Food Science and Quality Management
ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online)
Vol.52, 2016

Effect of Nitrogen Fertilizer Level on Grain Yield and Quality of Malt Barley (Hordeum vulgare L.) Varieties in Malga Woreda, Southern Ethiopia

Biruk Gezahegn Demelash Kefale
Department of Plant and Horticultural Sciences, Hawassa University College of Agriculture, P.O. Box 05, Hawassa, Ethiopia

Abstract
A field experiment was carried out during the 2013 cropping season at the Malga district, Sidama zone, SNNPRS, to determine the effects of nitrogen (N) fertilizer level on grain yield and quality of malt barley (Hordeum vulgare L.) varieties. Factorial combination of three malt barely cultivars (Sabini, Bahat and local) and five rates of N fertilizer (52.5, 64, 75.5, 87 and 98.5 kgha^{-1}) were laid out in a randomized complete block design (RCBD) with three replications. The variety Bahat exhibited higher values in productive tillers, thousand-kernel weight, kernels per spike, harvest index, grain yield, hectoliter weight, and grain protein contents. On the other hand, the Local variety exhibited greater values in spike length, plant height and straw yield. Considering N rate, almost all agronomic parameters except harvest index increased in response to N rates up to 98.5 kgha^{-1}. Based on the present finding, the maximum grain yield (4918.3 kgha^{-1}) was obtained from Bahat variety with the highest levels 98.5 kgha^{-1}N fertilizer application. But the grain from such combination was beyond the acceptable grain protein contents for malting purpose. However, N fertilizer rate of 75.5 N kg$ha^{-1}$for Bahat produced optimum (4578.7 kgha^{-1}) yield with acceptable grain protein content for malt barley production in the study area.
Keywords: Nitrogen fertilizer, Malt barley variety, Quality, Yield.

1. INTRODUCTION

Barley (*Hordeum vulgare* L) is one of the most important cereal crops, mainly grown by smallholder farmers at mid- and high altitudes in NW Ethiopia, predominantly between2200–3000 m a.s.l (Asmare *et al.*, 1998). Malt barley is used for preparing alcoholic beverages, mainly beer. ORDA (2008b) estimated that about 15,945 tons of malt barley is produced annually in Ethiopia. However, the combined annual malt barley consumption of the six breweries in the country was estimated as 48,330 tons, which is expected to double owing to the expansion of the existing breweries. Most of the demand for malt is met through imports, which account for 69% of the total annual requirement (ORDA, 2008a).

To satisfy the ever-increasing demand for raw materials by the beverage industry, and to ensure dependable and higher cash returns to the farmers, expansion of the malt barley production is very important since immense potential areas are available for malt barley production to meet the national demand. However, its production has not expanded, and productivity at farm level has remained low. One reason for the low productivity of the crop is the poor soil fertility of farmlands, mainly aggravated by continuous cropping, overgrazing, high soil erosion and removal of crop residues, without any soil amelioration. Nitrogen is deficient in most Ethiopian highland soils (Taye *et al.*, 2002).

On the other hand, quality requirements for malt barley are fairly strict, and directly related to processing efficiency and product quality in the malting and brewing industries. Excessively higher protein content is undesirable, because of the strong inverse correlation between protein and carbohydrate content; thus high protein content leads to a low malt extract level (Fox *et al*., 2003). Grain N content is thus a determining factor of malt quality; high grain N content not only means lower carbohydrate content and lower malt extract level, but also makes the barley more difficult to modify, causing problems for the maltster. The preferred grain N level is not greater than 1.6–1.8% (Zhao *et al.*, 2006).

Thus, grain yield and quality of malt barley varieties is significantly influenced by rate of N fertilizer that means when assessing grain yield of cultivars in different rate of N fertilizer in different barely varieties. Thus, malt quality and grain yield fluctuation leads to significant loss for beverage industry, individual farmers at national level. Therefore, identification of appropriate varieties of malting barley and the use of appropriate production practices are critical to the production of quality malting barley. However, there are no studies have been carried out on the interaction between N fertilizer rate and different malting barley varieties under Malga Woreda. The present investigation was conducted with the aim of identifying appropriate malting barley varieties, with their respective optimum level of N fertilizer, for the barley-growing areas of Malga Woreda south, Ethiopia. Thus, the objectives of the study were:

- ✓ To evaluate the response of different malt barely varieties to N fertilizer levels,
- ✓ To determine the optimum N levels for malt barely varieties that would enhance grain yield without affecting the necessary malting qualities; and

- ✓ To identify the best variety for yield potential, protein content and N requirement under study area.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

This experiment was conducted at Malga Woreda, southern Ethiopia during 2013 main cropping season (August - December. 2013). Malga Woreda is located about 310 km from the capital city of Addis Ababa, and 35 km from Southern Nation Nationalities and People's Region (SNNPRS) capital city of Hawassa in the southeastern part of the country in Sidama zone. It lies at 7.1–7.017^0 N and 38.35-38.5833^0 E at an altitude of ranging from 1501 to 3000 masl. The study area has a mean annual rainfall and temperature ranging from 1201-1600 mm and 12.6–20℃, respectively.

2.2. Experimental Treatments and Procedures

The experiment involved a factorial combination of three malt barely cultivars (Sabini, Bahat and Local) and five rates of N fertilizer (52.5, 64, 75.5, 87 and 98.5 kgha^{-1}). The experiment was conducted using a randomized complete block design with three replications. Accordingly, the treatments and treatment combinations including the control treatment were assigned randomly to the experimental units within a block.

The experimental field was prepared following the conventional tillage practice before planting the malt barely varieties. In accordance with the specifications of the design, a field layout was prepared and each treatment was assigned randomly to experimental plots within each block. The blocks were separated by a 1 m wide-open space, whereas the plots within a block were 0.5 m apart from each other. Each plot consisted of 12 rows of 3 m in length and spaced 20 cm apart. The net plot size was 7.2 m^2 (2.40 m × 3 m). The net plot size was 1.60 x 2.2 m (central 8 rows of 2.2 m length)

Malt barely varieties seed, sown at the recommended rate of 125 kgha^{-1}, were planted in rows by using a manual row marker on August 25, 2013. A blanket application of DAP (Diammonium phosphates 18% N and 46% P_2O_5) was applied across all treatments at the time of sowing and UREA (46% N) fertilizer as per rate of treatment were applied as top-dressing at mid tillering stage which coincided with 30 days after planting. All other recommended cultural practices were properly followed to produce a successful crop.

2.3. Agronomic Data Collection

Days to 50% crop emergence, 50% tillering, 50% grain filling and 50% physiological maturity were recorded when 50% of plants reached the respective phenological stages. . The number of seedlings was estimated by counting seedlings at 20 days after crop emergence. Productive number of tiller was determined just before harvest from randomly selected 0.50 m sections of four rows within the net plot, and finally converted to a m basis. Spike length per plant was determined from 10 randomly taken plants. Plant height was determined on 10 mother tillers (main shoots) at late flowering stage.

Yield and yield components and related traits consisted of number of grain per spike, 1000-kernel weight, total aboveground biomass, harvest index, grain yield, straw yield, grain protein content and hectoliter weight. The grain was harvested within the range of end of November to early December 2013, depending on the maturity date of each variety.

Harvest index (HI) was calculated as the ratio of grain yield to the aboveground biomass yield, expressed as a percentage. The grain moisture level and hectoliter weight (HLW) were determined by a Sinar AP 6060 Moisture Analyzer instrument. Thousand-kernel weight (TKW) was measured from the sample by a sensitive balance and grain yield was adjusted to a 12.5% moisture basis. Grain protein content was determined by multiplying the N content by the conversion factor of 6.25 according to the standard macro-Kjeldhal procedure. Straw yield was calculated as the difference between aboveground biomass and grain yield.

2.4. Soil Sampling and Physico-chemical Analysis

Soil samples were collected from representative points within the experimental field (0-30 cm depth) before planting to make two composite samples. Similarly, surface soil samples of the same depth were collected just after harvest for each treatment by taking samples from three points within each plot.

Soil analyses for specific parameters relevant to the current study were carried out at the soil laboratory of Hawassa Agricultural Research Center (HARC. The pre-planting soil samples were analyzed for available nitrogen, available phosphorus, organic carbon, pH (in water), and texture (pipette method). Similarly, post-harvest analyses of total N, available P, and soil pH were determined on a plot basis.

Soil texture was expressed by using Bouyoucos hydrometer method (Day, 1965). Available P was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen *et al*. (1954). The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 soil: water mixture by using a pH meter, and Organic Carbon was determined by following Walkely and Black wet oxidation method as described by Jackson (1958). Total Nitrogen was determined by using Kjedahl method as described by Jackson

(1958).

2.5. Statistical Analysis

The data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out with MSTATC soft ware (MSU, 1991). Significance differences between and among treatments were delineated by LSD (least significance difference). Correlation analyses were determined through simple correlation coefficient between yields and yield components and soil analysis results of laboratory. The interaction and use of the same biometrical equations were done according Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Some Soil Physico-chemical Properties of the Study Area

The results of the laboratory analysis of some physico-chemical properties of the soil used for the experiment was silt in texture and slightly acidic in reaction, with a pH of 6.0 (Table 1).

The clay content of soil increased with the depth of soil profile. Like the clay content, the distribution of sand fraction increased with depth of the soil profile (Table 1). Based on the distribution of the soil separates, the A and B-horizons were grouped into silty loam and sandy clay loam, respectively. The percent pore-space in different horizons from AP to Bt2 ranged from 57.9 to 46.4%. According to Berhanu (2005), the bulk density of clay, clay loam, sandy clay loam and silt loam soil ranges from 1.0-1.6g/cm3.

The OC content of the soil profile decreased with depth from a maximum value of 4.044 in AP horizon to 0.413 in Bt2 (Table 1). Similar to OC and total N content also decreased with depth from 4.044 to 0.413 mg/kg soil and 0.35 to 0.036 %, respectively. The results of available P showed similar trend with that of OC and total N. The results were in agreement with the observation of Sahlemedhin (1999) who reported that N and P are tied to humus content of the soil and their value decrease, as doe's organic matter.

3.2. Response of Malt Barely Varieties to Rates of Nitrogen Fertilizer

3.2.1. Crop Phenology

The main effects of varieties and N rates as well as their interactions did not affect the duration of crop emergence significantly; and seedlings from all plots reached 50% emergence at 7 days. In line with this, Quinones (1997) stated that once the germination process is set, seedling emergence might take less than a week, depending on soil temperature, moisture availability and seeding depth. However, there were detectable differences among varieties in days to heading and days to maturing (Table 2 and 3), in which varieties Bahat and Sabini early heading and maturing was recorded compared to the Local.

Table 1. Selected physical and chemical properties of the experimental soil at Malga Woreda, Southern Ethiopia 2013 cropping season

Depth (cm)	Horizon	pH (H_2O)	PD (g/cm3)	BD (g/cm3)	PS (%)	Total N (%)	Av.P (ppm)	OC (%)	Particle size distribution (%)			Textural Class
									Sand	Silt	Clay	
0-40	Ap	6.0	2.38	0.99	57.9	0.35	37.7	4.044	38	50	12	Si
40-90	Bt1	5.54	2.50	1.38	46.8	0.043	34.8	0.495	56	18	26	Scl
90-160+	Bt2	5.35	2.50	1.34	46.4	0.036	33.8	0.413	54	20	26	Scl

Sl - silt-loam, Scl - sandy clay loam, PD =particle density, BD = bulk density, PS = pore space, OC = organic carbon, Av.P = available phosphorus

The data analysis data revealed a non-significant difference among N rates and their interactions (Table 2 and 3) on heading and maturity. On contrary to these observations, several research reports are available demonstrating significant effect of fertilizer N on days to heading and maturity (Batey, 1984; Archer, 1988). In fact, these phenological stages were reported to be promoted by N application (Evans *et al.,* 1975).

3.2.2. Growth Parameters

3.2.2.1. Plant Height

The analysis of variance indicated highly significant ($P<0.01$) plant height differences caused by interaction effect of the two factors (Table 2 and 4). The highest mean plant height (132.2 cm) was obtained from Local variety with the highest rate of N fertilizer (98.5 kg Nha^{-1}) (Table 4). The Local cultivar exceeded the two other cultivars; these may be due to genotypic behavior in combination with the environmental conditions, which were suitable for the Local than the others, varieties.

3.2.2.2. Spike Length

Spike length varied significantly (P<0.001) among varieties (Table 2). The Local cultivar exceeded the two other cultivars in mean values of (23.12 cm) (Table 3). These may be due to genotypic behavior in combination with the environmental conditions, which were suitable for Local variety than the others, varieties. But the main effects of N rates as well as their interactions did not affect the spike length.

3.2.2.3. Straw Yield

There was a considerable difference in straw yield (P<0.01) as result of the interaction effect of the two factor (Table 2 and 4). The highest mean straw yield (9127.7 kg Nha^{-1}) was obtained from Local variety with the highest N fertilizer application rate (98.5 kg Nha^{-1}), while the lowest mean straw yield (3455.3 kg Nha^{-1}) from Sabini variety with the lowest application rate of N fertilizer (51.5 kg Nha^{-1}). The Local variety produced more straw yield than Bahat and Sabini; implying an advantage of the total above ground dry-matter production from the relatively late maturing variety. This type of variety is preferable for integrated crop-livestock production systems where the farmer has multiple uses for the barely crop. Barely straw represents one of the major dry season feed sources for the large livestock population of Ethiopia Tilahun *et al.* (1996a).

3.2.3. Yield Components and Grain Yield

3.2.3.1. Number of Productive Tillers

The difference between varieties in relation to tillering was highly significant at P<0.001 (Table 2 and 3). The highest number of productive tillers was recorded in variety Bahat, as compared to Sabini and Local. The current data agree with the report by Gooding and Davies (1997) which states that differences between varieties tend to diminish towards flowering when the number of tillers is largely a function of environmental conditions.

Bahat and Sabini produced 19.08 and 6.5% more tiller m^2, respectively than Local variety (Table 3). The lower number of tillers in the Local might be attributed to the death of the late (secondary and/or tertiary) tillers due to the prevailing moisture stress late in the growing season. In line with this observation, Stoskopf (1985) reported a better chance of early-formed tillers to survive and produce spikes: they develop before the onset of high temperatures that can elevate tiller mortality. It is generally assumed that as secondary tillers die without producing spikes which is deleterious to grain production, as they waste assimilate, water, and nutrients that would otherwise have contributed to grain yield (Stoskopf, 1985; Gooding and Davies, 1997).

The main effect of N fertilizer rates caused significant (P<0.05) difference in number of productive tillers, but a non-significant difference from interaction (Tables 2). Tillering is enhanced by increased light and N availability during the vegetative crop phase (Evans *et al.,* 1975). According to Mangle and Kirkby (1996), nitrogen stimulates tillering, may be due to its effect on cytokine synthesis. Others reported that barely reacts to early N by producing more tillers per plant and by exhibiting a higher percentage survival of tillers (Batey, 1984; Archer, 1988).

Table 2. ANOVA table of selected agronomic parameters

Source of variation	Mean square											
	DH	PM	PT	SPL	PLH	KPS	TKW	HI	GY	SY	HLW	GPC
R	6.4	237.9	3.5	1.1	7.9	6.75	12.69	0.15	16187.2	24444.2	0.1	0.009
V	1424.8	2595.4**	1292***	30***	3716***	496***	148.9***	812.4***	2811521***	26419269***	11***	5.42***
NR	2.8	257.5	73.3*	4.3	174.4**	20.9**	42.7***	15**	2783896***	7544731***	14.1***	9.81***
V*NR	4.13	217.6	13.3	6.4	153.2**	6.1	4.7	30.95	638360.2**	2962065**	2.4**	0.133**
Error	**1.58**	**225.8**	**6.7**	**1.2**	**5.1**	**1.14**	**0.18**	**0.64**	**31412.8**	**30381.3**	**0.2**	**0.090**
CV (%)	**19.3**	**11.9**	**3.1**	**5.0**	**12.1**	**9.4**	**14.5**	**13.7**	**14.5**	**13.0**	**0.6**	**0.78**

R=Replication, V=Variety, NR=Nitrogen rate, DH=Days to heading, PM=Days to physiological maturity, PT=Productive tiller, PLH=Plant height, SPL=Spike length, NKS=Number of kernel/spikes, GY=Yield yield, HI=Harvest index, TKW=1000-kernel weight SY=Straw yield, HLW=Hectoliter weight, and GPC=Grain protein contents. *, **, *** are significant at P ≤ 5, 1 and 0.1% probability levels, respectively.

Table 3. Effects of varieties and nitrogen fertilizer rate on some agronomic parameters during 2013 cropping season at Malga

Treatment	Days to heading	Days to physiological maturity	Number of productive tillers	Spike length (cm)	KNPS	HI (%)	TKW (g)
Cultivar							
Bahat	77.90^{b}	118.50^{b}	94.60^{a}	22.10^{b}	31.10^{a}	44.50^{a}	44.50^{a}
Sabini	77.10^{b}	117.50^{b}	81.90^{b}	20.30^{c}	27.70^{b}	43.00^{b}	42.10^{b}
Local	94.40^{a}	140.80^{a}	76.60^{c}	23.10^{a}	19.90^{c}	37.40^{c}	39.20^{c}
SE (M) ±	**2.50**	**225.8**	**6.70**	**1.20**	**1.14**	**0.64**	**0.18**
LSD 5%	**1.20**	**0.73**	**1.90**	**0.83**	**1.60**	**1.40**	**1.02**
N rate kg ha^{-1}							
52.50	83.00	123.60	80.90^{b}	21.90	23.70	42.70^{a}	39.40^{d}
64.00	83.50	124.10	81.80^{b}	21.92	26.40	40.20^{b}	41.10^{c}
75.50	82.40	123.10	87.40^{a}	20.70	26.40	38.30^{c}	43.60^{ab}
87.00	83.20	122.20	85.60^{a}	22.20	28.00	36.90^{d}	44.90^{a}
98.50	83.10	135.10	86.20^{a}	22.50	26.40	36.30^{d}	42.30^{b}
SE (M) ±	**2.50**	**225.80**	**6.70**	**1.20**	**1.14**	**0.64**	**0.18**
LSD 5%	**NS**	**NS**	**2.54**	**NS**	**2.05**	**1.87**	**1.50**
CV %	**19.30**	**11.90**	**3.10**	**5.00**	**9.40**	**13.70**	**14.50**

Mean values within column followed the same letters are not significantly different (P < 0.05), KNS=Kernel number per spike, HI=Harvest index and TKW=Thousand kernel weight.

3.2.3.2. Kernel Number per Spike

Kernels number per spike (KNPS) was significantly different among the tested varieties (P<0.001), where Bahat produced the highest number of kernels per spike (31.06) (Tables 2 and 3). Reports have shown the variation of number of kernels per spike as a function of barely genotype (Brown *et al.,* 1987; Ryan *et al.,* 2009). Schulthess (1992) also reported genotypic differences in spikelets per spike that in turn resulted in higher numbers of grains per spike.

The main effect of N fertilizer rates exhibited significant differential effect on kernels number per spike (NKPS) (P<0.001) (Table 2). However, their interactions were not significant in influencing kernels number per spike. KPS had a linear and positive response to N fertilizer rate (Table 3) and exhibited significant differences between the lowest N rate and the rest of applied N treatments (P<0.01) (Table 3). The highest and the lowest mean value of KPS 28 and 23.7 were obtained from the 87 kg N ha^{-1} and 52.5 kg N ha^{-1} fertilizer application, respectively (Table 3). Several reports had shown a high response of number of grains per spike to N application rate (Singh *et al.,* 1992; Mooleki and Foster, 1993; Schulthess *et al.,* 1997). Tilahun *et al.* (1996a) reported great variation of grains per spike between the highest N level and the lowest application. The results of the experiment showed that plants had high ability to absorb applied N or to translocate and assimilate N for the synthesis and development of spikelets during the post-anthesis phase.

3.2.3.3. Thousand Kernel Weight

Thousand-kernel weight (TKW) was significantly different among the tested varieties (P<0.001), where Bahat produced the highest thousand-kernel weight 44.5 (Tables 2 and 3). This is may be due to the suitable genetic behavior of Bahat cultivar with environment factors which may led to an increased in photosynthesis process and accumulations of carbohydrate in kernel to produce heavy kernels and consequently increased kernels weight per spike. Reports have shown variation of number of kernels per spike as a function of barely genotype (Alam *et al*., 2007; Zeidan, 2007; Rashid and Khan, 2008; and Bagheri and Sadeghipour, 2009). Schulthess (1992) also reported genotypic differences in spikelets per spike that in turn resulted in higher numbers of grains per spike. On the contrary, the Local variety recorded the lowest value of thousand-kernel weight.

The main effect of N fertilizer rate exhibited significant differential responses in thousand-kernel weight (TKW) (P<0.001) (Table 2). However, the interaction effect of both factor were not significant in influencing thousand-kernel weight. TKW had a linear and positive response to N fertilizer rates (Table 3) and exhibited significant difference between the lowest N rate and the rest of applied N treatments (P<0.01) (Table 3). The highest mean TKW (44.87 g) was obtained from the 87 kg N ha^{-1} rate exceeding the lowest and the maximum N rate (98.5 kg Nha^{-1}) by 1.54 and 1.16%, respectively (Table 3). A positive and linear response of TKW to N rate has also been reported (Amsal *et al.,* 2001). The subsequent decline in kernel weight with increasing N rate was attributed to suboptimal assimilation of nutrients, and, hence, shriveled seeds of barely.

3.2.3.4. Grain Yield

The analysis of data revealed significant difference due to interaction effects on grain yieldha^{-1}) (P<0.01) (Table 2 and 4). The highest mean grain yield (4918.3 kg Nha^{-1}) was obtained from the highest application rate of N fertilizer (98.5 kg Nha^{-1}), while the lowest mean grain yield (2891 kg Nha^{-1}) from Local variety with the lowest application rate of N fertilizer (51.5 kg Nha^{-1}). These findings are in line with those obtained by other authors (Alam *et al*., 2007; Zeidan, 2007; Rashid and Khan, 2008; and Bagheri and Sadeghipour, 2009), who found significant variations between barley genotypes in grain yield.

Grain yield increased almost linearly in all varieties with increasing rates of N up to 98.5 kg Nha^{-1} (Table 4). Several studies reported positive and linear responses of grain yield to incremental rates of N (Gauer *et al.,* 1992; and Ali, 2010). The higher response of grain yield to the highest N rates in the current study could attribute to the favorable climatic conditions. The applied N was able to stimulate the production of an optimal number of grains or to influence other yield components favorably, implying sub-optimal utilization efficiency of the crop.

3.2.3.5. Harvest Index

Harvest index measures the portion of the grain yield to the total above ground plant dry matter (Ortiz-Monasterio *et al.,* 1997a). Bahat and Sabini varieties were significantly different from the Local (P<0.01) in harvest index HI (Table 2). The earlier and more recently released varieties, Bahat and Sabini, exhibited the highest mean HI 44.5 and 43.0% respectively, than the Local variety (Table 3). This is associated with early utilization of growth factors before stress due to high temperature and low precipitation occurred. Besides, the minimal competition within the grains per spikes of Bahat and Sabini might have facilitated the movement of nutrients into the grain. Donald and Hamblin (1976) emphasized the enhanced efficiency of more recent varieties in terms of dry matter accumulation in the grain both under moderate and high fertility conditions.

Table 4. Interaction effects of malt barely varieties and N fertilizer rates on some growth, yield and quality parameter during 2013 cropping season at Malga

Treatments	Plant height (cm)	Straw yield (kg/ha)	Grain yield (kg/ha)	Protein contents (%)	Hectoliter weight (kg)
V1N1	97.80^{e}	5581.60^{g}	3987.40^{d}	10.20^{e}	66.87^{d}
V1N2	104.00^{d}	4586.70^{i}	3867.30^{de}	10.50^{d}	66.76^{de}
V1N3	103.70^{d}	6217.60^{ef}	4578.70^{b}	10.80^{c}	68.00^{cd}
V1N4	106.30^{cd}	5483.70^{g}	4502.00^{bc}	11.40^{b}	68.56^{c}
V1N5	115.00^{b}	6056.70^{f}	4918.30^{a}	12.10^{a}	76.76^{a}
V2N1	83.70^{h}	3455.30^{k}	3303.50^{f}	10.10^{e}	66.80^{de}
V2N2	91.00^{f}	3897.30^{j}	3485.70^{ef}	10.50^{d}	67.16^{d}
V2N3	86.00^{g}	5071.30^{h}	4235.30^{cd}	10.80^{c}	66.73^{de}
V2N4	98.80^{e}	4702.30^{i}	4265.00^{c}	11.40^{b}	68.30^{e}
V2N5	106.00^{cd}	6319.50^{e}	4489.70^{bc}	12.10^{a}	69.86^{b}
V3N1	107.80^{c}	4782.00^{i}	2891.70^{e}	8.72^{h}	66.16^{e}
V3N2	115.80^{b}	7503.30^{c}	3532.40^{ef}	9.05^{g}	66.43^{e}
V3N3	117.70^{b}	6668.40^{d}	3277.00^{f}	9.38^{f}	66.30^{b}
V3N4	129.60^{a}	8422.00^{b}	3701.20^{e}	9.98^{e}	67.30^{d}
V3N5	132.20^{a}	9127.70^{a}	3682.00^{e}	10.68^{c}	67.13^{d}
SE (M) ±	4.90	30381.30	31412.80	0.04	0.20
LSD (P<0.05)	2.95	254.65	251.10	0.16	0.85
CV %	12.10	14.53	13.01	0.78	0.62

Mean values within column followed the same letters are not significantly different (P<0.05), V1, V2 and V3 represent for variety Bahat, Sabini and Local respectively and N1, N2, N3, N4 and N5 represent for N fertilizer rates 52.5, 64, 75.5, 87 and 98.5 kgha^{-1} respectively.

The main effect of N fertilizer rate was significant on HI (P<0.01) (Table 2), while the interaction was not significant in influencing harvest index. There was a negative and linear response to applied N rate (P<0.05), where the highest (42.7%) and the lowest (36.3%) mean HI values were obtained from the minimum and the maximum rate of N application, respectively (Tables 3). This could be accounted for by the enhanced aboveground biomass yield in response to the incremental rates of N fertilizer in contrast to grain yield due to the climatic conditions during the growing season. In contrast, a mean HI of about 50% with a positive trend due to increasing N rate had previously reported in Ethiopia (Taye *et al.,* 2002).

3.2.4. Quality Parameters

3.2.4.1. Hectoliter Weight

Hectoliter weight (HLW) was significantly ($P<0.001$) different as result of the interaction effect of the two factors (Table 2). The highest hectoliter weight (71.76 kg) was record in variety Bahat with the highest application rate of N fertilizer (98.5 kg Nha^{-1}) (Table 4). This variety also had the highest thousand-kernel weight compared to the other two cultivars. According to the Ethiopian quality standard, the acceptable grain size (thousand-kernel weight) and test weight (hectoliter weight) for barley are in the range 25–35 g and 48–62, respectively (EQSA, 2006). The results of the present experiment exhibited an acceptable thousand-kernel weight and hectoliter weight in all varieties (Tables 4).

Low values of HLW indicate poor grain filling, and, therefore, climatic influences leading to grain shriveling can impair specific weight through reduced packing efficiency (Gooding and Davies, 1997). Many authors (Pushman and Bingham, 1976; and Gooding and Davies, 1997) reported that, under more favorable growing conditions slight increase specific weight in response to N application.

3.2.4.2. Grain Protein Content

Grain protein was significantly ($P<0.01$) different as result of the interaction effect of the two factors (Table 2). The highest hectoliter weight (12.1%) was record in variety Bahat and Sabini with the highest application rate of N fertilizer (98.5 kg Nha^{-1}) (Table 4). According to the Ethiopian standard authority, the protein level of the raw barley quality standard for malt should be between 9–12% (EQSA, 2006). The results of the current study showed that all interactions, except the interaction between the highest level of N fertilizer rate (98.5 kg/ha) with varieties Bahat and Sabini, had grain protein content within the acceptable range (Table 4).

With low available nitrogen in the soil, malt barley responds well to applied fertilizer, showing increases in both yield and protein content. However, too much nitrogen can increase protein beyond levels set by the maltsters. This increase in protein may lengthen steeping times, make germination more erratic and create undesirable qualities in the malt (Johnston *et al.,* 2007). In addition, moisture stress during grain filling can result in a higher protein level and reduced plumpness; therefore, the timing of precipitation is also vital. The protein content and yield will increase with an increased rate of nitrogen; however, the protein content will increase at a slower rate. As an example, when the Nitrogen application doubles the yield, the protein content may only see a one to two percent increase (McLelland *et al.,* 1999).

4. SUMMARY AND CONCLUSIONS

Based on the present finding, the maximum grain yield (4918.3 $kgha^{-1}$) was obtained from Bahat variety with the highest levels 98.5 $kgha^{-1}$N fertilizer application despite it was not acceptable for malting barley because of its high protein content. Nevertheless, fertilizer application rates of 75.5 and 87 $kgha^{-1}$ for Bahat produced optimum yield with acceptable grain protein content for malting purpose where 75.5 $kgha^{-1}$ economical.

It is obvious that fertilizer recommendations for crops in most cases are based on a soil test for plant available nutrients. However, a major limitation is that, for the same sites, plant species 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 better yield and quality of malt barely varieties.

5. REFERANCES

Alam M.Z., S.A. Haider and N.K. Paul, 2007. Yield and and Yield Components of Barley (*Hordeum vulgare* cultivars in Relation to Nitrogen Fertilizer. J. Appl. Sci. Res., 3(10): 1022-1026.

Ali, E.A., 2010. Grain yield and nitrogen use efficiency of pearl millet as affected by plant density, nitrogen rate and splitting in sandy soil. American-Eurasian J. Agric. and Environ.

Amsal Tarekegn and D.G. Tanner. 2001. Effects of fertilizer application on N and P uptake, recovery and use efficiency of bread wheat grown on two soil types in central Ethiopia. Ethiopian Journal of Natural Resources 3(2): 219-244.

Asmare Yallew, Alemu Hailiye, Alemayehu Assefa, Melkamu Ayalew, Tessema Zewudu, Berihane Assayegn & Halima Hassen 1998. Barley production practices in Gojam and Gondar. In: Chilot Yirga, Fekadu Alemayehu & Woldeyesus Sinebo (eds.). *Barley based farming system in the high lands of Ethiopia.* Ethiopian Agricultural Research Organisation. Addis Ababa, Ethiopia. pp. 67-89.

Archer, J. 1988. Phosphorus. pp. 57-64. In: John Archer (ed). Crop Nutrition and Fertilizer Use. Farming Press Ltd., USA.

Batey, T. 1984. Plant growth and composition as predictors of N requirements. pp. 227-232. In: Nitrogen Requirement of Cereals. MOA, Fisheries and Food, Reference 385, London.

Bagheri, A. and O. Sadeghipour, 2009. Effects of salt stress on yield, yield components and carbohydrates content

in four hullless barley (*Hordeum vulgare* L.) cultivars. J. Biol. Sci., 9: 909-912.
Berhanu Bekele, 2005. Food barley in Ethiopia. pp 53–82, in: S. Grando and H. Gomez Macpherson (eds.). Food Barley: Importance, Use and Local Knowledge. Proceedings of the International Workshop on Food Barley Improvement, 14–17 January 2002, Hammamet, Tunisia. ICARDA, Aleppo, Syria.
Brown, S.C., J.D.H. Keatinge, P.J. Gregory and P.J.M. Cooper, 1987. Effects of fertilizer, variety and location on barley production under rainfed conditions in Northern Syria. I. Root and short growth. Field Crops Res., 16: 2.
Day, P. R. 1965. Hydrometer method of particle size analysis. In: Back, C.A. (eds.), Method of Soil Analysis. Amer. Soc. Agron. Madison Winscowin . Agron. No 9, Part 2. pp. 562 - 563.
EQSA (Ethiopia Quality Standards Authority) 2006. *Malting Barley Specification.* Addis Ababa, Ethiopia.
Donald, C.M. and J. Hamblin. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Adv. Agron. 28: 361-405.
Evans L.T., L.F. Wardlaw, and R.A. Fischer. 1975. Wheat. In: Evans, L.T. (ed.) Crop Physiology. Cambridge University Press, Cambridge.
Fox G.P., Panozzo J.F., Li C.D., Lance R.C.M., Inkerman P.A. & Henry R.J. 2003. Molecular basis of barley quality.*Australian Journal ofAgricultural Research* 54: 1081–1101
Gauer, L.E., C.A. Grant, D.T. Gehl and L.D. Bailey, 1992. Effect of nitrogen fertilization on grain protein content, nitrogen uptake and nitrogen use efficiency of six spring wheat (*Triticum aestivum* L.) cultivars in relation to estimated moisture supply. Sci., 72: 235-241.
Gooding, M.J., and W.P. Davies. 1997. Wheat Production and Utilization. CAB Int., Wallingford, UK.
Gomez, K.A and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. (2nd Ed.) John Wiley and Sons. Inc. New York.
Jackson, M. L., 1958. Soil Chemical Analysis Practice Hall of India. New Delhi.
Johnston, Adrian, Scott Murrell and Cynthia Grant. 2007. Nitrogen Fertilizer Management of Malting Barley: Impacts of Crop and Fertilizer Nitrogen Prices (Prairie Provinces and Northern Great Plains States).
Mangle, K. and E.A. Kirkby, 1996. Principle of Plant Nutrition. Panimo Publishing Corporation. New Delhi, India.
McLelland, M., K. Panchuk, B. Green, D. Campbell, J. Foster, Dr. B. Harvey, Dr. B. Rossnagel and Dr. N. Kendall. 1999. Malting Barley. Agriculture and Food: Alberta Government.Mooleki, S.P. and R.K. Foster. 1993. Effects of N and P rates and proportional timing of N application on rainfed wheat in Zambia. Plant and Soil 149: 73-86.
MSU, 1991. Users Guide to MSTATC. Michigan State University (MSU), East Lansing.
Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of Available Phosphorus in Soil by Extraction with Sodium Bicarbonate. USA. Circular. 939: 1-19
ORDA (Organization for Rehabilitation and Development in Amhara) 2008a. Baseline survey of six malt barley potential woredas of north and south Gondar zones of the Amhara region, Ethiopia. Malt barley promotion project of ORDA-Oxfam GB. Draft report, April 2008. Bahir Dar, Ethiopia.
ORDA (Organization for Rehabilitation and Development in Amhara) 2008b. Ethiopia: Malt barley value chain study. Options for growing a new channel in Amhara region.Bahir Dar, Ethiopia.
Ortiz-Monasterio, J.I., R.J. Pena, K.D. Sayre, and S. Rajaram. 1997a. CIMMYT's genetic progress in wheat grain quality under four nitrogen rates. Crop Sci. 37(3): 892-898.Quinones, 1997. Manual on Wheat Agronomy, SG2000, Addis Ababa, Ethiopia.
Pushman, F.M., and J. Bingham. 1976. The effect of granular N fertilizer and foliar spray urea on the yield and bread making quality of winter wheat. J. Agric. Sci. 87: 281-292.
Rashid, A. and R.U. Khan, 2008. Comparative Effect of Varieties and Fertilizer Levels on Barley (*Hordeum vulgare*). Int. J. Agric. Biol., 10(1): 124-126.
Ryan, J., M. Abdel Monem and A. Amri, 2009. Nitrogen fertilizer response of some barley varieties in semi-arid conditions in Morocco. J. Agric. Sci. Technol., 11: 227-236.
Sahlemedhin Sertsu, 1999. Draft guideline for regional soil testing laboratories. NFIA, Addis Ababa Ethiopia.
Schulthess, U., B. Feil, and S.C. Jutzi. 1997. Yield independent variation in grain nitrogen and phosphorus concentration among Ethiopian wheats. Agron. J. 89(3): 497-506.
Schulthess, U. 1992. The impact of Vertisol management systems on wheat production in the Ethiopian highlands. Ph.D. Thesis, Swiss Federal Institute of Technology, Zurich.
Singh, R.V., V.K. Dubey, and M.D. Vyas. 1992. Effect of seed rate and nitrogen level and method of fertilizer placement on bread wheat under late-sown condition. Indian J. Agron. 37: 43-46.
Stoskopf, N. 1985. Wheat. In: Cereal Grain Crops. Reston Publishing Company, Reston, VA.
Taye Bekele, Yesuf Assen, Sahlemedhin Sertsu, Amanuel Gorfu, Mohammed Hassena, D.G. Tanner, Tesfaye Tesemma, and Takele Gebre. 2002. Optimizing fertilizer use in Ethiopia: Correlation of soil analysis with fertilizer response in Hetosa Wereda, Arsi Zone. Addis Ababa: Sasakawa-Global 2000.
Tilahun Geleto, Tanner, D.G., Tekalign Mamo and Getinet Gebeyehu. 1996a. Response of rainfed bread and

durum wheat to source, level and timing of nitrogen fertilizer at two Vertisol sites in Ethiopia. pp. 127-147. In: The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Zeidan, M.S., 2007. Response of Some Barley Cultivars to Nitrogen Sources and Rates Grown in Alkaline Sandy Soil. Research J. Agric. and Biological Sci., 3(6): 934-938.

Zhao F.J., Fortune S., Barbosa V.L., McGrath S.P., Stobart R., Bilsborrow P.E., Booth E.J., Brown A. & Robson P. 2006. Effects of sulphur on yield and malting quality of barley.*Journal ofCereal Science* 43(3): 369-377. Day, P. R. 1965. Hydrometer method of particle size analysis. In: Back, C.A. (eds.), Method of Soil Analysis. Amer. Soc. Agron. Madison Winscowin . Agron. No 9, Part 2. pp. 562 - 563.