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RESEARCH ARTICLE

INTEGRATED USE OF ORGANIC AND INORGANIC FERTILIZER IMPROVES MALT BARLEY YIELDS, QUALITY AND SOIL PROPERTIES ON NITISOLS OF CENTRAL HIGHLANDS OF ETHIOPIA

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ABSTRACT: Declining soil fertility is one of the major problems causing reduction of malt barley yield and quality in Ethiopia. A field experiment was carried out to determine the effect of organic and inorganic fertilizer application on yield and yield components of malt barley at Welmera district. The experiment was laid out in randomized complete block design with three replications. Analysis of variance showed significant difference among treatments for most yield and yield components. Combined application of 50% vermicompost and 50% recommended NP resulted in the highest plant height (103.5 cm), spike length (7.9 cm), biomass yield (12793 kg/ha) and grain yield (3558.5 kg/ha). Application of organic fertilizer improved soil pH, OC, total N and available P of the soil. The highest net benefits (41843 Birr/ha) with marginal rate of return (14802.1%) was also recorded for the same treatment. Therefore, the application of half recommended rate NP together with half of vermicompost, based on N equivalence is recommended to obtain grain yield and improve soil fertility.

Key words/phrases: Compost, FYM, Malt barley, Nitrogen, Phosphorus, Vermicompost.

INTRODUCTION

In Ethiopia, barley is ranked fifth among cereals based on area of production but third based on yield per unit area. It covers 7.56% of the land under grain crop cultivation with national average yield of 1.96 t/ha (CSA, 2017). The potential yield goes up to 6 t/ha (Habtamu Admas *et al*., 2015) indicating a productivity gap of about 4 t/ha. If this yield gap can be narrowed down, Ethiopia would fall among the major barley producing countries. The application of organic and chemical fertilizers is essential for barley production and to replenish the soil nutrient depletion. Although Ethiopia has favourable environment and considerable market opportunities for increased production of high-quality malting barley, its production has not been expanded enough to benefit most barley growers, malt factories

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and breweries (Berhane Lakew and Zewdie Bishaw, 2016).

The most important factors that reduce yield of barley in Ethiopia are soil nutrient depletion /poor soil fertility management, soil acidity problem and unbalanced organic and inorganic nutrient application (ICARDA, 2008). Low soil fertility is worsened by low input, continuous cultivation and overgrazing (FAO, 2006). This problem can be ameliorated by application of chemical fertilizers. However, the high cost cannot make chemical fertilizers affordable to the resource poor small holder farmers in the country. This calls for efficient use of organic fertilizer sources, crop residues and other organic sources along with the inorganic fertilizers in an integrated soil fertility management (ISFM) (IFPRI, 2010).

However, information on the integrated uses of organic and mineral amendments, their effects on yield and grain quality of malt barley, and soil chemical properties in the highland of Ethiopia are scarce. This field experiment was, therefore, conducted to evaluate the effect of appropriate integrated nutrient management on sustainable production of malting barley production at Welmera district, Ethiopia.

Therefore, the objectives of the current study were to investigate the effects of the combined uses of organic and mineral amendments on the yield and quality of malting barley, on selected soil chemical properties.

MATERIALS AND METHODS

Description of the study site

The experiment was conducted on selected farmer's field at Welmera district (Telecho and Robgebeya kebele) in West Showa Zone, Oromia Region, during 2015–2017 main growing season (Fig. 1). The experimental site was located at 30 km west of Addis Ababa along the Ambo road. Geographically, the district is located at 8°50′ to 09°20′N and 38°20′ to 38° 40′E at an altitude of 2400 metres above sea level. Its mean annual rainfall was 1044 mm. Mean maximum and a minimum temperature were 22 and 6.1°C, respectively and with mean relative humidity of 60.6% (HARC, 2017) (unpublished data). The main rainy season is from June to September and accounts for 70% of the annual rainfall. The environment is seasonally humid and the major soil type is Nitisols with average pH of 5.24, OM content of 1.8%, TN content of 0.17% and phosphorus 4.55 mg/kg (IUSS, 2006).

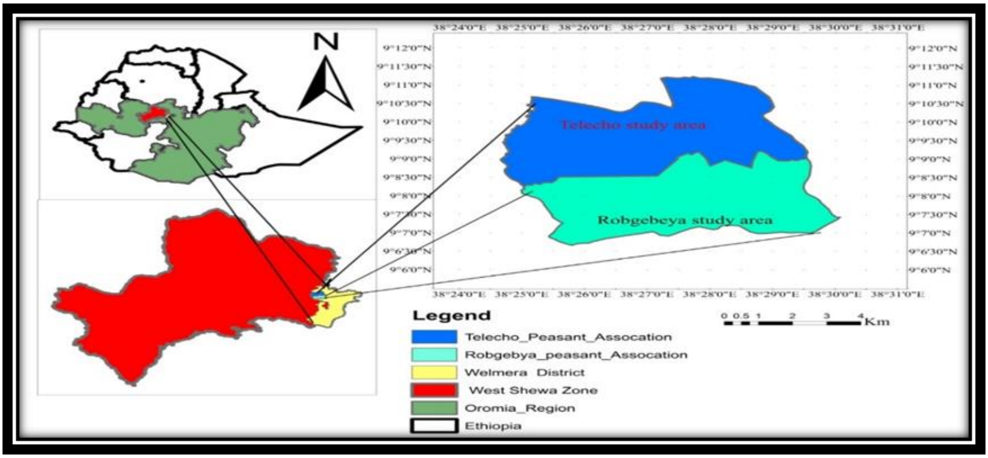

Fig. 1. Map of the study area.

Treatment set up and experimental design

The experiment had eleven treatments, which consisted of sole and various combinations of mineral fertilizers (NP, NPS and NPSB) and organic amendments (compost and vermicompost). The treatments were:

T1 = Recommended NP

T2 = NPS (100 kg/ha)

T3 = NPSB (100 kg/ha)

T4 = Recommended vermicompost (4.2 ton ha-1) based on N equivalency

T5 = Recommended compost (8.4 ton ha-1) based on N equivalency

T6 = 50% recommended VC based on N equivalency + 50% NP

T7 = 50% recommended VC based on N equivalency + 50% NPS

T8 = 50% recommended VC based on N equivalency + 50% NPSB

T9 = 50% recommended VC + 50% compost based on N equivalency

T10 = 50% recommended comp based on N equivalency + 50% NP

T11 = 50% recommended FYM based on N equivalency + 50% NP

These treatment combinations were laid down in Randomized Complete Block Design (RCBD) with three replications consisting of a total of 33 experimental plots. The experimental plot size was 3 m x 2.4 m (7.2 m^2) and test crop malt barley (Var. HB 1847) was used.

Preparation of compost, farmyard manure (FYM) and vermicompost

Compost was prepared by pit method from 30% faba bean, 20% barley crop residues, 30% animal manure, 10% green leaves, 5% ash and 5% forest soil, FYM was made of fresh cow dung, urine and organic bedding materials for dairy cows, and dried for one month in the shade while 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. The raw materials were put up in layers in the following sequence according to Suparno *et al*. (2013):

1. A layer of crop residues/green plants (20 cm) = 60%
2. A layer of manure (animal dung, sheep manure) (5–10 cm) = 30%
3. A layer of topsoil/ash (2–4 cm) = 10%

The decomposition process was facilitated by earthworms and fresh organic matters incorporated in the compost bin and above 75% moisture was maintained for free motility and breathing 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 began, 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 use as fertilizer.

Samples were collected from well decomposed farmyard manure, compost and vermicompost before they are 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 1.06% N and 1.68% P for vermicompost, 0.84% N and 0.88% P for compost both on 55% dry weight basis and 1.04% N and 0.91% P for farm yard manure on 50% dry weight basis.

Experimental procedures

The experimental fields were cultivated by oxen-drawn traditional plough to the depth of 20 cm on the farmer's holding during the main season. In accordance with the specifications of the design, a field layout was prepared and each treatment was also assigned randomly to experimental units within a block. Urea as N source was applied at the rate of 23 kg N ha^{-1} for half rate recommended and 46 kg N ha^{-1} for full dose recommended.

Split application of nitrogen was used. Half of nitrogen was applied at planting time and the remaining half at tillering stage of the crop after weeding. This application was done during light rainfall to avoid losses of N through leaching. Compost and vermicompost were applied as dry matter, uniformly spread and incorporated in the top 15 cm soil layer by hand hoe one month prior to planting. All experimental plots at each site were seeded with two-row malting barley (Var. HB 1847) at the recommended seeding rate of 125 kg ha^{-1}. Sowing was conducted in the 3rd to 4th week of June. Seeds were drilled by hand at 0.20 m spacing between rows for all sites in the plot size of 2.6 m × 4 m. The spacing between plots and replications was 0.5 and 1 m, respectively. Weeds were controlled manually by hand weeding removal. Insecticides and "tilt" was applied to control shoot fly.

Soil sampling and analysis

The soil samples were collected two times. First a three-representative soil sample was collected at the depth of 0–20 cm with auger before application of the treatment, the second after harvesting of the treatments. During this time, eleven composite soil samples were collected from each experimental plot to investigate the effect of organic and inorganic fertilizer on improvement of soil characteristics. 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 ratio of 1:2.5 (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) and exchangeable Potassium (K) was extracted by ammonium acetate and determined using flame photometer as described in Baker and Suhr (1982).

Data collection and measurements

The measurements of yield attributing factors were taken at physiological maturity of the crops prior to harvest. Days to heading (50%), days to physiological maturity (90%), and plant height and spike length of barley were recorded from each plot. The test crop was harvested from the net plot areas manually using sickle at the ground level and dry matter yield of the above ground biomass was determined. Grain moisture content was determined and grain yield was adjusted to 12.5% moisture content. Harvest index (%) was calculated as the percentage ratio of grain yield to air dried total above ground biomass yield. Thousand seeds weight were determined by using seed counter and weighting 1000 seeds sample taken from each barley plot. Harvest index was calculated by dividing grain yield to the total above ground biomass yield and expressed in percentage.

$$HI = GY/BY * 100$$

whereas GY=Grain yield and BY=Biomass yield The number of grain was counted by grain counter machine and the thousand counted grain was weighed and taken as thousand kernel weight.

Grain moisture and hectoliter weight was determined on dockage free samples using a standard laboratory hectoliter weight apparatus (grain analysis computer (GAC) 2100) as described in the AACC (2000) method no 55–10. Protein content is the major quality parameter of malting barley and it was determined with a near infrared reflectance spectrometer (Foss NIRS-500, Foss GmbH, Rellingen, Germany). Germination energy was determined taking one hundred barley grains which were spread on wetted (4 ml distilled water) filter paper lined on Petri dishes (90 mm) and allowed to germinate at nearly 100% relative humidity set at a temperature of 16°C germination cabinet for three days as described in Analytica EBC (1998) method 3.6. The Petri dishes were observed every day and the numbers of germinated seeds were recorded. After one day of seed setting in Petri dishes, few of the seeds were terminated. Within three days after seed setting in Petri dishes maximum number of seeds were germinated. A seed was considered to be germinated as seed coat ruptured, plumule and radicle came out and were >2 mm long.

Germination energy is the total number of grains that germinate over 72 h of incubation under specified conditions (Woonton *et al*., 2005) or percentage of seeds germinated at 72 h (Bamforth and Barclay, 1993). Sieving test (grain size): Hundred grams of the grain sample was placed at the top of the sieve (>2.8 mm, >2.5 mm, >2.2 mm and <2.2 mm sieve sizes) and the grain was sieved into four fractions within five minutes. The four fractions were weighed at each sieve site. Grains were size graded using slotted sieves (2.8, 2.5 and 2.2 mm apertures) following the standard procedure of the Holeta

Research Centre micro-malt laboratory.

Analysis of variance

Analysis of variance was carried out according to Gomez and Gomez (1984) using statistical analysis software (SAS, 2001). Mean separation was computed using Least Significance Difference (LSD) at 5% probability level (Steel and Torrie, 1986). Simple correlation was generated to examine the relationship between different yield and yield components of food barley using the same software.

Economic analysis

For economic evaluation, partial and marginal budget analyses were used based on the local market price of barley yield and fertilizer cost as described in CIMMYT (1988). The economic analysis was performed to investigate the economic feasibility of the treatments for malt barley production. The average yield was adjusted downwards by 10% to reflect the difference between the experimental plot yield of and the production yield by farmers. Hence, the partial budget, dominance and marginal rate of return were calculated. The partial budget was calculated using an average yield that was adjusted downwards by 10%, because we assumed that farmers would get ~10% less yield than what is achieved on an experimental site. The average open market price for barley (18 Ethiopian Birr (ETB) per kg or 0.81 US$/kg) and the official prices for N (urea) and P (DAP) were used for the analysis (urea-N: 0.54/0.47 = 1.15 US$/kg, DAP-P: 0.67/0.24 = 2.79 US$/kg). The total variable costs were calculated from the cost of urea-N and DAP-N applied. The cost of organic fertilizer was not included because organic fertilizer is usually produced from waste materials on the farm, and there is a limited market to sell organic fertilizer.

A dominance analysis was used to indicate the most economically viable options. This was done by arranging the treatments according to increasing total variable costs. The net benefit for each treatment was calculated by subtracting the total variable costs from the revenue provided by the crop. If the net benefit of a treatment was less than that of a treatment with lower total variable costs, then the treatment was considered to be dominated, and the treatment with the higher total variable costs and lower net benefit was rejected. For a treatment to be considered a worthwhile option for farmers, the minimum acceptable marginal rate of return (i.e., the gain achieved by a treatment using higher investment over one with a lower investment, expressed as a percentage of the difference in the investment cost) should be over 50% (CIMMYT, 1988). However, the minimum acceptable marginal rate of return is assumed to be 100% in this study according to Amanuel Gorfu *et al.* (1991).

RESULTS AND DISCUSSION

Effects of organic and inorganic fertilization on soil chemical properties

The laboratory results of the analysis of the selected physico-chemical properties of the soil are presented in Table 1. The pH (H_2O) mean value of the soils of the experimental site was 4.9, which was classified as strongly acidic, 4.5 to 5.5, according to the current classification of Ethiopian soils (Ethio SIS, 2013). The mean value of the soil organic carbon for the study area was 1.89, which was within the high range of the classification. Total nitrogen (TN) mean value of the soil was medium (0.17). The mean value of the available phosphorus for the experimental area was 5.11, which was very low (Bashour and Saegh, 2007). The mean value of the cation exchange capacity of the experimental site was 15.64 cmol kg^{-1}, which was medium (Hazelton and Murphy, 2007).

Table 1. Effects of organic and inorganic fertilization on soil chemical properties of the sampling site.

Treatment	Soil pH	OC (%)	TN (%)	Avi. P (mg/kg)	CEC (Cmol (+) kg^{-1}soil)
Recom.NP	4.65	1.83	0.16	5.56	15.85
NPS (100 kg /ha)	4.96	1.84	0.15	5.91	14.77
NPSB (100 kg /ha)	4.98	1.95	0.16	3.98	15.76
Vermicompost (4.2 ton ha^{-1})	5.08	1.83	0.18	4.65	16.85
Compost (5.5 ton ha^{-1})	5.00	1.83	0.17	5.51	17.73
50% VC + 50% NP	4.81	1.95	0.18	5.99	14.71
50% VC + 50% NPS	4.98	1.75	0.18	4.90	15.72
50% VC + 50% NPSB	4.87	1.93	0.17	4.76	16.74
50% VC + 50% Comp	4.8	1.95	0.18	5.14	16.88
50% Comp + 50% NP	4.87	1.95	0.18	4.67	14.77
50% FYM + 50% NP	4.87	1.95	0.17	5.16	15.82
Mean	4.90	1.89	0.17	5.11	15.96

VC=4.2 ton ha-^{1}, Comp=5.5 ton ha^{-1}, FYM=4.4 ton ha^{-1} were used

Effect of integrated organic and inorganic fertilizer on phenology and growth of malt barley

The data showed that days to 50% heading was highly and significantly ($p<0.001$) affected by integrated application of organic and inorganic fertilizers (Table 2). The delayed in days to 50% heading (77.3 days) was recorded from full application of vermicompost alone and earliness to attain days to 50% heading (72.2 days) at full dose application of NPS treatment. The days to 90% physiological maturity was significantly ($p<0.05$) affected by different organic and inorganic fertilizer rates. The result showed that longest days for 90% physiological maturity was recorded from application of vermicompost and the lowest and earliness to attain days to 90% physiological maturity was recorded from the treatment application of NPS fertilizer.

The applications of organic and inorganic nutrient sources either alone or in combination had a significant ($p<0.05$) effect on parameters such as plant height and spike length of malt barley. The highest barley plant height and spike length (103.5 cm and 7.85 cm) were obtained from the application of 50% VC and 50% N and P, respectively. Similarly, the lowest value of plant height and spike length (95.1 cm and 7.25 cm) was obtained from sole application of compost (Table 2). This result is in line with the finding of Girma Chala and Zeleke Obsa (2019) who reported that combined application of 50% compost and 50% of inorganic nitrogen and phosphorus fertilizers increased plant height and spike length of wheat.

Table 2. Response of organic and inorganic fertilizers on phenology and growth of malt barley.

Treatments	**HD**	**DPM**	**PH (cm)**	**SL (cm)**
Recom.NP	72.8^{ef}	130.4^{bc}	102.2^{ab}	7.57^{abc}
NPS (100 kg/ha)	72.2^{f}	129.7^{c}	102.9^{ab}	7.62^{abc}
NPSB (100 kg/ha)	72.8^{ef}	131.0^{abc}	100.6^{ab}	$7.60a^{bc}$
Vermicompost (4.2 ton ha^{-1})	77.3^{a}	132.9^{a}	98.6^{ab}	7.317^{bc}
Compost (5.5 ton ha^{-1})	76.1^{b}	132.3^{ab}	95.1^{b}	7.25^{c}
50% VC + 50% NP	76.2^{b}	132.3^{ab}	103.5^{a}	7.85^{a}
50% VC + 50% NPS	73.8^{de}	129.8^{c}	99.5^{ab}	7.57^{abc}
50% VC + 50% NPSB	75.1^{bc}	131.8^{ab}	100.4^{ab}	7.60^{abc}
50% VC + 50% Comp	75.8^{b}	131.9^{ab}	100.8^{ab}	7.53^{abc}
50% Comp + 50% NP	$75.0b^{cd}$	132.5^{a}	99.2^{ab}	7.70^{ab}
50% FYM + 50% NP	74.4^{cd}	132.1^{ab}	102.5^{ab}	7.50^{abc}
LSD (0.05)	1.2	1.9	6.82	0.38
CV (%)	1.8	1.8	8.4	6.2

HD=heading date, DPM=Date of physiological maturity, PH=plant height, SL=Spike length, VC=4.2 ton ha^{-1}, Comp=5.5 ton ha^{-1}, FYM=4.4 ton ha^{-1} were used.

Grain yield and yield component of malt barley

Table 3 showed application of organic and inorganic fertilizers significantly increased yield and yield components of malt barley ($p<0.001$) (Table 3). The application of half of 50% VC with 50% NP gave the highest grain yield 3558.5 kg ha^{-1} compared to grain yield of 3111.6 kg ha^{-1} obtained from the application of recommended nitrogen and phosphorus fertilizers (NP). This indicates that the positive synergistic effect of applied 50% VC + 50% recommended NP fertilizers on productivity of the crop.

The application of integrated organic and inorganic nutrient sources was sufficient to increase grain yield of barley significantly (Table 3). Similarly, Getachew Agegnehu *et al*. (2014) found that application of all combinations of fertilizers, significantly increased barley yield over the application of organic fertilizers alone (compost and vermicompost).

Therefore, this study has clearly indicated that it is possible to properly produce barley through integrated nutrient application approach, rather than applying nutrient from one source alone. Other studies also showed that integrated application of organic and inorganic forms of fertilizers significantly increased in yield of barley under field conditions (Wondimu Bayu *et al*., 2007; Girma Chala and Zeleke Obsa, 2019).

Table 3. Response of organic and inorganic fertilizers on yield and yield component of malt barley.

Treatments	**GY (kg/ha)**	**BY (kg/ha)**	**TKW**	**HI (%)**
Recom.NP	3111.6^{ab}	12195^{ab}	36.4^{de}	26.0^{ab}
NPS (100 kg/ha)	2932.1^{bc}	11162^{abcd}	35.6^{e}	26.7^{ab}
NPSB (100 kg/ha)	2913.2^{bcd}	10780bcde	35.7^{e}	27.4^{ab}
Vermicompost (4.2 ton ha^{-1})	2360.3^{de}	9326^{cde}	39.1^{ab}	26.2^{ab}
Compost (5.5 ton ha^{-1})	2316.6^{e}	9051^{e}	39.6^{a}	26.3^{ab}
50% VC + 50% NP	3558.5^{a}	12793^{a}	37.5^{bcd}	28.2^{ab}
50% VC + 50% NPS	2669.8b^{cde}	10958^{abcde}	37.3^{cde}	24.7^{b}
50% VC + 50% NPSB	2961.3b^{c}	11291^{abc}	39.5^{a}	26.2^{ab}
50% VC + 50% Comp	2408.5^{cde}	9326^{cde}	39.7^{a}	26.6^{ab}
50% Comp + 50% NP	3210.6^{ab}	10918^{abcde}	38.0^{abcd}	31.0^{a}
50% + 50% NP	2770.2b^{cde}	10303^{bcde}	38.6^{abc}	27.4^{ab}
LSD (0.05)	290.2	1099	1.7	3.3
CV (%)	12.65	12.67	5.6	15.2

VC=4.2 ton ha^{-1}, Comp=5.5 ton ha^{-1}, FYM=4.4 ton ha^{-1} were used. GY=Grain yield, BY=Biomass yield, TKW= Total kernel weight

The highest TKW (39.7 g) was obtained from the integrated application of 50% vermicompost with 50% compost based on N equivalence as compared to sole application of inorganic fertilizer (Table 3). The lowest TKW recorded at application of NPS fertilizer might be due to sole the application of inorganic fertilizer which was immediately or easily available to plants. The harvest index of barley was significantly ($p<0.001$) influenced by the integrated application of recommended (NP) rate of organic and inorganic fertilizers (Table 3). The highest harvest index (31%) was obtained with the integrated application of 50% Comp + 50% NP (30/34.5 kg/N/P ha) as compared to other treatments.

Quality parameters

Hectolitre weight

The highest hectolitre weight (71.39 kg hl^{-1}) was recorded from half doses application of vermicompost (2.1 ton ha^{-1}) with half dose of recommended NP followed by half doses application of compost (2.75 ton ha^{-1}), half dose of recommended NP and the lowest (64.18 kg hl^{-1}) hectolitre weight was recorded from application of full dose of compost (5.5 ton ha^{-1}) treatment (Table 4). Low values of HLW indicated poor grain filling treatment. This may be due to late heading leading to grain shriveling that can impair specific weight through reduced packing efficiency (Gooding and Davies, 1976). Biruk Gezahegn and Demelash Kefale (2016) argued that slight increase in specific weight happened in response to nitrogen application. The hectolitre range (64–71 kg hl^{-1}) was within the standards set for hectolitre weight by National Standard Authority ranged from 60 to 65 kg hl^{-1} (Minale Liban *et al*., 2011), and that of the acceptable test weights (hectolitre weight) for malt barley (66.1–72.8 kg hl^{-1}) (Graham *et al*., 2014).

Grain protein content

The highest (13.42%) grain protein content was recorded from the treatment with full dose of vermicompost alone (5.5 ton ha^{-1}) whereas the lowest grain protein content (10.65%) was obtained from combined application of vermicompost and half dose of recommended NP (2.1 ton ha^{-1}). According to the Ethiopian Standard Authority and Asella Malt Factory (AMF), the protein level of the raw barley quality standard for malt should be between 9–12% (EQSA, 2006). The current study showed that grain protein contents were within the acceptable range for all treatments, except for the treatments with full dose of vermicompost and compost alone.

Grain moisture content (%)

The highest grain moisture content (12.38%) was recorded from the application of full dose of compost (5.5 ton ha^{-1}), whereas the lowest grain protein content (10.63%) was obtained from alone application of recommended nitrogen and phosphorus fertilizers. Fox *et al*. (2003) reported that the maximum reasonable industrial specification of malt barley moisture content for safe storage is 12.5%, whereas the EBC standard, a moisture content of 12–13.5% is accepted.

Table 4. Effect of organic and inorganic fertilizers on malt barley quality parameters.

Treatments	HLW (kg/ha)	MC (%)	GS (%)	GPC (%)	GE (%)
Recom.NP	68.76	10.63	91.53	11.90	96.27
NPS (100 kg/ha)	66.55	11.28	94.94	11.79	95.62
NPSB (100 kg/ha)	65.35	11.44	91.92	11.83	95.16
Vermicompost (4.2 ton ha^{-1})	65.02	12.25	90.91	12.42	98.31
Compost (5.5 ton ha^{-1})	64.18	12.38	92.73	12.28	97.78
50% VC + 50% NP	71.39	12.04	95.09	10.65	96.28
50% VC + 50% NPS	69.62	11.73	96.74	11.55	96.18
50% VC + 50% NPSB	68.95	11.42	84.48	11.05	92.06
50% VC + 50% Comp	68.64	12.22	93.47	11.34	96.38
50% Comp + 50% NP	70.28	12.18	93.34	11.06	95.72
50% FYM + 50% NP	68.26	12.32	94.62	11.22	96.24
Mean	67.91	11.81	92.71	11.55	96.00

HLW=Hectoliter weight, MC=Moisture content, GS=Grain size, GPC=Grain protein content, GE=Germination energy

Germination energy

The highest germination energy (98.31%) was recorded from the application of full dose of vermicompost (4.2 ton ha^{-1}) whereas the lowest grain protein content (92.06%) was obtained from application of half recommendation of nitrogen, phosphorus, sulfur and boron (NPSB) fertilizers with half dose of vermicompost based on N equivalence ratio. A minimum of 95% germination on a three days germination test is an absolute requirement. Any factor which interferes with the uniformity of germination or reduces the vigour of grain growth during processing will reduce the quality of malts produced (Woonton *et al.*, 2005).

Economic analysis feasibility

As indicated in Table 5, the net farm benefit was calculated taking possible field variable costs and all benefits (grain yield). The maximum farm net benefit (41,843 ETB/ha) was recorded at 50% of N/P_2O_5 rates of 30/34.5 kg ha^{-1} combined with 50% (2.1 ton ha^{-1}) vermicompost fertilizer. Therefore, it is safe to recommend that application of half of the recommended rate of NP with half of vermicompost fertilizers based on N equivalence can maintain soil fertility, reduce cost of inorganic fertilizers and increase productivity.

Table 5. The effect of integrated use of organic and inorganic fertilizers on partial budget and marginal rate of return (MRR) for malt barley production.

Treatment	**GY (kg/ha)**	**AD GY (kg/ha)**	**GFB (EBT ha^{-1})**	**TVC (EBT ha^{-1})**	**NB (EBT ha^{-1})**	**MRR (%)**
Recom.NP	3112	2800	39206	3701.7	35504.5	
NPS (100 kg/ha)	2932	2639	36944	3040.16	33904.3	241.9
NPSB (100 kg/ha)	2913	2622	36706	3072.2	33634.1	D
Vermicompost (4.2 ton ha^{-1})	2360	2124	29740	3308.8	26430.9	D
Compost (5.5 ton ha^{-1})	2317	2085	29189	2889.1	26300.1	31.2
50% VC + 50% NP	3559	3203	44837	2994.1	41843.0	1480.2
50% VC + 50% NPS	2670	2403	33639	3112.4	30527.08	D
50% VC + 50% NPSB	2961	2665	37312	4271.5	33040.86	216.9
50% VC + 50% Comp	2409	2168	30347	2866.0	27481.1	395.6
50% Comp + 50% NP	3211	2890	40454	2925.2	37528.4	D
50% FYM + 50% NP	2770	2493	34905	3504.8	31399.8	D

Cost of NPS=13.26 ETB/kg, Cost of NPSB=13.58 ETB/kg, Cost of urea=13.09 ETB/kg, price of vermicompost, compost and FYM is 0.71, 0.5 and 0.5 ETB/kg, respectively and VC=4.2 ton ha^{-1}, Comp=5.5 ton ha^{-1}, FYM=4.4 ton ha^{-1} were used

CONCLUSION

Information on crop response to integrated use of inorganic and organic fertilizer is very important to come up with profitable and sustainable crop production. The application of 50% vermicompost and 50% inorganic NP fertilizer resulted in economically optimum grain yield and yield components of malt barley. Therefore, based on cost benefit analysis, the treatment of half of the recommended inorganic NP rate and half of the recommended vermicompost was economically feasible for barley production in the study area.

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