International Journal of Research Studies in Agricultural Sciences (IJRSAS)
Volume 4, Issue 4, 2018, PP 29-43
ISSN No. (Online) 2454–6224
DOI: http://dx.doi.org/10.20431/2454-6224.0404005
www.arcjournals.org

Effect of Nitrogen Fertilizer Levels on Grain Yield and Quality 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. Both main and interaction effect of N and variety affected leaf area, number of productive tillers per plant, number of spikes, grain per spike and grain yield. However, days to 50% heading, days to 85% physiological maturity, plant height, straw yield, harvest index, thousand grain weight, grain size, grain protein content and germination energy were only affected by main effects of N levels and varieties. The higher (6170.70 kgha-1) grain yield were obtained with the combination of Ibon174/03 variety and application of 36 kg N/ha. But, the grain yield from such combination was not economically feasible a well as high protein content. 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, Quality, Variety and Yield.*

1. 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).

In Ethiopia, barely is a dependable source of food in the highlands areas. Its grain is used for the preparation of different foodstuffs, such as *injera*, *kolo*, and local drinks, such as *tela*, *borde* and beer (Melle *et al*., 2015). Very recently it is being adopted for preparation of bread all alone or mixed with wheat. 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. To maximize yield and quality 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) is the main component of fertilizer programs for producing high quality of malt barley. At Wolmera District little effort was made to determine agronomic requirement of malt barley crop. 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 improve malt barley quality and productivity in the central highland of Ethiopia through determining optimal nitrogen fertilizer application rate and identifying the best performing varieties.

2. Materials and Methods

2.1 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*.

2.2 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. 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). 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.

2.3 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.

2.4 Data Collection and Analysis

Days to 50% heading was recorded as the number of days taken from the day of sowing to the date of when 50% of the plants produced head. Days to 85% physiological maturity was determined as the number of days from sowing to the time when the plants reached 85% maturity based on visual observation. Leaf Area was determined by measuring the length of leaf from the base to the tip and the width of the leaf from five plants in each plot and was determined by leaf area meter at flowering stage. The fertile tillers per plant were counted from five random plants randomly selected from five rows, at the time of physiological maturity. Average plant height of main stem was measured from five random plants by measuring from the ground level to the tip of spike excluding the awns/bear at harvest. Spikes length was randomly selected from each unit area in each plot and was measured from the base to the top of the spike excluding awns. Number of grain was taken as average number of grain per spike of five random plants and was expressed as average number per plant. Total biomass weight was taken after harvesting from the whole plant parts, including leaves and stems, and seeds from whole rows of plot. The straw yield was measured by subtracting the grain yield from the total above ground biomass yield. Grain yield was measured after harvesting and threshing, the crop from whole plot. Harvest index was calculated by dividing grain yield to the total above ground biomass yield and expressed in percentages.

Thousand grains were counted by grain counter machine and the thousand counted grain was weighed and taken as thousand grain weight. 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). The same to HLW, grain moisture levels were measured by apparatus (grain analysis computer (GAC) 2100) as described in the AACC (2000). 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 by taking one hundred barley grains were spread on wetted (4ml distilled water) filter paper lined on Petri dishes (90mm) and allowed to germinate at nearly 100% relative humidity set at a temperature of 16°C germination cabinet for 3 days as described in EBC (1998) method 3.6. Hundred gram of the grain sample was placed at the top of the sieve (>2.8mm,>2.5mm,>2.2mm and <2.2mm sieve sizes) and the grain was sieved into four fractions within five minutes. Grains were size graded using slotted sieves (2.8, 2.5 and 2.2mm apertures) following the standard procedure of the Holetta research center micro-malt laboratory.

2.5 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 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.

3. Result and Discussion

3.1 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).

Table1. *Physico- Chemical properties of the soil before sowing*

Soil depth (cm)	Physical properties				Chemical properties						
	Clay (%)	Silt (%)	Sand (%)	Textural Class	pH (H_20)	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.

3.2 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.

Table2. *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.

Table3. *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 ($p \leq 0.05$).

3.3 Phenological Parameter of Malt Barley

3.3.1 Days To 50% Heading And Days To 85% Physiological Maturity

Days to 50% heading of malt barley as affected by nitrogen fertilizer levels and varieties was presented in table 4. The longest (91.33) days to heading were recorded from the highest (54 kg ha^{-1}) N fertilizer rate, while the shortest (73.5) days to heading were obtained from control treatments. Increased levels of N fertilizer from control (0 N) to highest (54 kg Nha^{-1}), days to heading increased consistently. This might be attributed to the behavior of increased N fertilizer increases vegetative growth of crops thereby it delaying heading time. In agreement with the result, Mekonen (2005) reported that a day to heading was significantly delayed when N fertilizer was applied at the highest rate for wheat and barley production compared to the lowest rate. Rashid *et al*. (2007) also reported that N application significantly affected days to heading of barley. There were significant ($p \leq 0.01$) difference among the barley genotypes for days to heading (Table 4). Explorer variety had the longest duration (92.42) days to heading, whereas Ibon174/03 variety had the shortest duration (72.42) days to heading (Table 4). This might be due to variation in genotypes. Similarly, Daniel *et al*. (2013) reported that barley genotypes differ in days to heading.

The main effect N levels and varieties of malt barley had highly significant ($p \leq 0.01$) effect on days to physiological maturity. The longest (143) days to physiological maturity were recorded from the highest dose (54 kgha^{-1}) N fertilizer rate, while the shortest (125) days to physiological maturity were recorded from control treatments. This might be attributed to the behavior of the fertilizer N which increases vegetative growth of crops thereby delaying physiological maturity. Moreover, under normal condition crops may take long days to maturity to exploit the available moisture and nutrients in the soil. Similarly, Woinshet (2007) reported as high rates of nitrogen prolong days to physiological maturity. Among the genotypes compared for days to physiological maturity, Explorer variety had the longest (145 days) duration while Ibon174/03 variety had the shortest (126 days) duration to physiological maturity. This variation was due to genetic difference of malt barley varieties. Similarly, Wosene *et al*. (2015) reported that genotypes could differ in days to physiological maturity.

Table4. *Main effect of nitrogen levels and varieties on phenological parameters of malt barley at HARC*

Nitrogen rate (kg ha^{-1})	**Days to heading**	**Days to physiological maturity**
0	73.50^{d}	125.25^{c}
18	78.27^{c}	135.45^{b}
36	85.31^{b}	140.15^{a}
54	91.33^{a}	143.25^{a}
LSD (5%)	2.80	3.72
Varieties		
Holker	84.33^{b}	138.33^{b}
Ibon174/03	72.42^{d}	126.33^{c}
HB-1963	79.83^{c}	135.17^{b}
Explorer	92.42^{a}	144.67^{a}
Mean	82.25	136.25
LSD $_{(0.05)}$	2.82	3.57
CV (%)	4.10	3.14

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

3.4 Growth Parameter of Malt Barley

3.4.1 Leaf Area at Flowering Stage

Leaf area of malt barley crop was significantly ($p \leq 0.01$) affected by the interaction of nitrogen rate and varieties (Table 5). The maximum leaf area (23.27cm^2) was obtained with the combination of 54 kg Nha^{-1} and HB-1963 variety, whereas the least leaf area (11.50cm^2) was recorded with combination of control (0 N) and Ibon174/03 variety. This implies that an increase in leaf area of plants contribute for increment of solar radiation absorption. As a result, the process of photosynthesis and the growth of yield components could increase. Moreover, Minale *et al*. (2006) also found that with increasing the levels of nitrogen, leaf area of barley also increased. The development of individual leaf area and total leaf area of crop plant ultimately contributed towards higher grain yield.

Table5. *Interaction effect of nitrogen levels and varieties on leaf area (cm^2) of malt barley at HARC*

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	14.57^{gf}	17.20^{d}	18.93^{c}	19.30^{c}	17.5
Ibon174/03	11.50^{i}	14.13^{g}	15.57^{ef}	17.13^{d}	14.58
HB-1963	16.77^{ed}	21.83^{b}	23.07^{ba}	23.27^{a}	21.23
Explorer	12.47^{ih}	13.40^{gh}	15.97^{ed}	16.87^{d}	14.68
Mean	13.83	16.64	18.38	19.14	16.99
LSD (5%)			1.24		
CV (%)			5.19		

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

3.4.2 Number of Productive Tillers Per Plant at Maturity Stage

Both main and interaction effect of nitrogen levels and varieties had highly significant ($p \leq 0.01$) difference on number of productive tillers per plant of malt barley (Table 6). The maximum (13.90) number of productive tillers at maturity stage was recorded with combination of 54 kg Nha^{-1} and Ibon174/03 variety, while the lowest (4.47) number of productive tillers at maturity stage was obtained in control treatment and Holker variety. This might be due to the role of N fertilizer in accelerating vegetative growth of plants and nitrogen stimulates tillering, that could be due to its effect on cytokine/protein synthesis. The results were in agreement with Abdullatif *et al*. (2010) reported increasing in the number of productive tillers with nitrogen fertilization. Similarly, Evans *et al*. (1975) found that tillering is enhanced by increased light and N availability during the vegetative crop phase.

Table 6. *Interaction effect of nitrogen levels and varieties on productive tillers of malt barley at HARC*

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	4.47^{j}	5.00^{ih}	7.20^{gf}	9.403^{ed}	6.52
Ibon174/03	6. 70^{gfh}	6.87^{gh}	11.30^{b}	13.90^{a}	9.69
HB-1963	6.97^{gfh}	9.93^{d}	10.93^{cb}	11.03^{cb}	9.72
Explorer	5.47^{ji}	6.90^{gh}	7.07^{gf}	8.20^{ef}	6.91
Mean	5.90	7.50	9.12	10.63	8.30
LSD (5%)			1.25		
CV (%)			9.63		

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

3.4.3 Plant Height

Mean values for nitrogen rates showed that plant height increased with each increment of nitrogen rates from the control to the highest rate. The tallest plant height (93.43cm) was recorded from 54 kg Nha^{-1}, while the shortest plant height (79cm) was recorded in the control (0 N). Such increment of plant height along with increase of N fertilizer rate might be related to the effect of nitrogen which promotes vegetative growth as other growth factors are in conjunction with it. This result is in agreement with Minale *et al*. (2011) and Wakene *et al*. (2014) who reported that plant height of barely was increase with increasing rates of N fertilizer. This may be due to the sufficient nitrogen in soil (Table 7) and abundant amount of rain fall. Mean plant height for the variety averaged over N rates showed that Explorer variety had the shortest plant height (61cm) while HB-1963 variety had the tallest plant height (101cm) because of the fact that it is a tall variety. The HB-1963 variety exceeded the three other varieties; these may be due to genotypic behavior in combination with the environmental conditions, which were suitable for the HB-1963 variety than the others, varieties.

Table7. *Main effect of nitrogen levels and varieties on plant height and spike length of malt barley at HARC*

Nitrogen rate (kg ha^{-1})	**Plant height (cm)**	
0	78.71^{c}	
18	87.04^{b}	
36	87.15^{b}	
54	93.43^{a}	
LSD (5%)	2.60	
Varieties		
Holker	96.04^{b}	
Ibon174/03	87.87^{c}	
HB-1963	101.04^{a}	
Explorer	61.38^{d}	
Mean	86.58	
LSD (5%)	2.62	
CV (%)	3.63	

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

3.4.4 Number of Grains Per Spike

Number of grains per spike responded significantly to the main effect of N rates, the varieties and their interaction (Table 8). The highest (30.60) number of grain per spike were obtained with combination of 54 kg N ha^{-1} and HB-1963 variety, whereas the lowest (16.53) number of grains per spike were recorded with combination of control treatments and Explorer variety (Table 8). In agreement with the result Assefa *et al*. (2017) reported that nitrogen increased the number of grains per spike and this parameter is the best indicator of barley response to nitrogen. There was variation among varieties on number of grains per spike. Thus variation of number of grains per spike was come from genotypic variation of barley. In line with this result Adane (2015) reported genotypic differences of barley in spikelet per spike that in turn resulted in higher numbers of grains per spike.

Table 8. *Interaction effect of nitrogen levels and varieties on number of grains per spike of malt barley at HARC*

Varieties	Nitrogen rate (kg ha^{-1})				
	0	18	36	54	Mean
Holker	17.20^{gh}	19.17^{f}	21.40^{e}	25.87^{e}	20.91
Ibon174/03	19.27^{f}	22.13^{ed}	28.17^{b}	26.37^{c}	23.99
HB-1963	23.40^{d}	26.00^{c}	28.93^{b}	30.60^{a}	27.23
Explorer	16.53^{h}	18.10^{gf}	20.90^{e}	19.30^{f}	18.71
Mean	19.1	21.35	24.85	25.53	22.71
LSD $_{(0.05)}$			1.42		
CV (%)			3.74		

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

3.5 Grain Yield, Straw Yield and Harvest Index

3.5.1 Grain Yield

Significant ($p \leq 0.001$) differences among nitrogen rate treatments, varieties and their interaction for grain yield of malt barley (Table 9). 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) (Table 9). 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. When the N fertilizer rates increased from 0 to 18 and 36 kg Nha^{-1} the mean grain yield was increased by 30.7 and 39.8%, respectively, indicating increasing response with increasing N fertilizer rates. This result were in agreement with Amare (2015) reports who mentioned that significant increases in grain yields of malt barley crop with increasing levels of N fertilizer.

Table9. *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 ($p \leq 0.05$).

3.5.2 Straw Yield

There were significant ($p \leq 0.05$) differences among nitrogen rate treatments and varieties for straw yield of malt barley while their interaction was not significant (Table 10). The highest straw yield was obtained from the highest N rate (54 kg ha^{-1}) with increase of 21, 38 and 67% over the control treatment, 18, 36 and 54 kg Nha^{-1}; respectively. It suggests that nitrogen application enhances the vegetative growth of barley crop that delays senescence which ultimately increase biological yield. In agreement with this report, Amsal *et al.* (2000) reported that N rate significantly enhanced the straw yield of wheat, since N usually promotes the vegetative growth of a plant. There were also significant differences ($p \leq 0.05$) between the Explorer variety and the rest of the varieties for straw yield across N rate treatments. The highest (10046 kg ha^{-1}) mean straw recorded HB-1963 variety, whereas the lowest (5931 kgha^{-1}) mean straw yield obtained from Explorer variety (Table 10). The significant was may be genetic variation.

3.5.3 Harvest Index

The ability of a variety to partition the dry matter into economic (grain) yield is indicated by its harvest index of malt barley which was significantly ($p \leq 0.05$) varied among varieties and N rate treatments (Table 10). The control treatment had resulted in the highest harvest index (39.37%), followed by N rates of 18 kg/ha with a harvest index value of 38.8%. This result indicated that as increased the applied N rate, harvest index of barley was decreased. In line with Munir (2002) and Demelash (2016) reported that applied N fertilizer rate were increased while the mean harvest index were decreased. There were also highly significant ($p \leq 0.05$) differences between the Holker and the rest of the varieties for harvest index across N rate treatments. This could be accounted for the enhanced above ground biomass yield in response to the incremental rates of N in contrast to grain yield during the growing season. In the case of Ibon174/03, HB-1963 and Explorer varieties, statistically all were at par for their HI ranging from 36.09 - 40.19 % suggesting nearly an equal early assimilation and utilization of nitrogen nutrients of those varieties while lowest harvest index (31.7 %) was recorded for variety Holker. There was variation in harvest index of different barley varieties due to barley inherent variability.

Table1. *Main effect of nitrogen levels and varieties on total biomass, straw yield and harvest index of malt barley at HARC*

Nitrogen rate (kg ha^{1})	Straw yield (kgha^{-1})	Harvest index (%)
0	6533.3^{c}	39.37^{a}
18	7909.1^{b}	38.80^{a}
36	8996.2^{b}	36.94^{ba}
54	10919.3^{a}	32.66^{b}
LSD (5%)	1267.45	4.83
Varieties		
Holker	9333.3^{a}	31.73^{b}
Ibon174/03	9138.7^{a}	39.61^{a}
HB-1963	10045.8^{a}	36.09^{ba}
Explorer	5930.6^{b}	40.19^{a}
Mean	8612.12	36.90
LSD (5%)	1279.60	4.77
CV (%)	17.80	15.70

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

3.6 Quality Parameters

3.6.1 Thousand Seed Weight

Significant ($p \leq 0.05$) differences among varieties for thousand seed weight of malt barley while nitrogen rate and their interaction was non-significant (Table 11). The highest (56g) thousand seed weights was produced from HB-1963 variety, whereas the lowest (44g) thousand seed weights obtained from Explorer variety (Table 11). This might be due to the suitable genetic behavior of HB-1963 variety with the environmental factors which may led to an increased in photosynthesis process and accumulation of carbohydrates in grain to produce heavy grains and consequently increased grains weight per spike. Similarly, Rashid and Khan (2008); and Yetsedaw *et al*. (2013) reported that variation of thousand grain weight as a function of barely genotype. Thousand seed of malt barley weights had a linear and negative response to N fertilizer rates and exhibited non-significant difference among control and the rest of applied N treatments (Table 11). Thousand seed of malt barley weight should be >45 g for 2-rowed barley and > 42 g for 6-rowed barley (Anonymous, 2012).

3.6.2 Hectoliter Weight

Hectoliter weight of malt barley was significantly ($p \leq 0.01$) different to the main effect of varieties and N levels, while the interaction effect was not significantly affected (Table 11). The highest (68 kg hl^{-1}) hectoliter weight was recorded from the highest applied N fertilizer (54 kg Nha^{-1}), whereas the lowest (67 kg hl^{-1}) hectoliter weight was obtained from control treatment (Table 14). Moreover, Biruk and Demelash (2016) who found that under more favorable growing conditions slight increase specific weight in response to N fertilizer application. The highest (69 kg hl^{-1}) hectoliter weight of malt barley was recorded for variety HB-1963 variety while the lowest (65.95 kg hl^{-1}) hectoliter weight was obtained from Holker variety. There was variation in hectoliter weight of different barley varieties due to barley genetic. On the other hand, Rick *et al*. (2014) reported that the acceptable test weights (hectoliter weight) for barley were in the range 66.1- 72.8kg hl^{-1}. The current results exhibited an acceptable hectoliter weight in all varieties for all N fertilizer rates.

3.6.3 Grain Moisture Content

The mean moisture content of malt barley was significantly ($p \leq 0.05$) different among the varieties (Table 11). The highest (13.25%) mean moisture content was obtained from HB-1963 variety, whereas the lowest (11.97%) mean moisture content was observed from Explorer variety. The difference moisture content among varieties was due to genetic variation. 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. Fox *et al*. (2003) reported that the maximum reasonable industrial specification of malt barley moisture content for safe storage is 12.5%, while the European Brewing Convention (EBC) standard moisture content lie 12-13.5 % is accepted. The moisture content was in the acceptable range in all varieties and all N fertilizer rates, except Explorer variety which is slightly low (Table 11).

3.6.4 Grain Size (Sieve Size)

The mean grain size of malt barley was highly significant ($p \leq 0.01$) among varieties. Sieve test analysis results using 2.8mm and 2.5mm sieve size responded significantly ($p \leq 0.01$) to variety (Table 11). The maximum (96.74%) mean grain size percentage was obtained from HB-1963 variety, while the minimum (84.48%) grain size from Explorer variety. Fox *et al*. (2003) reported that the genetic and environmental effects in improving grain size, and varieties with high grain size implies in uniformity in grain size. Industry standards on large grain are based on the total percentage of grain >2.5mm. High grain plumpness and uniformity are desirable quality characteristics since potential malt extract is directly associated with barley grain size. The grain size percentage should be >90% for 2-rowed barley and >80% for 6-rowed barley (Anonymous, 2012). The mean seed sizes fulfill the standard requirement of the industry according to EBC and Ethiopia malt factory, except Explorer variety (Table 11).

3.6.5 Grain Protein Content

Grain protein content of malt barley was highly significant ($p \leq 0.01$) difference to the main effect of N fertilizer levels and varieties, while the interaction effect was non-significantly ($p \leq 0.05$) affected (Table 11). As N fertilizer increases grain protein content also increased. The highest (13.42%) grain protein content was recorded from the highest N fertilizer application (54 kg Nha^{-1}), whereas the lowest (10.61%) grain protein obtained from control treatment. Similarly, Adane (2015) found that with low available nitrogen in the soil, malt barley responds well to applied fertilizer, showing increases in both grain yield and protein content. Increasing in protein may increase steep times, create undesirable qualities in the malt, excessive enzymatic activity and low extract yield (Johnston *et al*., 2007). It also slows down water uptake during steeping, potentially affecting final malt quality. The highest (12.58%) grain protein content was recorded from Holker variety. The lowest grain protein content (10.42%) in the Explorer variety might be due to the low grain N uptake. The variation in grain protein content was due to genetic variation of malt barley varieties. 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). Both main effect of N fertilizer rate and varieties had grain protein content within the acceptable range, except at the highest (54 kg ha^{-1}) N fertilizer rates and Holker variety (Table 11).

3.6.6 Germination Energy

The analysis of variance for germination energy of malt barley was significantly ($p \leq 0.05$) different among varieties (Table 11). The highest (98.08%) value was obtained from HB-1963 variety, while the lowest (92%) germination energy was observed from Explorer variety. Moreover, Biadge *et al.* (2017) found that the differences in the genetic factors determining germination energy of malt barley varieties after three days and a minimum of 95% germination on 3 days germination test is an absolute requirement. Similarly, EBC (1998) reported that germination energy of malt barley should >95%. The germination energy was in the acceptable range in all varieties, except Explorer variety. The germination energy did not show significant differences among nitrogen levels, but the germination energy varied between 95-96.17%. Germination energy was slightly decreased as N rates increase.

Table2. *Main of nitrogen levels and varieties on grain quality parameter of malt barley at HARC*

N rate (kg ha^{-1})	TGW(g)	HLW(kg/hl)	MC (%)	GS (%)	GPC (%)	GE (%)
0	51.33	66.79^{b}	12.90	91.53	10.61^{c}	96.17
18	51.25	66.79^{b}	12.79	91.94	11.23^{b}	95.63
36	50.53	67.15^{ba}	12.83	91.92	11.41^{b}	95.15
54	50.26	68.37^{a}	12.42	90.91	13.42^{a}	95.00
LSD (5%)	NS	1.5	NS	NS	0.39	NS
Varieties						
Holker	51.75^{b}	66.37^{b}	13.08^{a}	92.73^{b}	12.58^{a}	95.75^{b}
Ibon174/03	52.23^{b}	67.18^{b}	12.65^{ba}	95.09^{ba}	12.04^{b}	96.08^{b}
HB-1963	55.473^{a}	69.00^{a}	13.25^{a}	96.74^{a}	11.73^{c}	98.08^{a}
Explorer	43.87^{c}	65.95^{b}	11.97^{b}	84.48^{c}	10.42^{d}	92.00^{c}
Mean	50.83	67.27	12.73	92.26	11.67	95.47
LSD (5%)	2.05	1.49	0.72	2.37	0.39	1.99
CV (%)	4.83	2.65	6.85	3.08	4.02	2.50

Means followed by the same letters are not significantly different at ($p \leq 0.05$). GW = Thousand grain weight, HLW = Hectoliter weight, MC = Moisture content, GS = Grain size, GPC = Grain protein content, GNC = Grain nitrogen content, GE = Germination energy, NS = Non-significant

3.7 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 12. 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.

Table12. *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.

4. Conclusion and Recommendation

Information on crops response to N fertilizer rates and improved variety is crucial to come up with profitable and sustainable malt barley production. The objective was to increase yield and yield components of malt barley production with good manageable agronomic practices at Wolmera District in 2017. Days to heading and maturity, leaf area, number of tillers, plant height, and seed per spike, straw yield and hectoliter weight of malt barley were increased with N fertilizer rates increased. Grain yield and protein content 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 grain protein content while low nitrogen rates leads to optimum grain yield with acceptable quality. Among malt barley varieties Ibon174/03 and HB-1963 varieties had good performance. The application of 36 kg/ha N fertilizer rates and Ibon174/03 variety which generated optimum grain yield with requirement quality, and 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 with acceptable premium quality 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, acceptable quality 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 quality of malt barely varieties.

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Citation: *Terefe, D.,et al. (2018). Effect of Nitrogen Fertilizer Levels on Grain Yield and Quality of Malt Barley (Hordeum Vulgare L.) Varieties at Wolmera District, Central Highland of Ethiopia. International Journal of Research Studies in Agricultural Sciences (IJRSAS), 4(4), pp.29-43, http://dx.doi.org/10.20431/ 2454-6224.0404005*