E longitude, 30 and 60 km west of Addis Ababa, respectively, at an altitude of about 2400 m above sea level (Fig. 1). The mean annual rainfall of the study area was 1100 mm, of which about 85% falls from June to September and the rest from March to May. According to Holetta Agricultural Research Center Meteorological Report, the mean annual temperature was about 14.3^oc, with the mean maximum and minimum temperatures of 21.7^oc and 6.9 ^{o}c, respectively (Fig. 2).

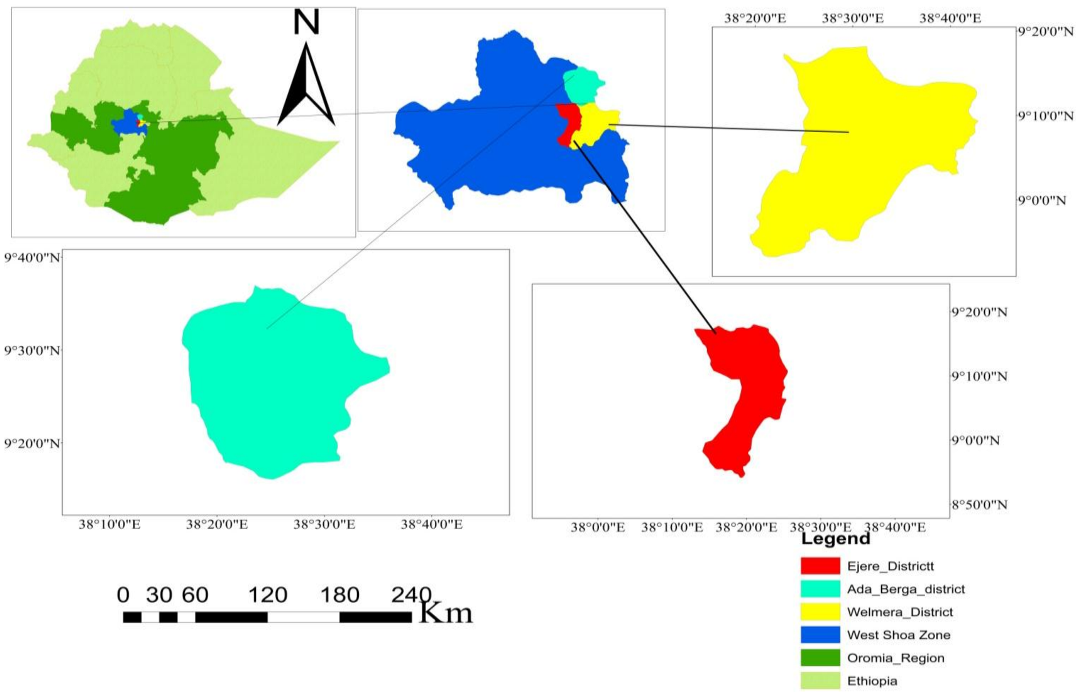

Figure 1. Maps of the study area

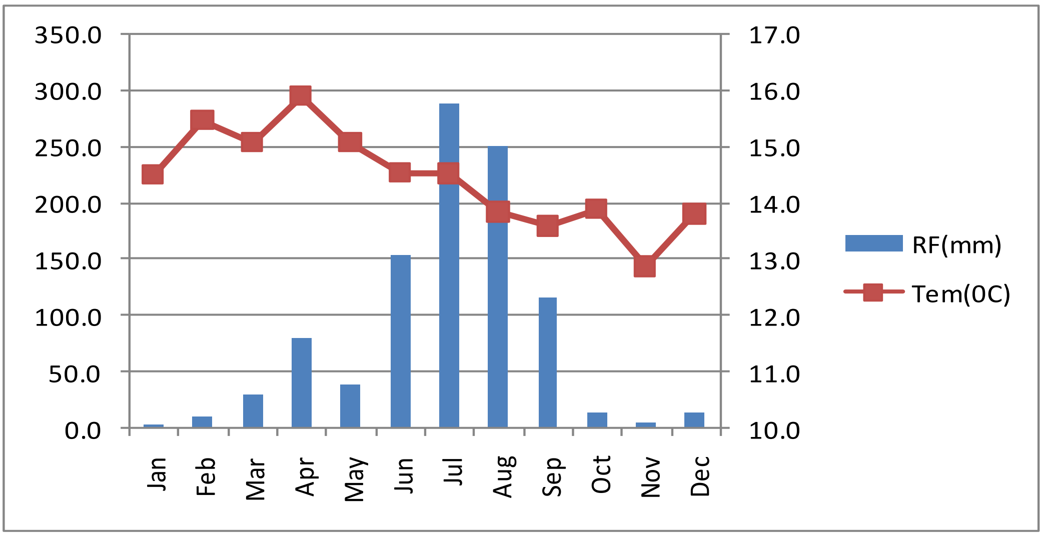

Figure 2. Annual rainfall and average maximum and minimum temperature at Holetta from 2006 to 2015.

The major soil types of the trial sites are Eutric Nitisols (FAO-WRB, 2014) and Barley variety (HB-1307) was used as test crop for the experiment. The rates of organic fertilizers applied were calculated based on the recommended N equivalent rate of the inorganic fertilizer source for the test crop. This means samples of each organic fertilizers listed below were taken and analyzed for their N content and then the rate to be applied for the crop (on hectare basis) was determined as indicated in Table 1.These treatment combinations were laid down in randomized complete block design with three replications. Compost was prepared following the standard procedure for compost preparation.

Table 1. Selected treatment combinations of organic and inorganic nutrient sources

No.	Treatments	Description
1	Recommended NP	60 kg N ha^{-1} N and 30 kg P_2O_5 ha^{-1}
2	NPS	150 kg ha^{-1}
3	NPSB	150 kg ha^{-1}
4	Vermicompost	7.6 t ha^{-1}
5	Compost	6.8 tha^{-1} compost
6	50% VC + 50% NP	3.8 t ha^{-1} VC + 30 kg N ha^{-1} + 15 kg P_2O_5 ha^{-1}
7	50% VC + 50% NPS	3.8 t ha^{-1} VC + 75 kg/ha NPS
8	50% VC + 50% NPSB	3.8 t ha^{-1} VC + 75 kg ha^{-1} NPSB
9	50% VC + 50% Comp	3.4 t ha^{-1} VC + 15 kg P_2O_5 ha^{-1} compost
10	50% Comp + 50% NP	3.4 t ha^{-1} compost + 30 kg N ha^{-1} + 15 kg P_2O_5 ha^{-1}
11	50% FYM + 50% NP	1.75 t ha^{-1} FYM + 30 kg N ha^{-1} + 15 kg P_2O_5 ha^{-1}

Note: FYM = Farmyard manure; VC = Vermicompost

Similarly, vermicompost (VC) was produced by using earthworms and the same inputs, i.e. cattle manure and straw as bedding materials for the vermicomposting and bulking in the composting process. Vermicomposting differs from composting in several ways (Gandhi *et al*., 1997). It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10–32°C (not ambient temperature but temperature within the pile of moist organic material). The vermicompost was prepared from organic materials such as green plants, animal dung, pulse straw, leaves and ash. According to Suparno *et al*. (2013), the raw materials were put up in layers in the following sequence: 1) about 60% a layer of crop residues/green plants (20 cm);2) 30% of a layer of manure (animal dung, sheep manure) (5-10 cm) = ; and 3) 10 of a layer of topsoil/ash (2-4 cm).

The decomposition process was facilitated by earthworms and fresh organic matters incorporated in the compost bin and above 75% moisture was maintained for free mobility and breathe of the worms. Because worms breathe through their skin, they need appropriate moisture content in the bedding for easy stretching of their body. Then when decomposition properly begins, about a month later, the worms, species of *Eisenia foetida* collected from Ambo Agricultural Research Centre were added into the bedding and they fed on fresh organic matter. Three months later, the important end product vermicompost (the worm casting) was ready for fertilization.

Samples were collected from well decomposed farmyard manure, compost and vermicompost before they were applied to the field. Then their N and P contents were analyzed in the laboratory to determine the rate of application of each treatment, which was based on recommended N equivalent rate for the test crop. The contents of N and P before application in the analyzed samples were 0.78% N and 1.87% P for vermicompost and 0.88% N and 0.68% P for conventional compost, both on 55% dry weight basis and 1.72% N and 0.76% P for farmyard manure on 50% dry weight basis. Manure and compost were applied to the field three weeks before sowing and thoroughly mixed in the upper 15 to 20 cm soil depth. Nitrogen and P fertilizers were applied in the form of Urea and DAP, respectively. To minimize the loss and increase efficiency of N fertilizer half of its rate was applied as a split at planting and the remaining half was side dressed at tillering stage of the crop, whereas all P rates were applied as basal during planting time. The seed was drilled at the recommended seed rate of 125 kg ha^{-1} in row on 25^{th}, 28^{th} and 26^{th} June of 2015, 2016 and 2017, respectively, based on the onset of the main rainy season. All the recommended agronomic management practices were carried out during the crop growth period.

Data collection and analysis

Composite surface soil samples were collected from experimental fields (0-20 cm depth) before treatment application. Similarly, soil samples were also collected after harvest of the crop from each plot and then composited by replication to obtain one representative sample per treatment. The collected samples were analyzed for the determinations of pH, organic carbon (OC), total N and available P. Soil pH was determined with a pH electrode at soil: water of 1:2.5 (w/v) (Carter, 1993). Organic carbon was determined by the method of Walkley and Black (1934) and total N using Kjeldahl method (Jackson, 1958). Available P was determined following the procedures of Bray and Kurtz (1945).

The collected agronomic parameters were grain yield, above-ground total biomass, plant height and spike length (average of 10 plants). Grain and total biomass yields were measured based on plant samples taken from ten central rows (2m by 4m = $8m^2$), plant height (cm) was measured by taking ten randomly selected plants per plot from the soil surface to the tip of the crop at full maturity stage. Grain yield was adjusted to a moisture content of 12.5% before weighing and any forms of statistical analysis. The agronomic data were subjected to analysis of variance (GLM procedure) using SAS statistical computer package (SAS, 2002). The total variability for each trait was quantified using separate and pooled analysis of variance over years and locations using the following model (Gomez and Gomoz, 1984):

$$Tijk = \mu + Ri + Lj + R(L)ij + Fk + LF(jk) + eijk$$

Where T_{ijk} is total observation, μ = grand mean, R_i= is effect of the i^{th} replication, L_j=is effect of the j^{th} location, $F_{k\ =}$ is the effect of the k^{th} fertilizer, LF= is the interaction, and R (L) $_{ij}$ and e_{ijk} are the variations due to random error location, LF $_{(ik)}$ is the interaction of k^{th} location with i^{th} fertilizer and e_{ijk} is the random error location with fertilizer. Duncan multiples range test (DMRT) at 5% probability level was used to detect differences among means. Finally, economic analysis was performed, following CIMMYT (1988).

Partial budget analysis

Relevant data were collected using data collecting formats to conduct a preliminary assessment of economic yield levels. These include mainly the costs of inputs (labor + seed + N fertilizer) and the prices of outputs (yield). The economic analysis was undertaken based on the procedure recommended by CIMMYT (1988). It was analyzed separately by calculating gross benefit (GB), total costs that vary (TCV), net benefit (NB), and the marginal rate of return (MRR) for each treatment. Economic optimum yield levels were identified using preliminary partial budgeting and dominance analysis. Partial budgeting is widely used to better understand the economic implication of adopting new technologies by smallholders (Assefa *et al*., 2015). Barley yields were adjusted downwards by 10% to more closely approximate yields under farmers' condition. The economic analysis was calculated as follows: TVC= the sum of cost of input (N fertilizer price), AGY=grain yield × 10/100; AGY = total grain yield minus adjusted grain yield, GB = adjusted grain yield × total variable cost, NB = gross benefit minus total variable cost, MRR% = change of net benefit divided to change of total variable cost × 100. Three years average market grain price of food barley (ETB 12 per kg grain), farm-gate price of N and P fertilizers (ETB 12 and 15 per kg), respectively and labor for the sprayer valued at ETB 50 per person-day were used.

Results and Discussion

Soil analysis of the experimental sites before sowing

Soil analysis of the experimental sites was presented in Table 2. The analysis of particle size distribution of the surface layers of the experimental field indicated that the soil had a composition of clay (72.5%), silt (11.25%) and sand (16.25 %), which is categorized in to clay. The pH (H_2O) value of the experimental soil was 4.8, which was strongly acidic in reaction. FAO (2000) reported that the preferable pH ranges for most crops and soil productive index are 4 to 8. However, different crops have different requirements. Thus, the pH of the experimental soil is almost within the range for productive soils. The organic carbon and total nitrogen content of the soil before planting were found to be 2.24% and 0.13%, respectively. According to Westerman (1990) rating, soil organic matter content is very low (<1%), low (1.0 to 2.0), medium (2.1 to 4.2), high (4.3 to 6), and very high (>6). The result showed that the organic matter in the soil was medium. Percent total nitrogen (TN %) is rated by Havlin *et al*. (1999) as very low (<0.1), low (0.1 to 0.15), medium (0.15 to 0.25), and high (>

0.25). The result showed that the total nitrogen level in the soil was low for crop production.

The organic carbon content of the soil before planting was found to be 1.26%. Tekalign (1991) described the percentage of carbon content < 0.5, 0.5-1.5, 1.5-3.0, >3.0% as very low, low, moderate and high, respectively. Hence, the result showed that the total amount of carbon was low. The cation exchange capacity of the experimental soil before sowing was 14.6 $cmol_c kg^{-1}$. According to Murphy (2007) rating, the CEC content of the soil before sowing was very low (<6), low (6 to 12), medium (12 to 25), high (25 to 40), and very high (>40). The result showed that the cation exchange capacity of the study areas was medium. The carbon to nitrogen ratio (C/N ratio) was 10.23, which signify a relatively high rate of mineralization and low rate of N immobilization. Normally, agricultural soils have a ratio of 10. The available phosphorus content of the experimental area before sowing was 7.84 mg kg^{-1}. Tekalign (1991) described soils with available P < 10, 11-31, 32-56, >56 ppm as low, medium, high and very high, respectively. Hence, the result showed that the total amount of available soil P level was low.

Table 2. Mean physio-chemical properties of the soil before sowing at 0-20 cm depth

Soil texture			Soil chemical properties					
Clay (%)	Silt (%)	Sand (%)	pH (H_20)	TN (%)	CEC (%)	OC (%)	N/C (Ratio)	Av. P (ppm)
72.5	11.25	16.25	4. 8	0.14	14.6	1.26	10.22	7.84

Note: CL=Clay, CEC=Cation exchange capacity, OC=Organic carbon, TN=Total nitrogen, C/N=Carbon to nitrogen ratio, Av. P=Available phosphorus.

Soil analysis results of the experimental sites after harvesting

The laboratory analysis results of different physico-chemical properties of soil after harvesting is presented in Table 3.The highest pH values of 5.18 and 5.12 were recorded from full doses of vermicompost and compost, respectively . The lowest soil pH (4.06) was recorded from the recommended nitrogen and phosphorus, indicating that inorganic fertilizers such as urea have acidifying effect. The available phosphorus contents recorded from full dose of vermicompost and compost after harvesting were 15.46 and 14.44 ppm, respectively, which were improved to medium due to the addition of organic fertilizers. The average organic carbon and total N contents of the soil after harvesting were 1.55% and 0.23%, respectively (Table 3).

Both organic carbon and total N contents of the experimental soil after harvest were improved due to the application of organic fertilizers, which is in agreement with the findings of other studies (Agegnehu *et al*., 2005). Similarly, Eghball *et al*. (2004) reported that the residual effects of vermicompost and compost applications significantly increased electrical conductivity, pH levels and plant available P and NO_3-N concentrations where the lowest pH and nutrient content were observed on plots not treated with organic fertilizer. Sharma *et al*. (1990) also indicated that the use of organic fertilizer might have made the soil more porous and pulverized, to allow better root growth and development, thereby resulting in higher root cation exchange capacity (CEC). According to Sanchez (1996) the application of organic fertilizer directly influences the availability of native or applied phosphorus. Generally, the above results indicate that the integrated use of nutrient sources have significant improvement in the overall condition of the soil as well as agricultural productivity if best alternative option is adopted in the area.

Table 3. Physico- chemical soil properties of the experimental area after harvesting

Treatments	pH (H_2O)	TN (%)	Av. P (ppm)	OC (%)	Exchangeable bases (meq/100g)			
					Ca	Mg	K	Na
Recom.NP	4.06	0.16	7.24	1.12	12.54	4.36	0.46	0.02
NPS	4.24	0.18	9.17	1.16	11.64	3.48	0.435	0.02
NPSB	4.52	0.24	11.86	1.64	11.88	3.68	0.524	0.03
Vermicompost	5.18	0.26	15.46	1.86	11.72	4.84	0.482	0.02
Compost	5.12	0.28	14.44	1.74	11.65	3.86	0.418	0.02
50% VC + 50% NP	4.84	0.24	12.38	1.42	11.72	4.64	0.463	0.03
50% VC + 50% NPS	4.82	0.24	12.86	1.54	12.42	4.47	0.451	0.024
50% VC + 50% NPSB	4.86	0.26	14.04	1.72	12.63	4.39	0.446	0.02
50% VC + 50% Comp	4.88	0.24	14.24	1.66	11.18	3.86	0.433	0.02
50% Comp + 50% NP	4.76	0.22	12.62	1.58	11.78	4.64	0.428	0.02
50% FYM + 50% NP	4.86	0.24	14.28	1.58	11.82	4.65	0.436	0.03
Mean	**4.74**	**0.23**	**12.59**	**1.55**	**11.91**	**4.26**	**0.45**	**0.022**

Note: Comp = Compost; TN = Total nitrogen; VC = Vermicompost

Response of barley yield and yield components to integrated nutrient application

Analysis of variance over three year cropping seasons showed that the year effect was significant ($p \leq 0.05$ and 0. 01) for plant height, thousand grain weight, grain and biomass yield of food barley (Table 4). The highest mean grain yield (3609.9 kg ha^{-1}) and total biomass (10474kg ha^{-1}) were obtained in 2017 cropping season. Similarly, the highest mean plant height (108.6 cm) and thousand grain weight (40.04 gm) were recorded in 2017 growing season. This suggests that year 2017 was favorable cropping season for barley production in terms of growing factors, particularly climatic factors such as rainfall amount and distribution.

The combined analysis of variance revealed that the effect of integrated organic and inorganic fertilizers was highly significant ($p<0.01$) for plant height, spike length, grain yield and total biomass of food barley and significant ($p<0.05$) for days to physiological maturity and thousand grain weight. This study clearly indicated that the productivity of barley was significantly affected by the different treatments, where applications of inorganic and organic nutrient sources either alone or in combination significantly ($p<0.05$) improved grain yield, total biomass, plant height and spike length of barley (Table 4). The highest barley spike length of 8.3cm, grain yield of 4277 kg ha^{-1} and thousand grain weight of 40.1gram were obtained from the application of 50% vermicompost (VC) and 50% N and P. However, the application of recommended N and P fertilizers resulted in the highest total biomass yield of 9937 kg ha^{-1} and plant height of 111.9 cm. The rest set of the treatments gave inferior results under all tested parameters and the separate application of compost or vermicompost without inorganic fertilizer gave the lowest grain yield (Table 4).

Table 4. Response of integrated nutrient source application on barley yield and yield components

Factor	GY (kg ha^{-1})	BY(kg ha^{-1})	Pht (cm)	SL (cm)	DPM	TGW(gm)
Year						
2015	3310.7^{b}	8866^{b}	102.4^{ab}	6.9	134.9	38.9^{ab}
2016	3095.9^{c}	78o9^{c}	98.5^{ab}	7.4	138.4	36.8^{ab}
2017	3609.9^{a}	10474^{a}	108.6^{a}	7.2	136.8	40.04^{a}
LSD (0.05)	281.4	882.9	2.4	ns	ns	0.91
Treatment combinations						
Recommended NP	3911.5^{b}	9937.2^{a}	111.9^{a}	7.56^{b}	134.3^{bc}	37.1^{bc}
NPS	3782.6^{bc}	9381.3^{abc}	105.9^{cd}	6.71^{cd}	134.2^{bc}	37.6^{bc}
NPSB	3494.1^{cd}	9089.1^{abc}	106.7^{bcd}	6.8^{cd}	131.0^{c}	36.9^{c}
Vermicompost	2992.1^{e}	7465.7^{de}	104.5^{cd}	6.8^{cd}	140.1^{ab}	39.2^{ab}
Compost	2889.7^{e}	6792.9^{e}	101.7^{e}	6.8^{cd}	140.5^{a}	39.9^{a}
50% VC + 50% NP	4277.1^{a}	9557.8^{ab}	109.2^{b}	8.3^{a}	137.9^{ab}	40.1^{a}
50% VC + 50% NPS	3390.0^{d}	8452.4^{bcd}	105.9^{cd}	7.1^{c}	136.3^{abc}	39.9^{abc}
50% VC + 50% NPSB	3438.0^{d}	8261.2^{cd}	105.8^{cd}	7.1^{c}	135.2^{abc}	38.9^{abc}
50% VC + 50% Comp	2741.6^{e}	6964.3^{e}	104.2^{de}	6.5^{d}	136.6^{abc}	38.0^{abc}
50% Comp + 50% NP	3797.2^{bc}	9490.3^{ab}	107.4^{bc}	7.8^{b}	136.1^{abc}	37.4^{bc}
50% FYM + 50% NP	3748.1^{bc}	9404.0^{abc}	106.8^{bcd}	6.9^{c}	136.6^{abc}	38.2^{abc}
DMRT	276.4	1050.8	2.648	0.436	5.197	1.87
CV (%)	12.9	20.04	4.09	10.09	6.27	8.01

*, ** = significant at P< 0.05 and P< 0.001, respectively; ns= not significant. Means in a column with the same letter are not significantly different from each other; Pht = plant height; SL= spike length; DPM= days to physiological maturity, TGW= thousand G weight, BY= biomass yield; GY= grain yield

Therefore, the results of this study clearly indicated that it is possible to fairly increase barley yield through the combined application of organic and inorganic nutrient sources rather than applying nutrient from one source. In line with the current results of this study, previous research findings indicated that the integrated soil fertility management treatments containing both organic and inorganic nutrient sources significantly improved grain yields of crops (Tekalign *et al.*, 2001; Agegnehu *et al.*, 2005; Girma *et al.*, 2017) under farmers' field condition. They could be considered as alternative options for sustainable soil and crop productivity in the highlands of Ethiopia. Moreover, the crop has responded differently to application of N and P fertilizers on different soil types.

Table 5. Marginal analysis of organic and inorganic fertilizer effects on barley 2015-2017

Treatments	GY ($kgha^{-1}$)	Adj. GY ($kgha^{-1}$	Fert cost	Labor cost	TVC	Gross B	Net Benefit	MRR (%)
Recom.NP	3911.5	391.15	3520.4	0	3810	42244.2	38434.2	
NPS	3782.6	378.26	3404.3	0	4260	40852.1	36592.1	D
NPSB	3494.1	349.41	3144.7	0	5000	37736.3	32736.3	D
Vermicompost	2992.1	299.21	2692.9	1500	1500	32314.7	30814.7	54.9
Compost	2889.7	288.97	2600.7	1000	1000	31208.8	30208.76	121.2
50% VC + 50% RNP	4277.1	427.71	3849.4	750	2655	46192.68	43537.7	805.4
50% VC + 50% NPS	3390	339	3051	750	2880	36612	33732	D
50% VC + 50% NPSB	3438	343.8	3094.2	750	3250	37130.4	33880.4	40.1
50% VC + 50% Comp	2741.6	274.16	2467.4	750	750	29609.3	28859.28	200.9
50% Comp + 50% NP	3797.2	379.72	3417.5	500	2405	41009.8	38604.8	588.9
50% FYM + 50% NP	3748.1	374.81	3373.3	250	2155	40479.5	38324.5	112.1

The economic analysis further revealed that the application of 50% vermicompost as N equivalent plus 50% N and P fertilizers resulted in the highest marginal rate of the return (MRR) of 805.4% (Table 5) suggesting for one ETB invested in wheat production, the producer would collect additional ETB 8.05 after recovering his investment. Since the MRR assumed in this study was 100%, the treatment with application of 50% of the recommended N as vermicompost and 50% of the recommended NP gave an acceptable MRR. Therefore, the application 50% VC (based on N equivalent rate) and 50% N and P fertilizers mentioned above was found to be economical for the production of food barley on Nitisols of the study area and similar locations in the central highlands of Ethiopia.

The study demonstrated that the three years results were significantly different from each other most probably attributed to seasonal differences and the carry over effect of the previous year fertilizer application during the experimental period. The integrated use of organic and inorganic fertilizers plays a critical role in a both short-term nutrient availability and longer- term maintenance of soil organic matter and sustainability of crop productivity in most smallholder farming systems in the tropics. The effects of organic nutrient sources such as farmyard manure and compost are not immediate as inorganic nutrient sources, but their effects are long-lasting and sustainable.

Interventions to increase nutrient use efficiency and reduce NP losses to the environment must be accomplished at the farm level through a combination of improved technologies and carefully crafted local policies that promote the adoption of improved fertilizer management practices while sustaining yield increases. Improved fertilizer management plays an important role in the global quest for increasing nutrient use efficiency. The results of soil analysis after harvesting revealed that the application organic fertilizer improved soil pH, OC, total N, available P and exchangeable cations. The three year result showed that the integrated application of organic and inorganic fertilizers improved productivity of barley as well as the fertility status of the soil. Applications of organic fertilizers not only improve the nutrient content of soils, but also the physical and biological condition of soils.

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