EFFECTS OF NITROGEN FERTILIZER RATES ON GRAIN YIELD AND QUALITY OF MALT BARLEY (*Hordeum vulgare* L.) VARIETIES IN KOFELE WOREDA, WEST ARSI ZONE, ETHIOPIA

M.SC. THESIS

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HAWASSA UNIVERSITY

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BY

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This is to certify that the thesis entitled"**Effects of Nitrogen Fertilizer Rates on Grain Yield and Quality of Malt Barley (*Hordeum vulgare* L.) Varieties in Kofele Woreda, West Arsi Zone**" submitted in partial fulfilment of the requirements for the degree of Master's with specialization in **Plant Science (Agronomy),** the Graduate Program of the Department/School of **Plant and Horticulture**, and has been carried out by Ahmed Geleto Kusa Id. No ________________________, under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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Name of co-advisor1	Signature	Date

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We, the undersigned, members of the Board of Examiners of the final open defence by **Ahmed Geleto Kusa** have read and evaluated his/her thesis entitled "**Effects of Nitrogen Fertilizer Rates on Grain Yield and Quality of Malt Barley (*Hordeum vulgare* L.) Varieties in Kofele Woreda, West Arsi Zone**", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfilment of the requirements for the degree of Master of Science in Plant Science (Specialization: Agronomy).

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DEDICATION

I dedicate this thesis manuscript was to all my families**,** for their consistent and unreserved encouragements with love and affection, care, blessing and moral supports in all aspects for their committed partnership at my study period, and to my lovely Daughter, Ajaiba, Kadija, Mariyam, and Son Umar &Adugna Ahmed, my wife for their moral supports, inspires, advices and strengths me, enduring love of inspiration and ideas exchanges that always with me when I needs their help in the success of my life throughout the period of my study in Hawassa University.

DECLARATION

By my signature below, I declare and confirm that this thesis is the result of my own work.
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ABBREVIATIONS AND ACRONOMIES

AGDBM	Above Ground Dry Biomass Yield
AMF	Asella Malt Factory
ANOVA	Analysis of Variance
CSA	Central Statistical Agency
CV	Coefficient of variation
DE	Days to Emergence
Df	Degrees of freedom
DH	Days to Heading
DPM	Days to Physiological Maturity
EIAR	Ethiopian Institute of Agricultural Research
EQSA	Ethiopia Quality Standards Authority
ESA	Ethiopian Standard Authority
EUCORD	European Co-operative For Rural Development
FAO	Food and Agricultural Production
GPC	Grain Protein Content
GY	Grain Yield
HI	Harvest Index
IAR	Institute of Agricultural Research
LSD	Least Significance Difference
MoANR	Ministry of Agriculture and Natural Resources
NET	Non Effective Tillers
NSPS	Number of Seeds per Spike
NTT	Number of Total Tillers
OECD	Organization for Economic Co-operation and Development
ORDA	Organization for Rehabilitation and Development in Amhara

PH	Plant Height
SY	Straw Yield
TKW	Thousand Kernel Weight
USDA	United States Department of Agriculture

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Effects of Nitrogen Fertilizer rates on Grain Yield and Quality of Malt barley (*Hordeum vulgare* l.) Varieties in Kofele Woreda, West Arsi Zone, Ethiopia

By

Ahmed Geleto

Major Advisor: Hussein Mohammed (PhD) Co-advisor: Andargachew Gedebo (PhD)

ABSTRACT

Malt barley being an important cash crop of Kofele Woreda and was cultivated for both home consumption and for market. However, its productivity and grain quality was constrained mainly by low yielding varieties and application of low levels of N fertilizers. Thus, a field experiment was conducted to evaluate the effects of nitrogen fertilizer rates on growth, yield, yield components and quality of malt barley varieties and to determine economic optimum rates of nitrogen fertilizer that give high grain yield of acceptable malt quality. A three malt barley varieties (Traveler, IBON and Local) and four levels of N fertilizer rate (0, 50, 100 and 150 kg N ha^{-1}) was arranged in three replications of RCBD. Data was collected on 12 agronomic and seven malt quality traits. The study revealed that the N main effect was significant for all agronomic and quality traits except for TKW, HI, and GPR. There was significant difference among the varieties in DH, DM, PH, SL, NET, KPS, GPR, GPS, HLW and GE. The VxN interaction was significant for DH, DM, PH, SL and two of the seven quality traits (AE and HLW; malt quality traits were less affected by GxE interaction. The study revealed that nitrogen fertilization with 150kg ha^{-1} nitrogen fertilizer rate improved barley yield and quality.The maximum (3904.75kg ha^{-1}) and minimum (2977.25kg ha^{-1}) grain yield were observed from Travelear treated with 150 kg ha^{-1} N and IBON treated with 0 kg ha^{-1} N, respectively. In the present investigation, quality parameters increased with an increase in N rate, application of 150 kg N ha^{-1} gave the highest quality parameters studied except sieve test. Partial budget analysis revealed maximum net benefit of Birr 78095 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2675.7*% with the treatment Traveler variety with combination of 150kg N ha^{-1}. The lowest net benefit of (Birr 59545 ha^{-1}) was recorded from IBON barley variety treated with 0 kg ha^{-1} Nitrogen fertilizer rate. Therefore, production of Traveler variety in combination with 150 kg N ha^{-1} was economical, and recommended for production of malt barley in the study area.*

Keywords: Grain Yield, Malt Quality, Nitrogen Fertilizer.

1. INTRODUCTION

1.1. Background

Barley (*Hordeum vulgare* L.) is an annual cereal crop, which belongs to the *Gramineae* family (Zhou, 2010). 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 (USDA, 2019). It was one of the most important staple foods and economically important cereal crops in Ethiopia next to Teff, Maize, Wheat, and Sorghum (CSA, 2014).

In Ethiopia Barley was ranked fifth of all cereals, based on area of production, but third based on yield per unit area. It covers 7.56% of the land under grain crop cultivation with a yield of 1.96 tha^{-1} (CSA, 2016), whereas the potential yield goes up to 6 t ha^{-1} on experimental plots (Habtamu et al., 2014) indicating a productivity gap of about 4 t ha^{-1}.

Barley is an important food grain and malt crop cultivated in the highlands of Ethiopian, with malt barley a major source of income for smallholder farmers (Agegnehu et al., 2014). Recently, the demand for malt barley has increased significantly in Ethiopia because of the increasing number of beer industries in the country and more attention is now being given to meeting the demand for this crop. Malt barley is one of the most economically important cereals in the Arsi high lands of Ethiopia. However, growth, grain yield and quality response of malt barley varieties to N fertilizer rates in the study area is limited.

In Ethiopia, malt barely covers an area of 950,742.01 hectares of land with the production of 23,780,102.92 in quintals wit productivity of 25.2 q ha^{-1}. In Oromiya region, it covers 451,279.26 with total annual production of about 1.08 million tons. In Kofele, it covers

17,437.02 hectares of land with production of 213,401.13 quintals and productivity of 12.25 q ha^{-1} (CSA, 2020).

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 hectolitres to roughly 4 million Hectolitres (Abu Tefera, 2014). Despite the immense potential for producing malt barley in Ethiopia, only about 2% of total barley produced goes in to local malt factory breweries in the country (Tefera, 2012). Only one-third can be supplied from locally produced barley. The remaining two-thirds are imported primarily from Belgium and France (ORDA, 2008). 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.

Nitrogen is one of essential plant macro nutrients affecting plant growth, development and yield performance. It is a major component of proteins and nucleic acids. Generally, its deficiency consequences stunted plant growth, senescence of leaves and sterility of flowers, poor tiller formation, shrivelled seeds and low grain yield. Its excess levels also cause plant lodging, disease susceptibility, prolonged flowering and maturity dates. Wakene et al. (2014) reported that nitrogen significantly increases number of days to heading, maturity and grain filling period; and number of fertile tillers, total biomass and straw yields of barley were also significantly increased by application of N. The growth and yield performance of crop varieties vary from environment to environment because of their differential response to variable environments. The positive response of varieties to the increased rate of fertilizer is essential if the price of the increased yield surpasses its cost of production.

The grain protein content of malt barley always increases with the amount of applied N fertilizer whether or not a yield increase resulted (Castro et al., 2008; Jankovic et al. 2011; Kilic et al., 2010; Sainju et al., 2013; Wade and Froment, 2003). Similarly, several researchers reported a linear increase of grain N concentration with increasing rate of fertilizer nitrogen (Chen et al. 2006; Edney et al. 2012; O'Donovan et al. 2014; Sinebo et al., 2004). A study by O'Donovan et al. (2011) illustrated the negative impact of high N fertilizer rate on malt 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.

Previous research work has revealed that application of Nitrogenous fertilizers should be suitably adjusted to fit the maximum uptake rate in relation to amount of dry matter accumulation (Sharma et al., 1998). Nitrogen efficiency, especially in light soils, can be increased and losses reduced through scheduling of Nitrogen application to match with its uptake by the growing plants.

The reference rates for the fertilizer use in most part of Kofele distinct is 100$kg\ ha^{-1}$ NPSB and 50 $kg\ ha^{-1}$ urea for barley. However, there are huge research gaps on recommendation of full necessary agronomic practices like population per hectare, fertilizer rates and fertilizer use efficiency and other physiological studies have not been under taken. As a result of this fact, most of the farmers in this district do not use Nitrogen fertilizer and few others use very much below the blanket recommended rate of 41 $kg\ ha^{-1}$.

Variety has also played an important role in yield and quality of malt barley. The yield and quality specifications of a given malt barley variety are determined by its genetic makeup and the physical conditions during growth, including the amount of nitrogen applied (Glen et al., 2006;

Australian Govt., 2008). 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 malt barley and the use of appropriate production practices are critical to the production of quality malt barley.

Barley is one the major cereal crops grown in Kofele woreda. However, no study has been carried out on the Nitrogen fertilizer rate and different malt barley varieties in Kofele Woreda. So, the present study was conducted with the aim of identifying appropriate malt barley varieties, with their respective optimum rate of Nitrogen fertilizer application in malt barley growing areas of Kofele Woreda. The specific objectives of the study were the following:

1. To evaluate the effect of different Nitrogen levels on grain yield, yield components and quality of malt barley,
2. To investigate the difference in yield potential and malt quality of different malt barley varieties
3. To study the interaction between malt barley varieties and rates of Nitrogen applied concerning yield and malt quality parameters.
4. To find out the economically optimal rate of Nitrogen fertilizer application for production of malt barley.

2 LITERATURE REVIIEW

2.1 Origin and Distribution of Barley (Hordeum vulgare L.)

Barley is one of the cereals crops, belongs to the genus Hordeum L. in the tribe Triticeae of the family Poaceae, grown throughout the temperate, tropical and sub-tropical region of the world (Singh et. al., 2012). It originated in wild state in the Fertile Crescent, a crescent-shaped region of South east Asia" known as the Fertile Crescent" includes parts of Jordan, Lebanon,Syria, Southern Turkey, Iraq and Western Iran located in the present-day Middle East and as well as in the high land parts of Ethiopia (Ashley et. al., 2014). The earliest cultivation and domestication of barley is believed to have begun some 8,000 to 10,000 years ago in the area of the Middle East known as the Fertile Crescent, while in Ethiopia as early as 3000 B.C (MoANR, 2016; Bayeh and Berhane, 2011; Teferi et. al., 2015). The crop is introduced by Europeans to the New World in the sixteenth and seventeenth centuries, it is now grown worldwide with greater concentration in temperate areas and high altitudes of the tropics and subtropics (Bayeh and Berhane, 2011).

2.2 Barley Production

Barley (Hordeum vulgare L.) was one of the oldest cultivated crops and has been under cultivation in Ethiopia for at least the past 5,000 years according to some sources, based on evidence that it was cultivated as early as 3000 years B.C. (Harlan 1969; Hailu and Joop 1996). It has a long history of cultivation in Ethiopia and it is reported to have coincided with the history of plow culture (Zemede, 2000). The crop has been produced in Ethiopia, since ancient times. The greatest diversity of barley in terms of morphological types, genetic races, disease-resistant lines, and endemic morphotypes exists in Ethiopia (MoANR, 2016).

Next to morocco, Ethiopia is the second largest producer of barley in sub-Saharan Africa (FAO, 2014). It has been one of the most important cereals of staple food habit crop and a major source of carbohydrate and protein for the highland population. It grown in the Ethiopian highlands in almost all region of the country by small holders at altitude ranging from 1500 and 3500 m.a.s.l, but it is predominantly cultivated between 2000 and 3000 m.a.s.l. (Wondimu et. al., 2013 and Jimera et. al., 2015). It ranks fifth (both food and malt barley) together in the country after Teff, Maize, Wheat and Sorghum in area coverage and also fifth in total production after Maize, Teff, Sorghum and Wheat during the 2017/18 main rainy cropping season (CSA, 2018). It is produced largely in the southeast, central and northwest parts of the country and small amount is produced in the rest of north and south regions (MoANR, 2016). The main barley producing areas in Ethiopia are located in Arsi, Bale, Shewa, Tigray, Gonder, Wellega, Gojam and Welo zones. It is produced twice a year i.e., during the main season (June-December), and the short rainy season (March-July), also produced under residual moisture stress in some areas from September to January (Abebe et.al., 2010; Woldeab et.al., 2015; Teferi et.al., 2015 and Fekadu et.al., 1995). At national level, during the 2017/18 main rainy cropping season almost 951,993.15 ha of land is covered by food and malt barley and over 2.05 million tons are produced annually (CSA, 2018).

2.3 Economic Importance of Malt Barley

Barley was primarily used as animal feed and to produce malt, with smaller proportion is allocated for seed and direct human consumption. It is also used for production of starch, either for food or for chemical industry (OECD, 2004). Barley straw is used for animal bedding in developed countries but also for animal feeding especially in rural areas of developing countries.

Malt is the second largest use of barley and constitutes an important cash crop of resource poor farmers in many developing countries.

The main use of malt is in the production of alcoholic beverages, even though malt and malt products are increasingly becoming important in the bakery and barley food industries. Barley contains 75% carbohydrates, 9% protein and 2% fat. Each grain contains 3.3 calories. It is rich in Zinc (50 ppm), Iron (60 ppm), and soluble fibre (Anneli and Bjom, 1981). Malt barley is one of the most important crops for food, feed, malt and income generation for many smallholder farmers in the highlands of Ethiopia (FAO, 2013). Malt barley accounts for about 90% of the raw materials cost in beer production in Ethiopia (USDA GAIN, 2014). It has become a very important industrial crop in the country since the establishment of Saint George (Qiddus Giorgis) Brewery in 1974. The demand for malt has increased further since the establishment of Assela Malt Factory in 1984. The inauguration of Gondar malt factory in 2015 and the blooming of many more breweries created greater demands for malt barley (Berhane et al., 2016). There have been some unusual trends in the Ethiopian barley sub-sector, despite the fact that Ethiopia is the second largest barley producer in Africa, accounting for about 25 per cent of the production on the continent. While the country has consistently been a net exporter of food barley, it has been deficient in malt barley. With an increase in domestic demand, the size of the deficit has grown significantly in recent years (Shahidur et al, 2015).

2.4 Malt Barley Specific Quality Parameters

Malt Barley is one of the principal ingredients for beer making. Malt Barley must meet the special quality specifications. Maltsters require barley that malts homogenous and modifies quickly, requires no or little cleaning and that will deliver malt of an acceptable and consistent quality (Grain protein content, Grain protein Ratio, Hectoliter weight, Germination capacity, Sieve Test and protein use efficiency) to brewers.

Therefore, maltsters set certain quality standards for malt barley to ensure that the end product is produced in the most economical way possible (SABBI, 2012). Malt barley must fulfil most important quality parameters such as high germination rates, good grading, and an adequate amount of protein in the grain, which are dependent on growing, harvesting and storage conditions.

2.4.1 Germination

One of the key qualities of malt barley is,its ability to germinate rapidly and synchronously. Dormancy can interfere with the rapid and uniform germination of barley, thereby reducing the resultant malt quality. The failure of barley grain to germinate at an acceptable level (> 96 percent) could introduce problems during the malt process (Woonton et al. 2005). The Germination Capacity (GC) and Germinative Energy (GE) are the two tests used for assessing the barley grain dormancy. Germinative Capacity is the determination of the percentage of living grains within a sample of barley, while Germinative Energy is the determination of the percentage of grains which can be expected to germinate fully if sample is malted normally at the time of the test (Analytica-EBC, 1997). Any factor, which interferes with the uniformity of germination or reduces the vigour of kernel growth during processing, will reduce the quality of malt produced. Several of the characteristics such as grain consistency, thousand kernel weight, grain N content, and seed batch are a problem because of their impact on germination. Consistency of grain quality is important in the malt industry. Batches of seed with comparable germination characteristics are desirable so that adjustments can be made during malt to reduce the impact of variable or substandard grain (Howard et al., 1996). Germination can also be reduced if barley encounters excessive levels of moisture during germination, a phenomenon called water sensitivity.

Considering the effect of N fertilizer, the lowest and the highest germination were obtained with no application of N and with the application at 70 kg N ha^{-1} respectively. 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. Study of genotype by environment in malt barley reported that Miscal-21 showed low germination energy as compared to other barley varieties (Muluken, 2013). Generally, this indicates the need for determination of seed dormancy period for each variety before commencing to malting process. However, combined analysis over locations revealed that there were non-significant differences among varieties for mean germination energy and germination capacity test though Miscal-21 showed relatively low mean value. Nonetheless, as per the suggestions of Kinaci and Donmez (1998) and ESA (2001), 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 (Wondimu et al.,2013).

2.4.2 Protein content

Protein content is affected by genotype, cultural practices and growing environments. Malt barley with high protein content results in lower extracts. It also slows down water uptake during steeping, potentially affecting final malt quality. A very low protein level, on the other hand, results in a lack of enzymes necessary to modify the barley kernel and to break down the starch during brewing. Low protein content also impairs the brewing performance due to poor yeast amino acid nutrition (EQSA, 2006).

The desirable range of protein is 9.0-11.0 per cent for 2-rowed and 9.0-11.5 per cent for six rowed barley. In barley, the major storage protein is called hordein, and this comprises 40-50 per cent of total grain protein. This component is soluble in aqueous alcohol and comprises 4 fractions designated A, B, C and D. There have been several studies on relationship between individual horde infractions and Malt Quality, but still there is need of further revelations (Fox et al. 2003). Malt barley with high protein content results in lower extract for the brewery.

It also slows down water uptake during steeping, potentially affecting final malt quality. A very low protein level, on the other hand, results in a lack of enzymes necessary to modify the barley kernel and to break down the starch during brewing. Each brewer defines the malt protein level that is best for them based on their process, their yeast and the type of beer they are making. Generally, malters to meet many brewers' needs (Howard et al., 1996) can use barley protein within the range of 11 – 12.5%. However, according to the Ethiopian standard authority, the protein level of the raw barley quality standard for malt should be between 9 -12% (EQSA, 2006). 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 molesters.

2.4.3 Moisture content

Malt barley over 13.5 per cent moisture didn't store well. Moisture levels need to be low enough to inactivate the enzymes involved in seed germination and the growth of disease micro organisms (Fox et al. 2003). Thus moisture content can affect grain quality as well as its Germinative capacity. Moisture levels need to be low enough to inactivate enzymes involved in seed germination and to prevent heat damage and growth of disease microorganism. Quality and Germination capacity may also significantly deteriorate (Plankinton et al., 2014). The result of an experiment done on malt barley varieties showed that the moisture content were not significantly different among the varieties. The moisture content of varieties varied between 10.00-11.9% (Biadgi, et al., 2016).

2.4.4 Kernel plumpness

One important factor affecting the size, shape and uniformity of barley kernels is the number of rows of kernels on the barley spike. Barley spikes can be two rowed or six-rowed. In both types, there are three spikelets at each node of the rachis but in two rowed barley only the central spikelet is fertile, while in six rowed barley all three spikelets are fertile. Two-rowed barley grain is generally preferred for malting, although six rowed cultivars are preferred in some markets. Kernels of six-rowed cultivars are expected to be smaller and more variable in size and shape than those of two-rowed cultivars, because kernels from lateral florets tend to be smaller and less symmetrical than those from central florets (Ayoub et al., 2002). The parameters of Hectoliter weight, thousand grain weight and kernel plumpness were used to assess the desired shape and size of barley grains. Smaller grain generally has lower starch and higher protein levels, thus reducing the extract potential. Large grains generally have increased levels of starch and therefore more extract potential (Fox et al. 2003). Plump kernels produce malt with a higher extract, which is an important aspect in the brewing process.

A low kernel plumpness percentage is the result of unfavourable conditions during the grain-filling period, as late ears ripen too fast or if an initial yield potential exceeds the capacity of the environment at the grain-filling stage. Certain varieties however, also tend to constantly have low kernel plumpness and for this reason breeders specifically select for lines with high kernel plumpness (Howard et al., 1996). Study on malt barley genotypes under diverse agro ecologies of North western 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.

2.4.5 Hectoliter weight

Grain Specific Weight is measured in kg/Hectolitre, and is an indication of the density of the grain. Specific weight is predominantly a genetic trait of varieties, but poor crop nutrition and application can reduce specific weight. Hectoliter weight in small grains including Wheat, Oats and Barley is an important component of crop quality and value. The Hectoliter weight of a representative sample of your crop will give an indication of how it compares to the industry standard. A lower test weight equals lower value (Jim Isleib, 2012). Several factors influence the Hectoliter weight of small grains, including drought, nutrient deficiencies, temperature extremes, plant lodging, insect damage and adverse weather events like frost and hail. There are also genetic differences among varieties. These factors influence the plant during the period of grain fill, when stress is most likely to reduce Hectoliter weight (Fox et al., 2003). When available nitrogen is deficient, Hectoliter weight will be lower. However, once Nitrogen requirements are met, additional Nitrogen has the potential to result in reduced test weight. Managing Nitrogen carefully to meet, but not exceed yield goals maximizes likelihood of a good Hectoliter weight.

Varieties showing superior test weight results in trials may be a good choice. Grain hardness and Hectoliter weight are quality parameters considered by the processing industry for which they set specific standards for milling and end use. Hectoliter weight is related to the flour volume obtained from a specific weight of grain. These parameters have different responses across test sites and fertilizer rates (Girma et al., 2012).

2.5 Effects of Nitrogen Fertilizer on Yield and Quality of Malt Barley Varieties

Studies result show that grain protein content of malt barley increased with late-season N application. Therefore, it should be taken into account that N top-dressing of malt barley at its late stage will increase protein content in grain beyond the upper limit for malting use (Kara, 2010). Study on integrated organic and mineral nutrient sources indicates that, the N requirement of the crop at its latest stage is expected to be fulfilled by the mineralization of organic amendments so that growers need to be cautious about top dressing at booting stage (Kassu et al., 2018). Time of application of nitrogen is known to exert considerable influence on the yield and quality of crop.

The research work has revealed that application of Nitrogenous fertilizers should be suitably adjusted to fit the maximum uptake rate in relation to amount of dry matter accumulation (Sharma et al., 1998). Nitrogen efficiency, especially in light soils, can be increased and losses reduced through scheduling of Nitrogen application to match with its uptake by the growing plants. Method of N application in malt barley may decrease the grain protein level to acceptable levels by the brewing industry. Increase in yield attributing characters of malt barley due to application of nitrogen in three splits might be due to the prevented losses of Nitrogen through leaching and volatilization as compared to application in single dose and two split applications. Barley crop was benefited through adequate supply of Nitrogen at different growth stages, which may have positive influence on yield attributes (Singh and Singh, 2005). Application of Nitrogen as full basal, lower availability of nitrogen resulted into nitrogen deficiency at growth and development stage and hence a weak growth was observed. Roy and Singh (2006) also reported similar trend on yield attributing characters by crop.

Significant interaction effects between sowing dates, Nitrogen levels and its scheduling on pooled basis indicated that significantly higher grain yield of malt barley was recorded with 90 kg N ha^{-1} applied in three equal splits under normal sown condition (Narolia and Yadav, 2013). Plant use efficiency of nitrogen depends on several factors including application time, rate of nitrogen applied, cultivar and climatic conditions (Moll et al., 1982). In most cases, applying nitrogen during growing season is more efficient than applying it at planting. Ramos et al. (1995) found that split nitrogen equally between sowing and tillering, or else with the greater proportion applied at tillering lead to higher grain yield.

Roy and Singh (2006) indicated that N fertilizer strategies for malt barley should ensure relatively small amount of available one-third N at sowing for crop establishment and initial tiller development. Additional one-third N would then be applied at first irrigation (35 days after sowing) and one-third N at flowering (70 days after sowing) gained the highest values of all the yield components, grain yield and nutrient uptake. Splitting Nitrogen fertilizer to many doses increase efficiency of the fertilizers used by decreasing leaching largely and increased both yield and quality of crops in favour of the highest number of splitting as indicated by Ali (2010). Maximum efficiency should be obtained by the latest possible application compatible with the stage of development that still permits rapid N uptake (Olsen and Kurtz, 1982).

It is therefore evident that the highest values are obtained when supplementary nitrogen applications are done at cardinal growth stages, viz. sowing, spikelet initiation, spikelet differentiation and ear emergence (Taalab et al., 2015).

3 MATERIALS AND METHODS

3.1 Description of the 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 7° 37'N and 38° 38.5'E at an altitude of 2,673 m.a.s.l. Annual average rainfall of the area is 2100-2200mm, while minimum and maximum average annual temperatures are 11°C and 24.5°C, respectively (Kofale Woreda ANR Burao, 2019).

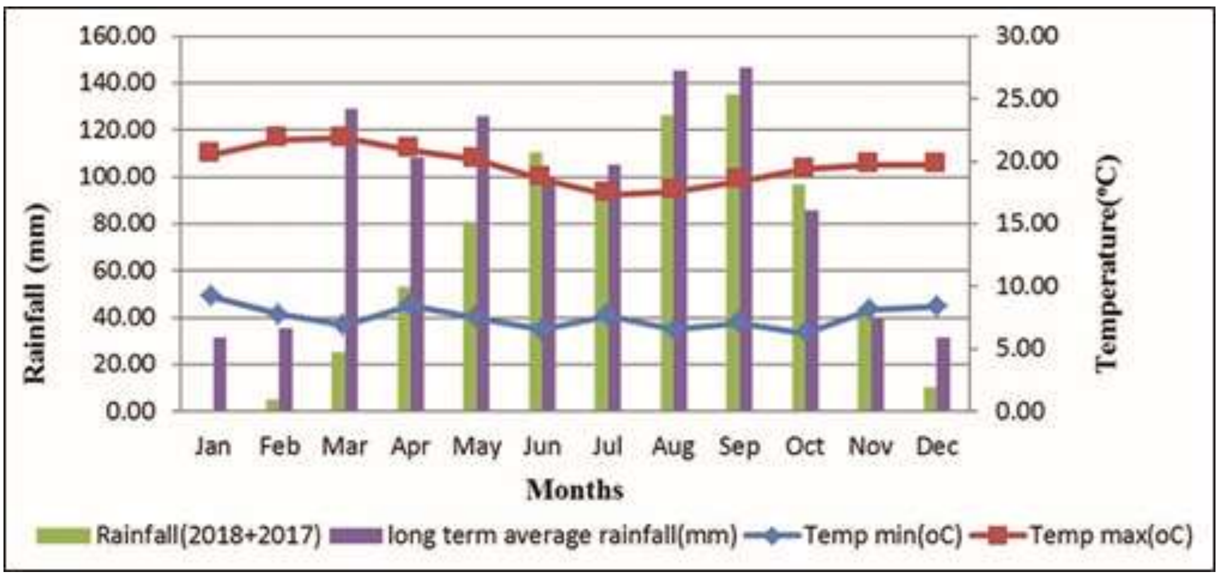

Figure 1. Long term average rainfall, maximum and minimum monthly average temperature of Kofole District

3.2 Treatments and 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 with RCBD design. 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 malt quality. IBON 174/03 was released by Holota Agricultare Research Center in 2012 and has productivity of 3 to 5.7-ton ha^{-1} at research field and matures in 120 days (MoA, 2016). The fertilizer was applied as follows.100 *kg* ha^{-1} NPSB (19 N, 37.7 P2O5, 6.95 S and 0.1B) was applied at planting while 0, 50, 100 and 150 *kg* ha^{-1} of urea was applied 1/3 at the time of sowing and 2/3 top dressed after 1st weeding. The distance between adjacent plots and adjacent blocks was 0.5 m and 1 m, respectively. Each plot had eight rows each 2 m long and spaced 25 cm apart. Gross plot area was 4 m^2 (2 x 2 m). The outer most one row on both sides of each plot was considered as border row and hence net plot area consisted of six rows with area of 3 m^2 (1.5 x 2 m). The total area for the experiment was 236 m^2.

3.3 Experimental Procedures

The land was ploughed three times prior to sowing and levelled properly. Planting was done at seed rate of 125 *kg* ha^{-1} in August 20, 2011 E.C. by drilling in rows spaced 25 cm apart. Weeds were controlled by hand as often as required.

3.4 Soil Sampling and Physico-chemical Analysis

Soil samples was collected from representative points randomly within the experimental site (0-30 cm depth) before planting across experimental field from 9 place using auger and was composited. Then, the composite sample was air-dried at room temperature under shade and was mixed thoroughly to produce 1.0 kg of a representative sample. The composite sample was taken before planting and analyzed at the soil laboratory of Hawassa Agricultural Research Center (HwRC). The soil was ground to pass through a 2 mm sieve, whereas for organic carbon (OC) and nitrogen (N) determination, the soil was ground to pass through a 0.5 mm sieve. The soil samples were analyzed for available nitrogen, available phosphorus, organic carbon, pH, and texture.

Soil texture was expressed by using Bouyoucos hydrometer method (Day, 1965). The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 soil to water dilution ratio by using a pH meter, and organic carbon was determined following Walkely and Black wet oxidation method as described by Jackson (1958). Available P was determined following the procedure described by Olsen et al. (1954). Available S was determined by KH_2PO_4 (Johnson and Fixen, 1990). Available B was determined using hot water method (Sippola and Ervio, 1977).

A grain and straw Nitrogen concentration were determined by using Kjeldahl method. Grain, straw and total N uptakes, and N-use efficiency, N-recovery efficiency, and N-utilization efficiency were computed using the basic data measured in the field and laboratory as described below:

Grain N uptake (GNUF) = grain yield × grain N concentration GYF x grain N

Straw N uptake (SNUF) = Straw yield × straw N concentration

Total N uptake (TNUF) = GNUF + SNUF X 100

Where

GYF....... is grain yield with fertilizer N,

GY0...... is the corresponding grain yield without N-fertilizer application for the same

genotype, and replication and

NF.......... is the rate of N fertilizer applied.

TNUF..... is total N uptake with fertilizer N,

TNU0.... is the corresponding total N uptake without N fertilizer application for the same genotype and replication and

NF.......... is the rate of N fertilizer applied.

3.5. Data collected

3.5.1. Crop Phenology and Growth Parameters

Days to 50% Heading (DH): DH was determined as the number of days taken from the date of sowing to the Date of Heading of 50% of the plants from each plot by visual observation. Days to 90% Physiological Maturity (DM): DM was determined as the number of days from sowing to the date when 90% of the peduncle (straw) turns yellow (straw color) and when grains are difficult to break with thumb nail. Plant Height (PH) in cm: PH was measured from the soil surface to the tip of the spike excluding awns of ten randomly selected plants from the net plot area at Physiological Maturity. Spike Length (SL) in cm: SL was measured from the bottom of the spike to the tip of the spike excluding the awns from ten randomly selected main spikes from the net plot.

3.5.2. Yield components and yield

Total Number of Effective Tillers (TNET) m^{-2}: It was determined as the number of tillers bearing seeds from 0.5 m length of five rows from the net plot and converted to per meter square of net plot at physiological maturity by counting the number of tillers. Non-Effective Tillers (NET): Non-Effective Tillers was determined at physiological maturity as the number of tillers that bear no seeds from 0.5 m length of five rows from the net plot and converted to per meter square of net plot. Number of kernels per spike (NKPS): Number of kernels per spike was calculated as average number of kernels from ten randomly taken spikes from the net plot area.

Thousand kernels weight (TKW) in g: Thousand kernel weight was determined based on average weight of three samples of 1000 kernels at 12.5% moisture content taken from the grain yield of each net plot by using electronic seed counter and weighed with sensitive balance. Aboveground dry biomass (AGDB) in *t* ha^{-1}: Aboveground dry biomass was determined from plants harvested from the net plot area after sun dried to a constant weight and converted to kg per hectare. Grain yield (GY) in *kg* ha^{-1}: Grain yield was taken by harvesting and threshing the seed yield from the net plot area. The grain weight of each plot was recorded in *kg* $plot^{-1}$ and converted to *kg* ha^{-1}. The yield was adjusted to 12.5% moisture content.

Harvest index (HI) in %: Harvest index was calculated from ratio of grain yield per plot to total aboveground dry biomass yield per plot multiplied by 100. Straw yield (SY) in *kg* ha^{-1}: Straw yield was obtained as the difference between the total aboveground dry biomass and grain yield.

3.5. 3. Quality parameters

Sieve Test (ST): Sieve test was carried out using 2.2, 2.5, 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.

Hectoliter weight (HLW): Hectoliter weight is flour density produced in a Hectoliter of the seed and it was determined using Hectoliter weight analyzer.

Protein content: Total nitrogen in the seed was analyzed by wet-oxidation procedure of the modified Kjeldahal procedure (Nelson and Sommers, 1973). Grain protein content was determined by multiplying the N content by the conversion factor of 6.25 according to the standard macro-Kjeldhal procedure (AOAC, 1970).

Germinating Energy (GE in %): Germination energy was determined from 100 seeds germinated in a petridish after 72 hours as per Bam *et al*. (2006). The germinated kernels were counted and the result was expressed as percentage of the total.

$$\text{Germination (\%)} = \frac{Total\ number\ of\ seeds\ set\ for\ test}{Number\ of\ germinated\ seed} * 100$$

Germination capacity (GC): 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.

3.6. Statistical Analysis

Analysis of variance (ANOVA) was carried out with SAS software version 9.2 (SAS Institute, 2008). Significant differences between treatments were delineated by LSD (least significance difference). A correlation analysis was done by determining Pearson moment correlation between yield and yield components and between grain yield and soil chemical properties (pH, available N and P, OC, B, S).

3.6.1. Economic Analysis

Economic analysis was made using the prevailing inputs at planting and for outputs at the time of crop harvest. Partial budget analysis was conducted for average yield of the different treatment combinations. Prices of malt barley, urea and NPSB were used for the analysis. A treatment was considered worth to farmers when it’s minimum acceptable rate of return (MAR) is 100% (CIMMYT, 1988), which is suggested to be realistic. This enables to make farmer recommendations from marginal analysis. The economic analysis was based on the formula developed by CIMMYT (1988).

4. RESULTS AND DISCUSSION

4.1. 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 32%, 30%, and 38%, 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 (Gupta, 2000). It is one of the inherent soil properties less affected by management and which determines nutrient status, organic matter content, air circulation and water holding capacity of a given soil. Based on the study conducted the textural class of the study area was clay loam.

Table 1 Selected physico-chemical properties of the experimental site

Soil physical properties	Tested results
Sand (%)	32
Silt (%)	30
Clay (%)	38
Particle size	Clay loam
Soil chemical properties	**Tested results**
pH	5.73
Organic matter content (%)	3.31
Total nitrogen (%)	0.13
phosphorus (ppm)	19.21
Calcium (cmol/kg)	6.28
Magnesium (cmol/kg)	1.02
Available potassium (ppm)	0.20
CEC (cmol/kg)	41.00

Soil pH results were found to be moderately acidic with a pH value of 5.73 (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 aluminium toxicity.

Low soil pH impedes the CEC of the soil by altering the surface charge of colloids (finest clay particles and soil organic matter) (McCauley et al. 2005). Low CEC implies that soil will have less exchangeable cations required as crop nutrients; nutrients are weekly adsorbed and hence may be leached out. According to Murphy (1968), 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 moderately 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, 19.21ppm for available phosphorous (P). The organic matter content of the surface Soil could be rated as medium according to Landon (2014) 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 Lap top 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 soil was 0.13 and was rated as low according to Landon (2014).

Cation exchange capacity was the capacity of the soil to hold and exchange cations. It was 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 41 cmol kg^{-1} (Table 1) which could be categorized as high range (FAO, 2006). 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 (2006) except for Available potassium which was small (Table 1). Limited availability of soil nutrients affects crop production and productivity.

4.2. Phenological Parameters of Barley

4.2.1. Days to Heading

The analysis of variance revealed that,the main effect of variety and Nitrogen rate as well as the interaction effect of variety and rates of Nitrogen application were significant ($P<0.001$) for day to heading (Appendix Table 1 and Table 2). Days to Heading showed an increasing tendency with rising N rates. Increasing rates of Nitrogen from 0-150 kg N ha^{-1}, days to heading was increased from 80.22 to 87.11 days. Latest Days to Heading (87.11) was recorded under 150 kg ha^{-1} nitrogen fertilizer rate while the earliest Days to Heading (80.22 kg ha^{-1}) was recorded under 0 kg ha^{-1} Nitrogen fertilizer rate (Table 2). IBON variety took Minimum Days to Heading (76.33 days) while Traveler variety has taken Maximum Days to Heading (93.58 days) which is statically higher than that of the remaining two varieties.

The interaction effect of N rate and variety on Days to Heading of barley was significant. The highest Days to Heading was recorded from Traveler barley variety under 150 kg ha^{-1} N rate followed by local variety under 150 kg ha^{-1} N rate while the shortest Day to Heading was observed for IBON under 0 kg ha^{-1} N rate.

The effect of variety might be due to the genetic makeup of the variety as IBON 174/03 was early maturing, whereas Traveler was late maturing variety (MoA, 2012). Similarly, Derebe (2018) reported that barley genotypes differ in days to heading. The difference in Nitrogen fertilizer rates might be related to extended vegetative growth stage that delay Days to Heading when higher rates of N are applied. Rashid *et al*. (2007) also reported that N application significantly affected days to heading in barley. The result indicates that as the amount of Nitrogen fertilizer applied at tillering increases, Days to Heading also increases.This is in line with Nakano *et al.* (2008) who reported that plants that received 8 g N m^{-2} at active tillering headed slightly later than those that received 0 g N m^{-2}.

4.2.2. Days to Physiological Maturity

Days to 90% physiological maturity was ($P< 0.001$) affected by the main effects of variety and rates of Nitrogen application, as well as their interaction (Appendix Table 1 and Table 2). The longest Physiological Maturity (146.30) was observed at 150kg $ha^{-1}$of N rate application on Travler barley variety. The shortest physiological maturity was (128.83) was observed at 0 kg ha^{-1} of N rate application on IBON malt barley variety. From interaction, Maximum Physiological Maturity was observed from Travler barley variety under 150 kg ha^{-1} N rate followed by Local barley variety under 150kg ha^{-1} N rate. On the other hand, the Minimum Physiological Maturity was obtained at IBON barley variety under 0 kg ha^{-1}N rate applications.

This variation may be due to difference in the genetic makeup. The maturity of barley plant was hastened under lower N rates than under the higher N rates. This result agrees with Woinshet (2007) who reported that high rates of Nitrogen prolong Days to Physiological Maturity. The shorter Days to Physiological Maturity when applying full-recommended Nitrogen fertilizer at planting might be due to loss of the applied nitrogen fertilizer as the crop could not use it efficiently at planting and hence lower nitrogen uptake, which result in lower vegetative growth and shorter days to physiological maturity. Similarly, Derebe *et al.* (2018) and Wosene et al. (2015) reported that genotypes could differ in Days to Physiological Maturity.The longer Days to Physiological Maturity might be due to Nitrogen fertilizer applied at tillering was used by the plant as the plant had developed roots to efficiently uptake the N applied at the stage which could result in extended vegetative growth and delayed Physiological Maturity. This is also in line with Kedir and Ashenafi (2020) and Ketema and Mulatu (2017) who reported variation of physiological maturity of food barley varieties with different Nitrogen fertilizer rates.

Table 2 Effect N rate and variety on Phonological Parameters of Barley

Treatments		**DH**	**DPM**
	0	80.22[d]	135.00[d]
N rates (kg ha^{-1})	50	81.33[c]	136.00[c]
	100	84.33[b]	137.00[b]
	150	87.11[a]	138.70[a]
	LSD $_{0.05}$	0.84	2.17
	Local	79.83[b]	141.30[b]
Varieties	Traveler	93.58[a]	146.30[a]
	IBON	76.33[c]	128.83[c]

LSD $_{0.05}$	0.72	0.88
V*N	***	***
CV (%)	1.09	1.10

*Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at p<0.05 level of significance. DH= day to heading and DPM = day to physiological maturity

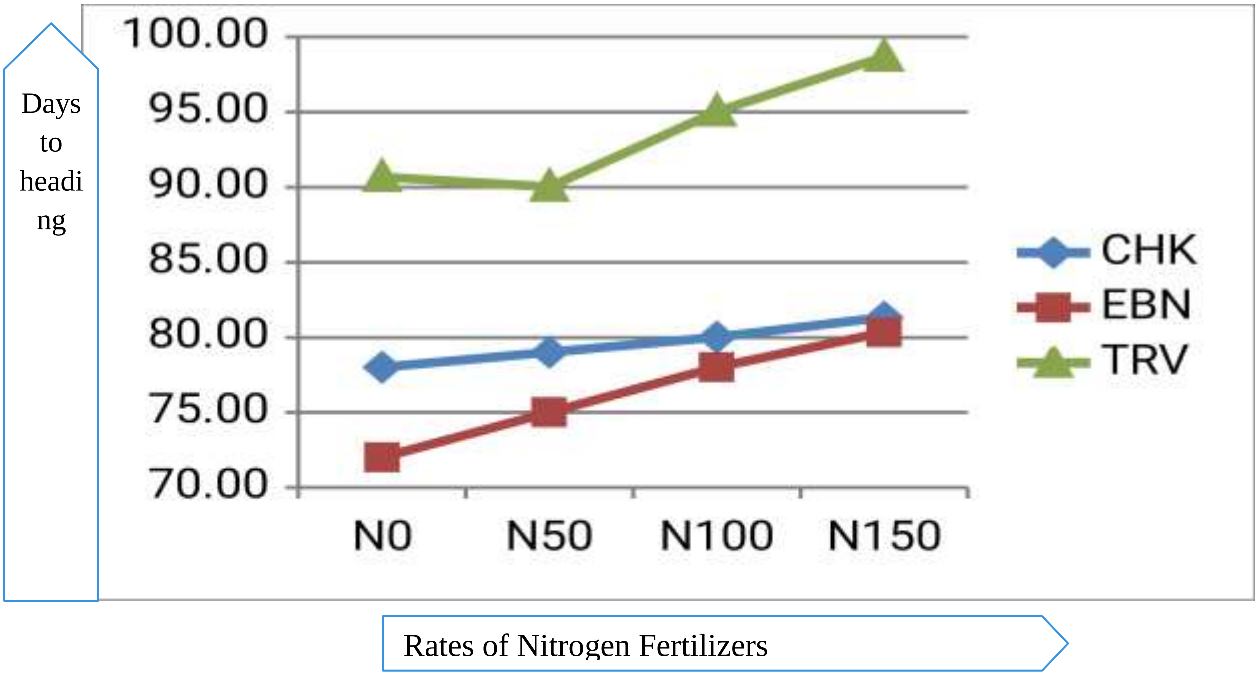

Figure. 2. Variety x N Interaction for Days to Heading

Since the lines were not parallel there is VxN interaction. However, the interaction is not of cross-over type. There was no rank change. Traveller was the latest variety and IBON was the earliest maturing variety under all N levels. However, the difference between the varieties was not constant over the three N levels implying interaction due to heterogeneity of errors. The difference between the Local and Ebon is widest under No. Under N 150 the mature almost in equal number of days.

4.3. Growth Parameters of Barley

4.3.1. Plant Height

Plant height was ($P < 0.001$) affected by main effect of variety and Nitrogen rate, and interaction of variety with nitrogen rate (Appendix Table 3 and Table 3). Maximum Plant Height (97.58cm) was observed for 150kg ha^{-1} Nitrogen fertilizer rate, where as the minimum Plant Height

(91.30cm) was observed for 0kg ha^{-1} Nitrogen fertilizer rate. The maximum Plant Height recorded at 150 kg ha^{-1} Nitrogen fertilizer rate was statistically superior to the rest Nitrogen fertilizer rates.

This result was similar with the finding of Biruk and Demelash (2016) who indicated highly significant plant height differences resulted by main effects of N rates and varieties.

. The result showed that Plant Height increases at an increasing rate of Urea levels. Ali et al. (2010) also reported similar results of Plant Height increment with urea rate increase and significant increments in Plant Height due to application of high Nitrogen rate. Similar findings were also reported by Ketema and Mulatu (2018) and Kedir and Ashenafi (2020) who reported that different nitrogen fertilizer rates significantly affected Plant Height and higher growth of Food barley varieties. This result was in consistent with Biruk and Demelash (2016), who reported that varietal difference in Plant Height might be due to genetic behaviour in combination with environmental conditions.

4.3.2. Spike Length

Spike length was significantly ($P < 0.01$) affected by varieties and Nitrogen rates. Moreover, this parameter was also significantly ($p < 0.05$) affected by the interaction effect of variety and nitrogen rate (Appendix Table 1 and Table 3). The longest spikes were recorded from IBON variety followed by Travler variety. The difference of the varieties in spike length could be due to the genotypic difference of the varieties. The longest spike (11.69 cm) was recorded from the plot treated with 150 kg $ha^{-1}$of Nitrogen fertilizer rate application which improved by 25% as compared the shortest spike length (9.58 cm) obtained from the 0 kg ha^{-1} of nitrogen fertilizer rate application plot (Table 3). Maximum Spike length was obtained from IBON variety with combination of 150 kg N ha^{-1} while the minimum number of Spike length was obtained from Local variety with 0 kg ha^{-1} N rates. Spike length was also significantly increased with increasing N level. Spike length varied from 5.15 to 6.89 cm as the N level increase from 50 to 150 kg N ha^{-1} (Table 4).

The result was agreed with Biruk and Demelash (2016) study spike length varied significantly ($P < 0.001$) among the barley varieties. Similarly,this also coincides with the study of Kedir and Ashenafi (2020) and Ketema and Mulatu (2018) who reported that applications of Nitrogen fertilizer leads to the higher yield components and spike length as compared with the Non-Nitrogen fertilizer treated treatments.

4.3.3. Number of Tillers

The analysis of variance revealed number of tillers was significantly ($p < 0.001$) affected by only main effect of Nitrogen rates. But non-significantly affected ($p < 0.05$) by main effect of variety and interaction of variety and Nitrogen rates (Table 3 and Appendix Table 1). The highest (20.36) number of tillers of variety was obtained at 150 kg ha^{-1} Nitrogen fertilizer rate and it was statistically superior to the 100 kg ha^{-1} Nitrogen fertilizer rate and similar with that of the rest rates of Nitrogen fertilizers. On the other hand, the minimum (15.61) number of tillers of the variety was obtained at 0 kg ha^{-1} Nitrogen fertilizer rate, which was statistically inferior with that of the rest of Nitrogen fertilizer rates.

The lowest numbers of tillers per variety (15.61) were recorded for barley at 0 kg ha^{-1} Nitrogen fertilizer rate treated plot; which might be due to the role of N in accelerating vegetative growth of plants. The highest number of tillers per variety was obtained at 150 kg ha^{-1} Nitrogen rate was improved by 21% as compared to the lowest number of tillers per variety at 0 kg ha^{-1} nitrogen fertilizer rate. This may be the contribution of N fertilizer, as the treatments that received N responded more total tillers compared with less N received treatments. This as stated by Bakht *et al*. (2010) might be due to the fact that nitrogen is an essential nutrient for growth and development of the plant.

The results agreed with that of Abdullatif, et al. (2020) who reported increasing in the number of effective tillers with Nitrogen fertilization. Bereket, et al. (2018) and Abdollahi, et al. (2018) also reported that Nitrogen fertilization has significant effect on effective number of tillers of barley. Giday et al. (2014) also reported positive and significant increase in number of productive tillers with increasing rates of N fertilizer on Teff. Similar findings were also reported by Ketema and Mulatu (2018) who reported that increasing the rate of Nitrogen application up to 150 kg N ha^{-1} significantly increased total tillers number across to all varieties.

Additionally, Rashid and Khan (2008) disclosed that number of total tillers of barley varieties significantly by application of Nitrogen fertilizer. Similarly, Munir (2002) reported that tiller number of barley varieties were significantly increased with increasing rate of Nitrogen fertilizer application.

Table 3 Effect of N rate and variety on Growth Parameters of Barley

Treatments		**PH (cm)**	**SL (cm)**	**NT**
	0	91.30^{b}	$9.58d^{d}$	15.61^{c}
N rates (kg ha^{-1})	50	92.58^{b}	10.19^{c}	16.97^{b}
	100	93.23^{b}	10.97^{b}	17.94^{b}
	150	97.58^{a}	11.69^{a}	20.36^{a}
	$LSD_{0.05}$	2.92	0.48	1.16

	Local	106.50[a]	10.04[b]	17.16
Varieties	Traveler	90.00[c]	10.87[a]	17.60
	IBON	93.32[b]	10.91[a]	17.79
	$LSD_{0.05}$	2.53	0.42	NS
	V*N	***	*	NS
	CV (%)	2.78	5.73	7.46

*Means followed by different letters in a column differ significantly and those followed by the same letter a

Were not significantly different at p<0.05 level of significance. PH= plant height= Spike length and NT = Number of Tiller

4.4. Yield and Yield Components of Barley

4.4.1 Non-Effective (unfertile) Tillers

The analysis of variance indicated that,the main effect of variety and Nitrogen fertilizer rate exhibited significant ($p<0.01$) differences on non-effective tillers, but their interaction was not significant (Table 4 and Appendix Table 1). The highest non effective tillers (4.33) was obtained by the application of 0 kg N ha^{-1} nitrogen rate where as the lowest non effective tillers (2.72) was obtained by the application of 150 kg N ha^{-1} Nitrogen rate. The maximum non effective tillers were recorded at 0 kg N ha^{-1} Nitrogen rate which was statistically superior to all the rest Nitrogen rates. On the other hand, the lowest non effective tiller was observed at 150 kg N ha^{-1} Nitrogen rate and this was statistically inferior with that of 0 kg N ha^{-1} Nitrogen rate and with the rest fertilizer rates. Regarding malt barley varieties, the highest non-effective tillers of (4.00) was obtained by Travler barley variety where as the lowest non effective tillers (2.89) was obtained by IBON barley variety. The maximum Non-Effective Tillers were recorded at Travler barley variety were statistically superior to IBON barley variety and similar with that of the local barley variety. On the other hand, the lower non-effective tillers were observed at IBON barley variety and this was statistically inferior with that of the rest barley varieties.

This revealed that Contribution of N fertilizer, as the treatments that received N responded more compared with zero and less N received treatment and number of fertile tillers significantly affected with variation of malt barley varieties (Table 4).The lowest numbers of non effective tillers were recorded for all varieties at lower Nitrogen rate treated plot; which might be due to the role of N in accelerating vegetative growth of plants. Number of fertile tillers plant was the most important character, which ensured highest yield.

This result is consistent with finding of Biruk and Demelash (2016) number of fertile tillers highly significantly affected by the difference between barley varieties and rates of Nitrogen. Similarly, Wakene *et al.* (2014) indicated that highly significant differences were observed between plant heights, productive tillers m^{-2}.

4.4.2. Number of Kernels Per Spike

Analysis of variance had shown that number of kernels per spike was highly significantly ($p < 0.001$) affected by both main effect of nitrogen rates and malt barley varieties. However, this parameter was also insignificantly ($p < 0.05$) affected by the interaction effect of variety and Nitrogen rate (Table 4 Appendix Table 7).

An Increasing the rate of Nitrogen application up to 150 kg N ha^{-1} Nitrogen rate significantly increased number of kernels per spike for all varieties. Increasing trends of number of kernels per spike was observed when rates of fertilizers increased.This might be due to the addition of fertilizer application rates in the experimental site there was increased the appearance of seeds in their spikes. The results were in conformity with that of Wakene *et al.* (2014) who stated that increasing N rates up to optimum level significantly increased number of seed spike^{-1}.

4.4.3. Thousand Kernel weight

The analysis of variance indicated that the effect of variety and Nitrogen rate application, as well their interaction over thousand kernel weight were not significant (Appendix Table 8).

Table 4 Effect of N rate and variety on yield and yield components of barley

Treatments		**TKW (g)**	**NKS**	**NET**
N rates (kg ha^{-1})	0	51.68	28.36^{c}	4.33^{a}
	50	53.11	28.808^{c}	3.91^{b}
	100	54.32	29.91^{b}	3.19^{b}
	150	58.29	31.22^{a}	2.72^{b}
	LSD $_{0.05}$	NS	0.82	0.70
Varieties	Local	51.35	41.16^{a}	4.00^{a}
	Traveler	55.63	35.75^{b}	3.72^{a}
	IBON	56.07	37.00^{b}	2.89^{c}
	LSD $_{0.05}$	NS	0.71	0.61
	V*N	NS	NS	NS
	CV (%)	20.79	3.53	19.63

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at $p<0.05$ level of significance. TKW= Thousand kernel weight, NKS = Number of Kernels per Spike and NET = Non Effective Tiller

4.4.4. Aboveground biomass

The analysis of variance showed that above ground dry biomass was significantly affected by different rates of Nitrogen fertilizer ($P<0.01$). The difference between varieties in biomass yield was non-significant. The highest aboveground biomass (11.925 t ha^{-1}) was observed at 150 kg ha^{-1}nitrogen fertilizer rate. The maximum aboveground biomass obtained at 150 kg ha^{-1} Nitrogen fertilizer rate was statistically superior to that of the rest Nitrogen fertilizer rates.

Contrary to this, minimum aboveground biomass (8.125 t ha^{-1}) was obtained at 0 kg ha^{-1}nitrogen fertilizer rate (Table 5 and appendix Table 2).

The Minimum aboveground biomass obtained at 0 kg ha^{-1} Nitrogen fertilizer rate was statistically inferior with that of the rest Nitrogen fertilizer rates. The highest aboveground biomass of barley obtained at 150 kg ha^{-1} Nitrogen fertilizer rate lead to an improvement of 32 % than the 0 kg ha^{-1} Nitrogen fertilizer rate. This might be due to the significant increases in plant height, tiller, spike length, number of spikelet per spike and grain yield from N application which ultimately contributed to the increased crop biomass yield.

In general, aboveground dry biomass was increased with increase in N rate, which might be due to improved root growth and increased uptake of nutrients favoring better growth, and delayed senescence of leaves of the crop due to synergetic effect of the nutrients (N). In addition, this might be due to highest fertilizer rates in the root zone due to high nutrient amount in 150 kg ha^{-1} N rates leads to make a favourable condition for barley physiological and photosynthesis processes. Different studies revealed that an adequate nutrient in the root zone leads to improve aboveground biomass and grain yield of barley.

This result also agreed with the finding of Wakene *et al*. (2014); that highest biomass yield of 8.78 t ha^{-1} was recorded under treatment that received 120 kg N ha^{-1} while the lowest biomass yield of 6.51 t ha^{-1} was obtained at treatment received zero nitrogen rate.

Further increase in N levels significantly enhanced the biological yield as Nitrogen at 120 kg ha^{-1} yielded maximum (11642.78kg) biological yield followed by 80 kg ha^{-1} (9392.22kg). Minimum (7224.11kg) biological yield was provided by N at 40 kg ha^{-1} (Hadi *et al*., 2012).

The current finding was in line with Ketema and mulatu. (2018) who reported that fertilizer supply had a marked effect on the aboveground biomass, grain yield, and straw yield. The maximum aboveground biomass (12.35 t ha^{-1}) was obtained from 69 kg ha^{-1} of Nitrogen fertilizer application.

However, the lowest (7.78 t ha^{-1}) aboveground biomass was recorded from control or unfertilized plot. This result also agrees with the finding of Woodshed et al. (2017) who found that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased the biomass by 11.5 t ha^{-1}. This was due to the fact that Sulfur enhanced the formation of chlorophyll and encouraged vegetative growth and B helps in N absorption.

4.4.5. Straw yield

Analysis of variance showed that the straw yield of Malt Barley was significantly ($P<0.01$) affected by only main effects of different Nitrogen fertilizer rates application while non significantly influenced by barley varieties and their interaction ($P<0.05$) (Appendix Table 10). Higher straw yield of 7527.5 kg ha^{-1} was obtained at 150kg ha^{-1} Nitrogen fertilizer rate (Table 5) which was statistically superior to that of 0 and 50 kg ha^{-1} fertilizer rates and similar with that of 100 kg ha^{-1} fertilizer rate. Contrary to this, the lower straw yield of 5300.25kg ha^{-1} was observed at no fertilizer condition and it was statistically inferior to the rest Nitrogen fertilizer rates (Table 5).

The highest straw yield observed at 150 kg ha^{-1} Nitrogen fertilizer rate is 29.60% which is higher than the straw yield observed at 0 kg ha^{-1} Nitrogen fertilizer rate. The study reveals showed that there is a positive relationship between the amounts of Nitrogen fertilizer on the straw yield production. The mean separation revealed that increasing rate of Nitrogen increased straw yield of barley varieties up to higher level of Nitrogen application. Similar to the grain yields, the straw yields continued increasing significantly with the increase in N fertilizer rate. This might be significant increases in plant height, tiller, spike length, number of spikelets per spike and grain yield from N application ultimately contributed to the increased crop biomass yield.

Additionally, might be due to the increase in N fertilizer rate in the root zone leads to make a favorable condition for barley physiological and photosynthesis processes. As N fertilizer is one of the main components of essential nutrient for growth and development of the plant to produce their food, supplying adequate N fertilizer could lead to increase both aboveground biomass and straw yield. This may be due to the increase in physiological or physical growth contributes to the total above ground biomass production for 150 kg ha^{-1} Nitrogen fertilizer rate treatment, which has a direct relation with growth and development.

Many researchers such as Kedir and Ashenafi, (2020); Zelalem, (2017) and Ketema and Mulatu (2018) have reported similar results in barley straw yield production. The current result was in line with the finding of Shafi *et al*. (2011) who reported that straw yield of barley was affected by different N levels. In consistent with this result Biruk and Demelash (2016) reported that considerable difference in straw yield was attained between barley varieties and Nitrogen rates. Similarly, the rate of fertilizer application significantly affected straw yield of wheat (Bekalu and

Mamo, 2016). According to Abebe, straw yield increased with increasing the fertilizer rates, as Nitrogen increases vegetative growth of plants, especially at higher doses. Besides, the significant increase in plant height, spike length and number of fertile tillers due to increase in N rate contributed to the significant increase in straw yield. Berek et, *et al. (*2014) also reported that wheat straw yield increased with increase in N rates.

4.4. 6. Grain Yield

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 (3904 kg ha^{-1}) from 150 kg ha^{-1} Nitrogen fertilizer rate and it had a significant difference with 0 kg ha^{-1} Nitrogen fertilizer rate and statistically the same with that of rest Nitrogen fertilizer rates (Table 5 and appendix Table 9). Contrary to this, minimum grain yield (2977 kg ha^{-1}) 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 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 barley varieties had significant ($p<0.05$) influence on grain yield (Table 5 and appendix Table 2). Maximum grain yield (3904 kg ha^{-1}) was observed from Traveler, which was significantly superior to the remaining two varieties. Moreover, the minimum (2977 kg ha^{-1} grain yield obtained from IBON which was at par with the local barley variety. The highest grain yield of barley obtained at Traveler variety lead to an improvement of 13.61% over IBON barley variety.

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 (Kaizz *et al*., 2012). 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.

Nitrogen was an integral component of many compounds essential for plant growth processes including chlorophyll, which is responsible for the dark green color of stems and leaves, which enhances vigorous vegetative growth, plant height, branching and/or tillering, leaf production and size enlargement and many enzymes (Gemechu, 2011). Nitrogen also mediates the utilization of potassium, phosphorus and other elements in plants. The result affirmed that addition of supplementary N at growing stage attributed to partition of N to grain yield for subsequent growth and development.

The current finding is also in line with Ketema and mulatu. (2018) who reported that fertilizer supply had a marked effect on the aboveground biomass, grain yield, and straw yield. The maximum aboveground biomass (11.925 t ha^{-1}) was obtained from 150 kg ha^{-1} of Nitrogen fertilizer application.

The VxN Interaction was non-significant for grain yield.

4.4.7. Harvest index

Analysis of variance revealed that, harvest index was not significantly affected by main effect of Nitrogen fertilizer rates and malt barley varieties. Moreover, the effect of Nitrogen, varieties and their interaction on HI were not significant (Appendix Table 2).

Table 5 Effect of N rate and variety on yield and yield components of barley

Treatments		ABGM(T/ha)	AY(kg/ha)	SY (kg/ha)	HI (%)
	0	8.125^{d}	2977.25^{c}	5300.25^{c}	36.20
N rate (kg ha^{-1})	50	9.65^{c}	3478.75^{b}	6325^{b}	35.86
	100	10.775^{b}	3903.75^{b}	7012.5^{a}	36.00
	150	11.925^{a}	3904.75^{a}	7527.5^{a}	37.85
	LSD$_{0.05}$	3.87	935.89	1812.25	NS
	Local	9.95	3654.25^{b}	6491.5	36.21
Varieties	Traveler	10.425	4029,66^{a}	6520	38.18
	IBON	10	3532.25^{b}	6612.5	35.05
	LSD$_{0.05}$	NS	511	NS	NS
	V*N	NS	NS	NS	NS
	CV (%)	11.15	14.08	15.36	14.92

*Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at p<0.05 level of significance. ABM = above ground biomass per hectare, AY = Actual grain yield per hectare, SY = straw yield per hectare and HI = harvest index

4.5. Grain quality parameters

4.5.1. Grain protein contents

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 (Appendix table 3). 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 6). Increasing the application of N fertilizers from nil to 150 kg N ha^{-1} remained at par to each other, consistently increased grain protein contents.

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 accum ulation of storage proteins.

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 6). 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. (2011 and 2013) who reported that grain protein content is influenced largely by both genotype and environment.

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).

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 6).

4.5.2. 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 (Appendix table 3).

The highest (58.01kg 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 6). Hectoliter weight was found to increase with increasing nitrogen application rates from zero to 150 kg ha^{-1} this might be due to the fact that, N is an essential component of the proteins used to build cell materials and plant tissues. Moreover, Bruk (2013) found 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}) was recorded from the Local variety and it was statistically superior while the lowest hectoliter weight (56.22 kg ha^{-1}) was recorded from IBON barley variety (Table 6). Significantly higher hectoliter weight between 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.

Rick *et al*. (2014) reported that the acceptable standard of Hectoliter weight for barley was in the range of 66.1- 72.8 kg ha^{-1}. Therefore, Hectoliter weight was little lower than in the stated ranges in this study.

4.5.3. Grain protein Ratio

Analysis of variance indicated that mean grain protein ratio of malt barley was only significant ($P< 0.01$) among varieties (Appendix Table 3 and Table 6).

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*. (2011 and 2013) who reported that grain protein content is influenced largely by both genotype and environment.

Table 6 Effect of N rate and variety on grain quality parameters of barley

Treatments		**GPR**	**PC**	**HLW**
	0	11.43	9.58^{c}	54.86^{c}
N rate (kg ha^{-1})	50	11.23	10.87^{b}	56.44^{b}
	100	10.51	12.12^{a}	57.48^{a}
	150	11.08	12.13^{a}	58.01^{a}
	LSD $_{0.05}$	NS	0.69	0.68
	Local	12.03^{a}	11.84^{a}	57.37^{a}
Varieties	Traveler	10.10^{c}	10.38^{b}	56.50^{b}
	IBON	11.06^{b}	11.30^{a}	56.22^{b}
	LSD $_{0.05}$	0.83	0.60	0.59

V*N	NS	NS	NS
CV (%)	8.90	6.39	1.23

*Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at p<0.05 level of significance. HLW = Hectoliter weight, PC = Grain protein content and GPR= Grain protein Ratio

4.5.4. **Sieve test**

Sieve test was done to test the plumpness of barley grains. Plump barley was a sum of barley that remains on the top of a 2.2, 2.5, 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) (Appendix Table 3 & Table7). The highest mean sieve test was obtained on local variety with 0 and 50 kg ha^{-1} nitrogen application. The lowest sieve test was scored with variety Traveler at 150 kg ha^{-1} fertilizer rate (Table 7). The difference in varieties in grain size could be related to genetic and environmental effect. Moreover, Fox *et al*. (2003) 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- and 2.5-mm slotted screen for two rowed malt 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 malt barley genotypes under diverse agro ecologies of north-western Ethiopia, indicates that three genotypes 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 fulfilled 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 was in line with the findings of Getachew (2014) 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 Holeta. O'Donovan *et al*. (2012) 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 (2012) reported that sieve test (grain size percentage) >90% is settled for 2-rowed barley such as IBON 174/03 and Traveler variety.

4.5.5. **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 did not significantly influence germination capacity (Appendix Table 3 and Table 7).

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. 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 (Berhan, 2017). Nonetheless, as per the suggestions of Kinaci and Donmez (1998) and ESA (2001), 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 (Wondimu *et al*.,2013).

4.5.6. Protein use efficiency

Protein use efficiency of the test varieties increased linearly with increased N rates and was significantly higher for 100kg N ha^{-1} than unfertilized plot (Table 7). In the present investigation, the concentration of protein in the grain increased on average by 67% from 0 to 100 kg ha^{-1} N increment. In current study varieties had no effect on protein use efficiency (Table 7)

Protein use efficiency increased with increasing N rate in a linear fashion, indicating a direct impact of N fertilizer rate on malt 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 malt barley production. Several other studies have also reported that N fertilizer rate was a major factor affecting malt barley grain yield and quality and could result in increased protein use efficiency and protein concentration (O'Donovan et al. 2011, 2014, 2015; Sainju et al. 2013, 2015; Smith et al. 2016). 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 malt barley.

Growing malt 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 malt extract levels (Bertholdsson 1999; Edney et al. 2012; Emebiri and Moody 2004; O'Donovan et al., 2015; Weston et al. 1993).

Table 7 Effect of N rate and variety on grain quality parameters of barley

Treatments		GC	AE	ST
	0	98.11^{b}	6.22^{b}	3.80^{a}
N rate (kg ha^{-1})	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
	Local	98.83	14.49	3.55
Varieties	Traveler	98.83	12.69	2.24
	IBON	98.50	8.48	2.48
	LSD $_{0.05}$	NS	NS	NS
	V*N	NS	NS	NS
	CV (%)	0.60	53.22	52.37

*Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at p<0.05 level of significance. GC= germination capacity, AE = protein use efficiency and ST= Sieve Test

4.5.7. Partial Budget Analysis of Malt Barley Yield and Quality to N fertilizer and varieties

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 in Table 8. Partial budget analysis was done using procedure described by CIMMYT Economics Program

(1988) 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 was 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 8). As a result, the partial budget analysis revealed maximum net benefit of Birr 101550 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2675.7% with the treatment Traveler variety with combination of 150 kg N ha^{-1}(Table 8). However, the lowest net benefit of (Birr 56815.00 ha^{-1}) was recorded from Ibon barley variety treated with 0 kg ha^{-1}nitrogen fertilizer rate (Table 8).

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 8 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^{-1})	Total Return (Birr ha^{-1})	Total cost (Birr ha^{-1})	Net Income (Birr ha^{-1})	MRR(%)
EBN	0	2840.75	56815	0	56815	0
EBN	50	3318.75	66375	805	64765	987.577
EBN	100	3696.25	73925	1610	72315	937.88
EBN	**150**	**4273.5**	**85470**	**2415**	**83055**	**1334**

TRV	0	3183.75	63675	0	63675	802.4
TRV	50	3658	73160	805	72355	1078.2
TRV	100	4081	81620	1610	80010	950.9
TRV	**150**	**5198.25**	**103965**	**2415**	**101550**	**2675.7**
CHK	0	2908	58160	0	58160	1879.5
CHK	50	3459.25	69185	805	68380	1269.5
CHK	100	3934.25	78685	1610	77075	1080
CHK	**150**	**4315.75**	**86315**	**2415**	**83900**	**847.8**

N.B: MRR = Marginal rate of return, Sale prices of Urea: 16.10 birr kg^{-1}, Sale price of malt barley: 20 birr kg^{-1}in local market. Family labor cost was not assigned because similar labor time was used on each treatment.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Barley was an important food grain and malt crop in the Ethiopian highlands with malt barley a major source of income for small holder farmers. Despite a favourable biophysical environment, production and productivity of malt barley was low in the country. The malt quality of barley was one of the economically important traits, which are controlled by environmental factors and management practices such as variety, rate and time of Nitrogen application. In Kofele district, barley was a major crop produced by small holder farmers. However, its production and productivity was low due to the use of inappropriate Nitrogen fertilizer rate and local low yielding varieties in the study area. This indicates the need to conduct research and determine the optimum Nitrogen rate for maximum productivity of malt barley crop. 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 to evaluate the effects of mineral Nitrogen fertilizer rates on growth, yield, yield components 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 in factorial arrengement 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 were the combinations of three malt barley varieties, namely Travler, IBON and Local and four levels of N (0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1} and 150 kg N ha^{-1}). Crop phonological traits such as day to heading, days to physiological maturity, growth parameters such as plant height, spike length, number of total tillers, number of fertile tillers,yield and yield components such as number of kernels per spike, Thousand kernal weight, straw yield, biomass yield, harvest index and actual grain yields and malt quality parameters such as grain protein content, Grain protein Ratio, Hectoliter weight, Germination capacity, Sieve Test and protein use efficiency were tested.

The result of this study revealed that,the phonological, growth and yield trait parameters were positively responded to barley varieties and Nitrogen fertilization. The study revealed that Nitrogen fertilization with 150 kg ha^{-1} rate improved barley yield and quality than the rest nitrogen fertilizer rates. Moreover, barley variety Traveler was more superior to the other varieties on most of the phonological and growth parameters, yield and yield components of barley however a significant variation among malt barley varieties was not observed regarding to quality.

The different barley varieties and Nitrogen fertilizer has shown a highly significant ($p<0.01$) influence on barley yield production. On the other hand, interaction effect of barley varieties and Nitrogen fertilizer didn't show significant variation on Malt Barley yield production. The highest aboveground biomass and actual grain yield of Malt Barley obtained at 150 kg ha^{-1} Nitrogen fertilizer rate lead to an improvement of 32 % and 23.37% than the 0 kg ha^{-1} Nitrogen fertilizer rate, respectively. Yield parameter like straw yield was significantly affected also. The maximum straw yield due to 150 kg ha^{-1} Nitrogen fertilizer rate was 29.60% higher than that observed under 0 kg ha^{-1} Nitrogen fertilizer rate, respectively. Moreover, the analysis of variance also revealed that barley varieties have shown a highly significant ($p<0.01$) influence on Malt Barley yield production. The highest aboveground biomass and actual grain yield of Malt Barley obtained at traveler barley variety lead to an improvement of 5% and 13.61% over the Local barley variety, respectively.

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 (3904.25 kg ha^{-1}) and IBON barley variety treated with 0 kg ha^{-1} Nitrogen fertilizer rate (2977 kg ha^{-1}), respectively. Growth and phonological parameters of barley significantly affected due to different barley varieties and Rates of Nitrogen fertilizer. However, the interaction effect of different barley varieties and Nitrogen fertilizer did not show significant variation in most barley parameters including quality parameters except day to heading, maturity date, and plant height and spike length. Nitrogen fertilization with 150 kg ha^{-1} Nitrogen fertilizer rate leads to an improvement of day to heading, day to physiological maturity, plant height and spike length a by 7.90%, 3%, 6.45% and 18% than 0 kg ha^{-1} Nitrogen fertilizer rate, 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 was less pronounced with the tested varieties and their interaction effect. Since excessive grain protein content was a major factor in the rejection of barley for malt, growers should plant varieties that maintain high yields and relatively low protein in response to N application.

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 101550 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2675.7% with the treatment Traveler variety with combination of 150 kg N ha^{-1}(Table 8). However, the lowest net benefit of (Birr 56815.00 ha^{-1}) was recorded from IBON barley variety treated with 0 kg ha^{-1} Nitrogen fertilizer rate.

5.2. Recommendations

- 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 $ha^{-1}$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 was a major factor in the rejection of barley for malt, growers should plant varieties that maintain high yields and relatively low protein in response to N application. As new malt barley varieties are developed and released for the malt industry, the Nitrogen responses of these varieties need to be understood and described.

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7. APPENDICES

Appendix Table 1. Analysis of variance for Yield and Yield Components of Barley

Source	DF	Mean square						
		DH	PM	PH	SL	NT	NET	TKW
REP	2	0.00***	0.25***	21.40***	0.18**	14.09*	2.31**	10.05 NS
VAR	2	880.99***	1008.25***	1850.46***	2.96*	4.75NS	3.85**	62.84 NS
N	3	71.15***	79.30***	79.40***	6.88**	34.93**	4.41***	15.01 NS
VAR *N	6	7.21***	7.66***	19.22***	1.39*	0.22NS	0.08NS	83.11NS

Appendix Table 2. Analysis of variance for Yield and Yield Components of Barley

Source	DF	Mean square				
		TB	NKS	AGY	SY	HI
REP	2	120734.54 NS	1.72NS	1.31*	1001258.99*	185.11*
VAR	2	115424.30 NS	46.28***	0.14 NS	7160.37 NS	10.50 NS
N	3	636819.29 ***	13.95***	3.41***	1182944.45***	54.57**
VAR *N	6	16386.88 NS	1.01NS	1.31 NS	73004.48NS	9.46 NS

Appendix Table 3. Analysis of variance for Grain quality parameters of Barley

Source	DF	Mean square					
		GPR	PC	HLW	GC	AE	SV
REP	2	8.08**	1.72NS	1.39NS	0.03 NS	121.40 NS	10.82*
VAR	2	11.21**	46.28***	4.31**	0.44 NS	114.10 NS	5.60 NS
N	3	1.41 NS	13.95***	17.30***	3.15**	486.41***	6.51*
VAR *N	6	0.91 NS	1.01NS	1.20NS	0.15 NS	244.59**	0.81 NS

Appendix Table 4. Ethiopian Standards for the most important malt quality parameters

Malt quality parameters	The acceptable Standards
Protein content	9.0-11.0 per cent for 2-rowed and 9.0-11.5 per cent for six rowed barley.
Hectoliter weight	66.1- 72.8 kg ha^{-1}.
Germination energy and germination capacity	90 to 95% or 96 to 98%
Kernel plumpness	Mean values of kernel retained on screen size (2.5 mm + 2.8 mm) ranged from 81.57% to 92.27%. Similarly, the mean kernel size that pass through the sieve which is < 2.2 mm screen ranged from 3.63% to 0.89%
Moisture content	The moisture content of varieties varied between 10.00-11.9% (Biadgi, et al., 2016).

BIOGRAPHICAL SKETCH

The author, Ahmed Geleto Kusa, was born in th West Arsi Administrative zone, Oromia Regional State from his father Geleto Kusa and mother, Ganeme Adema on January 5,1985. He attended his primary and elementary school education at Seimena Borko in September 1991 to 1998. Then he joined kofele High School for his secondary school from Septembe 1999 to June 2002 and completed the Ethiopian School Leaving Certificate Examination (ESLCE) in 2002. In November 2003 he jioned Nedjo ATVET to pursue his Advence Diplom in Plant Science and graduated on July 1, 2005. After graduation, he was employed at West Arsi Zone Agriculture &Natural Resourc office, As a Development agent where he served as an expert of Crop Development and Protection for five years. In September 2011, he joined the School of Graduate Studies of Madda Walabu University to pursue his Degree study in plant Science and graduated his B.sc in 2013. Finally,September 2018, he joined the School of Graduate Studies of Hawassa University to pursue his M.Sc study in Agronomy.