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ISSN: 2157-7110
Journal of Food Processing & Technology

Research Article

Malting Barley Grain Quality and Yield Response to Nitrogen Fertilization in the Arsi Highlands of Ethiopia

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ABSTRACT

The malting industry in Ethiopia is often challenged by the availability of barley that meets the quality and quantity requirements set by the industry. Field experiments were conducted to evaluate the effects of mineral nitrogen fertilizer rates on actual yield and quality response of malt barley varieties and to determine economic optimum rates of nitrogen fertilizer for the productivity of the crop arranged in randomized complete block design in factorial arrangement with three replications. The treatments are three malt barley varieties, namely traveler, ibon and local and four levels of N (0 kg N/ha, 50 kg N/ha, 100 kg N/ha and 150 kg N/ha. The study revealed that nitrogen fertilization with 150 kg ha^{-1} nitrogen fertilizer rate improved barley yield and quality than the rest nitrogen fertilizer rates. The different barley varieties and nitrogen fertilizer has shown a highly significant ($p<0.01$) influence on maize yield production. On the other hand, interaction effect of barley varieties and nitrogen fertilizer didn't show significant variation maize yield production. Moreover, the analysis of variance also revealed that barley varieties have shown a highly significant ($p<0.01$) influence on maize yield production. The maximum and minimum interaction mean values of actual grain yield were observed from traveler barley variety treated with 150 kg ha^{-1} nitrogen fertilizer rate (2078.10 kg/ha) and ibon barley variety treated with 0 kg ha^{-1} nitrogen fertilizer rate (1136.30 kg/ha), respectively. In the present investigation, quality parameters increased with an increase in N rates, application of 150 kg N ha^{-1} gave the highest quality parameters studied except sieve test. While, the quality parameters were less pronounced with the tested varieties and their interaction effect. The partial budget analysis revealed maximum net benefit of (Birr 39147 ha^{-1}) with an acceptable Marginal Rate of Returns (MRR) of 1007.33% with the treatment traveler variety with combination of 150 kg N ha^{-1}. However, the lowest net benefit of (Birr 22726.00 ha^{-1}) was recorded from Ibon barley variety treated with 0 kg ha^{-1} nitrogen fertilizer rate. Both grain yield and protein content increased with increased N rates application of 150 kg N ha^{-1} gave the highest net benefit and marginal rate of return with acceptable grain quality (protein content<9%-12%). Therefore, production of traveler variety with a combination of 150 kg N ha^{-1} was economical and uncertainly recommended for production of malt barley in the study area.

Keywords: Malt barley; Grain yield; Grain quality; Nitrogen fertilizer; Variety

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Received: 26-Aug-2021, Manuscript No. JFPT-24-12607; **Editor assigned:** 31-Aug-2021, PreQC No. JFPT-24-12607 (PQ); **Reviewed:** 14-Sep-2021, QC No. JFPT-24-12607; **Revised:** 02-Dec-2024, Manuscript No. JFPT-24-12607 (R); **Published:** 30-Dec-2024, DOI: 10.35248/2157-7110.24.15.1133

Citation: Jemal K, Geleto A (2024) Malting Barley Grain Quality and Yield Response to Nitrogen Fertilization in the Arsi Highlands of Ethiopia. J Food Process Technol. 15:1133.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is an annual cereal crop, which belongs to the *Gramineae* family. It is one of the most important cereal crops produced in the world today and it ranks fourth in both quantity of production and in area of cultivation of cereal crops after wheat, maize and rice. It is one of the most staple foods and economically important widely used cereal crops in Ethiopia next to teff, maize, wheat and sorghum. Malt barley is used for preparing alcoholic beverages, mainly beer. Barley can be cultivated at altitudes between 1500 m and 3500 m but, is predominantly grown between altitudes of 2000 m to 3000 m. In 2016/17, barley was produced on a total area of 0.96 million hectares in Ethiopia and total annual production during the main season was about 2.0 million tons [1].

The market potential for malt barley in Ethiopia is directly related to market demand for beer, which has shown significant growth in terms of consumption. From 2003 to 2011, beer production in Ethiopia increased from 1 million hectoliters to roughly 4 million hectoliters. 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 in the country. Only one-third can be supplied from locally produced barley [2]. The remaining two-thirds are imported primarily from Belgium and France. 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. Similarly, Woldeyesus et al. reported that low barley productivity in the highland of Ethiopia is due to low soil fertility. Moreover, recently acquired soil inventory data revealed that deficiency of most of nutrients such as, nitrogen, phosphorus, sulfur; boron and zinc are widespread in Ethiopian soils and similarly in the study area.

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 [3]. 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, as a result the preferred grain N level is not greater than 1.6%-1.8%.

Emebiri and Moody reported that nitrogen levels in soil and nitrogen fertilization are among the major factors that affect grain protein content in malting barley. The influence of agronomic practices was also highlighted in a study conducted in the United Kingdom where it was found that the way barley was treated in the field (eg. seeding rate, N rate, cultivar and other management practices) was the main factor influencing malting barley quality [4].

Nitrogen is the most yield-limiting nutrient in barley production; however, care must be taken when the grain is intended for the production of malt. Often, N management strategies which maximize grain yield do not optimize grain protein content and malt quality. Applying N rates to achieve maximum yields may cause grain protein concentration to exceed the maximum acceptable value for malting barley. The grain protein content of malt barley always increases with the amount of applied N fertilizer whether or not a yield increase resulted. Similarly, several researchers reported a linear increase of grain N concentration with increasing rate of fertilizer nitrogen. A study by O'Donovan et al. illustrated the negative impact of high N fertilizer rate on malting barley kernel characteristics and malt quality. Therefore, appropriate N fertilization rates need to be applied to malt barley to achieve a balance between optimum grain yield and protein concentration.

Variety has also played an important role in yield and quality of malt barley. The yield and quality specifications of a given malting barley variety are determined by its genetic makeup and the physical conditions during growth. Grain quality and yield of malt barley varieties is also significantly influenced by seed rate and time of nitrogen fertilizer application. Therefore, identification of appropriate varieties of malting barley and the use of appropriate production practices are critical to the production of quality malting barley. Malt barley grain should not possess high protein content with basal N application, as all nitrogen applied will be used to increase grain yield per hectare, not to increase protein content in the grain.

Malting barley is one of the most economically important cereals in the Arsi high lands of Ethiopia. However, information on the effect of N fertilization rate on grain yield and quality of malting barley, especially the relative response of different malting barley varieties to N fertilization rate in the Arsi highlands of Ethiopia has not been documented previously. More importantly, the level of N fertilizer that optimize yield and quality of malting barley need to be determined. We hypothesized that N rate and variety are the predominant drivers controlling grain yield and quality of malting barley. Therefore, objectives of this study were to evaluate the effects of mineral nitrogen fertilizer rates on yield and quality response of malt barley varieties and to determine economic optimum rates of nitrogen fertilizer for the productivity of the crop in the Arsi highlands of Ethiopia [5].

MATERIALS AND METHODS

Description of study area

This experiment was conducted on a farmer's field found in Germama Shinato Kebele, Kofale Woreda, West Arsi zone, South Ethiopia, during 2019/2020 main cropping season. Kofale has two Agro ecologies, namely Dega (90%) and Weyina-Dega (10%) and is located at 07°37'N and 38°38.5'E at an altitude of 2,673 m.a.s.l. Annual average rainfall of the area is

2100 mm-2200 mm, while minimum and maximum average annual temperatures are 11°C and 24.5°C respectively.

Treatment sand experimental design

The treatments consist of a factorial combination of four levels of nitrogen (0, 50, 100 and 150 Kg/ha^{-1}) and three cultivars (IBON 174/03, traveler and local) laid out in three replications of the Randomized Complete Block Design (RCBD). Traveler variety was of French origin and was introduced to the country and promoted to farmers in 2013 by Heineken Brewery S.Co for its high productivity (up to 7 t ha^{-1}) and for its good malting quality. IBON 174/03 was released by HARC in 2012 and has productivity of up to 3 ton ha^{-1} to 5.7 ton ha^{-1} at research field and matures in 120 days.

Data collection and analysis

Data collection was successively done on soil sampling, yield and quality parameters. Soil samples were collected from the experimental site at a depth of 0 cm-20 cm before and after harvesting [6]. 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 method; for total N content using Kjeldahl method; for exchangeable cations and Cation Exchange Capacity (CEC) using ammonium acetate method at the soil and plant analysis laboratory. Data were collected by sampling middle eight harvestable rows excluding the two border rows and one plant from the end of harvestable rows in both sides. Yield and quality parameters were collected and analyzed. Grain yield was adjusted to 12.5% moisture tester.

At maturity, plants from four randomly selected 0.5 m sample lengths per net plot were harvested at ground level, air-dried and partitioned into straw and grain. The grain and straw sub-samples were ground to pass through a 1 mm mesh for N concentration determination. Grain and straw nitrogen concentrations were determined by using the Kjeldahl method. Grain nitrogen was converted to grain protein by multiplying N concentrations by 6.25. One-liter grain sample was taken from each plot and hectoliter weight value of the grain samples was determined with a Dickey John automated apparatus and is expressed as kilogram per hectoliter. Sieve test was carried out using 2.2 mm, 2.5 mm, 2.8 mm size sieves and proportion of the seed trapped by each sieve was weighed and converted to percentage. Finally, the sums of all the three sieve sizes were used for sieve test. Germination capacity two hundred seeds was soaked in a flask with 0.3M H_2O_2 (hydrogen peroxide) and counted after 48 hours and converted to percentage to determine germination capacity [7].

The data were subjected to analysis of variance using the general linear model procedure (PROC GLM) of SAS statistical package version 9.3. Means for the treatments were compared using the MEANS statement with the Least Significant Difference (LSD) test at the 5% probability level. An economic analysis was done using partial budget procedure described by CIMMYT.

RESULTS AND DISCUSSION

Selected soil physical characteristics of the experimental site

Physical soil analysis showed that texture of soil was clay loam with sand, silt and clay percentage of 38%, 30% and 32%, respectively. Soil texture is the proportion of sand, silt and clay which is an important soil physical characteristic as it determines water intake rate (infiltration), water holding capacity in the soil, the ease of tilling, the amount of aeration and also influence soil fertility [8]. Based on the study conducted the textural class of the study area was clay loam (Table 1).

Table 1: Selected physico-chemical properties of the experimental site.

Soil physical properties	**Tested results**
Sand (%)	38
Silt (%)	30
Clay (%)	32
Particle size	Clay loam
Soil chemical properties	**Tested results**
pH	5.73
Organic matter content (%)	3.31
Available nitrogen (%)	0.13
Available phosphorus (ppm)	19.21

Calcium (cmol/kg)	6.28
Magnesium (cmol/kg)	1.02
Available potassium (ppm)	0.2
CEC (cmol/kg)	41

Soil pH results were found to be moderately acidic andosols with a pH value of 5.73 which is indicated at (Table 1). The low pH values in cropland could be due to high tillage frequency, high rates of inorganic fertilizer applications (especially ammonium fertilizers) and low amount of organic matter because of erosion or due to aluminum toxicity. According to Murphy, soil pH level<5.0 is rated as very strong acid, 5.1-5.5 strong acid, 5.6-6.0 moderate acidic and 6.1-6.5 is rated as slightly acidic. Based on the above ratings, soils of the study area were qualified acidic. So that the pH level of the study is conducive for barley production as normal soil pH for barley with amendment of soil with lime.

As indicated in Table 1, the analysis result before sowing was 0.13% for Total Nitrogen (TN), 3.31% for Organic Matter (OM) content, 19.21 ppm for available Phosphorous (P). The organic matter content of the surface horizon could be rated as medium according to Landon, who rated OM contents less than 2% as very low, 2 to 4 as low, 4 to 10 as medium, 10 to 20 as high and greater than 20 as very high.

Total nitrogen measures the total amount of nitrogen present in the soil, much of which is held in organic matter and is not immediately available to plants. It may be mineralized to available forms. However, total nitrogen cannot be used as a measure of the mineralized forms of nitrogen (NH_4^+, NO_3^- and NO_2^-) as much of it is held in the organic matter in the soil. Total nitrogen content in the surface horizon was 0.13 and was rated as low according to Landon.

Available P of the soil could be rated as high. The relatively higher available P in surface as compared to subsurface ones could be also attributed to the difference in organic matter contents of the layers [9]. According to FAO, the available P contents of the soils in the subsurface soils were rated as very low, where as that of the surface horizon were medium to high. Cation exchange capacity is the capacity of the soil to hold and exchange cations. It provides a buffering effect to changes in pH, available nutrients, calcium levels and soil structural changes. CEC is one of the most important chemical properties of soils and strongly affects nutrient availability for plant growth. Cation Exchange Capacity (CEC) of the soil was 40 Cmol (+) Kg^{-1} which could be categorized as high range. High CEC values could be attributed to the high basic cations content of the soils.

Exchangeable calcium, magnesium and available potassium are the dominant cations in the exchange sites in the soil of the study area. The magnitude of cations in the soil was 6.28.1.02 and 0.20 for exchangeable calcium, magnesium and available potassium, respectively. The exchangeable bases were in high range according to FAO except for available potassium which was small (Table 1). Limited availability of soil nutrients affects crop production and productivity. Thus, addition of single and/or combined fertilizers at the right time and rate might be required whenever there is nutrient deficiency in the study area [10].

Malting barley grain quality and yield response to nitrogen fertilization

Actual yield production of malt barley: Different rates of nitrogen fertilizer has significantly influenced the actual grain yield of barley per hectare production ($P<0.01$) from the result obtained highest yield was scored (1.56 tone/ha) from 150 kg ha^{-1} nitrogen fertilizer rate and it has a significant difference with 0 kg ha^{-1} nitrogen fertilizer rate and statistically the same with that of rest nitrogen fertilizer rates (Table 2). Contrary to this, minimum grain yield (1.19 tone/ha) was obtained at 0 kg ha^{-1} nitrogen fertilizer rate. The minimum grain yield obtained at control was statistically inferior with that of rest nitrogen fertilizer rates.

The highest actual grain yield of barley obtained at 150 kg ha^{-1} nitrogen fertilizer rate lead to an improvement of 23.37% than 0 kg ha^{-1} nitrogen fertilizer rate. The reduction of fertilizer from 92150 kg ha^{-1} nitrogen fertilizer to 0 kg ha^{-1} nitrogen fertilizer rate leads to reduction of grain yield by 23.37%. The data reveal that higher amount of fertilizer application associated with larger amount of grain yield production and less amount of fertilizer application leads to less amount of grain yield production per hectare.

The analysis also revealed that different varieties on barley had significant ($p<0.05$) influence on grain yield (Table 2). Maximum grain yield (1.61 tone/ha) was observed at traveler barley variety. The maximum grain yield obtained at traveler barley variety was statistically different with that of the rest treatments. Moreover, the minimum (1.41 tone/ha) grain yield obtained at Ibon barley variety it was significantly inferior to traveler barley variety and similar with the local barley variety. The highest grain yield of barley obtained at traveler barley variety lead to an improvement of 13.61% over Ibon barley variety.

The interaction effect of nitrogen fertilizer rates and type of verities on grain yield production of barley was analyzed as shown on analysis of varieties there was no significant interaction between nitrogen fertilizer rates and type of varieties on grain yield production of barley. The increased shoot dry matter yield in response to the increased rate of nitrogen application may probably be attributed to increased concentration of nitrogen fertilizer in the soil that may have enhanced root uptake of the nutrient possibly resulting in increased concentration of chlorophyll in the leaves, heightened rate of photosynthesis, high rate of leaf expansion, increased leaf number and dry matter accumulation in the aboveground biomass. This result is consistent with the result of that, nitrogen fertilizer plays an important role in canopy development, which in turn increases shoot dry matter [11].

The increase in grain yield in response with increasing rate of nitrogen could be attributed to enhanced availability of the nutrient for uptake by the plants and increased photo assimilate production that would eventually lead to improved partitioning of carbohydrate to the grains. The results of this study have indicated that application of nitrogen enhanced the grain yields of all food barley varieties. All tested varieties continued responding up to the highest N level.

The significant increase in grain yield in response to the increased application of N fertilizer could be attributed to enhanced availability and uptake of N by the roots of barley plants. Grain yield is a complex character depending upon a large number of environmental, morphological and physiological characters. Grain yields also depend upon other yield components. The highest grain yield of any crop is the result of all positive relationships of the yield components.

Improvement in barley yield with fertilizer application can be attributed to the stimulating effects of nutrients on plant growth that provides ideal condition for crop as the fertilizer N supply to plants need, which ultimately increased the grain yield of crop. The current result is in agreement with the achievements of Ahmad et al., Ahmad and Rashid and Imran et al., who suggested that an introduction of high yielding crop variety with balanced application of NP fertilizer can be increase the grain yield of the crop. On the other hand, highly significant differences were observed between number of tillers and productive tillers m^{-2}, biomass and grain yield as main effect of nitrogen fertilizer rate. Similarly, grain yield of wheat was highly significantly influenced by the rate of N fertilizer application.

Table 2: Effect of N rate and variety on actual grain yield and grain quality of malt barley.

Treatments		AY	GPR	PC	HLW
N rate (kg ha^{-1})	0	1190.99^{c}	11.43	9.58^{c}	54.86^{c}
	50	1391.52^{b}	11.23	10.87^{b}	56.44^{b}
	100	1561.54^{b}	10.51	12.12^{a}	57.48^{a}
	150	1561.93^{a}	11.08	12.13^{a}	58.01^{a}
	LSD $_{0.05}$	170.89	NS	0.69	0.68
Varieties	Local	1461.73^{b}	12.03^{a}	11.84^{a}	57.37^{a}
	Traveler	1611.87^{a}	10.10^{c}	10.38^{b}	56.50^{b}
	Ibon	1412.90^{b}	11.06^{b}	11.30^{a}	56.22^{b}
	LSD $_{0.05}$	144.99	0.83	0.6	0.59
	V*N	NS	NS	NS	NS
	CV (%)	14.08	8.9	6.39	1.23

Grain protein content: The main effects of barley varieties and N highly significantly (P<0.001) influenced the grain protein content. However, the two-factor interaction did not significantly influence the grain protein content of malt barley. Grain protein content increased almost linearly in response to the increased rate of nitrogen fertilizer application. The highest grain protein content (12.13%) was obtained at the highest rate of N (150 kg N ha^{-1}) which was statistically similar with 100 kg N ha^{-1} nitrogen rate and superior with the rest N rates; whereas the lowest grain protein content (9.58%) was obtained from unfertilized plot (Table 2).

Increasing the application of N fertilizers from nil to 150 kg N ha^{-1} remained at par to each other, consistently increased grain protein contest. Generally, grain protein contents obtained at the application of 150 kg N ha^{-1} exceeded that of the nil N by about 20.87%. The increase in grain protein with increasing nitrogen rate might be due to greater synthesis and accumulation of storage proteins. Nitrogen is the building block of protein in which nitrogen increases the plumpness of the cereal grains and protein content of both seeds and foliage.

The maximum grain protein content (11.84%) was attained by local variety, while the minimum grain protein content (9.38%) was from traveler variety so that it was in the range of beer making (Table 2). The significant variation of varieties in grain protein content might be related to their genetic variability. Variation in grain protein content of varieties agreed with the previous works of O'Donovan et al. who reported that grain protein content is influenced largely by both genotype and environment.

Adane 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. It also slows down water uptake during steeping, potentially affecting final malt quality [12].

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. 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.

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%. Therefore, both main effects of N fertilizer rate and barley varieties had grain protein content within the acceptable range (Table 2).

Hectoliter weight: Results showed significant differences ($P<0.001$) among nitrogen fertilizer rate treatments and malt barley varieties for hectoliter weight. However, the interaction effect of the two factors was not significant for hectoliter weight. The highest (58.01 kg ha^{-1}) hectoliter weight was recorded from the highest applied N fertilizer 150 kg ha^{-1}, whereas the lowest (54.86 kg ha^{-1}) hectoliter weight was obtained from control treatment (Table 2). Hectoliter weight was found to increase with increasing nitrogen application rates from zero to 150 kg ha^{-1} this might be N is an essential component of the proteins used to build cell materials and plant tissues. Moreover, Bruk who found that under more favorable growing conditions slight increase specific weight in response to N fertilizer application.

Regarding Barley varieties, the highest hectoliter weight (57.37 kg ha^{-1}) recorded from local and it was statistically superior while the lowest hectoliter weight (56.22 kg ha^{-1}) was recorded from Ibon barley variety (Table 2). Significantly higher hectoliter weight with the application different barley varieties might be due to their genetic variability which is related to quality of barley such as flour yield and protein content as N increases the plumpness and protein content of the cereal grains.

Similarly, the highest hectoliter weight (80.2 kg ha^{-1}) recorded from blended NPSB at 183 kg ha^{-1} (80.2 kg ha^{-1}) and it was statistically at par with the two preceding rates of NPSB while the lowest hectoliter weight (77.3 kg ha^{-1}) was recorded from the control treatment was reported by Dinkine. Rick et al. reported that the acceptable test weights (hectoliter weight) for barley were in the range 66.1 kg ha^{-1}-72.8 kg ha^{-1}. The current results exhibited an acceptable hectoliter weight in all blended fertilizer rates except 50 kg ha^{-1} NPSB fertilized treatment.

Rick et al. also reported that the acceptable standard of hectoliter weight for barley was in the range of 66.1 kg ha^{-1}-72.8 kg ha^{-1}. Therefore, hectoliter weight was little lower than in the stated ranges in this study.

Grain protein ratio: Analysis of variance indicated that mean grain protein ratio of malt barley was only significant ($P<0.01$) among varieties (Table 2). Better grain protein ratio in local malt barley variety is advantageous than traveler and Ibon 174/03 malt barley varieties, which might be due to genetic difference of the varieties. Variation in grain protein ratio of varieties agreed with the previous works of O'Donovan et al., who reported that grain protein content is influenced largely by both genotype and environment.

Sieve test: Sieve test is done to test the plumpness of barley grains. Plump barley is a sum of barley that remains on the top of a 2.2 mm, 2.5 mm, 2.8 mm size sieves. The mean seed size test of malt barley was significant ($P<0.05$) between main effects of N fertilizer rate application and did not show a significant effect on interaction and main effects variety ($P<0.05$) (Table 3).

The highest mean sieve test was obtained on local variety with 0 kg ha^{-1} and 50 kg ha^{-1} nitrogenrates application. The lowest sieve test and was scored at with variety traveler at 150 kg ha^{-1} fertilizer rate (Table 3). The difference in varieties in grain size could be related to genetic and environmental effect. Moreover, Fox et al. also mentioned that the genetic and environmental effects in improving grain size and varieties with high grain size implies in uniformity in grain size. The standard requirement for official AMF grade is specified at 90% or more of seeds retained over 2.8 mm and 2.5 mm slotted screen for two rowed malting barley varieties. The interaction of preceding crop and N fertilizer rate revealed that grading percentages sieve size decreased as the N rate increased.

Study on malting barley genotypes under diverse agro ecologies of northwestern Ethiopia, indicates that three genotype had the large mean percentage of kernels trapped by 2.8, 2.5 and 2.8+2.5 mm size sieves. From the tested genotypes, only two fulfills the standard greater than 80% of the kernel that passed through 2.5+2.8 mm size sieve. Genotype that had high percent of screen loss had small kernel size much below the standard as observed in the test using 2.2 and <2.2 mm size sieve. Genotype by location interaction was also significant for sieve size test and grain protein; indicating differential performance of genotypes across locations with respect to these traits.

This study is in line with the findings of the Getachew, who reported that interaction of preceding crop and N fertilizer rate revealed that grading percentages for 2.8 mm sieve size increased as the N rate increased, but decreased for 2.5 mm sieve size at Holetta. O'Donovan et al. also reported that, plumpness increased with increasing seeding rate, however; the largest decreases in kernel plumpness tended to occur at seeding rates above 300 seeds m^2 with a relatively minor decline as seeding rate increased from 100 to 300 seeds m^{-2}. Anonymous reported that sieve test (grain size percentage) >90% is settled for 2-rowed barley such as Ibon 174/03 and traveler variety.

Germination capacity: Analysis of variance indicated that germination capacity was significantly (P<0.01) influenced by only nitrogen fertilizer rate application while the main effect of variety and their interaction were not significantly influenced germination capacity (Table 3).

Higher (99.33) germination capacity was obtained from 150 kg ha^{-1} nitrogen fertilizer rate followed by 100 kg ha^{-1} nitrogen fertilizer rate. While, the lowest (98.11) germination capacity was obtained from unfertilized plot. This was similar with Biadge et al. who reported that germination energy was significantly different among varieties and different rates of nitrogen fertilizer application. Generally, the normal germination of malt barley increased linearly no much difference as the rates of applied N increased from the nil N to highest N rate. The overall mean germination was above Ethiopian national seed germination standard. Nonetheless, as per the suggestions of Kinaci and Donmez and ESA, all varieties demonstrated required standard set for malt barley quality for both germination energy and germination capacity which ranged from 90% to 95% and 96% to 98% respectively.

Protein use efficiency: Protein use efficiency of the test varieties increased linearly with increased N rates and was significantly higher for 100 kg ha^{-1} N than unfertilized plot (Table 3). In the present investigation, the concentration of protein in the grain increased on average by 67% from 0 kg ha^{-1} to 100 kg ha^{-1} N increment. In current study varieties had no effect on protein use efficiency (Table 3).

Protein use efficiency increased with increasing N rate in a linear fashion, indicating a direct impact of N fertilizer rate on malting barley grain quality. In this study, increasing N rates to achieve maximum grain yields caused grain protein content to exceed the maximum acceptable value (11.5%) for malting, suggesting that careful N fertilizer management is necessary for malting barley production. Several other studies have also reported that N fertilizer rate was a major factor affecting malting barley grain yield and quality and could result in increased protein use efficiency and protein concentration. In the current investigation, the test varieties differed in their protein use efficiency in response to N fertilization, suggesting the importance of variety selection for malting barley. Growing malting barley cultivars with relatively low protein may mitigate the negative effects of N on grain protein concentration and kernel plumpness while maintaining or increasing yield potential and malting extract levels.

Table 3: Effect of N rate and variety on grain quality parameters of barley.

Treatments		GC	AE	ST
N rate (kg ha^{-1})	0	98.11^{b}	6.22^{b}	3.80^{a}
	50	98.33^{b}	4.88^{b}	3.17^{a}
	100	99.11^{a}	18.85^{a}	2.44^{b}
	150	99.33^{a}	17.58^{a}	1.62^{c}
	$LSD_{0.05}$	0.58	6.18	0.77
Varieties	Local	98.83	14.49	3.55
	Traveler	98.83	12.69	2.24
	Ibon	98.5	8.48	2.48
	$LSD_{0.05}$	NS	NS	NS
	V*N	NS	NS	NS
	CV (%)	0.6	53.22	52.37

Partial budget analysis of malt barely yield production: The market price of malt barley grain was 20.00 Eth-birr kg^{-1} and a price for urea was 16.10 Eth-birr kg^{-1}. While the cost of other production practices like cost of labor, seed and weeding were assumed to remain the same or insignificant among the treatments. Partial budget analysis of the combination of nitrogen levels with different barley varieties was presented. Partial budget analysis was done using procedure described by CIMMYT economics program recommendations, which stated that application of fertilizer with the marginal rate of return above the minimum level (100%) is economical.

Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation for farmers. The results in this study indicated that the application of N fertilizer rate along with malt barley varieties resulted in higher net benefits than the unfertilized/low N fertilizer level treated treatments (Table 4). As a result, the partial budget analysis revealed maximum net benefit of Birr Birr 39147 ha^{-1} with an acceptable Marginal Rate of Returns (MRR) of 1007.33% with the treatment traveler variety with combination of 150 kg N ha^{-1}. However, the lowest net benefit of (Birr 22726.00 ha^{-1}) was recorded from Ibon barley variety treated with 0 kg ha^{-1} nitrogen fertilizer rate (Table 4).

Therefore, production of traveler variety with a combination of 150 kg N ha^{-1} was economical and uncertainly recommended for production of malt barley in the study area and other areas with similar agro-ecological condition.

Table 4: Partial budget analysis of barely yield production under barley varieties and N fertilizers rate in Kofele district.

Varieties	N rate (kg ha^{-1})	Yield (kg/ha)	Total return (Birr/ha)	Total cost (Birr/ha)	Net income (Birr/ha)	MRR (%)
EBN	0	1136.3	22726	0	22726	0
EBN	50	1327.5	26550	805	25745	375.031
EBN	100	1478.5	29570	1610	27960	275.155
EBN	150	1709.4	34188	2415	31773	473.665
TRV	0	1273.5	25470	0	25470	260.994
TRV	50	1463.4	29268	805	28463	371.801
TRV	100	1632.4	32648	1610	31038	319.876
TRV	150	2078.1	41562	2415	39147	1007.33
CHK	0	1163.2	23264	0	23264	657.681
CHK	50	1383.7	27674	805	26869	447.826
CHK	100	1573.7	31474	1610	29864	372.05
CHK	150	1726.3	34526	2415	32111	279.13

CONCLUSION

Barley is an important food grain and malting crop in the Ethiopian highlands with malting barley a major source of income for smallholder farmers. Despite a favorable biophysical environment, production and productivity of malt barley is low in the country. The malting quality of barley is one of the economically important traits, which are controlled by environmental factors and management practices such as variety, rate and time of urea application. In Kofele district, barley is a major crop produced by small holder farmers. However, its production and productivity is low due to the use of inappropriate nitrogen fertilizer rate and local low yielding varieties in the study area. Therefore, this study was conducted at Kofele district, West Arsi zone, Oromiya region to investigate response of malt barley varieties to rates of nitrogen fertilizer with the objectives of to evaluate the effects of mineral nitrogen fertilizer rates on yield and quality response of malt barley varieties and to determine economic optimum rates of nitrogen fertilizer for the productivity of the crop.

The experimental design of the trial was randomized complete block design in factorial arrangement with three replications, in which nitrogen fertilizer rates were used as the one factor and three barley varieties were used as another factor. The treatments are the combinations of three malt barley varieties, namely travler, Ibon and local and four levels of N (0 kg N/ha, 50 kgN/ha, 100 kg N/ha and 150 kg N/ha.

Crop yield and quality parameters were tested. The different barley varieties and nitrogen fertilizer has shown a highly significant ($p<0.01$) influence on maize yield production. On the other hand, interaction effect of barley varieties and nitrogen fertilizer didn't show significant variation maize yield production. The highest actual grain yield of maize obtained at 150 kg ha^{-1} nitrogen fertilizer rate lead to an improvement of 23.37% than the 0 kg ha^{-1} nitrogen fertilizer rate. Moreover, the analysis of variance also revealed that barley varieties have shown a highly significant ($p<0.01$) influence on maize yield production. The highest actual grain yield of maize obtained at traveler barley variety lead to an improvement of 13.61% over the local barley variety.

The maximum and minimum interaction mean values of grain yield were observed from traveler barley variety treated with 150 kg ha^{-1} nitrogen fertilizer rate (2078.10 kg/ha) and Ibon barley variety treated with 0 kg ha^{-1} nitrogen fertilizer rate (1136.30 kg/ha), respectively. In the present investigation, quality parameters increased with an increase in N rates, application of 150 kg N ha^{-1} gave the highest quality parameters studied except sieve test. While, the quality parameters were less pronounced with the tested varieties and their interaction effect. Since excessive grain protein content is a major factor in the rejection of barley for malting, growers should plant varieties that maintain high yields and relatively low protein in response to N application. As new malting barley varieties are developed and released for the malting industry, the nitrogen responses of these varieties need to be understood and described.

Overall, the use of appropriate crop verities with optimum nitrogen rate may maintain satisfactory crop yield and quality, reduce the costs of production and therefore increase profitability and improve soil fertility to enhance long-term sustainability of the cropping system.

As a result, the partial budget analysis revealed maximum net benefit of Birr Birr 39147 ha^{-1} with an acceptable Marginal Rate of Returns (MRR) of 1007.33% with the treatment traveler variety with combination of 150 kg N ha^{-1}. However, the lowest net benefit of (Birr 22726.00 ha^{-1}) was recorded from Ibon barley variety treated with 0 kg ha^{-1} nitrogen fertilizer rate. Therefore, production of traveler variety with a combination of 150 kg N ha^{-1} was economical and uncertainly recommended for production of malt barley in the study area and other areas with similar agro-ecological condition.

RECOMMENDATION

Based on the findings obtained from one cropping season, the following recommendations are made.

- This experiment was conducted at a given site in one season. Therefore, conducting the same experiment for one or more seasons and initiating similar experiments with different environmental conditions with the inclusion of more nitrogen rates and varieties with consideration of the economic evaluation, under diverse management practices is recommended for the validity of this finding.
- In the study, production of traveler variety with a combination of 150 kg N ha was economical and uncertainly recommended for production of malt barley in the study area and other areas with similar agro-ecological condition.
- Since excessive grain protein content is a major factor in the rejection of barley for malting, growers should plant varieties that maintain high yields and relatively low protein in response to N application. As new malting barley varieties are developed and released for the malting industry, the nitrogen responses of these varieties need to be understood and described.

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