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Effect of Nitrogen Fertilizer Levels on Grain Yield, N Uptake and N Use Efficiency of Malt Barley (Hordeum Vulgare L.) Varieties at Wolmera District, Central Highland of Ethiopia

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Abstract
A field experiment was carried out during the 2017 cropping season at Holetta Agricultural Research center to determine the effect of nitrogen fertilizer levels on grain yield and quality of malt barley (*Hordeum vulgare* L.) varieties at Wolmera district, central highland of Ethiopia. The treatments include a factorial combination of four nitrogen levels (0, 18, 36, and 54 kg Nha^{-1}) and four malt barley varieties (Holker, Ibon174/03, HB-1963, and Explorer). The experiment was laid in a randomized complete block design with three replications. The higher (6170.70 $kgha^{-1}$) grain yield were obtained with the combination of Ibon174/03 variety and application of 36 kg N/ha. The highest (130$kgha^{-1}$) grain N uptake were recorded with combination of HB-1963 variety and application of 54 kg N/ha rates, while the lowest (47$kgha^{-1}$) grain N uptake were obtained with combination of control treatment and Explorer variety. The highest nitrogen use efficiency (327.03%) was recorded with the combination of 18 $kgha^{-1}$ N fertilizer along with Ibon174/03 variety. The highest net benefits (49,015.45 $EBha^{-1}$) with marginal rate of return (136%) were obtained from the combination of 36 kg Nha^{-1} with Ibon174/03 variety. Therefore, application of 36 kg Nha^{-1} fertilizer rates and Ibon174/03 variety was found to be better both agronomically and economically feasible for malt barley production in Wolmera area.
Keywords: Nitrogen fertilizer, Nitrogen uptake, Nitrogen use efficiency and Variety

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 Russian federations with a production of about 8 million tons, whereas Canada, USA and Argentina barley production was estimated 7.3, 3.1 and 2.8 million tons respectively (USDA, 2017). Ethiopia is the second largest producer of barley in Africa next to Morocco, accounting for about 26 percent of the total barley production in the country (Shahidur *et al*., 2015). It is the fifth important cereal crop next to *tef*, maize, sorghum and wheat in the country's domestic production with total area coverage of 959,273.36 hectares and total annual production of about 2.03 million tons in main season, whereas the mean barley productivity was 2.1 tons ha^{-1} (CSA, 2017). In Ethiopia, barley production is highly concentrated in Oromia National Regional State with total area coverage of 454,662.78 hectares and total annual production of about 1.09 million tons, whereas the mean barley productivity was around 2.4 tons ha^{-1} in main cropping season (CSA, 2017).

Malt barley is a high-opportunity crop, with great room for profitable expansion, particularly when connected with the country's commercial brewing and value-added industries (Berhane, 2011). Despite the importance of malt barley and its many useful characteristics, there are several factors affecting its production. The most important factors that reduce yield of barley in Ethiopia are poor soil fertility, use of low yielding varieties, water logging, drought, frost, soil acidity (low soil pH), diseases and insects, poor crop management practices, limited availability of improved varieties and weed competition. Poor soil fertility and use of low yielding varieties are among the most important constraints that threaten barley production in Ethiopia (Paul *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. Observation by Haileslassie *et al*. (2005) showed that the annual depletion rate of nitrogen from the soil has attained 122 kg/ha at the national level. To maximize yield and N uptake of malt barley, it has been shown that N management practices should be adjusted according to anticipated availability of water and N in the soil (McKenzie *et al.,* 2008) and the needs of particular varieties (Edney *et al*., 2014).

Nitrogen (N) absorption by plants is comprised of three major steps: uptake, assimilation and remobilization. Fixed nitrogen, which can be provided by soil microbes or as synthetic fertilizer, is taken up as nitrate (NO_3^-) or ammonium (NH_4^+) and utilized for multiple metabolic processes, including amino acid synthesis as well as signaling and storage molecules (Stitt *et al*., 2002). More than half of the nutrients applied are not used by the plant and are lost into the environment, giving rise to profound impacts ranging from air and water contamination to the undermining of ecosystems (Han *et al*., 2016). Agronomic practices like low fertilizer level, poor management practices and use of low yielding varieties are the most yield limiting factors in malt barley production in the study area. However, there were rare/few scientific findings on the effect of nitrogen fertilizer levels on the productivity of different varieties for the study area. Thus, proper nitrogen fertilizer rates on malt barley varieties have to be determined for optimum barley yield and premium malt quality. Therefore, the objective of this study was to determine grain yield, N uptake and NUE of malt barley in the central highland of Ethiopia through determining optimal nitrogen fertilizer application rate and identifying the best performing varieties.

Materials and Methods

Description of the Study Area

The experiment was conducted at Holetta Agricultural Research Center on station during 2017 main cropping season. Holetta is located at 29 km West of Addis Ababa. The experimental site is found at an altitude of 2400 m.a.s.l and lie in a geographic coordinate of 09^{o} 03′ 19.43" N latitude and 38^{o} 30′25.43"E longitudes. According to the weather record from the Holetta Research Center Meteorology Station, the total rainfall of the study area during the main cropping season (2017) was 1041mm. The mean minimum and maximum temperatures were 6.6 and 24.1 ^{0}C, respectively. The mean relative humidity was 58.7%. The soil type of the area is acidic Nitisols.

Soil Sampling and Physico-Chemical Analysis

A composite soil sample was taken before planting to determine the threshold level of plant nutrients in the soil. Soil samples were randomly collected in a diagonal pattern before sowing from a depth of 0-20cm. Similarly, surface soil samples of the same depth were collected after harvest from each plot by taking samples from three points within each plot and composited and analyzed in the laboratory for soil physical and chemical properties. The soil samples were air dried and passed through a 2 mm sieve for physico-chemical analysis. The soil was analyzed for texture and soil total nitrogen, available phosphorous, pH, OM, OC, CEC, C/N before sowing and after harvest (on plot bases). The samples that were taken before and after planting were analyzed at Holetta Agriculture Research Center soil laboratory. Texture of the soil was determined by the hydrometer method according to (Bouyoucos, 1962). Total soil N was analyzed by Kjeldhal digestion method with sulphuric acid (Jackson, 1962). Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter, potentiometer (FAO, 2008). Organic carbon content was determined by the volumetric method (Walkley and Black, 1934). The available P content of the soil was determined following Bray II method (Bray, 1945). The cations exchange capacity (CEC) of the soil was determined following the 1N ammonium acetate extraction (pH7) method.

Experimental Design and Experimental Procedures

Factorial combination of four nitrogen levels (0, 18, 36 and 54 kg Nha^{-1}) and four malt barley varieties (Holker, Ibon174/03, HB-1963 and Explorer) were evaluated in this study. The treatments were laid in factorial arrangement, using randomized complete block design with three replications. The plot size was 3 m x 2 m. Spacing between plots and blocks were 0.5 m and 1 m, respectively. Each plot consisted of 15 rows with spacing of 20 cm. Treatments were assigned randomly to experimental plots within a block. The land was prepared with tractor using mounted mould board plough and disc harrowed to break big soil clods into small sizes. The varieties, Ibon174/03, HB-1963 and Explorer which are recently released for highland areas and Holker (standard check) were used for the field experiment. Barley seed was drilled in rows in each plot uniformly. Urea (46% N) and triple super phosphate (46% P_2O_5) were used as sources of N and P, respectively. Triple super phosphate (46 % P_2O_5) was applied to all plots uniformly at sowing time, while nitrogen fertilizer was added to the soil at the rates of 18, 36 and 54 N kg ha^{-1}. To avoid N losses by leaching, urea application was done in two splits i.e. half at sowing time and the other half at the stages of tillering. Malt barely varieties were sown at the recommended rate of 125 kg ha^{-1} and planted in rows by using a manual row marker.

Data Collection and Analysis

Plant tissue sampling and analysis for nitrogen content

At maturity five plants were collected from each plot and partitioned into grain and straw. The straw samples were washed with distilled water to clean the samples from contaminants such as dust. The grain and straw samples were oven dried at 70^{0} C to constant weight. After drying, straw samples were milled and sieved through 0.5 mm size sieve. The samples were analyzed for nitrogen content following wet digestion by Kjeldhal-method using H_2S0_4 (Jackson, 1962). Total N uptake was obtained by summing up the N uptakes by grains and straw. TNU = N uptake of grain + N uptake of straw.

N uptake of grain = $\frac{GNC * GY}{100} kg/ha$ N uptake of straw = $\frac{SNC * SY}{100} kg/ha$

Where, GNC = Grain nitrogen concentration (%), GY = Grain yield (kg ha^{-1}),
SNC = Straw nitrogen concentration (%) and SY = Straw yield (kg ha^{-1})

Agronomic N use efficiency = $\left(\frac{Gf - Gu}{Na}\right)$ Where, Gf = Grain yield in the fertilized plot (kg ha^{-1}), Gu = Grain yield in the unfertilized plot (kg ha^{-1}) and Na = Quantity of nitrogen applied (kg ha^{-1}).

Physiological nitrogen efficiency (PNE) = $\left(\frac{Yf - Yu}{Nf - Nu}\right)$ Where; Yf = Biological yield (grain plus straw) of the fertilized plot (kg ha^{-1}), Yu = Biological yield in the unfertilized plot (kg ha^{-1}), Nf = Nitrogen accumulation in the fertilized plot (kg ha^{-1}), Nu = Nitrogen accumulation in the unfertilized plot (kg ha^{-1}). Agronomic and physiological nutrient use efficiencies were calculated following Mengel and Kirby (2001).

Apparent recovery nitrogen efficiency (ARNE): $\left(\frac{Nf - Nu}{Na}\right)$ Where, Nf = Nitrogen accumulation by the total biological yield in the fertilized plot Nu=Nitrogen accumulation by the total biological yield (straw plus grain) in the unfertilized plot (kg ha^{-1}); Na = Quantity of nitrogen applied (kg ha^{-1}).

Statistical and Economic Analysis

The data was subjected to analysis of variance (ANOVA) as per the design used in the experiment using statistical analysis software version 9.0 (SAS, 2004), and interpretation were made following the procedure of (Gomez and Gomez, 1984). Mean separation was conducted using the least significant difference test (LSD) to evaluate the different nitrogen levels on malt barley varieties and grain quality on Nitisols at 5% level of significance. The correlation analysis was performed to determine relations between phenological, growth parameter and yield and yield components as influenced by nitrogen application rates.

Relevant data to conduct preliminary assessment of economic yield levels was collected using data collecting formats. These include mainly the costs of inputs (labor + seed + fertilizer) and the prices of outputs (yield). The 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. The field price of 1 kg of malt barley that farmers receive from sale for the crop was taken as 10 birr based on the market price of malt barley at Wolmera near the experimental site, 29 km from Addis Ababa. Seed cost of improved malt barley variety was 19.80 birr for 1 kg. Costs of fertilizer (Urea) were 8.83 birr per 1 kg and laborer expenses were 35 birr. Barley yields were adjusted downwards by 10% to more closely approximate yields. The cost benefit analysis was calculated as follows: TCV = the sum of cost input (labor + seed + N fertilizer), AGY = grain yield x 10/100; GB = adjusted grain yield x variable cost of grain yield (price of yield), NB = gross benefit-total variable cost, MRR% = change of net benefit divided to change of total variable cost x 100.

Result and Discussion

Soil Properties before Sowing

The soil sample of experimental site was found to be clay in texture (11.2% sand, 16.3% silt and 72.5% clay). The pH value was 4.5 and strongly acidic according to the rating done by Tekalign (1991). The lower nutrient level and other chemical properties indicated that the experimental soil had some limitations with regard to its use for crop production. Therefore, to neutralize soil acidity lime were applied. Total nitrogen and cation exchange capacity (CEC) of the soil, before planting were found to be 0.1% and 15.4 cmol (+)/kg, respectively. The total nitrogen and cation exchange capacity (CEC) of soil was low and medium, respectively, according to the rating done by Havlin *et al*. (1999) and Murphy (2007). The organic carbon and organic matter was found to be 1.3 and 2.3%, respectively (Table 1). This data indicates organic carbon and organic matter were to be low and medium, respectively according to the rating done by Tekalign (1991) and Westerman (1990). The value of available phosphorous and carbon to nitrogen ratio (C/N) were found 8.3 mg/kg and 13%, respectively. The total amount of available P in soil was low, according to the rating of Tekalign (1991).

Table 1. Physico- Chemical properties of the soil before sowing

Soil depth (cm)	Physical properties				Chemical properties						
	Clay (%)	Silt (%)	Sand (%)	Textural Class	pH ($H_2$0)	TN (%)	CEC (cmol(+)/kg)	OC (%)	OM (%)	C/N (Ratio)	Av.P (mg/kg)
0-20	72.5	16.3	11.2	Clay	4.5	0.1	15.4	1.3	2.3	13	8.3

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

Soil Properties after Harvesting

The soil analysis data showed significantly ($p \leq 0.01$) differences among nitrogen rate treatments, varieties and their interaction for total nitrogen (Table 3). Higher (0.243%) soil total nitrogen were recorded with combination of 54 kg Nha^{-1} and Explorer variety, while the lowest (0.10%) soil total nitrogen were obtained with combination of control treatment and Ibon174/03 and HB-1963 varieties (Table 2). Total nitrogen was increased with increasing the applied nitrogen fertilizer rate. Moreover, Paul *et al*. (2014) indicated that soil total N show significant linear increased to N fertilizer rate. According to the rating done by Havlin *et al*. (1999) mean TN was low, except at application of 54 kg N/ha which was considered as medium.

Table 2. Interaction effect of nitrogen levels and varieties on soil total nitrogen (TN) of malt barley at HARC

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	0.111^{ed}	0.132^{cd}	0.141^{cb}	0.164^{b}	0.137
Ibon174/03	0.100^{e}	0.123^{ed}	0.136^{cbd}	0.141^{cb}	0.125
HB-1963	0.100^{e}	0.122^{ed}	0.137^{cbd}	0.137^{cbd}	0.124
Explorer	0.122^{ed}	0.141^{cb}	0.151^{cb}	0.243^{a}	0.164
Mean	0.108	0.130	0.141	0.171	0.138
LSD $_{(0.05)}$			0.02		
CV (%)			9.2		

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

There was significance ($p < 0.05$) difference between N fertilizer levels, whereas the interaction and varieties did not showed significance difference on soil pH (Table 3). The highest (5.73) soil pH were obtained from control treatments, while the lowest (5.59) soil pH were recorded from the highest (54 kg) N/ha fertilizer application. As the rate of N source fertilizer increased, releasing of hydrogen ions to the soil might have increased, hence increasing acidity (decrease pH) of soil. This result is in agreement with Brady and Weil (2002) found that nitrogen fertilizer, apart from increasing the content of nitrate in soil that leads to its leaching results in changes in soil pH and many other soil properties. However, this decline in soil pH value is not as such detrimental to growth of barley as it is naturally tolerant to the obtained range of pH and the crop. Barley crop does well in moderately to slightly acidic soils (5.5 - 6.5 pH) (Donahue, 1995; Tisdale *et al*., 2002). The main effect due to varieties had highly significant ($p \leq 0.01$) effect on available phosphorous (Table 3). However, N fertilizer levels and interaction effect did not showed difference significant. According to rating done by Tekalign (1991) the soil laboratory test result showed that the mean available P was medium. The slight increment available phosphorous after harvest could be due to the lime added for optimizing the soil pH and the residual P left from TSP. This result indicated that the available phosphorous was a more essential factor for optimum barley growth in the study area.

The mean CEC of the soil was high, according to rating done by Murphy (2007). The high CEC in soils of study area might be due to the high content of clay soil. These results indicated that there was no statistical significant difference between by main effects of N levels and varieties on organic carbon and organic matter. However, the result showed that the mean organic carbon and organic matter of soil was under moderate, according to rating done by Tekalign (1991) and Westerman (1990), respectively. Results of the study indicated that there was highly significant difference between N levels on carbon nitrogen ratios, while varieties effect and interaction effect did not exhibit significant difference on carbon nitrogen ratios (Table 3). The highest (15.95%) C/N ratios were recorded from control treatments, whereas the lowest (10.85%) carbon nitrogen ratios were obtained from the highest (54 kg ha^{-1}) N fertilizer application. The control treatment had resulted in the highest C/N (15.95%), followed by N rates of 18 kg/ha with a C/N value of 14.25%. This might be due to increased amount of total nitrogen in the soil. The data indicated that the C/N ratios of barley in the soil decreased at the rate of N fertilizers increasing.

Table 3. Main effect of nitrogen levels and varieties on soil chemical properties at HARC

N rate (kg ha^{-1})	pH	Ava. P(%)	CEC(cmol(+)/kg)	0C (%)	0M (%)	C/N (%)
0	5.73^{a}	12.02	29.2	1.74	3.00	15.95^{a}
18	5.64^{ba}	12.19	29	1.82	3.15	14.25^{b}
36	5.69^{ba}	12.08	30	1.73	2.98	12.55^{c}
54	5.59^{b}	12.56	29.5	1.743	2.99	10.85^{d}
LSD (5%)	0.12	NS	NS	NS	NS	1.41
Varieties						
Holker	5.70	12.45^{cb}	28.8	1.76	3.04	13.60
Ibon174/03	5.62	12.16^{cb}	30	1.79	3.08	13.49
HB-1963	5.67	12.78^{ba}	29	1.72	2.96	12.61
Explorer	5.66	13.49^{a}	29.6	1.73	2.99	13.76
Mean	5.66	12.47	29.38	1.75	3.02	13.36
LSD (5%)	NS	1.49	NS	NS	NS	NS
CV (%)	2.5	10.10	3.8	4.0	3.98	12.64

Av.P=Available phosphorus, CEC= Cation exchange capacity, OC=Organic carbon, OM=Organic matter, C/N= Carbon to nitrogen ratio, NS = Non significant. Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Grain Yield

Significant ($p \leq 0.001$) differences among nitrogen rate treatments, varieties and their interaction for grain yield of malt barley (Table 5). The varieties Ibon174/03 and HB-1963 showed better performance of grain yield at the 18, 36 & 54 kg Nha^{-1} application which may be due to the highest response varieties to N and use efficiency. The Holker variety obtained the maximum grain yield at the N rate application of 54 kg ha^{-1}. The Explorer variety obtained the maximum grain yield at the N rate application of 36 kg ha^{-1}. While the lowest (3145 kg ha^{-1}) grain yields were obtained with combination of the control (0 N) and Holker variety. In general, in this study grain yield ranged between 3145kg ha^{-1} (Holker) and 6171kg ha^{-1} (Ibon174/03). This large grain yield variation among barley varieties under different nitrogen rate treatments could help in the selection of better varieties for different N supply environments. Grain yield production of barley varieties boosted with increased N fertilizer rates from 0 to 36 kg Nha^{-1} and then decrease (Table 5). This result were in agreement with Amare (2015) and Nadir *et al.* (2015) reports who mentioned that significant increases in grain yields of malt barley crop with increasing levels of N fertilizer.

Table 5. Interaction effect of nitrogen levels and varieties on grain yield of malt barley at HARC

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	3144.80^{h}	4394.80^{ed}	4713.20^{bcd}	5071.20^{bc}	4361.10
Ibon174/03	4608.90^{cd}	5886.50^{a}	6170. 70^{a}	5964.60^{a}	5657.68
HB-1963	4014.70^{ef}	5636.80^{ba}	6028.20^{a}	6092.8^{a}	5443.13
Explorer	3189.80^{h}	3567.20^{gh}	3896.70^{gf}	3426.50^{gh}	3500.03
Mean	3739.55	4888.90	5226.40	5180.58	4740.48
LSD $_{(0.05)}$			602.50		
CV (%)			7.34		

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Chemical Analysis of Plant Tissues

Nitrogen concentration in grain and straw

Grain nitrogen concentration was highly significant ($p \leq 0.01$) influenced by main effect of nitrogen rates and varieties, whereas the interaction effect was non-significant (Table 10). The highest (2.15%) grain nitrogen concentration was obtained from the highest (54 kg ha^{-1}) N fertilizer rates, while the lowest (1.69%) grain N concentration was recorded from control plots. This result indicated that nitrogen concentrations in grain increase in response the increasing N fertilizer levels. The highest (1.98%) grain nitrogen concentration was calculated from Holker variety. However, varieties Holker and Ibon174/03 statistically a par for their grain N concentration and nearly an equal early assimilation of nitrogen nutrients of those varieties while the minimum grain N concentration (1.67 %) was recorded from Explorer variety. This might be due to genetic variation of malt barley varieties. The highest straw N concentration (0.89%) was obtained by the combination of HB-1963 variety and application of (54 kg ha^{-1}) N fertilizer rates, whereas the lowest straw N concentration (0.25%) was recorded from the combination of Holker variety and control treatment. Similarly, Girma *et al*. (2012); Sheoran *et al*. (2015) stated that grain and straw nitrogen concentration increased with the N fertilizer levels.

Table 6. Interaction effects of N levels and varieties on straw N concentration of malt barley

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	0.25^{i}	0.63^{e}	0.69^{dc}	0.73^{c}	0.58
Ibon174/03	0.41^{h}	0.59^{fe}	0.69^{dc}	0.83^{b}	0.63
HB-1963	0.57^{f}	0.68^{dc}	0.70^{dc}	0.89^{a}	0.68
Explorer	0.48^{g}	0.54^{f}	0.68^{dc}	0.70^{dc}	0.67
Mean	0.43	0.61	0.69	0.83	0.64
LSD $_{(0.05)}$			0.04		
CV (%)			4.17		

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Nitrogen uptake of malt barley varieties

The mean nitrogen uptakes in grain indicated that there was highly significant ($p \leq 0.01$) interaction effects of N levels and varieties (Table 7). The highest (130.42 kg ha^{-1}) uptake of nitrogen by grain was obtained with the combination of Ibon173/04 variety and 54 kg Nha^{-1} fertilizer rates. The lowest (47.05 kg ha^{-1}) uptake of nitrogen was recorded with combination of control treatments and Explorer variety. This might be due to relatively higher grain yield and grain N concentration in these treatments that resulted in increased N uptake by grain. N uptakes by straw was highly significant ($p \leq 0.01$) influenced by the main effect of nitrogen rates and varieties (Table 10). The maximum uptake of nitrogen by straw (90.45 kg ha^{-1}) was obtained from 54 kg Nha^{-1}, the minimum N uptake of straw (28.28 kg ha^{-1}) was recorded from control treatments. This might be due to relatively higher straw yield and straw N concentration that resulted in increased N uptake by straw. Among varieties the highest straw N uptake (72.03kg ha^{-1}) were calculated from HB-1963 variety but, there was no statistical difference with Ibon174/03 variety. The minimum straw N uptake (42.62 kg ha^{-1}) was recorded from Explorer variety. This might be due to genetic variation of malt barley varieties. The results of the present study agree with findings of many authors, Fowler (2003); Bereket *et al.* (2014) who reported that the highest plant nitrogen uptake were obtained on soil treated with the highest rates of nitrogen fertilizer application.

Table 7. Interaction effects of N levels and varieties on grain nitrogen uptake of malt barley at HARC

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	57.55^{hi}	84.67^{de}	91.54^{dc}	112.96^{b}	86.68
Ibon174/03	90.59^{dc}	111.56^{b}	118.13^{b}	130.42^{a}	112.68
HB-1963	77.94^{fe}	100.10^{c}	113.29^{b}	129.67^{a}	105.25
Explorer	47.05^{i}	52.16^{i}	65.65^{hg}	70.20^{fg}	58.77
Mean	68.28	87.12	97.15	110.81	90.85
LSD (5%)			10.98		
CV (%)			7.24		

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Nitrogen use efficiency by malt barley varieties

Agronomic nitrogen efficiency

There was a significant difference between the interaction effect of nitrogen levels and varieties on agronomic nitrogen use efficiency (Table 8). The maximum (90.12) agronomic nitrogen use efficiency was recorded with the combination of 18 kg Nha^{-1} and HB-1963 variety, whereas the minimum (4.38) agronomic nitrogen use efficiency of nitrogen was obtained with the combination of 54 kg Nha^{-1} and Explorer variety. The agronomic nitrogen use efficiency was decreased with increasing rates of nitrogen fertilizer, which indicated efficient use of nitrogen at lower rate of nitrogen fertilizer application. It might be due to the capability of yield increase per kilogram N declined remarkably with increasing nitrogen. Similarly, Abebe (2012) asserted that high agronomic efficiency could be obtained if the yield increment per unit N applied is high because of reduced losses and increased N uptake. Different varieties show different agronomic use efficiency of nitrogen under the same environmental condition. The highest mean ANUE (61.51) were recorded from HB-1963 variety while the lowest mean (14.99) obtained from Explorer variety (Table 8). This might be due to genetic variation of malt barley varieties plus levels of nitrogen fertilizers. This result was in agreement with Getachew *et al.* (2016) who reported that agronomic nitrogen use efficiency of different genotypes was different.

Table 8. Interaction effects of N levels and varieties on agronomic nitrogen efficiency of malt barley at HARC

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	--	69.44^{b}	43.57^{c}	35.67^{cd}	49.56
Ibon174/03	--	70.97^{b}	43.38^{c}	25.11^{ed}	46.49
HB-1963	--	90.12^{a}	55.93^{cb}	38.48^{cd}	61.51
Explorer	--	20.96^{ed}	19.63^{fed}	4.38^{fe}	14.99
Mean	--	62.87	40.63	25.91	43.1
LSD $_{(0.05)}$		9.20			
CV (%)		22.04			

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Physiological nitrogen efficiency

Physiological nitrogen efficiency were significantly ($p \leq 0.05$) influenced by the main effects of N levels and varieties (Table 10). The highest (79.59) physiological nitrogen efficiency were recorded from the lowest (18 kg ha^{-1}) N fertilizer rates, whereas the lowest (45.27) physiological efficiency of nitrogen obtained from 54 kg Nha^{-1} fertilizer rates. Results indicated that physiological efficiency of all varieties decreased with increasing N fertilizer rates. Likewise, Getachew *et al*. (2016); Nano (2017) reported that the physiological nitrogen efficiency of genotypes of barley was decreased significantly with increasing N application. The ability of the plant to transform applied nutrient acquired from sources to total yield decreased whenever nitrogen fertilizer rates rises. Genotypes had significant ($p \leq 0.05$) influence on physiological nitrogen efficiency. The highest (96.76) physiological nitrogen efficiency was recorded from the HB-1963 variety, whereas the lowest (84.5) physiological nitrogen efficiency were calculated from the Explorer varieties (Table 10). However, Ibon174/03 and HB-1963 varieties were statistically par in terms of physiological nitrogen efficiency. Similarly, Singh and Arora (2001) reported that varieties had significant differences on physiological nitrogen efficiency.

Apparent recovery nitrogen efficiency of malt barley

Interaction effect of N levels and varieties on apparent recovery nitrogen efficiency of malt barley was presented in Table 9. The highest (350.77%) apparent recovery nitrogen efficiency were recorded with combination of 18 kg Nha^{-1} and Holker variety but, with the same N rate there were no statistical difference between Ibon174/03 and HB-1963 varieties. The lowest (87.57%) apparent recovery nitrogen efficiency were obtained with the combination of 54 kg N/ha and Explorer variety. This data indicated that apparent recovery nitrogen efficiency of barley was decreased with increasing nitrogen application. Because, at high rates of nitrogen fertilizer applied the plant did not take up nitrogen. Similarly, Mandana *et al*. (2011) mentioned that the apparent recovery nitrogen efficiency of malt barley varieties decreased whenever nitrogen fertilizer rates increased.

Table 9. Interaction effects of nitrogen levels and varieties on apparent recovery nitrogen efficiency of malt barley

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	--	350.77^{a}	230.97^{cb}	222.53^{cb}	268.09
Ibon174/03	--	257.08^{b}	199.10^{cbd}	210.31^{cb}	222.16
HB-1963	--	253.06^{b}	181.05^{cbd}	194.29^{cbd}	209.47
Explorer	--	162.143^{ced}	120.43^{ed}	87.57^{i}	123.38
Mean	--	255.76	182.88	178.67	205.77
LSD (5%)		79.52			
CV (%)		19.78			

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Nitrogen harvest index of malt barley

Nitrogen harvest index was significantly ($p \leq 0.05$) influenced by the main effects of N levels and varieties (Table 10). The highest nitrogen harvest index (71.79%) was recorded from control treatments, while the lowest nitrogen harvest index (55.02%) were obtained from 54 kg Nha^{-1} fertilizer rates. This could be due to partitioning of the total nitrogen content more to the vegetative part of the crop than to the grain and increased the total aboveground biomass yield. Nitrogen harvest index was decreased with increasing N rates. Mohammad *et al*. (2010); Tamado, (2015) mentioned that, nitrogen harvest index of wheat and barley was decreased significantly with increasing N application. In contrary, Girma *et al*. (2012) who reported that nitrogen harvest index increased with the increasing nitrogen levels. Different malt barley varieties had significant ($p \leq 0.05$) influenced on nitrogen harvest index. The maximum nitrogen harvest index (66.05%) was recorded from the variety Ibon173/04, whereas the lowest nitrogen harvest index (59.26%) was calculated from HB-1963 variety (Table 10). Similarly, Fageria and Baligar (2005) who reported that significant varieties differences on nitrogen harvest index. This might be due to genetic variation of malt barley varieties plus levels of nitrogen fertilizers.

Table 10. Grain N concentration, straw N uptake, total N uptake, physiological N efficiency and N harvest index of malt barley as influenced by main effects of varieties and N levels at HARC

N rate (kg ha^{-1})	GNC (%)	SNuPt (kg ha^{-1})	PNE	NHI (%)
0	1.69^{c}	28.28^{c}	0.00^{c}	71.79^{a}
18	1.79^{b}	53.47^{b}	79.6^{a}	63.03^{b}
36	1.82^{b}	62.14^{b}	65^{a}	60.57^{b}
54	2.15^{a}	90.45^{a}	45.3^{b}	55.02^{c}
Varieties				
Holker	1.98^{a}	58.46^{b}	92.7^{b}	61.97^{ba}
Ibon174/03	1.94^{a}	62.00^{ba}	95^{ba}	66.05^{a}
HB-1963	1.87^{b}	72.03^{a}	96.7^{a}	59.26^{b}
Explorer	1.67^{c}	42.62^{c}	84.5^{c}	62.26^{ba}
Mean	1.87	58.78	47.2	62.48
LSD $_{(0.05)}$	0.06	10.91	17.5	5.13
CV (%)	4.06	22.23	24.7	9.46

Means followed by the same letters are not significantly different at ($p \leq 0.05$). GNC = Grain nitrogen content, SNuPt = Straw N uptake, PNE = Physiological efficiency of N, NHI = Nitrogen harvest index and NS = Non-significant

Nitrogen use efficiency of malt barley

The interaction effect of nitrogen levels and varieties were highly significant ($p \leq 0.01$) influenced nitrogen use efficiency of malt barley (Table 11). The highest nitrogen use efficiency (327.03%) was recorded with the combination of 18 kgha^{-1} N fertilizer along with Ibon174/03 variety. The lowest nitrogen use efficiency (63.45%) was obtained with the combination of 54 kg N/ha fertilizer and Explorer variety. Nitrogen use efficiency was decreased with the increase in rate of N fertilizer dose in malt barley. The reason for the decline in nitrogen use efficiency as the level of nitrogen increased was a decline in nitrogen uptake efficiency and utilization efficiency of malt barley. This is in agreement with Barraclough *et al*. (2014); Gaju *et al*. (2014) who reported that nitrogen use efficiency of malt barley varieties were decreased significantly in responses to increasing N fertilizer rates. This study indicated that the development and use of malt barley varieties with higher NUE can contribute to a reducing in the amount of N to be applied without decreasing grain yield and quality.

Table 11. Interaction effects of nitrogen levels and cultivars on N use efficiency

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	--	244.15^{b}	130.92^{e}	93.91^{f}	156.33
Ibon174/03	--	327.03^{a}	171.41^{d}	110.46^{ef}	202.97
HB-1963	--	313.15^{a}	167.45^{d}	112.83^{ef}	197.81
Explorer	--	198.18^{c}	108.24^{f}	63.45^{g}	123.29
Mean	--	270.63	144.51	95.16	170.10
LSD (5%)		22.21			
CV (%)		10.44			

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Nitrogen uptake efficiency

Interaction effects of N fertilizer levels and varieties were significantly ($p \leq 0.01$) affected by nitrogen uptake efficiency (Table 12). The highest (9.48) nitrogen uptake efficiency was recorded with the combination of 18 kg N/ha and HB-1963, while the lowest (2.81) nitrogen uptake efficiency was obtained with the combination of 54 kg Nha^{-1} and Explorer variety. The current data indicated that at high N fertilizer application, the ability of the plant to take up nitrogen from the soil was decreased. In agreement with this result, Yadeta and Patricia (2012) reported that N uptake efficiency of barley was higher at lower rates of N fertilizer application but drastically decreased with further increases in the rate of nitrogen fertilizer.

Table 12. Interaction effects of nitrogen levels and varieties on N uptake efficiency of malt barley at HARC

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	--	7.83^{b}	4.47^{d}	3.78^{e}	5.36
Ibon174/03	--	9.11^{a}	5.26^{c}	4.28^{ed}	6.22
HB-1963	--	9.48^{a}	5.28^{c}	4.26^{ed}	6.34
Explorer	--	4.46^{d}	2.99^{f}	2.81^{f}	3.42
Mean	--	7.72	4.5	3.78	5.33
LSD (5%)		0.66			
CV (%)		9.92			

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

Nitrogen utilization efficiency of malt barley

Nitrogen utilization efficiency of malt barley was significantly ($p \leq 0.01$) affected by both main effect N rates and varieties, and their interaction. The highest (51) nitrogen utilization efficiency of malt barley was recorded with the combination of control treatments and Ibon174/03variety, whereas the lowest (23.79) nitrogen utilization efficiency was obtained from Explorer variety with the combination of 54 kg Nha^{-1} (Table 13). Nitrogen utilization efficiency of malt barley decreased with increase in rates of nitrogen fertilizer. Similarly, Nigussie *et al*. (2012) also reported that the highest NUtE of barley were measured from the lowest N fertilizer application. This result indicated that, the higher dry matter partitioning to the grain per unit of total plant nitrogen for Ibon174/03 variety at control treatment. Similarly, Singh and Arora (2001) reported that genetic variation highly influences on nitrogen utilization efficiency.

Table 13. Interaction effects of nitrogen levels and varieties on N utilization efficiency of malt barley at HARC

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	40.40^{cb}	31.17^{egdf}	29.31^{eghf}	25.62^{ih}	31.63
Ibon174/03	51^{a}	35.94^{cd}	32.56^{ed}	25.86^{igh}	36.34
HB-1963	43.26^{b}	33.13^{ed}	31.72^{edf}	26.48^{ighf}	33.65
Explorer	36.14^{cd}	44.29^{b}	36.61^{cd}	23.79^{i}	35.21
Mean	42.71	36.13	32.55	25.44	34.21
$LSD_{(0.05)}$		5.49			
CV (%)		9.64			

Means followed by the same letters are not significantly different at ($p \leq 0.05$)

The Effects of Nitrogen Rate and Varieties on Economic Feasibility of Malt Barley Production

Partial budget analysis of the combination of nitrogen levels with different varieties was presented in Table 14. The highest net benefit of ETB 49,015.45 ha^{-1} and marginal rate return of 136.36 % with value to cost ratio of ETB 7.5 per unit of investment was obtained from combination 36 kg Nha^{-1} and Ibon174/03 variety for malt barley production followed by net benefit of ETB 47,732.50 and marginal rate of return of 225.47 % with value to cost ratio of ETB 7.3 per unit of investment from combination 36 kg Nha^{-1} and HB-1963 variety. The lowest net benefit of ETB 23,026.35 ha^{-1} and marginal rate of return of 427.88 % with value to cost ratio of ETB 2.9 per unit of investment was obtained from combination 54 kg Nha^{-1} and Explorer variety. Increasing nitrogen fertilizer along with different varieties provided the lowest net return, whereas decreasing nitrogen fertilizer rates with different varieties was profitable. Therefore, the combination of 36 kg Nha^{-1} fertilizer rate with Ibon174/03 variety was economically feasible for barley production in Wolmera area.

Table 14. Partial budget analysis of nitrogen rates and varieties of malt barley at Holetta on station conditions

Treatment combination	TVC ($ETBha^{-1}$)	GY (kg ha^{-1})	AdY (kg ha^{-1})	GB ($ETBha^{-1}$)	NB ($ETBha^{-1}$)	MRR (%)
0N + Holker	1250.00	3144.76	2830.29	22642.28	21392.31	
18N + Holker	4213.87	4394.79	3955.31	31642.50	27428.61	203.66
36N + Holker	5296.24	4713.15	4241.84	33934.73	28638.54	111.78
54N + Holker	6586.94	5071.16	4564.05	36512.42	29925.52	99.71
0N+Ibon174/03	2475.00	4608.90	4148	41480.01	39005.01	
18N+Ibon174/03	5438.87	5886.48	5297.83	52978.30	47539.42	287.95
36N+Ibon174/03	6521.24	6170.73	5553.66	55536.62	49015.45	136.36
54N+Ibon174/03	7811.94	5964.57	5368.11	53681.10	45869.22D	
0N + HB-1963	2475.00	4014.67	3613.20	36132.03	33657.03	
18N+HB-1963	5438.87	5636.76	5073.09	50730.90	45292.00	392.56
36N+HB-1963	6521.24	6028.19	5425.37	54253.70	47732.50	225.47
54N+HB-1963	7811.94	6092.83	5483.54	54835.40	47023.5 D	
0N + Explorer	2475.00	3189.84	2870.86	28708.60	26233.63	
18N+ Explorer	5438.87	3567.17	3210.46	32104.60	26665.72	14.58
36N+ Explorer	6521.24	3896.70	3507.03	35070.33	28549.10	174.00
54N+ Explorer	7811.94	3426.48	3083.83	30838.34	23026.3 D	

AGY (kg/ha) = Adjusted grain yield, GB (GY) = Gross benefit, TVC (EB/ha) = Total variable costs, NB (Birr/ha) = Net benefit and MRR (%) = Marginal rate of return, D = Dominated treatment and EB = Ethiopian Birr.

Conclusion and Recommendation

Malt barley production is heavily dependent on available nutrient in the soil and other environmental conditions for plant growth. The objective was to increase yield and N uptake of malt barley production with good manageable agronomic practices at Wolmera District in 2017. Carbon nitrogen ratio, agronomic nitrogen efficiency, physiological N efficiency, apparent recovery of nitrogen efficiency, nitrogen use efficiency, nitrogen uptake efficiency and utilization efficiency and nitrogen harvest index of malt barley were decreased whenever N dose increased. Grain yield and total N uptake of malt barley were increase with increasing N fertilizers rates, but grain yield decreased at a point (54 kg N/ha). On the same way, high nitrogen rates leads to high N uptake and low nitrogen use efficiency, while low nitrogen rates leads to optimum grain yield as well as high nitrogen use efficiency. The application of 36 kg ha^{-1} N fertilizer rates and Ibon174/03 variety which generated high NUE and optimum grain yield with economically reasonable. Therefore, the combination application of 36 kg ha^{-1} N fertilizer rates and Ibon174/03 variety were recommended for the study location and similar agro-ecologies in the highlands of Ethiopia.

For remunerative malt barley production in the central highlands of Ethiopia, increasing malt barley yield from different varieties with good agronomic practices is crucial in the future. The combinations of 36 kg N/ha fertilizer rates and Ibon174/03 variety gave optimum grain yield, high NUE and the best net benefit in the study area and hence can be recommended for wider use at Wolmera area. However, it is obvious that fertilizer recommendations for crops in most cases are based on a soil test for plant available nutrients. But, a major limitation is that, for the same sites, plant varieties and management systems, the absolute plant yields may differ from year to year due to different weather conditions. Therefore, it would be too early to reach at a conclusive recommendation since the current study was carried out only in one location for one cropping season. Hence, further studies replicated over seasons and across locations are needed to recommend agronomical optimum and economically feasible level of N fertilizer with better grain yield and N uptake of malt barely varieties.

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