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Effect of Nitrogen Fertilizer Rate on Grain Yield and Malt Quality of Three Malt Barley (*Hordeum vulgare* L.) Varieties at Arsi Zone, Ethiopia

Fasil Shimelis*, Zenebe Mulatu

Kulumsa Agricultural Research Center, Ethiopian Institute of Agricultural Research, Asella, Ethiopia

Email address:
fasrabit1982@gmail.com (F. Shimelis)
*Corresponding author

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Abstract: Grain yield and malt quality of barley are largely influenced by the specific variety, soil property and applied nitrogen fertilizer rates. Consequently, nitrogen fertilizer application could lead to tradeoff between grain yield and malt quality and grain yield resulting in significant loss for beverage industries and farmers. Thus a field experiment was carried out during 2018/2019 main cropping season on Nitisol at Arsi Zone of Ethiopia to study the effect of grain yield and malt quality response of malt barley (Hordeum vulgar L.) Varieties to different rates of nitrogen fertilizer. Factorial combination of three malt barley varieties (Holker, Ibon and Fanaka) and five rates of nitrogen fertilizer (11.5, 23, 34.5, 46 and 57.5 kg N ha^{-1}) were laydown in split plot arrangement Nitrogen fertilizer rate as main plot and varieties as sub plot replicate three times. Data on soil sample analysis results revealed that, the soil physic-chemical property didn't show significant variation in both before planting and after harvest. The interaction effects of nitrogen fertilizer rate and varieties had significant influence on grain yield, thousand kernel weight and hectoliter weight. Malt extract content and germination energy were significantly affected by main effect of malt barley varieties, while grain protein content affected only by nitrogen rate. Thus application of 57.5 kg N ha^{-1} to Ibon malt barley variety produced better (2.629 t ha^{-1}) grain yields at the study area. From this point of view it can be conclude that Ibon Varity fertilized with 57.5 kg N ha^{-1} was found to be better in terms of both yield performance and economic feasibility for malt barley production in study area.

Keywords: Grain Yield, Grain Quality, Malt Barley, Varieties, Nitrogen, Fertilizer Rate

1. Introduction

Barley (*Hordeum vulgare* L.) belongs to family poaceae and is a fast growing, cool season, annual grain crop that could be used as forage as well as cover crop to improve soil fertility [14]. Global barley production is estimated about 141.7 million tons [28].

Many countries grow barley as a commercial crop. Globally European Union, Russia, Canada, USA and Argentina are the top five largest world barley producers where, European Union produces the greatest quantities with an estimated of 20.5 million tons followed by Russian federations about 8 million tons, whereas Canada, USA and Argentina barley production was estimated 7.3, 3.1 and 2.8 million tons respectively [28].

Ethiopia is the second largest producer of barley in Africa next to Morocco. It accounts 5.6 percent of the total cereal production in the country [12, 24]. It is the fifth important cereal crop next to teff, 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, the mean barley productivity was 2.1 tons ha^{-1} [9]. Ethiopia is also recognized as a center of diversity, as its barley germplasm has global significance since landraces include disease resistance traits [8].

In Ethiopia, Barley production started long years ago and is largely grown as a food crop. It is growing in the central and northern parts of Ethiopia, including; Oromia, Amhara, Tigray, and Southern Nations, Nationalities, and People's

Region, [1]. The use of malt barley as a row material in brewery factories has increased its value and the demand of farmers to produce [1]. There are many types of malt barley – from light to dark, but most of variations are related with two principal themes: germination and kilning. Some of the principal characteristics used to define malting quality are protein (low, moderate, or high), malt extract (high), enzyme activity (moderate to high), and beta glucan (low). Despite the immense potential for producing malt barley in Ethiopia, only about 2% of total barley produced goes into malt factory for the six local breweries [27]. Only one-third can be supplied from locally produced barley. The remaining two-thirds are imported primarily from Belgium and France [19, 1].

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. Soils in the highlands of Ethiopia usually have low levels of essential plant nutrients, low availability of nitrogen and it is the major constraint to cereal crop production [26, 5].

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 low malt extract level [13]. 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. Although, varieties playes an important role in quality and yield of malt barley, grain quality and yield of malt barley is significantly influenced by rate of N fertilizer. Consequently assessing grain yield and malt quality response of varieties to different rate of N fertilizer is important since malt quality and grain yield fluctuation leads to significant loss for beverage industries and farmers. However, no studies have been carried out sofar on the interaction between Nitrogen fertilizer rates and different released malt barley varieties under Lemu- Bilbilo Woreda. The present investigation was conducted with the main objective of identifying appropriate malting barley varieties, with their respective optimum level of N fertilizer, for malt barley-growing areas of Lemu-Bilbilo Woreda, Arsi Zone, Ethiopia. The present study was with the major objective to identify the effects of different nitrogen fertilizer rate on the grain yield and malting quality of malt barely varieties and to assess the optimum rate of Nitrogen fertilizer and barley variety that would enhance grain yield without affecting the malt quality.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted during the main cropping season of 2018 at Lemu Bilbilo wereda at Bekoji negeso kebeles of west Arsi Zone. It is geographically located from 07° 30" 37" N - 39° 11" 31"E with altitude ranging 2450-2780 m.a.s.l. It receives mean annual rainfall of 951.5 mm, with minimum and maximum temperatures of 4.05 and 19.88°C, respectively. The dominant soil type of experimental area is luvisoil and slightly acidic (pH = 6). The major crops that grown in this wereda are cereal crops (wheat, food and malt barley), legume crops (faba bean, field pea), oil crops (linseed and Ethiopian mustard), and vegetable crops (Potato, cabbage and carrot) [16].

2.2. Treatment and Experimental Deign

The field experiments was laid out in Split-plot design with nitrogen fertilizer rates as main plot and malt barley varieties as sub-plot, replicated three times. The main plot factors contained five rates of N fertilizer (11.5, 23, 34.5, 46, 57.5 N kg ha^{-1}) and the sub-plot factor contained three malt barley varieties (Holker, Ibon and Fanaka). The gross and net plot area of was 10.4 and 7.8 m^2 respectively. The land was ploughed using oxen and plots was level manually TSP was apply at sowing time, while nitrogen fertilizer in the form of urea was added to the soil at the rates of 1/2 at planting time and the rest 2/3 was apply at mid tillering stage to avoid leaching. Malt barely varieties was sown at the recommended rate of 125 kg ha^{-1} and planted in rows by using a manual row marker. Proper hoeing and weeding of the experimental fields were carried out uniformly as per research recommendations.

2.3. Data Collection

Data collection was successively done on soil sampling and analysis, grain yield and malt barley quality parameters. Soil samples were collected from the experimental site at a depth of 0-20 cm before and after harvesting. The samples were prepared following the standard procedures and analyzed for selected soil physico-chemical properties. Soil samples were analyzed for pH using a ratio of 2.5 ml water to 1 g soil, for available P using Bray-II method, for organic C content using (Jackson, 1958) method; for total N content Kjeldahl method was used. Grain protein and moisture content in the malt barely varieties were determined using near infrared (NIR) spectroscopy (NIR Grain analyzer model 1241). Germination energy in percent was determined from 100 seeds germinated in a Petri dish after 72 hours.

$$Germnation\ energy(\%) = \frac{\text{number of seeds germnated}}{\text{total number of seeds set}} * 100$$

2.4. Data Analysis

The data was subjected to analysis of variance (ANOVA) following the standard procedure for split plot design. Variety and nitrogen fertilizer interaction were performed using PROC GLM Procedure of SAS software version 9.1 [22]. Mean separation was employed following the significance of mean squares using Least significant difference (LSD) at 5% level of significance.

3. Results and Discussion

3.1. Physico-chemical Analysis of Soil

Analytical data of soil pH, organic matter, organic carbon and total N determined from the composite surface (0-20 cm) soil samples collected from each plots of the experimental field before planting and after harvesting of malt barley (Table 1). The results revealed that, the soil physic-chemical property didn't show significant variation between before planting and after harvesting (Table 1). The average soil pH of the experimental field were 6.2 and 6.0 before and after sowing respectively. Ranging from 5.30 to 5.59 qualifies for the strongly acidic soil reaction class (pH 5.1-5.5) set by [28] while working with Ethiopian soils. The average total nitrogen was 0.23 and 0.29% before and after sawing respectively. Total nitrogen increased with increasing the applied nitrogen fertilizer rates.

Table 1. *Some physio- chemical properties of soil after harvest.*

	Treatments	Soil Parameters				
	Rate of N	PH	OM%	OC%	N%	P (ppm)
After planting	11.5	5.9	4.9	5.5	0.2	13.5
	23	5.8	5.8	5.8	0.25	12.1
	34.5	6	6	6	0.3	9.5
	46	5.9	5.9	5.9	0.3	11.4
	57.5	5.9	5.9	5.9	0.4	13.2
	Mean	6	4.8	5.8	0.29	11.8
Before planting		6.2	4.92	4.07	0.23	12.23

Where: OC% = Organic carbon, OM% = Organic matter, N% = Total nitrogen, P (ppm) = available Phosphorus.

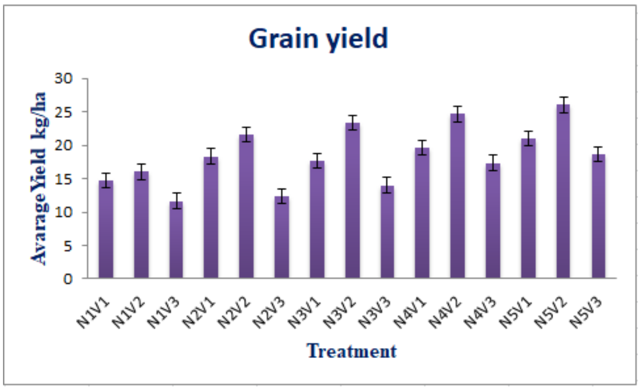

Figure 1. *Interaction effect of Nitrogen fertilizer rate and malt barley varieties on grain yield.*

3.2. Grain Yield t ha^{-1}

The analysis of variance of this study showed that, grain yield was significantly ($P < 0.001$) different on the interaction effect of the two factors. The highest grain yields (2.63 t ha^{-1}) were obtained from variety Ibon fertilized with 57.5 kg N ha^{-1}, whereas the lowest grain yield (1.39 t ha^{-1}) at was from variety Fanaka with 11.5 kg N ha^{-1} (Figure 1). The large grain yield variation among barley varieties under different nitrogen fertilizer rates could help in the selection of better varieties for different nitrogen available environments. This result was in line with finding [3] who mentioned significant increases in grain yields of malt barley with increasing nitrogen fertilizer rates. Similarly, the current result was supported by many authors [2], who reported that, accumulation of dry matter of barley increased with higher doses of nitrogen fertilizer rates. [3] Also confirmed the significant increases in grain yields of malt barley with increasing nitrogen fertilizer rates. In addition [23] reported that nitrogen applied at the rate of 60 kg ha^{-1} resulted in maximum thousand grain weight, biological yield and grain yield.

3.3. Quality Parameters

3.3.1. Thousand Kernel Weight

The analysis of variance of this study showed that, thousand kernel weights had significant ($P < 0.001$) difference as result of the interaction effect of the two factors. The highest mean thousand kernel weight (55.2) was obtained from Ibon variety with 57.5 kg N ha^{-1}, while the lowest (44.9) thousand kernel weight from Holker and Ibon varieties with 23.0 kg N ha^{-1} and 11.5 kg N ha^{-1} respectively. Generally thousand kernel weights increased almost linearly in all varieties with increasing nitrogen fertilizer rates in this study. In agreement with this [20, 6, 29] reported that, variation in thousand kernel weight as a function of barley genotype and nitrogen fertilizers. Thousand kernel weight of malt barley should be >45 g for 2-rowed barley and >42 g for 6-rowed barley [4]. Therefore the result of the current study exhibited within the acceptable thousand kernel weight (Table 2).

3.3.2. Hector Litter Weight

According to this study Hectoliter weight (HLW) was significantly ($P< 0.05$) affected by the interaction effect of the two factors. In this experiment the highest (72.3 and 71.3 kg) hectoliter weight were recorded from variety Ibon along with the highest nitrogen rate 57.5 and 46.0 kg N ha^{-1} followed by (70.6 kg) from Holker with 57.5 kg N ha^{-1}. Whereas the lowest (65.0 kg) hectoliter weight was obtained from variety Holker with 11.5 kg N ha^{-1}. Generally HLW should increase along with increasing nitrogen fertilizer rates in which the highest and lowest (72.3 and 65.0 kg) HLW were recorded from variety Ibon with 57.5 kg N ha^{-1} and from Fanake with 11.5 kg N ha^{-1} (Table 2). [21] reported that the acceptable test weights (hectoliter weight) for barley were in the range 66.1- 72.8 kg. Thus the current results exhibited acceptable hectoliter weight in all varieties for all nitrogen fertilizer rates (Table 2).

Table 2. *Interaction effect of N fertilizer rates and malt barley varieties on TKW and hectoliter weigh.*

Treatment		Parameters	
N kg ha^{-1}	Varieties	TKW	HLW kg
	Holker	45.0^{f}	65^{gh}
	Ibon	44.9^{f}	67.3^{d-f}
11.5	Fanaka	$47.0d^{ef}$	64.6^{h}
	Holker	46.3^{ef}	67^{e-g}
	Ibon	45.3^{f}	68.6^{c-e}
23	Fanaka	49.6^{c-e}	66.0^{f-h}
	Holker	45.0^{f}	67.6^{d-f}
	Ibon	45.3^{f}	69.3^{b-d}
34.5	Fanaka	46.0^{d-f}	65.2^{gh}
	Holker	46.3^{ef}	68.6^{c-e}
	Ibon	54.3^{ab}	71.3^{ab}
46	Fanaka	52.3^{bc}	66.3^{f-h}
	Holker	51.6^{bc}	70.6^{bc}
	Ibon	$55.2.0^{a}$	$72.3.0^{a}$
57.5	Fanaka	50.0^{cd}	67.6^{d-f}
LSD 0.05%		3.56	2.04
CV%		6.13	2.1

Mean values within column followed the same letters are not significantly different at 5% level of significant; LSD (0.05%) = Least significant difference at 5% level; CV = Coefficient of variation. NS = non-significant different, TKW = Thousand kernel weigh and HLW kg = Hectoliter weight.

3.3.3. Germination Energy

Germination energy of malt barley in this study was significantly ($p \leq 0.05$) different among varieties, while the effect of nitrogen fertilizer rate and interactions were non-significant. The highest (98.8%) germination energy was obtained from Ibon variety, while the lowest (96.4%) germination energy was recorded from Fanaka. The result shows that the number of grains germination energy was significantly different among varieties (Table 3). In conformity with this result,[7] reported the existence of differences in the genetic factors determining germination energy of malt barley. In addition to this, [25] noted that differences in the genetic factors determining germination, although there were environmental effects on their expiration. According to [10] germination energy of malt barley should be above 95%. The current result indicated that the germination energy was in the acceptable range in all varieties. However, germination energy did not show significant differences among nitrogen levels, despite the values varied from 95.5-97.5%. Germination energy also slightly decreased as N rates increase.

3.3.4. Grain Protein

Grain protein content of malt barley grains were significantly ($p < 0.05$) affected by main nitrogen fertilizer rates, while the effect of variety and interactions were non-significant. Grain protein content increased as N fertilizer increased from 11.5 to 57.5 kg N ha^{-1}.

The highest (12.5%) grain protein content was recorded from the highest N fertilizer application (57.5 kg N ha^{-1}), and the lowest (9.4%) from the lowest (11.5 kg N ha^{-1}, Table 3). The increase in grain protein content of malt barley with increasing N fertilizer rate was supported by [3] who reported that application of N fertilizer increased both grain yield and protein contain. Similarly, [17] found that an increase in N fertilizer application resulted in an increase in grain yield and protein content. However, in grain protein may increase steep times, consequently creates undesirable qualities in the malt. [15] also reported that, increasing in grain protein content of malt barley not only increased steep times but also created undesirable quality in the malt, due to excessive enzymatic activity and low extract yield. In addition it also slows down water uptake during steeping and affects final malt quality. According to the Ethiopian standard authority and Asella malt factory (AMF), the protein level of raw barley for malt should be 9-12.5% [11]. Analysis result of this study revealed that grain protein in all treatments was within the acceptable standard range for malt purpose despite significant variation among applied N- levels.

3.3.5. Malt Extract Content %

Analysis of variance indicated that mean extract content of malt barley was significant (P< 0.01) among varieties, while main effects of N fertilizer rate and its interaction with variety was not significant Table 3). Better extract content in Fanaka was advantageous than the other two varieties, which might be due to genetic difference of the varieties. The extract yield reflects the extent of enzymatic degradation and the solubility of grain components after malting and mashing [25]. Mean EBC hot water extract value ranged from 79-81.9% and the result of this study in line with settled requirement. In general, uniform and plump seed size increases extract content and quality in beer making. There was an increase of grain plumpness of spring barley along with higher sowing rate [18].

Table 3. *Effect of Nitrogen fertilizer rates on quality parameters of malt barley.*

Treatment	Parameters		
	GE%	GP%	EC%
N kg ha^{-1}			
11.5	97.5	9.4^{c}	79.7
23	96.7	9.5^{cd}	81.3
34.5	97.2	10.1^{c}	80.2
46	96.4	10.6^{b}	80.7
57.5	95.5	12.5^{a}	80.5
LSD 0.05%	NS	0.75	NS
CV%	2.04	5.4	1.4
Varities			
Holker	96.70^{b}	10	79.5^{b}
Ibon	98.80^{a}	10.6	79.8^{b}
Fanaka	96.40^{b}	9.8	81.9^{a}
LSD 0.05%	1.3	NS	0.3
CV%	2.08	7.3	1.1

Mean values within column followed the same letters are not significantly different at 5% level of significant; LSD (0.05%)= Least significant difference at 5% level; CV = Coefficient of variation. NS = non- significant different; GP%= Grain protein, GE% = Germination energy and EX= Malt extract content %.

4. Conclusion

Based on the present finding, the maximum grain yields (2.62 t ha^{-1}) with acceptable protein contain were recorded when the highest N fertilizer rate (57.5 kg N ha^{-1}) was applied for Ibon variety, Despite it is rare to get both maximum grain yield. Consequently 57.5 kg N ha^{-1} fertilizer rate with Ibon variety produced optimum yield with acceptable grain protein content for malting purpose as well as better economic benefit in the study area. Therefore Ibon malt variety with 57.5 kg N ha^{-1} fertilizer could be recommended for the study area and similar agro-ecologies. However, it should be further verified along with full agronomic package at a conclusive recommendation.

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