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Combination 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 yield and quality reduction of malt barley production in Ethiopia. For this reason, the 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 significance difference among treatment for most yield and yield component. The highest plant height (103.5 cm) and spike length (7.9 cm) and the highest biomass yield (12793 kg/ha) and grain yield (3558.5kg/ha) were recorded from the combination of 50% vermicompost with 50% of recommended NP. The highest net benefits (41843 Birr/ha) with marginal rate of return (14802.1%) was recorded at 50% N/P_2O_5 rates of 30/34.5 kg ha^{-1} combined with 50% (20.5qu ha^{-1}) vermicompost fertilizer. Therefore, to maintain soil fertility and to increase yield productivity, application of half of recommended rate of NP with half of vermicompost fertilizers based on N equivalence is recommended as the best management option and economically feasible.

Key words: Compost・FYM・Malt Barley・Nitrogen・Phosphorus・Vermicompost

INTRODUCTION

In Ethiopia, barley is ranked fifth of all 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 a yield of 1.96t ha^{-1} [1]. Whereas the potential yield goes up to 6 t/ha [2] indicating a productivity gap of about 4 tones/ha. Filling this yield gap would make Ethiopia among the major barley producing countries. 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 [3]. Among the most important constraints that threaten barley production in Ethiopia is poor soil fertility. Low soil fertility is worsened by low input, continuous cultivation and overgrazing [4].

To replenish the soil nutrient depletion, application of organic and chemical fertilizers is essential for barley production as well as soil fertility improvement. Ethiopia has favorable environment and considerable market opportunities for increased production of high quality malting barley; however, its production has not been expanded enough to benefit most barley growers, malt factories and breweries [5]. However, high cost of chemical fertilizers coupled with the low affordability of small holder farmers are the biggest problem for chemical fertilizer use. Moreover, the current prevailing high price and lack of proper supply system of inorganic fertilizers calls for more efficient use of organic fertilizer sources and crop residues and other organic sources along with the inorganic fertilizers to sustain the yield levels [6]. Researchers suggested that nutrient availability can be improved by nutrient application such as inorganic or organic fertilizer or their combination. Therefore, integration of organic and inorganic sources may improve and sustain crop yields without degrading soil fertility status [7]. Increasing the inputs of nutrients has played a major role in increasing the supply of food to a continually growing population. However, over application of inorganic fertilizers causes inefficient use, large losses and imbalances of nutrients. Accordingly, judicious use of integrated organic and inorganic nutrient is best alternative to supply nutrient to crop needs and improve soil conditions [7]. The best alternative is integrating organic and mineral fertilizers for tackling soil fertility depletion and sustainably increasing crop yields [8, 9]. However, information on the integrated uses of

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organic and mineral amendments and 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 contribute for the development of appropriate nutrient management strategies that can susain malting barley production, improve the livelihood of farmers and satisfy the increasing demands from the brewing.

Applying excessive fertilizer for barely beyond its requirement could cause lodging, which in turn accompanies economic loss. Most farmers in the Ethiopian highlands do not use fertilizer while few others use below the recommended rate. Application of optimum amount of fertilizer is crucial to alleviate the problem of yield reduction of barley. Therefore, the objective of this research was to study the effect of organic and inorganic fertilizer on yield and yield component of malt barley at Welmera District, Ethiopia in order to provide the crop with optimum nutrient and harvest the best yield.

MATERIALS AND METHODS

Description of the Study Site: The experiment was conducted on selected farmer's field at Welmera District (Telecho and Robgebya kebele) in West Showa Zone, Oromia Region, during 2015-2017 main growing season (Fig. 1). The experimental site was located at about 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 meters above sea level. Its mean annual rainfall is 1044 mm. Mean maximum and a minimum temperature are 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 [10].

Treatment and Experimental Design: The rates of organic fertilizers applied were calculated based on the recommended N equivalent rate of the inorganic source for the test crop.

Treatments:

T1 = Recommended NP
T2 = NPS (100kg /ha)
T3 = NPSB (100kg /ha)
T4 = Recommended Vermicompost (4.2 ton ha^{-1}) based on N equivalency
T5 = Recommended Compost (4.2 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 = 550% 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 3m x 2.4 m (7.2 m^2). The test crop used was malt barley (Var. HB 1847).

Soil Sampling and Analysis: The soil samples were collected two times. First 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 [11]. Organic carbon was determined by the method of Walkley and Black [12] and total N using Kjeldahl method [13]. Available P was determined following the procedures of Bray and Kurtz [14] and exchangeable Potassium (K) was extracted by ammonium acetate.

Data Collection and Measurements: The measurements of yield attributing factors were taken at physiological maturity of the crops prior to harvest. Days to heading, days to physiological maturity, 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 mater 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

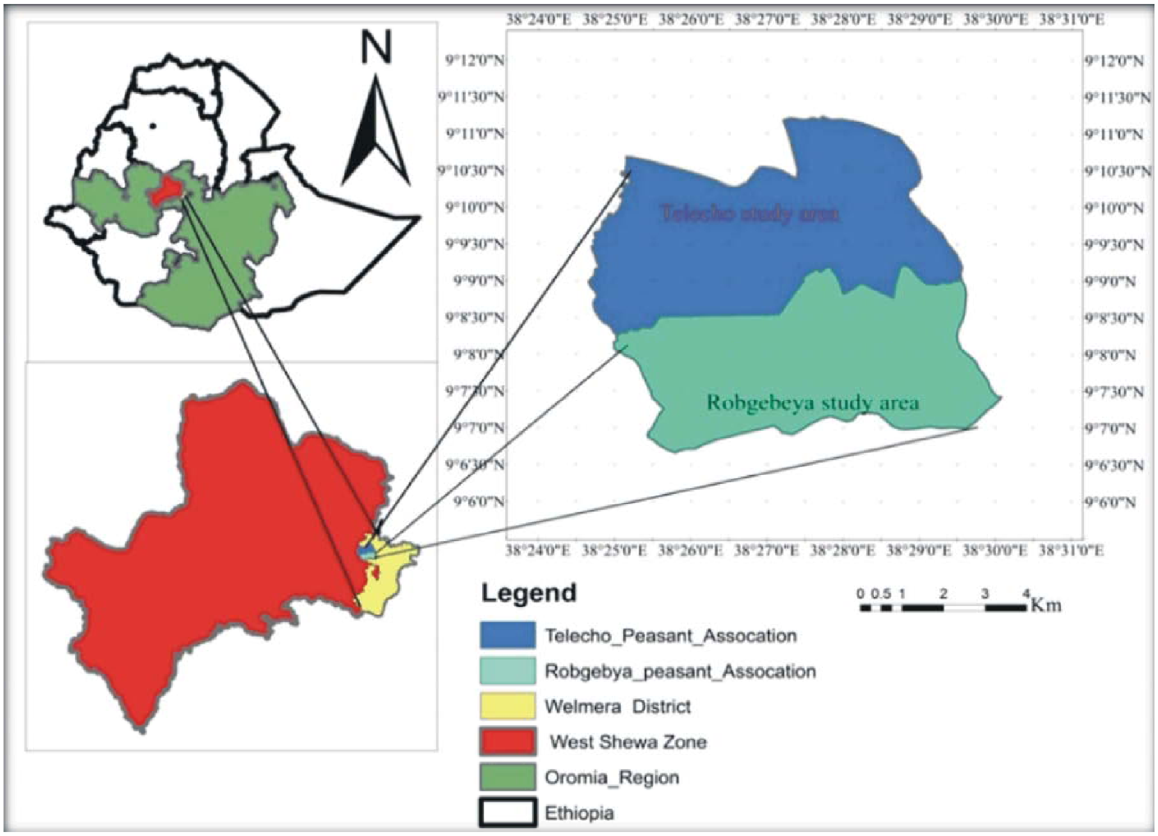

Fig. 1:

percentage ratio of grain yield to the total above ground biomass yield. Thousand seeds weight were determined by using seed counter and weighting 1000 seeds sample taken from each barley plots.

Analysis of Variance: Analysis of variance was carried out according to Gomez, *et al.* [15] using statistical analysis software [16]. Mean separation was computed using Least Significance Difference (LSD) at 5% probability level [17]. 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 the barley yield and fertilizer cost [18]. The economic analysis was performed to investigate the economic feasibility of the treatments, that is ISFM technology for malt barely production. The average yield was adjusted downwards 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 is achieved on an experimental site. The average open market price for teff (18 Ethiopian Birr (ETB) per kg, Cost of NPS=13.26ETB/kg, Cost of NPSB=13.58ETB/kg, Cost of urea=13.09ETB/kg, price of vermicompost, compost and FYM is 0.71, 0.5 and 0.5 ETB/kg, respectively and VC=4.2 ton /ha, Comp=5.5 ton/ha, FYM=4.4 ton /ha were used). 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% [18]. However, working in Ethiopia, Amanuel Gorfu *et al.* [19] suggested a minimum acceptable rate of return should be 100%. Therefore, the minimum acceptable marginal rate of return is assumed to be 100% in this study.

RESULTS AND DISCUSSION

Effects of Organic and Inorganic Fertilization on Soil Chemical Properties: Soil chemical properties such as pH, organic carbon (OC), N, P and K measured for samples taken after harvesting were affected by the application of organic and inorganic fertilizer. The result indicated relatively lower pH levels, medium OC% and TN%, low to moderate available P (mg/kg) and high exchangeable K (cmol$^+$/kg)were recorded due to the application of organic and inorganic fertilizer (Table 1) as rated by Tekalign Tadese [20] and Cottenie [21].

Chemical Properties of Vermicompost, Compost and FYM:

Table 1: Nitrogen content of Vermicompost and Compost

Parameters	Vermicompost value	Compost value	FYM value
TN (%)	1.06	0.84	1.04

TN%= Nitrogen content, FYM=farmyard manure

Table 2: Effects of organic and inorganic fertilization on soil chemical properties after crop harvesting

Treatment	Soil pH	OC (%)	TN (%)	Avi. P (mg/kg)	K (cmol$^+$/kg)
Recom.NP	4.65	1.83	0.16	5.56	0.85
NPS (100kg /ha)	4.96	1.84	0.15	5.91	0.77
NPSB (100kg /ha)	4.98	1.95	0.16	3.98	0.76
Vermicompost (4.2 tonha^{-1})	5.08	1.83	0.18	4.65	0.85
Compost (5.5 ton ha^{-1})	5.00	1.83	0.17	5.51	0.73
50% VC + 50% NP	4.81	1.95	0.18	5.99	0.71
50% VC + 50% NPS	4.98	1.75	0.18	4.90	0.72
50% VC + 50% NPSB	4.87	1.93	0.17	4.76	0.74
50% VC + 50% Comp	4.8	1.95	0.18	5.14	0.88
50% Comp + 50% NP	4.87	1.95	0.18	4.67	0.77
50% FYM + 50% NP	4.87	1.95	0.17	5.16	0.82

VC=4.2 ton /ha, Comp=5.5 ton/ha, FYM=4.4 ton /ha were used, OC=Organic carbon, TN=Total nitrogen, Ava. P = availably phosphorus, K=Potassium

Effect of Integrated Organic and Inorganic Fertilizer on Phenology and Growth of Malt Barley: Integrated application of organic and inorganic fertilizers showed highly significant difference (P<0.001) on heading date, date to physiological maturity, plant height and spike length (Table 3). The longest number of days to heading (77 days) and days to physiological maturity (133days) were noted from only full application of vermicompost fertilizer based on N equivalence (Table 3). Whereas, the highest plant length (103.5cm) and spike length (7.85cm) were measured from half of recommended application of NP with combination of half of vermicompost. The slow release and unavailability of important nutrients from organic sources might be attributed to the shortest plant height.

Grain Yield and Yield Component of Malt Barley: Significant variations were observed on yield and yield components of malt barley due to integrated application of organic and inorganic fertilizers (P<0.001). Grain yield and yield components of barley with integrated application of half of 50% VC with 50% NP gave higher yield compared to control plots (Table 4). Hence, the highest yields (3558.5 kg ha^{-1}) obtained over the control (2316.6 kg ha^{-1}) was due to integrated application of 50% VC + 50% RNP /kg (Table 4). This indicates that the synergistic effect of applied 50% VC + 50% recommended Fertilizers giving highest productivity. The lower yield (23160.3kg ha^{-1}) was recorded from sole application of full vermicompost based on N equivalence which is mainly attributed on the availability of plant nutrients [22].

Application of integrated organic and inorganic nutrient sources was sufficient to increase grain yield of barley significantly (Table 4). Similarly, Getachew Agegnehu *et al.* [8], found that application of all combinations of fertilizers, significantly increased barley yield over untreated control. The highest biomass yield (12793 kg ha^{-1}) was recorded from half of (50%) vermicompost with half of (50%) recommended NP fertilizer application.

Therefore, the result of 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. In line with the current result, the research findings of Girma Chala and Zeleke Obsa [22], Wondimu Bayu *et al.* [23]; indicated that integrated application of organic and inorganic forms under farmers' field condition showed the significance response on barley yield.

Table 3: Response of organic and inorganic fertilizer on phenological 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 (100kg /ha)	72.2^{f}	129.7^{c}	102.9^{ab}	7.62^{abc}
NPSB (100kg /ha)	72.8^{ef}	131.0^{abc}	100.6^{ab}	7.60^{abc}
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}	99.2^{ab}	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	75.0^{bcd}	132.5^{a}	95.1^{b}	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

VC=4.2 ton /ha, Comp=5.5 ton/ha, FYM=4.4 ton /ha were used, HD= Heading date, DPM=Date of physiological maturity, PH= Plant height, SL= Spike length.

Table 4: Response of organic and inorganic fertilizer on yield and yield component of malt barley

Treatments	GY(kg/ha)	BY(kg/ha)	TKW	HI (%)
Recom.NP	3111.6^{ab}	12195ab	36.4^{de}	26.0^{ab}
NPS (100kg /ha)	2932.1^{bc}	11162^{abcd}	35.6^{e}	26.7^{ab}
NPSB (100kg /ha)	2913.2^{bcd}	10780^{bcde}	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	2669.8^{bcde}	10958^{abcde}	37.3^{cde}	24.7^{b}
50% VC + 50% NPSB	2961.3^{bc}	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	2770.2^{bcde}	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, Comp=5.5ton/ha, FYM=4.4 ton /ha were used. GY= Grain yield, BY= Biomass yield, TKW= Total Kernel Weight, HI= Harvest index

The highest TKW (39.7g) was obtained from integrated application of 50% vermicompost with 50% compost based on N equivalence as compared to sole application of inorganic fertilizer (Table 4). The lowest TKW recorded 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 with integrated application of recommended (NP) rate of organic and inorganic fertilizers (Table 4). The highest harvest index (31 %) was obtained with 50% Comp + 50% NP (30/34.5 kg/ N/P ha) as compared to other treatments that received less combination of applied FYM, Vermicompost with inorganic fertilizers.

Quality Parameters

Hectoliter Weight: The highest hectoliter weight (71.39kg hl^{-1}) was recorded from half doses application of vermicompost (2.1 ton ha^{-1}) with half dose of recommended NP and followed by half doses application of compost (2.75 ton ha^{-1}) pulse half dose of recommended NP and the lowest (64.18kg hl^{-1}) hectoliter weight was recorded from application of full dose of compost (5.5ton ha^{-1}) treatment (Table 5). Low values of HLW indicate poor grain filling treatment. This is may be due to late heading leading to grain shriveling can impair specific weight through reduced packing efficiency. This is similar with authors [24, 25] that reported under favorable growing conditions slight increase specific weight happened in response to nitrogen application. The standards set for hectoliter weight by National Standard Authority ranged from 60 to 65 kg hl^{-1} [26]. The acceptable test weights (hectoliter weight) for malt barley are in the range 66.1–72.8kghl^{-1} [27]. The results of the present experiment exhibited an acceptable hectoliter weight in all treatments (Tables 5).

Grain Protein Content: The highest (13.42%) grain protein content was recorded on the application of full dose of vermicompost (5.5ton ha^{-1}) and the lowest (10.65%) from vermicompost (2.1 ton ha^{-1}) with half dose of recommended NP. According to the Ethiopian standard

Table 5: Effect organic and inorganic fertilizer on malt barley quality parameter

Treatments	HLW(kg/ha)	MC (%)	GS (%)	GPC (%)	GE (%)
Recom.NP	68.76	10.63	91.53	11.90	96.27
NPS (100kg /ha)	66.55	11.28	94.94	11.79	95.62
NPSB (100kg /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

Table 6: Integrated use of organic and inorganic fertilizer effect on partial budget and marginal rate of return (MRR) for malt barley production

Treatment	GY (kg/ha)	AD GY (kg/ha)	GB (EBTha^{-1})	TVC (EBTha^{-1})	NB (EBTha^{-1})	MRR (%)
Recom. NP	3112	2800	39206	3701.7	35504.5	
NPS (100kg /ha)	2932	2639	36944	3040.16	33904.3	241.9
NPSB (100kg /ha)	2913	2622	36706	3072.2	33634.1D	
Vermicompost (4.2ton ha^{-1})	2360	2124	29740	3308.8	26430.9D	
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	30527.08D	
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	37528.4D	
50% FYM + 50% NP	2770	2493	34905	3504.8	31399.8D	

GY=Grain yield, ADGY=Adjusted grain yield, GB= growth benefit, TVC=Total variable cost, NB=Net benefit, MRR= Marginal retune rate, VC=Vermicompost, FYM= Farm yard manure

authority and Asella malt factory (AMF), the protein level of the raw barley quality standard for malt should be between 9-12% [28]. The results of the current study showed that on all treatments had grain protein content within the acceptable range, except full dose application of vermicompost and compost applied (Table 5). This increase in protein may increase steep times, cause uneven water uptake during steeping, make germination more erratic/not uniform, create undesirable qualities in the malt, increased malt loss due to abnormal growth, excessive enzymatic activity, low extract yield, excessive nitrogenous compounds in the worst during brewing and chill haze formation in beer [29, 30].

Moisture Content: Moisture levels need to be low enough to inactivate the enzymes involved in seed germination as well as to prevent heat damage and the growth of disease microorganisms. Quality and germinated capacity may also significantly deteriorate [31]. Fox *et al.* [32] reported that the maximum reasonable industrial specification of malt barley moisture content for safe storage is12.5%, whereas, the EBC standard, a moisture content of 12-13.5 % is accepted. In this study the moisture content were in the acceptable range in all treatments (Table 5).

Economic Analysis Feasibility: As it is 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 (41843 Birr/ha) was recorded at 50% of N/P_2O_5 rates of 30/34.5 kg ha^{-1} combined with 50% (2.1ton ha^{-1})vermicompost fertilizer. Therefore, to maintain soil fertility, reduce cost of inorganic fertilizers and increase productivity, application of half of recommended rate of NP with half of vermicompost fertilizers based on N equivalencewas advised as the best management option even though other alternatives are still available.

CONCLUSION

Information on crop response of integrated use of inorganic and organic fertilizer is very important to come up with profitable and sustainable crop production.

The objective was to determine the effect of organic and inorganic fertilizer application on yield and yield components of malt barley at Welmera District. Application of vermicompost and NP nutrients which ultimately resulted in better performance of yield and yield components of malt barley. Integrated use recommended rate of vermicompost and NP fertilizer significantly affected yield and yield components of barley. The growth, yield and yield components of barley and responded significantly to the integrated application vermicompost and NP fertilizers. Application of integrated organic and inorganic nutrient sources was plenty to increase grain yield of barley significantly. Thus, highest yield of malt barley (3558.5 kg ha^{-1}) was obtained from the integrated use of half of recommended dose of vermicompost and recommended NP fertilizers. Therefore, based on cost benefit analysis half of recommended NP rate with half of vermicompost fertilizers application was economically feasible to the study area.

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