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RESPONSE OF YIELD AND QUALITY OF MALT BARELY (Hordeum distichon L.)VARIETIES TO RATES AND TIME OF NITROGEN FERTILIZER APPLICATIONS IN FARTA DISTRICT, NORTHWESTERN ETHIOPIA

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BAHIR DAR UNIVERSITY
COLLEGE OF AGRICUTURE AND ENVIRONM
GRADUATE PROGRAM IN AGRONOMY

RESPONSE OF YIELD AND QUALITY OF MALT BARE (*Hordeum distich L.*) VARIETIES TO RATES AND TIME OF APPLICATION OF NITROGEN FER FARTA DISTRICT, NORTHWEST ETHIOPIA

M.Sc. Thesis
By

Betselot Molla

October 2021
Bahir Dar, Ethiopia

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SUBMMITED IN PARTIAL FULFILMENT OF THE RE
DEGREE OF MASTER OF SCIENCE (M.Sc) IN

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THESIS APPROVAL SHEET

As member of the board of examiners of the Masters of Science (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. Betselot Molla entitled with €Response of Yield and Quality of Malt Barely (Hordeum distichon L.) Varieties to Rates and Time of Nitrogen Fertilizer Applications in Farta District, Northwestern Ethiopia€. We here certify that, this thesis is accepted for fulfilling the requirements for the award of the degree of Master of Science (M.Sc.) in Agronomy

Board of Examiners

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Name of External Examiner	Signature	Date
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DECLARATION

This is to certify that this thesis entitled with €Response of Yield and Quality of Malt Barely (Hordeum distichon L.) Varieties to Rates and Time of Nitrogen Fertilizer Applications in Farta District, Northwestern Ethiopia€ submitted in partial fulfillment of the requirements of the award of the degree of Master of Science in •Agronomy€ to the graduate program of College of Agriculture and Environmental Sciences, Bahir Dar University by Mr. Betselot Molla Mekonen (ID 10207291 PR) is an authentic work carried out by him under our guidance. The matter embodied in this thesis work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

Name of the student

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Name of the Advisors

1) Dr. Dereje Ayalew (Major Advisor)

Signature Date

2) Dr. Tilahun Tadesse (Co-Advisor)

Signature Date

ACKNOLEDGMENTS

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DEDICATION

This thesis is dedicated to my beloved families, for their affection, encouragement and inspiration throughout my study and in the rest of my life.

LIST OF ABBREVATIONS AND ACCRONYMS

ABoANR	Amhara Bureau of Agriculture and Natural Resource
ANOVA	Analysis of Variance
ARARI	Amhara Regional Agricultural Research Institute
ATA	Agricutural Transformation Agency
CEC	Cation Exchange Capacity
CIMMYT	Centre for International Maize and Wheat Improvement
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
EQSA	Ethiopian Quality Standard Authority
FAO	Food and Agricultural Organization
GB	Gross Benefit
GDP	Gross Domestic Product
GPC	Grain Protein Concentration
GY	Grain Yield
HI	Harvest Index
IAR	Institutes of Agricultural Research
ICARDA	International Center for Agricultural Research in Dry Areas
LSD	Least Significance Difference
MoA	Ministry of Agriculture
MRR	Marginal Rate of Return
NB	Net Benefit
NUE	Nitrogen Use Efficiency
RCBD	Randomized Completely Block Design
SAS	Statistical Analysis System
TSP	Triple Supper Phosphate
TVC	Total Variable Cost

Response of Yield and Quality of Malt Barely (Hordeum distichon L.) Varieties to Rates and Time of Nitrogen Fertilizer Applications in Farta District, Northwestern Ethiopia

By

Betselot Molla,

Advisors: Dr. Dereje Ayalew and Dr. Tilahun Tadesse

ABSTRACT

Barley is one of the most important multipurpose crops in Ethiopia. However, its productivity and quality in Ethiopia is mainly constrained by soil fertility problems, inadequate availability and use of inputs such as fertilizers, lack of high quality and high-yielding varieties and poor agronomic practices. An experiment on malt barley was conducted in Farat District during the main rainy season of 2020/2021. The objective of experiment was to determine the optimum nitrogen fertilizer rate and its appropriate time of application for maximum production and better quality of malt barely varieties. The treatments consisted of three N rates (34.5, 69 and 103.5 kg N ha^{-1}, three times of N fertilizer applications: T1 (2/3 at sowing + 1/3 at mid-tillering), T2 (1/3 at sowing +2/3 at mid-tillering), T3 (1/3 at sowing +1/3 at mid- tillering + 1/3 at anthesis) and two malt barley varieties (Holker and IBON 174/03), a total of 18 treatments were evaluated in factorial arrangement using Randomized Completely Block Design with three replications. All necessary data were collected properly and subjected to analysis of variance using SAS 9.0 version and mean separation for significant treatments was done by LSD. The result of the study showed that most of the traits studied were significantly affected by the main and interaction effects. Above ground biomass and grain yield were significantly affected by the combined effect of variety with nitrogen rate and N rate with its time of application. The total protein content was significantly influenced by the interaction of variety with rate of nitrogen and variety with time of N application. Generally, the highest grain yield (4.26 t ha^{-1}) was obtained when (69 Kg N ha^{-1}) was applied with two splits 1/3 at sowing + 2/3 at mid-tillering. The protein content recorded on this treatment combination was within the acceptable range for malting purpose. The partial budget analysis showed that the maximum net return ETB 82,627.50 with acceptable MRR (1824.20%) was obtained from this treatment combination. Therefore, aplication of 69 kg N ha^{-1} with two splits 1/3 at sowing + 2/3 at mid-tillering is recommended for Farat District and similar agro ecologies. Since the current study was conducted in a single location and only one year, it is better to repeat this experiment on multi-locations and over seasons to come up with reliable recommendation

Key words: Malt barley, malt quality, optimum nitrogen rate, protein content of malt barley

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Chapter 1. INTRODUCTION

1.1 Background and Justification

Agriculture is the dominant sector of Ethiopian economy and long term food security. This sector mainly depends on producing of different crops. Among cereal crop categories barley (*Hordeum vulgare* L.) is one of the most important multipurpose crops which is believed to be originated in the Fertile Crescent of the Near-East for about 10,000 years ago and recently it is also confirmed that it was grown on the Tibetan plateau in a similar era based on RBP2 gene studies (Badr *et al*., 2000; Wang *et al*., 2016 a, Wang *et al*., 2016 b). The global production volume of barley amounted to 156.41 million metric tons (FAO, 2019). Ethiopia is the first producer in Sub-Saharan Africa and eleventh in the world in barley production. In Africa barley production is mainly dominated by Ethiopia, Algeria and Morocco with an estimated production of 2.38, 1.65 and 1.16 million tons, respectively (FAO, 2019).

Barley is the fifth most important cereal crop in Ethiopia after teff, maize, sorghum, and wheat in area coverage while it is after maize, teff, wheat and sorghum in terms of production (CSA, 2020). The national area coverage of barley was 950,742.01 ha which is 7.39% of the land covered by grain crops (CSA, 2020). The total production of barley was estimated 2.38 million tones with an average yield of 2.50 t ha^{-1} while in Amhara region, the area coverage and average yield was estimated about 321,515.21 ha and 2.34 t ha^{-1}, respectively (CSA, 2020). Similarly in South Gondar Zone, the average harvested area and grain yield of barley was 25, 810.91 ha and 2.42 t ha^{-1}, respectively. Barely is grown in different environments at an altitude of 1500-3500 meter above sea level (m.a.s.l.) but predominantly cultivated with the range of 2000-3500 m.a.s.l. (Berhane Lakew *et al*., 1996).

Barley is one of the most important crop in the world and it is usually used as food for human beings and feed for animals, for poultry and it is also used as an input for industries for extracting malt to be utilized in brewing, distillation, baby foods, cocoa malt drinks and ayurvedic medicines (Singh *et al*., 2014). In Ethiopia barley is one of the major crops grown in the highland area of the country and used in different forms like bread, porridge, roasted grain (kolo) and for preparing alcoholic and non alcoholic drinks (Bayeh Mulatu and Berhane Lakew, 2011). Barley production in Ethiopia started long years ago and is largely grown as a food crop in the central and northern parts of Ethiopia, with the major regions of production namely Oromia, Amhara, Tigray, and Southern Nations, Nationalities, and People•s Region. Food barley is mainly grown for subsistence consumption by the rural farm households while malt barley is largely a commercial crop produced for industrial malt grain production. The malting and brewing industry are taking roots with both international and domestic brands operating in the country (Berhane Lakew *et al*., 1996).

The demand of malt barley has been increased year after year by breweries (Getachew Agegnehu *et al*., 2014). However, in Ethiopia the gap between malt barley production and demand is high (ICARDA, 2016). This is mainly due to the expansion of breweries and beer consumption levels in Ethiopia (Biadge Kefale *et al*., 2016). These days considerable efforts have been made to satisfy the ever-increasing demand for raw materials by the beverage industry with domestic production, to save significant foreign currency and to increase farmers income. Despite all efforts however, Ethiopia imports about 50% of the malt from international producers (Addisu Bezabih, 2018).

The low productivity and quality of barley in Ethiopia is mainly constrained by poor soil fertility, inadequate availability and use of inputs such as fertilizers, lack of improved varieties, poor cultural practices/crop management, the influence of several biotic and abiotic stress, poor access to markets and unattractive malt barley price (Taye Bekele *et al*., 2002; Bayeh Mulatu and Berhane Lakew, 2011; Kassu Tadesse *et al*., 2018). Fertilizer trials conducted in different parts of Ethiopia indicated that both grain yield and protein content increase with increasing nitrogen (Derebe Terefe *et al*., 2018; Melaku Tafes, 2019; Minale Liben *et al*., 2011). Nitrogen is one of the most important and widely used elements for plant growth and development and crop yield. In addition N is a vital component of nucleon proteins and nucleic acids which carry the heredity matrix control and direct the synthesis of protein and enzymes. However nitrogen is deficient in most

Ethiopian highland soils (Taye Bekele et al., 2002; Girma Chala, 2017). On the other hand, the optimum rate of nitrogen varies from location to location. Moreover, application of N at appropriate time of the crop growth stage is also another important agronomic practice to enhance nitrogen use efficiency and increase yield and quality of malt barley. Thus, splitting nitrogen fertilizer application according to the need of the crop is the best strategy to achieve high grain yield with acceptable malting quality (Grant Jackson, 2000).

1.2 Statement of the Problem

Malt barley productivity and quality in the study area is particularly constrained by varietal selection problems, poor soil-fertility and poor agronomic practices (rate and time of N application). According to the study of Lakew Desta et al. (2000) land degradation has been one of the problems observed in the highlands of Amhara region of Ethiopia, including the districts Farta, Fogera and Gondar Zuria. Low soil nutrient contents particularly N is one the most important problem which results in low productivity on farmlands due to continuous cropping, high soil erosion and removal of crop residues. Full nitrogen application at planting facilitates the nutrient losses due to excess leaching, run off and volatilization with an estimated value of 50%-70% as the crop have no well developed and efficient roots that can uptake and utilize the applied nitrogen fertilizer (Hodege et al., 2000). Split application of nitrogen fertilizer at different growth stage reduces loss of nitrogen and increase supply of N to the crop throughout its growth stage and finally increases grain yield (Roy and Singh, 2006). There is no adequate research finding that showed the effect of time of N application on malt barley in the study area. Varietal difference is also another important yield limiting factors of malt barley as varieties typically differ in response to the applied nitrogen (Fathi et al., 1997). The yield attributes and quality of malt barley seed is therefore, dependent on the type of the variety used, appropriate dose and time of N fertilizer application specific to each location. Limited research has been done to evaluate the yield and quality traits of malt barley varieties in response to different rates of nitrogen fertilizers in the Farta district. Generally, producers are still facing several challenges to boost productivity and increase quality of malt barley in the area. Further the crop production package made by Amhara regional Bureau of

Agriculture and Natural Resource (ABoANR) for malt is blanket recommendation, it is not location specific which is 150 kg ha^{-1} of urea with two split applications 2/3 at sowing and 1/3 at tillering (ABoANR, 2019). While different locations have different fertility status and demands different management practices. Currently, producers are advised to use this blanket recommendation for malt barley production. However, most farmers in the study area are not using this package recommendation of urea properly, rather they are using urea fertilizer only and that is during the time of sowing, while others use fertilizer which is below the recommendation rate. Generally, there is no common application of urea both interms of rate and time. Due to this the average yield of barley in the study area is very low which remained at 2.42 t ha^{-1} (CSA, 2020), whereas the yield can reaches up to **6** t ha^{-1} on experimental plots (Derebe Terefe et al., 2018). Further, information on the response of different malting barley varieties to N fertilization rate and appropriate time of application in this area is not well documented too. Hence this study was initiated with the following objectives.

1.3 Objective of the Study

1.3.1 General objective

The overall objective of the present study was to enhance the yield and quality malt barley varieties through the application of optimum rates and appropriate time of N fertilizer in Farta district, Northwestern Ethiopia

1.3.2 Specific objectives

- To evaluate the response of malt barley varieties to different rates and time of nitrogen fertilizer application; and

- To determine the optimum nitrogen fertilizer rate and its appropriate time of application for maximum production and quality of malt barely varieties.

Chapter 2. LITERATURE REVIEW

2.1 Botany, Center of Origin and Description of Barley

Barley (*Hordeum vulgare* L.), is a grass belonging to the family Poaceae, the tribe Triticale (Voltas *et al*., 1999) The cultivated and wild forms of barley are diploid species, with 2n=14. The wild barley (*Hordeum spontaneum*) is an ancestor of the cultivated barley (Young, 2001). Barley is debatable in its origin, possibly originating in Egypt, Ethiopia, Near East or Tibet (Duke, 1983). According to Badr et al (2000) barley was one of the first domesticated grain in the Fertile Crescent, an area of relatively abundant water in Western Asia and near the Nile river of North East Africa.

Barley is an annual, cool season bunchgrass that grows, 2-4 ft tall (Ball et al., 1996). It has hollow and jointed stems. The leaf surfaces and leaf margins of barley characterize as smooth, tapered, and arise on the stem above ground level (Brown, 1979). Its nodes and internodes of stems are hairless (Radford et al., 1968). Some varieties lack awans, but when present can reach 6 inches in length (Radford et al., 1968). Barley can be confused with other small grains before it reaches to flowering. It can be distinguished from wheat, rye, and oats by examining the leaf collar when it is pulled away from the stem. In addition to this, the leaf collar on a barley plant will have two overlapping appendages that clasp the stem, called auricles (Ball et al., 1996). Barley by itself also grouped in to six-rowed and two-rowed types. These groups refer to the differences in the arrangement of the seed heads in the spike. When viewing a head of six-rowed barley from above, there are six rows of kernels, three on each side of the rachis (seed head stem). In six-rowed barley, the three spikelets are fertile and can able to develop grains. However, in two-rowed barley, only the middle spikelet develops a kernel and the other two spikelets are sterile (Komatsuda et al., 2007). The two row varieties are preferable than six row types because of its uniform size, plump and possess other desirable characteristics like protein content, high diastatic power and a amylase activity for malt purposes (Singh et al., 1974).

2.2 Ecological Requirement of Barley Production

Barley is grown in diverse rain-fed agro-ecological zones of Ethiopia characterized with a wide range of climate. Ethiopia has suitable agro-ecology to produce malt barley and sustain the domestic demand. Barley is a cool-season crop that is adapted to high altitudes and grows best in temperature of 15-30 ºC. Based on the study of Chilot Yirga et al. (2002) barley can be grown in different ecologies, as it has large number of folk varieties and traditional practices existing in Ethiopia, which enables the crop to be more adaptable in highlands. It can be grown in diversified ecologies from 1800 to 3400m altitude in different seasons and production systems (Muluken Bantayehu, 2013). Barley can be grown in wide range of environments, even in unfavorable condition than other cereal crops (Amha Besufkad et al., 2018). However, barley requires a favorable environment to produce a plump and mealy grain (Berhanu Bekele et al., 2005).

Even though, barley can be grown on many soil types, the ideal soil for barley is a friable loam or sandy loam, well drained soil (Reid et al., 1979). Fertile soil increased both the yield and quality of barley as it provides sufficient amount of nutrients (Gorash et al., 2020). Growing barley on sandy soils causes uneven plant growth and development (Hannaway et al., 2004). It grows well when pH values are between, 6.0-8.5 (Midwest Cover Crops Council, 2012). Barley generally grows better than any other small grains in highly alkaline soils (Reid et al., 1979).

2.3 Importance of Barley

Barley is one of the most multipurpose cereal crops used for food, feed, malt and income generation for many smallholder farmers in the highlands of Ethiopia (Bayeh Mulatu and Berhanu Lakew, 2011). It is an edible grain commonly used in different forms like bread, porridge, roasted grain and for preparing alcoholic and non-alcoholic drinks. Moreover, the straws are used for animal feed, thatching roofs and bedding. 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 (Tallberg and Eggum, 1981). Barley is preferred over other cereals for malting purpose because its glumes and hull are firmly cemented to the kernel, which remain attached to the grain after threshing. This hull protects the coleoptiles from damage during processing, as coleoptiles grows and elongates under the hull. In addition the hull acts as a filter for separation of soluble materials (Singh et al., 2014). These days, as the modern malting practice started due to expansion of breweries and beer consumption levels in Ethiopia, malt is the second largest use of barely and it is considered as one of the cash crop in the country (Biadge Kefale et al., 2016).

2.4 Barley Production in Ethiopia

Ethiopia is known to be the center of diversity of barley (Hordium vulgare) and it has been in cultivation for atleast the past 5,000 years. The first Ethiopians have ever cultivated barley are believed to be the Agew people, in about 3000 BC (Zemede Asfaw, 1996). This long history of cultivation and the large agro-ecological and cultural diversity in the country has resulted in a large number of landraces (farmers• varieties) and rich traditional practices. However, malt barley production in Ethiopia has a very short phenomena and its production is mainly associated with the establishment of the St. George Brewery (Tadesse Kassahun, 2011). The diversity in the Ethiopian barley landraces has got an international recognition for its useful traits such as resistance to diseases and high nutritional quality which is of great importance to the generation of improved varieties through provision of genetic materials for breeding (Berhane Lakew et al, 1996).

Barley is cultivated in all regions of the country. However, it is largely grown in the central and northern parts of Ethiopia, with Oromia, Amhara, Tigray, and Southern Nations, Nationalities, and People•s Region (SNNPR) The two regional states Amhara and Oromia accounted more than 80% of the total barley production in the country (CSA, 2020). Improvements on barley in Ethiopia has been started for more than six decades, it has passed through different phases and has never satisfied the needs of farmers in the different barley production systems. Research was started at Debre Zeit Agricultural Research Centre (DzARC) in the 1950s. But more organized research on the crop began in

1966 with the establishment of the Holetta Agricultural Research Centre (HARC) which was under Institute of Agricultural Research (IAR) now the Ethiopian Institute of Agricultural Research (EIAR), to represent the central highlands of Ethiopia, with barley being a major focus in crop research (Bayeh Mulatu and Berhane Lakew, 2011). From the very beginning, barley research was started by creating nurseries and conducting variety trials targeting increased yields and identifying genotypes with a high level of disease resistance. Further, the research extends its work on determination of appropriate planting dates and rates of nitrogen fertilizer application for the highlands at Holetta on red soil. The first research outcomes were published in 1968 (IAR, 1968). Optimum cultural requirements (sowing date, seed and fertilizer rates) for both food and malting barley under Holetta conditions were determined (IAR, 1972). According to Bull (1987), the response of barley to the application of fertilizer was found to be very promising from a countrywide fertilizer response trial conducted on half-hectare plots at 92 locations.

Based on the base line surveys studied by Chilot Yirga et al. (1998), five traditional barley production systems are recognized within the major barley-growing agro-ecologies. Among these, late barley production system is one of the dominant system in highland area of Ethiopia such as South Gondar and North Wollo. This production system practiced during rainy season (June to October) and it is characterized by two separate planting seasons; the first cultivar is planted in May and the second is between mid-June and early Julay. The second production system is soil burning and is mainly practiced in highlands of North and Northwest Shewa , where water logging is a major constraint during rainy season. To alleviate this problem, farmers use guie (soil burning) and ploughing, 3-5 times of fields that have been left fallow for at least five years. Early-maturing farmer cultivars, such as ‘Demoye’ and ‘Magie’, are used in this system (Chilot Yirga et al., 1998). Early-barley production system is the one which is practiced in mid and highland areas of Gojam and Gondar and some parts of Shewa during the meher season. Early cultivars are grown that require 3.5-4 months to mature, such as ‘Semereta’ in Shewa; Gojam and Belga in North Gonder and Tebele in South Gonder. The cultivars are planted from mid-May to June and harvested in early September to early October. Barley is also grown under belg production system and which is mainly practiced in North and North West Shewa, North

Wollo, Bale and a few areas in Arsi. Belg barley is planted in February to early March and harvested in early July. Residual barley production system is one of the important systems which is practiced in some parts of Gojam, North and South Gonder, and West Shewa. Early-maturing cultivars ‘Belga’ in North Gonder and ‘Semereta’ in Gojam are common. Planting is carried out between September and October, immediately after harvest of the main-season barley crop (Chilot Yirga et al., 1998).

2.5 Production Status, Constraints and Prospects of Malt Barley in Ethiopia

Barley is one of the major cereal crops with strategic importance in Ethiopia and it ranks the fifth following teff, maize, sorghum and wheat (CSA, 2020). During the year 2019/2020 cropping season, the total area under barley cultivation was nearly 1.0 million hectare, while the production was estimated at 2.38 million tons with average yield of 2.50 t ha^{-1}. Ethiopia becomes the first producer of barley in Sub-Saharan Africa and eleventh in the world in barley production. In Africa barley production is mainly dominated by Ethiopia, Algeria and Morocco with an estimated production of 2.38, 1.65 and 1.16 million tons respectively (FAO, 2019). Even though Ethiopia is the first country in total barley production in the continent, but in terms of area coverage it is behind Algeria and Morocco. In addition, its average yields are significantly behind Kenya, Egypt and South Africa with specified values of 3.90, 3.30 and 2.6 t ha^{-1} respectively (FAO, 2019). Moreover, in high-performing countries of the developed world such as Germany, France and the Netherlands average barley yield is over 6 tons per hectare (FAO, 2019).

The production and productivity of malt barley in Ethiopia is mainly challenged due to abiotic factors (low soil fertility, inadequate availability and use of inputs such as fertilizers, high malting quality and high-yielding varieties and other agronomic practices), biotic factors (mainly weeds, insect pests and foliar diseases), poor access to markets and unattractive malt barley price (Bayeh Mulatu and Berhane Lakew, 2011; Berhane Lakew et al., 2017). On the other hand, there are also opportunities that malt barley production and productivity can be increased in Ethiopia since there is suitable production agro ecology, potential malt barley producing areas, booming of beer industries and increasing malt demand (Addisu Bezabih, 2018).

2.6 Importance Quality Traits of Malt Barley

2.6.1. Grain protein content

Protein content is one of the most determinant quality traits of malt barley. Application of optimum rate of nitrogen fertilizer to malt barley is essential to obtain high yields without affecting malting quality (Thompson et al., 2004). Both higher and lower protein content has its own effect on the final quality of malt to be produced. Higher protein content of a grain leads to lower carbohydrate content and decrease the extract yield (Fox et al., 2003). According to Verma et al. (2003) higher protein content in grain reduces the malt extract level. Lower protein content on the other hand limits yeast growth and lowers enzymatic activity during fermentation period (Emebiri et al., 2005; Pettersson, 2007).

Protein content is one of the important parameters in selecting malting barley, which is affected by genotype, cultural practices/crop management and growing environments (Riley et al., 1998; Paynter and Van, 2014). According to the study of Chen et al. (2006) grain protein content is affected by both rate and time of nitrogen fertilizer application. In addition to this, different studies have been conducted related to the effect of nitrogen and variety on quality of malt barley in Ethiopia. Accordingly, a research conducted by Minale Liben et al (2011) at mid- and high altitude in Northwest Ethiopia indicated that, grain protein content increased with increasing nitrogen rates in all varieties at all locations with the range of (8.9-11.8 %) when 46 and 115 Kg N ha^{-1} applied respectively. Similar trends was also observed by (Derebe Terefe et al., 2018; Meharie Kassie and Kindie Tesfaye, 2019; Melaku Tafes, 2019) that grain protein content increase with increasing rate of nitrogen.

Based on the study of Przulj et al. (2010) cereal breeders select barley for large grain, thin husk and low protein content to improve malt quality, and select barley for high protein content on account of animal feed. The standard of malt barley for protein concentration varies from country to country and even from brewery to brewery. Based on the Ethiopian standard authority, the protein content of malt barley grain should be within a range of 9 to 12% (EQSA, 2006). Generally, grain protein concentration (GPC) is a key quality criterion in malting barley production and failure to meet the required GPC specifications leads to rejection of the crop for malting.

2.6.2 Hectoliter weight

Hectoliter weight is a measure of grain sample density which can be an indicator of pre-harvest sprouting adversely affecting the grain. Different countries have their own quality standards. Based on the Ethiopian quality standard, the acceptable grain size (thousand kernel weight) and test weight (hectoliter weight) for barley are in the range 25 to 35 gram and 48 to 62, respectively (EQSA, 2006). Different studies indicated that hectoliter weight was increased with increased nitrogen rates (Minale Liben et al., 2011; Amare Aleminew and Adane legas, 2015; Derebe Terefe et al., 2018). Furthermore, hectoliter weight of barley can be differed among studied varieties, growing seasons and across locations (Minale Liben et al., 2011; Meharie Kassie and Kindie Tesfaye, 2019). Growing barley relatively in cooler air temperature increases the final quality of malt to be produced. Whereas high temperatures especially in grain filling period reduce the grain size and it affects the malting quality.

2.6.3 Germination

Germination is the process of by which a dormant seed starts to sprout and become a seedling under favorable condition. Quality of malt barley grain must have a minimum post-harvest dormancy and be able to germinate rapidly and uniformly (Woonton et al. 2005). Germination energy is the percentage by which a number of seeds in a given sample which germinate with a definite period of time. Studies signifies that, optimal germination performance such as the high vigour and germination capacity or viability of barley at the time of the malting process is without any doubt the most important quality criterion for malting barley (Lu et al., 2000; Munck and Moller, 2004) Based on the study of Derebe Terefe et al. (2018) and Melaku Tafes (2019) germination energy was affected by barley genotypes. According to European Brewery Convention (EBC, 1998) germination energy of barely should be greater than 95%.

2.7 Availability and Role of Nitrogen in Crop Production

2.7.1 Availability of nitrogen

Nitrogen comes from the two inorganic ions, NO_3^- and (NH_4^+) (Torres et al., 2014). Nitrogen is available in the soil in both organic and inorganic forms. The major inorganic forms of nitrogen are N2 gas, nitrate (NO_3^-), nitrite (NO_2^-), and ammonium (NH_4^+) whereas the organic forms include amino acids, proteins, nucleotides and nucleic acids. Nitrogen in the soil is mostly organically bounded. Due to this such organic compounds are available through the process of mineralization and the intermediate stage of formation of amino acids and other organic forms occur and they may be used by plants (Clarus et al., 2009). Most plants can absorb and utilize nitrogen when it is available in the forms of NO_3^- and NH_4^+ (Oh et al, 2008). Galloway and Cowling (2002) reported that mineral nitrogen can be gained from N_2-fixation, nitrogen fertilization and development of livestock, as well as wet and dry deposition from the atmosphere.

2.7.2 Role of nitrogen in crop production

Nitrogen is considered to be essential nutrients required by plants in the largest quantity. It is the main constituent of essential cellular components such as amino acids, proteins and nucleic acids. Nitrogen increases the leaf surface area, improving the succulence of many crops and plays a great role in different physiological processes (Torres et al., 2014). It promotes photosynthesis as it increases the amount of chlorophyll (Sedano et al., 2011). Li et al. (2014) reported that crop production mainly depends on the extent of the soil capacity to supply nitrogen. Similarly Sawan (2006) also noted that yield of an agricultural crop strongly depends on the supply of mineral nutrients, particularly nitrogen.

Both excess and deficiency of nitrogen in the soil has its own limitations. Excess nitrogen applications reduce nitrogen uptake efficiency, apparent recovery fraction of applied fertilizer nitrogen, physiological efficiency and decrease the grain yield (Wang et al., 2011). On the other hand, nitrogen deficiency significantly reduced leaf area, leaf Chlorophyll content and resulting in lower biomass production (Zhao et al., 2005). Optimum application of nitrogen increase economic yield and reduce production cost (King et al., 2003). However, optimization of nitrogen use efficiency and crop production is a complex problem and will require a compound set of solutions to get suitable and meaningful results (Waqar et al., 2014). This is mainly due to the problem of nitrogen loss by leaching, denitrification and volatilization (Ercoli, 2012). Nitrogen in the form of nitrate is easily lost through leaching and denitrification, while ammonium nitrogen is through volatilization, thus both are not stable in soil. So, improving nutrient use efficiencies in agriculture plays a great role for the development of sustainable nutrient management strategies, more efficient use of mineral fertilizers, increased recovery and recycling of waste nutrients, and better exploitation of the substantial inorganic and organic reserves of nutrients in the soil (Waqar et al., 2014).

2.8 Effect of Nitrogen on Yield and Quality of Malt Barley

Nitrogen fertilizer application is the most important agronomic practice which determines both grain yield and quality of malting barley (McKenzie et al., 2004; Sainju et al., 2013). Many studies have been investigated so far with related to rates of nitrogen fertilizer effect on yield and grain quality of malt barley varieties. The field experiments conducted by Minale Liben et al. (2011) at mid- and high altitude of Northwest Ethiopia indicated that grain yield and its protein content increased almost linearly as the N rate increased. Similarly (Castro et al., 2008; Sainju et al., 2013) reported that barley grain protein increases with increasing N application rate because barley plants continue to use available N even after yield requirements are met.

An experiment which was carried out at Malga district, Southern Ethiopia indicated that all agronomic parameters except harvest index increased in response to N rates up to 98.5

kg ha^{-1}). However, 75kg N ha^{-1} results optimum grain yield with acceptable protein content was recommended (Biruk Gezahegn and demelash Kefale, 2016). Both field and laboratory experiments carried out by Berhane Getie (2017) indicated that using 150 kg N ha^{-1} of N-fertilizer rate gave satisfactory crop yield and protein content, reduce the costs of production, and increase profitability. Singh and Singh (2005) at Varanasi observed that significant increase in grain and straw yield with increased doses of N from 20 to 80 kg ha^{-1}. Nitrogen fertilizer application increases yield of malting barley, it may also increase grain protein above desirable levels if it is applied excessively (Singh et al., 2014). Zhang et al. (2001) reported that malt gain having high protein content is associated with low carbohydrate and low malt extract. Thus it slows malting process and affects malt quality. On the other hand low protein content has also its own limitations that it retards yeas growth during fermentation (Emebiri et al., 2005). A research conducted by Melaku Tafes (2019), containing different N rates with malt barley varieties indicated that most of yield and yield related traits increase with increasing nitrogen. However, high nitrogen rate leads to high grain protein content while low nitrogen rates leads to optimum grain yield with acceptable quality. Further, field experiment also carried out by Meharie Kassie and Kindie Tesfaye (2019) at Arsi (Bekoj experimental site) indicated that application of N beyond 48kg N ha^{-1} did not increase the net benefit, but instead increase cost of production.

Most of experiments conducted in different areas indicated that, barley grain yield and protein content increased almost with an increase in N levels. Hence, malt barley grain yield, grain protein, and kernel plumpness characteristics are strongly related to yield potential and available N; Environmental factors such as drought stress that occur late in the season can adversely affect grain yield, and, in particular, quality characteristics. Thus, splitting nitrogen fertilizer application according to the need of the crop is the best strategy to achieve high grain yields with acceptable malting quality (Grant Jackson, 2000). Beside to this Demisie Egigu et al. (2015) reported that determination of optimum rates of nitrogen and selection of appropriate varieties are important agronomic decisions for malt barley production.

2.9 Effect of Time of Nitrogen Application on Yield and Quality of Malt Barley

Effect of nitrogen on yield and quality of malt barely has been investigated by different researchers however; concerning time of N application little works has been done. A field experiment which was conducted in China showed that full application of nitrogen at tillering and split application of N half at tillering and the remaining half at booting stage produced significantly higher grain yield than its application at booting stage alone (Sardana and Zhang, 2005). On the other hand application of nitrogen after tillering offers farmers• advantages, such as better estimates of the overall rate required based on likely yield potential and it avoids excessive tiller numbers of varieties that respond to early nitrogen by tillering profusely (Hills and Paynter, 2009).

Studies indicated that split nitrogen application had its own positive effect on grain yield commonly occurred in situations where wet conditions increased the risk of nitrogen loss early in the growing season (Roth and Marshall, 1987; Gravelle et al., 1988). A research conducted by Arregui and Quemada (2008) indicated that split applications of nitrogen are advantageous to take available soil moisture levels and crop yield potential into consideration at a time in the growing season when estimates may be more reliable than at sowing. On the other hand Easson (1984) reported that split application of nitrogen had non significant effect on grain yield and protein content as compared to full application at sowing, especially when topdressing was applied before the crop entered the stem elongation phase However, if high rainfall occurs at the time of sowing, and before significant crop uptake, applying all nitrogen to the seed can increase the risk of nitrogen loss by leaching, in these situations split applications can be advantageous (Easson, 1984). Overall many of the studies conducted in different countries indicated that both increasing rate of nitrogen and late applications affect the protein content of malt barley (Riley et al., 1998; Jurjescu and Pisan, 2010; Singh and Singh, 2005; Derebe Terefe et al., 2018; Meharie Kassie and Kindie Tesfaye, 2019).

2.10 Effect of varieties on Yield and Quality of Malt Barley

Barley varieties had significant effect on yield and quality related parameters. The yield and quality specifications of a given variety are also determined by its genetic makeup and the physical conditions during growth (Fox et al., 2006). Anonymous (2012) also reported that a marked difference among the malt barely varieties on grain size and kernel weight due to genotypic variation. The varieties also showed a consistent difference in grain protein content due to the genetic makeup and growing environmental condition (Molina-Cano et al., 2001). Genotype by environment interactions and stability study conducted using seven malt barley varieties in North western Ethiopia indicated that varieties showed significant variation both in grain yield and protein content. Accordingly, the highest grain yield (4.05 t ha^{-1}) was obtained from Miscal-21 at Debre Tabore experimental location while the lowest (1.00 t ha^{-1}) was recorded from genotype Arna at Lay Gaint. The protein content of genotypes was also ranged between 9.5% from HB-1533 and 10.8% for Miscal-21 (Muluken Bantayehu et al., 2010). Similarly, a field experiment conducted on performance evaluation of malt barley varieties in Eastern Amhara indicated that varieties showed significant variation in both grain yield and quality traits. The protein content recorded on the tested varieties ranged 9.85 to 11% and the maximum grain yield (3220, 3340 and 3351) (kg ha^{-1}) was obtained from Bahati, EH 1847 and IBON 174/03 variety, respectively (Abebe Assefa et al., 2021).

Malt barley varieties can be classified as two and six row, however the two row types are preferred over six rows due to its plumpness, uniform size and results higher grain yield (Singh et al., 1974). According to the study of Wondimu Fekadu et al. (2013) the current Ethiopian malt barley breeding requires great improvement and it has to be supported by modern molecular techniques, small scale micro malting and NIRS technology to identify and develop high yielding as well as high quality genotypes.

2.11 Nitrogen Use Efficiency of Malt Barley and Management

Nitrogen use efficiency (NUE) in barley is often defined as grain produced per unit of nitrogen fertilizer applied. The crop nitrogen use efficiency depends on different factors such as application time, rate of nitrogen applied, cultivar and climatic conditions (Moll et al., 1982). Ramos et al. (1995) observed that application of nitrogen in to two equally splits at sowing and tillering and greater proportion applied at tillering led to higher grain yield. Based on the study of Meharie Kassie and Kindie Tesfaye (2019) N-use efficiency, N-recovery efficiency and N-utilization efficiency of the test varieties decreased with increasing N fertilizer application rates in all the experimental years. Roy and Singh (2006) indicated that nitrogen fertilizer strategies for malting barley should ensure relatively small amount of available one-third nitrogen at sowing for crop establishment, one third nitrogen 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.

Another study which was carried out by Olsen and Kurtz (1982), indicated that maximum efficiency was observed by the latest possible application of nitrogen corresponding to the growth stage which increases rapid nitrogen uptake thus avoiding unnecessary vegetative growth, which able to reduce grain yield. Furthermore, the opportunities for nitrogen losses by leaching, denitrification, volatilization and runoff are reduced, due to the presence of active and well developed roots which can absorb and utilize the nitrogen fertilizer when it is applied. Efficient use of nitrogen fertilizers in barley production systems can results higher returns for producers and reduce the negative impact of excessive nitrogen application on the environment (Anbessa et al., 2009). It is, therefore, important to optimize the efficiency with which nitrogen fertilizer are used. Maximizing the nitrogen use efficiency of crop production can be achieved through optimizing the supply of nitrogen to meet the requirements of a crop during growth and development and growing nitrogen efficient crop genotypes (Bingham et al., 2012). Generally different studies indicated that nitrogen use efficiency of barley depends on several factors like rate of nitrogen, time of application, variety, climatic condition and others. And hence, genotype selection on the basis of N-recovery and N-utilization efficiency, apply optimum nitrogen rate in split form will probably the most effective method to improve the N-use efficiency.

Chapter 3. MATERIALS AND METHODS

3.1 Description of the Study Area

The experiment was conducted during the main cropping season of 2020/2021 at Woyibla Selamko kebele at Fogera National Rice Research and Training Center-sub station of Debre Tabour experimental site in Farta district (Figure 3.1). The district is located at 645 km far from Addis Ababa which is the capital city of Ethiopia. The altitude of the district ranges from 1920 to 4235 m.a.s.l. while the experimental site is located at an altitude of 2581 m.a.s.l. and latitude of 11º 51' 45.503" N and longitude 38º 01' 21.347" E. The major crops grown in the study area are barley, teff, potato, wheat, maize and faba bean.

Figure 3.1: Location map of the study area

Based on the weather data recorded by West Amhara Meteorological Agency station, the study area is characterized by unimodal rainfall distribution and the peak rainy season appears on July and August. The total average annual rain fall for ten years data (2010-2019) of the study area was 1424.2 mm. Similarly, the total average annual rain fall collected during the experimental year was 1739 mm. The annual mean minimum and maximum temperature of the area recorded within ten years (2010-2019) were 9.4 and 22.6 °C respectively. While annual mean minimum and maximum temperature of the main cropping season were 9.6 and 23.1 ℃ (Figure 3.2). Over all, the total rain fall received during the experimental period was higher than ten years average and it is suitable for malt barley production.

Before conducting the experiment, soil samples were collected at a depth of (0-20 cm) randomly from 15 spots five for each replication in diagonal pattern using auger and composited in order to produce one representative sample. Then soil physical and chemical properties were analyzed in Soil Chemistry and Water Quality Laboratory Section of Amhara Design and Supervision Works Enterprise. Accordingly, soil texture, pH, CEC, organic matter, organic carbon, total nitrogen and available phosphorous were analyzed following their respective standard methods and procedures.

The soil texture was determined by the bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured at 1:2.5 (soil to water ratio) as described by (Landon, 1991). While organic carbon and organic matter content were determined using wet digestion method (Walkely and Black, 1934). Total nitrogen was determined based on the principles of Landon (1991), while available phosphorus done using Olsen method (Olsen, 1954). Electrical conductivity (EC) (1:1 H_2O) was measured by following the methods described by Van Reeuwijk (1992).

The results from soil sample analysis showed that **the** texture of the soil was found to be clay loam. The pH of the soil was 5.82 (Table 3.1), which was moderately acidic (Kanyanjua et al., 2002). The soil pH value indicates as it is medium for malt barley production. The organic carbon (OC) and organic matter (OM) contents were 2.85 % and

4.902%, respectively, which was medium based on the rating of (Walkely and Black, 1934). The total nitrogen was 0.28%, which is medium (Landon, 1991)(Table 3.1). Available phosphorous was 9.83 ppm, which is low (Table 3.1). The low value of available phosphorous might be due to fixation with soil cations such as Al^{3+} and Fe^{2+}. The CEC of the soil was 24.2 cmol(+)/kg soil, which was medium (Landon, 1991). According to Landon (1991), CEC of the soils greater than 40 cmol(+)/kg is rated as very high and 25 - 40 cmol (+) /kg as high and CEC of soil from 15-25, 5 - 15 and < 5 cmol (+)/kg of soil are classified as medium, low, and very low, respectively.

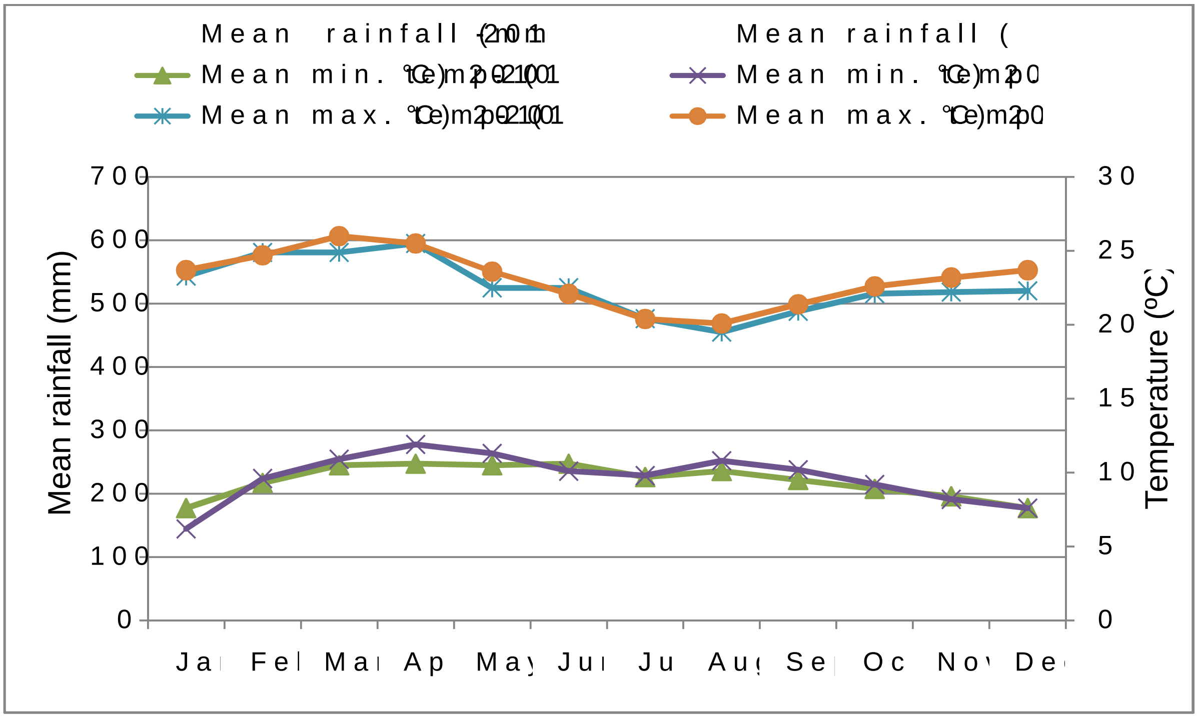

Figure 3.2: Mean annual rainfall (2010-2019), annual rainfall (2020) and monthly average minimum and maximum temperatures of the study area from and during the experimental period 2020

Table 3.1. Some of the selected soil physicochemical properties of the experimental site

Parameters	Mean values	Rating	References
pH (H_2O)	5.82	Moderately acidic	Walkely and Black (1934)
Organic C (%)	2.85	Medium	Walkely and Black (1934)
Organic matter (%)	4.902	Medium	Walkely and Black (1934)
C: N ratio	10.18	Medium	
Total N (%)	0.28	Medium	Landon (1991)
Ava. P (ppm)	9.83	Low	Olsen(1954)
EC (dS/cm)	0.175	Normal	Van Reeuwijk (1992)
CEC Cmol (+) / kg	24.2	Medium	Landon (1991)
Texture %			
Sand	28		
Silt	36		
Clay	36		
Textural classes	Clay loam		Bouyoucos (1962)

3.2 Experimental Planting Materials

Seeds of two malt barley varieties namely Holker and IBON 174/03 which are adapted to the agro-ecology of the study area were used for this study (Table 3.2). Currently, these two varieties are widely grown in Farta district by smallholder farmers.

Table 3.2. Description of malt barley varieties

Variety	Year of release	Breeder	Grain yield (t ha^{-1})		Altitudinal adaptation (masl)
			On-station	On farm	
Holker	1979	HARC	24-31	20-25	2300-3500
IBON 174/03	2012	HARC	30-57	-	2300-2800

Source: Crop Variety Registration (MoA, 1979-2012)

3.3 Experimental Treatments, Design and Procedures

Treatments consisted of three nitrogen rates (34.5, 69 (blanket recommendation) and 103.5 kg N ha^{-1}), three times of N application: T1=2/3 at time of sowing and 1/3 at mid-tillering, T2=1/3 at time of sowing and 2/3 at mid-tillering, T3=1/3 at sowing, 1/3 at mid-tillering and 1/3 at time of anthesis, two malt barley varieties (Holker and IBON 174/03). The experiment was laid in a factorial arrangement with three replications. The gross plot size comprises 3 m length and 2.4 m width while the net plot size was 2.5 m x 1.6 m (8 central rows of 2.5 m length) leaving the two outer most rows on both sides of each plot and 0.25 m row length at both ends of each plot excluded as border effects. Spacing between blocks, plots and rows was 1.5 m and 0.5 m and 0.2 m, respectively.

Before sowing, the field was cleaned and prepared properly to receive treatments. First ploughing was done by tractor, the 2nd and 3rd ploughing by using oxen. After preparing the experimental field for sowing, field lay out was done based on the design of the experiment and treatments were assigned to each experimental plot randomly. Seeds of malt barely varieties were sown in rows at the recommended rate of 125 kg ha^{-1} in rows using hand drilling on June 24, 2020. Phosphorus as TSP (46% P_2O_5) was applied in the rows at the time of sowing and nitrogen was applied based on the rate of treatments.

3.4 Data Collection

3.4.1 Phenological parameters

Days to 50% heading: This refers to the number of days from the date of sowing to the stage when 50% of ears or panicles fully emerged. The data was recorded by visual observation within a plot.

Days to 90% Physiological Maturity: The number of days from sowing to the time when the plants were reached 90% maturity based on visual observation. It was taken when leaves tend to senescence and the grains are difficult to break by thumb nail in each net plot.

3.4.2 Growth parameters

Plant Height (cm): the plant height was measured from ground level to the tip of the main stem excluding the awns on ten earlier tagged plants at physiological maturity. The average height was computed and expressed in centimeters.

Spike length (cm): the lengths of spikes from ten earlier tagged plants were measured and the average were worked out and expressed in centimeters.

3.4.3 Yield and yield related parameters

Total number of tillers: The total numbers of tillers in 1 meter square were counted from the net plot area at physiological maturity

Number of effective tillers: the number of effective tillers accommodated in 1 meter square quadrant in each experimental unit was recorded as number of effective tillers per meter square.

Number of kernels per spike: the seeds from each spike were separated manually and counted taking ten plants spike. The average of seeds per spike were calculated and expressed in numbers.

Aboveground dry biomass yield (t ha^{-1}): the weight in kilograms of sun dried above ground parts of the plants obtained from the central 8 rows of 2.5 m length in each plot was recorded.

Grain yield (t ha^{-1}): the net plot (8 rows) was marked by left over 0.25 m from top and bottom sides so as to avoid boarder effects. The crop in the net plot was harvested separately and total biomass yield from each net plot was recorded. After threshing, grains were separated, cleaned and weighed. The grain yield of each plot was adjusted at 12.5% moisture content by using moisture correction factor.

$$Mcf = \frac{\quad}{\quad}$$

Where: Mcf- Moisture correction factor

Y-Actual moisture content which was measured by moisture tester

X- The standard moisture content of cereal crops which is 12.5%

Based on the above equation adjusted grain yield was calculated in the following manner

Agy = Mcf x Grain yield obtained from each net plot

$$\text{Grain yield (Kg/plot)} = \text{Grain yield obtained from each net plot (Kg/plot)} \times \frac{100 - Y}{100 - 12.5}$$

Finally the yield was converted into hectare, where Agy = Adjusted grain yield

Harvest index (%): From the yield of grains and biomass, the harvest index was calculated by using formula of Donald (1962) as:

$$HI = \text{Grain yield (kg ha}^{-1}\text{) / Total biomass (kg ha}^{-1}\text{) x100}$$

3.4.4 Data for quality traits

Thousand kernels weight (g): the thousand seeds were counted from each plot and weighed using digital sensitive balance and the data was recorded in grams. The thousand seed weight for each plot was adjusted at 12.5 % moisture content.

Hectoliter weight: - Representative samples (250 g) of malt barley grain were prepared from each net plot and submitted to Adet Agricultural Research Center. Then the flour density produced in a hectoliter of the seed was determined.

Protein content: Representative samples of 250 g were prepared from each net plot and submitted to wards Amhara Regional and Agricultural Research Institute of food science and nutrition research laboratory. Grain protein content was determined using Infratec

1241 grain analyzer flour model using near-infrared transmittance technology. As it releases light it absorbs protein molecules and can predict the protein content of the grain and it displays the value in percent.

Germinating energy (GE %): It was determined from 100 seeds germinated in a petridish after 72 hours. Then the germinated kernels were counted and the result expressed as percentage of the total

$$\text{Germination energy} = \frac{\text{Number of germinated kernels}}{\text{Total number of samples used for germination}} \text{x100}$$

3.5 Data Analysis

3.5.1 Biological data analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS version 9.0 Statistical Software (SAS, 2002). Whenever the ANOVA results show significant differences among treatments, means were compared using least significance difference (LSD) test at 0.05 probability level of significance. Correlation analysis was done to study the association between yield, yield components and quality traits of malt barley.

3.5.2 Economic analysis

Economic analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988). Costs of fertilizer (urea) and labor which show variation between treatments were considered for analysis. The average grain and straw (yield) of barley was adjusted to 10% downwards to narrow the yield gabs between experimental plots and farmers fields. The average selling price of malt barley grain at Farta district from January up to March 2020 was (Eth-Birr 22.50 kg^{-1}) and the price of straw was estimated to be (Eth-Birr 0.5 kg^{-1}) was used for partial budget analysis. The total variable costs of urea and labor cost were calculated based on the current price of the locality during the planting time. And hence, the price of urea was (Birr 14.44 kg^{-1}) and the average labor cost for urea application was estimated 100 Ethiopian Birr man per day. The gross benefit was calculated by multiplying the grain and straw yield with its corresponding price that farmers receive for sale of the crop. The net benefits of each treatment were employed by subtracting the sum of all variable costs from the gross benefits of each treatment. All costs and benefits were calculated on hectare basis in Birr. Then dominance analysis was carried after arranging the treatments in its increasing order of TVC. A treatment considered as dominated if it has higher TVC but lower NB than a previous treatment was excluded from marginal rate of return analysis. Marginal rate of return (MRR %) was estimated the change in the net benefit to the change in total variable costs as it is indicated below.

$$MRR(\%) = \underline{\hspace{6cm}} \quad 100$$

According to the CIMYYT (1988) partial budget analysis methodology, treatments exhibiting the minimum acceptable level of MRR (>100%) was considered for the comparison of their NB, and the one exhibiting the highest NB was recommended.

Chapter 4. RESULTS AND DISCUSSION

4.1 Effect of variety, Rate and Time of Nitrogen Application on Phenology of Malt Barley

4.1.1 Days to 50% heading

The results of analysis of variance showed that days to 50% heading was very highly significantly ($P<0.001$) affected by the main effect of variety, nitrogen rate and its time of application. Moreover, the results of analysis of variance also indicated that days to 50% heading was highly significantly ($P<0.01$) affected by the combined effect of nitrogen rate with its time of application and variety with nitrogen rate. However, the interaction of variety and time of nitrogen application and the three way interaction effects were not statistically significant ($P>0.05$) on days to 50% heading (Appendix Table 1).

Regarding the combined effect of nitrogen rate and its time of application, the longest (74.17) days to 50% heading was recorded when 103.5 kg N ha^{-1} was applied in to two splits 1/3 at sowing and 2/3 at mid-tillering. This result was statistically on par from the application of 103.5 kg N ha^{-1} in to three splits applications of 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis. The shortest (64.50) days to reach 50% heading was observed when 34.5 kg N ha^{-1} applied in to two splits 2/3 at sowing and 1/3 at mid-tillering (Table 4.1). The prolonged days to 50% heading observed at higher rate of nitrogen with respective split application might be due to the vital role of nitrogen which promotes vegetative growth and development when higher rate is applied at different growth stages. In line with the present result Hiroshi et al. (2008) reported that application of higher rate of nitrogen at active growth stage delays days to 50% heading of bread wheat. Different studies conducted on barley and wheat indicated that, days to 50% heading tends to delay at higher rate of nitrogen fertilizer applications (Derebe Terefe et al., 2018; Melaku Tafes, 2019; Yohannes Erkeno and Nigussie Dechassa, 2019). In contrary to this study Demise Ejigu et al. (2015) observed that nitrogen rate had no significant effect on days to 50% heading.

Concerning interaction effects of N rate and variety, the longest (76.67) days to attain 50% heading was exhibited by Holker variety with the application of 103.5 kg N ha^{-1}. Whereas the shortest (61.44) number of days taken to 50% heading was recorded from IBON 174/03 variety sowing at 34.5 kg N ha^{-1} applications (Table 42). The longest days to 50% heading recorded from the interaction of 103.5 kg N ha^{-1} with Holker variety might be due to genetic differences between malt barley varieties and the role of high level of nitrogen which increases vegetative growth and thus delays days to heading. In line with the current result Demise Ejigu et al. (2015) and Melaku Tafese (2019) observed that barley genotypes showed significant variations on days to 50% heading.

Table 41. Interaction effect of N rates and its time of application on days to 50% heading of malt barley in 2020/2021 main cropping season in Farta district

N rates kg ha^{-1}	Days to 50% heading		
	Time of N application		
	T1	T2	T3
34.5	64.50^{d}	65.83^{cd}	65.17^{cd}
69	66.67^{cd}	70.50^{abc}	69.33^{abcd}
103.5	68.17b^{cd}	74.17^{a}	72.50^{ab}
Mean		68.56	
LSD (0.05)		5.72**	
SE±		4.01	
CV (%)		1.54	

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid- tillering; T3: 1/3 at sowing, 1/3 at mid- tillering 1/3 at anthesis

Table 42. Interaction effects of varieties and N rates on days to 50% heading of malt barley in 2020/2021 main cropping season in Farta district

N-rate (kg ha^{-1})	Days to 50% heading	
	Varieties	
	Holker	IBON 174/03
34.5	69.00^{c}	61.44^{e}
69	72.78^{b}	64.89^{d}
103.5	76.67^{a}	66.57^{d}
Mean	68.28	
LSD(0.05)	2.02**	
SE±	1.73	
CV (%)	1.54	

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent

4.1.2 Days to 90% physiological maturity

The results from analysis of variance showed that days to 90% physiological maturity was very highly significantly ($P<0.001$) affected by the main effect of variety, N rate and its time of application. Moreover, the interaction effect of N rate and variety, nitrogen rate with its time of application and the three way interactions were significantly ($P<0.05$) influencing days to maturity of malt barley. However, the interaction of variety with time of N application had no significant effect ($P>0.05$) on days to maturity (Appendix Table 1).

Concerning the interaction effect of variety, nitrogen rate and its time application, the prolonged (128.67) number of days to attain physiological maturity was observed when Holker variety received high level of N rate (103.5 Kg ha^{-1}) with three split application on 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis, while the earliest (109.33) days to physiological maturity was recorded from a combination of IBON 174/03 variety, lowest N rate (34.5 Kg ha^{-1}) with two split application of 2/3 at sowing and the 1/3 at mid-tillering (Table 4.3). The prolonged days to maturity might happened due to the genetic difference between varieties, inherent role of nitrogen which increases vegetative growth of crops when it is applied at different growth stages. In line with the current result Yohannes Erkeno and Nigussie Dechassa (2019) observed prolonged days to 90% physiological maturity when higher rate of nitrogen applied in to three splits on wheat crop. Similarly, Negasi Hailesilassie *et al*. (2020 reported that day to maturity tends to delay when higher rate of nitrogen fertilizer was applied on wheat crop compared to the control.

Table 4.3. Interaction effect of varieties, N rates and its time of application on days to 90% physiological maturity of malt barley in 2020/2021 main cropping season in Farta district

Varieties	Time of application	Days to 90% Physiological maturity		
		N- rates (kg ha^{-1})		
		34.5	69	103.5
Holker	T1	116.67^{efg}	118.33^{de}	119.00^{d}
	T2	117.33^{def}	121.00^{c}	124.33^{b}
	T3	117.33^{def}	122.67^{bc}	128.67^{a}
IBON 174/03	T1	109.33^{j}	111.67^{hi}	112.00^{hi}
	T2	110.33^{ij}	113.33^{h}	116.00^{fg}
	T3	111.33^{j}	115.33^{g}	117.33^{def}
Mean		116.78		
LSD(0.05)		1.74*		
SE±		0.85		
CV (%)		0.89		

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing, 1/3 at mid tillering, 1/3 at anthesis

4.2 Growth Parameters

4.2.1 Plant height

Plant height was highly significantly (P<0.01) influenced by the main effects of variety and significantly affected (P<0.05) by the main effects of N rate and its time of application. However, all interactions did not show significant difference on plant height (Appendix Table 2).

The tallest plant height (92.54 cm) was taken from Holker variety whereas the shortest (75.06 cm) was recorded from IBON 174/03 variety (Table 4.4). The variation in plant height probably due to the genetic difference between varieties. The result was in harmony with the study of Minale Liben et al. (2011), Amare Alemnew and Adane Legas (2015) and Demise Ejigu et al. (2015) who observed that plant height was significantly affected by the studied barley varieties.

Regarding the nitrogen rates, the highest value of plant height (87.06 cm) was recorded from treatments that received maximum rate of 103.5 kg N ha^{-1} followed by 69 kg N ha^{-1} while the shortest plant height (79.03 cm) was observed from the lowest rate of (34.5 N kg ha^{-1}) fertilizer applied (Table 4). The variation in plant height might be due to the vital role of N fertilizer in vegetative growth of crops. In line with the present study, Melaku Tafese (2019) reported that as the rate of N fertilizer increase from 11.5 to 57.7 (kg ha^{-1}) a significant increase in plant height was observed in barley crop. Similar findings were also reported by Demisie Ejigu et al. (2015) and Tilahun Chibsa et al. (2016) who stated that plant height showed increasing tendency from nil to the highest rate of N application on barley and wheat crops

Time of N application contributes a significant role on plant height of malt barley. The highest plant height (86.53 cm) was recorded from three split applications of N 1/3 at sowing, 1/3 at mid-tillerng and the remaining 1/3 at anthesis followed by a treatment received two split applications of N 1/3 at sowing and 2/3 at mid-tillering (Table 4). Whereas the shortest plant height (79.64 cm) was recorded when N was applied in two slits 2/3 at sowing and 1/3 at mid-tillerng (Table 4). The difference observed between applications time of N might be due to sufficient availability of N during its active growth stage of the crop. In line with the current study Singh et al. (2006) reported that highest plant height of barley was observed when N was applied in three equal splits. In contrast to the present study Yohannes Erkeno and Nigussie Dechassa (2019) reported that the tallest plant height (115.20cm) was recorded when highest rate N was applied in two equal splits 1/2 at mid-tillering and 1/2 at anthesis while the shortest plant height (99.40 cm) was observed when lowest N was applied in to three equal splits.

4.2.2 Spike length

The result of analysis of variance showed that a significantly difference (P<0.05) in spike length was observed due to the main effects of nitrogen rate. However, other main effects and all interactions did not significantly (P>0.05) affect the spike length of barley (Appendix Table 2).

As indicated in Table 4.5 the longest value of spike length (7.41 cm) was recorded at the highest rate of nitrogen of 103.5 kg ha^{-1} applications and it was statistically the same with the rate of 69 kg N ha^{-1}. On the other hand, the shortest spike length (7.12 cm) was recorded from the lowest rate of nitrogen (34.5 kg ha^{-1}) applications. The longest spike length at the higher rate of nitrogen might be due to the presence sufficient amount of nitrogen at active growth stage and thereby extend the spike length of barley crop. This result was in line with the study of Mohammadi (2014) and Ketema Niguse and Mulatu Kassaye (2018) who realize that spike length of barley was significantly increased with increasing N level. In contrast to the present study Demise Eggu et al. (2015) observed non significant effect of N rates on spike length.

Table 44. Main effects of varieties, N rates and its time of application on plant height of malt barley in 2020/2021 main cropping season in Farta district

Treatments	Plant Height (cm)
N rates (Kg ha^{-1})	
34.5	79.03^b
69	85.32^a
103.5	87.06^a
LSD (0.05)	2.93*
SE±	3.54
Time of N application	
T1	79.64^b
T2	84.91^a
T3	86.53^a
LSD (0.05)	2.94*
SE±	3.54
Varieties	
Holker	92.54a
IBON-173/04	75.06^b
LSD (0.05)	2.40**
SE±	3.54
Mean	83.80
CV (%)	5.17

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing, 1/3 at mid tillering 1/3 at anthesis

Table 45. Main effects of N rates on spike length of malt barley in 2020/2021 main cropping season in Farta district

Treatments	Spike length (cm)
N rates (kg ha^{-1})	
34.5	7.12^{b}
69	7.31^{ab}
103.5	7.41^{a}
Mean	7.28
LSD (0.05)	0.23*
SE±	0.27
CV (%)	4.61

Means with the same column followed by the same letter (s) are not significantly differ at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent

4.3 Yield and Yield Related Parameters

4.3.1 Total number of tillers

The results of analysis of variance showed that main effect of variety, N rate and its time of application exhibited a very highly significant effect ($P<0.001$) on the total number of tillers per m^{2}. Moreover, total number of tillers was highly significantly ($P<0.01$) influenced by the interactions of nitrogen rate and its time of application and variety with rate of N application. However, the interaction of variety with its time of application, and the three way interaction did not significantly ($P>0.05$) affect the total number of tillers (Appendix Table 2).

Concerning the interaction effect of N rate and its time of application, more number of tillers (547.33 m^{-2}) was recorded when 103.5 kg N ha^{-1} applied with two splits 1/3 at sowing and the remaining 2/3 of N added at mid-tillering stage. This result was statistically on par with the application of (69 kg N ha^{-1}) with similar splits, whereas the lowest number of total tillers (380.00 m^{-2}) was obtained when 34.5 kg N ha^{-1} was applied in two splits of 2/3 at sowing and 1/3 at mid-tillering (Table 46). The higher number of tillers m^{-2} was observed on such treatment combination might be due to the vital role of N which encourages tillers population when higher rate was applied during active growth stage of crops. In harmony with the current study Arvani and Behzad (2020) observed significant difference for the split application of nitrogen in terms of tillers m^{-2} when N was applied 1/3 at sowing and 2/3 at time of tillering on wheat crop. Similarly, Mehta et al. (2005) reported that number of tillers m^{-2} increase in response to increasing rate of nitrogen on rice.

Analysis of variance also indicated that total number of tillers was influenced by the combined effect of variety with different rate of N fertilizer application. Applying (103.5 kg N ha^{-1}) on IBON 174/03 variety gave the maximum (533.33 m^{-2}) number of total tillers followed by the application of (69 Kg N ha^{-1}) with similar variety. Whereas, the minimum (385.56 m^{-2}) number of total tillers was obtained when (34.5 Kg N ha^{-1}) was applied on Holker variety (Table 4.7). This difference might be happened due to the positive contribution of increasing nitrogen accelerates vegetative growth, cell division and the genetic difference between varieties. In line with the present result Ketema Niguse and Mulatu Kassaye (2018) obtained the maximum number of total tillers when highest rate of N was applied on EH 1493 variety. The result obtained by Mohammadi (2014) also indicated that the total number of tillers increase from the application of highest level of nitrogen (150 kg ha^{-1}) but statistically on par with application of (100 kg N ha^{-1})

4.3.2 Effective number of tillers

The results from analysis of variance indicated that main effect of variety, N rate and its time of application exhibited a very highly significant effect (P<0.001) on the effective number of tillers per m^{2}. Moreover, effective number of tillers was highly significantly (P<0.01) influenced by the combined effect of N rate with its time of application and variety with N rates. However, the interaction effect of variety with time of nitrogen fertilizer application and three way interactions had non-significant effect (P>0.05) on effective number of tillers (Appendix Table 2).

Regarding the interaction effect of N rate and its time of application, the highest number of effective tillers (530.00 m^{-2}) was counted by the application of 103.5 kg N ha^{-1} with two splits 1/3 at sowing and the remaining 2/3 at tillering. This was followed by the application of 69 kg N ha^{1} with similar split and 103.5 kg N ha^{-1} applied in to three split applications of 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis. The lowest number of effective tillers (359.15 m^{-2}) was recorded when 34.5 kg N ha^{-1} was used in two split applications of 2/3 at sowing and 1/3 at mid-tillering (Table 4.6). The variation might be due to the result of proper split application of nitrogen fertilizer at different growth stage reduces loss of nitrogen and increase supply of N to the crop throughout its growth stage and thereby increase effective tillers which bearing spikes. The present result was in line with the result obtained by Tilahun Chibsa et al. (2016) who reported that the maximum numbers of tillers were recorded when higher rate of nitrogen was applied in two splits The current result was also supported by the study of Yohannes Erkeno and Nigussie Dechassa (2019) who noted that effective numbers of tillers were increased when higher rate of nitrogen was applied in three split applications. Similarly, Singh et al. (2006) also reported that effective number of tillers of barley was increased when nitrogen was applied in to three split applications.

Concerning the interaction effect of N rate with varieties, the highest value (520.67 m^{-2}) was obtained when high rate of N (103.5 kg ha^{-1}) was applied on IBON 174/03 variety followed by the application (69 kg N ha^{-1}) on similar variety. Whereas the lowest number of effective tillers (367.89 m^{-2}) was counted when low rate of N (34.5 kg ha^{-1}) was applied on Holker variety (Table 4.7). The maximum number of effective tillers observed at high rate of N application on such variety might be due to the positive role of nitrogen fertilizer which enhances tiller population due to the function of Cytokines synthesis and the genetic variations between the studied varieties which bearing better effective tillers. In line with the current study (Derebe Terefe et al. 2018; Ketema Niguse and Mulatu Kassaye, 2018) observed that N rate and barley variety had showed interaction effect on effective number of tillers per plant. The authors further stated that the maximum number of effective tillers was obtained when a variety interacts with highest rate of nitrogen.

.Table 46. Interaction effects of N rate and its time of application on total and effective number of tillers of malt barley in 2020/2021 main cropping season in Farta district

Treatments	Total number of tillers (m^2)	Effective number of tillers (m^2)
34.5 KgN ha^{-1}+ T1	380.00^{f}	359.15^{e}
34.5 KgN ha^{-1} +T2	396.67^{ef}	382.17^{de}
34.5 KgN ha^{-1}+ T3	405.17^{ef}	393.02^{de}
69 Kg N ha^{-1} + T1	442.17^{de}	423.50^{cd}
69 Kg N ha^{-1} + T2	525.50^{ab}	516.53^{a}
69 Kg N ha^{-1}+ T3	469.67^{cd}	461.20^{bc}
103.5 Kg N ha^{-1}+ T1	433.33^{de}	415.33^{cd}
103.5Kg N ha^{-1}+ T2	547.33^{a}	530.00^{a}
103.5 Kg N ha^{-1}+ T3	494.50^{bc}	485.17^{ab}
Mean	454.93	440.67
LSD (0.05)	46.69**	48.23**
SE±	32.74	33.81
CV(%)	1.28	1.26

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing; 1/3 at mid tillering 1/3 at anthesis

Table 47. Interaction effect of varieties and N rate application on total and effective number of tillers of malt barley in 2020/2021 main cropping season in Farta district

	Total number of tillers (m^2)			Effective number of tillers (m^2)		
Varieties	N- rates (kg ha^{-1})					
	34.5	69	103.5	34.5	69	103.5
Holker	385.56^{c}	440.78^{b}	450.11^{b}	367.89^{d}	427.44^{bc}	432.00^{b}
IBON 174/03	402.33^{c}	517.44^{a}	533.33^{a}	388.33^{cd}	506.67^{a}	520.67^{a}
Mean		454.93			440.67	
LSD (0.05)		37.78**			39.32**	
SE±		32.51			33.82	
CV (%)		1.28			1.26	

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent

4.3.3 Number of kernels per spike

The result of analysis of variance showed that the main effect of nitrogen rate, time of N application and variety had highly significant effect ($P<0.01$) on number of kernels per spike. However, all two way and three way interactions had no significant effect ($P>0.05$) on this particular yield related trait (Appendix Table 3).

The maximum number of kernels per spike (27.61) was recorded from highest rate of N (103.5 Kg ha^{-1}) application followed by 69 kg N ha^{-1} while the minimum number of kernels per spike (25.33) was obtained at lowest rate of N (34.5 kg ha^{-1}) applications (Table 4.8). The number of kernels per spike increases with nitrogen rise and it might be happened due to sufficient availability nitrogen that crops can uptake, assimilation and remobilization of N for the synthesis and development of spikelet during anthesis phase (Demissie Ejigu et al., 2015; Melaku Tafese, 2019). Similarly Derebe Terefe et al. (2018) also reported that number of kernels per spike was significantly increased with increasing nitrogen.

Concerning the main effect of time of N application, the highest number of kernels per spike (27.50) was counted with split application of N 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis. This result was followed by two split application of nitrogen 1/3 at sowing and 2/3 at mid-tillering. The lowest number of kernels per spike (25.33) was recorded from split application of N 2/3 at sowing and 1/3 at mid-tillering (Table 4.8). The highest number of kernels per spike observed on such split application might be due to sufficient availability of nitrogen due to proper application at different growth stages. In line with the current result, Roy and Singh (2006) observed that number of grains was increased with three split applications of nitrogen than one or two applications. Closely related to this finding, Singh and Singh (2005) reported that number of grains per spike was increased with two split applications of N (1/3 at sowing and 2/3 at tillering).

Regarding the varieties, the highest number of kernels per spike (27.37) was recorded from Holker variety while the minimum number of kernels per spike (25.85) was obtained fr

IBON 174/03 (Table 4.8). The variation on number of kernels per spike might be due to the genetic difference between the studied varieties. This result was confirmed by the study of Biruk Gezahegn and Demelash Kefale (2016); Derebe Terefe et al. (2018); Melaku Tafese (2019) who observed that number of kernels per spike was significantly affected by the studied varieties. In contrary to the present finding Demise Ejigu (2015) observed non significant variation on number of kernels per spike between varieties.

Table 4.8. Main effects of varieties, N rates and its time of application on number of kernels per spike of malt barley in 2020/2021 main cropping season in Farta district

Treatments	Number of kernels per spike
N rates (Kg ha^{-1})	
34.5	25.33^{b}
69	26.89^{a}
103.5	27.61^{a}
LSD (0.05)	0.79**
SE±	0.95
Time of N application	
T1	25.50^{b}
T2	26.83^{a}
T3	27.50^{a}
LSD (0.05)	0.79**
SE±	0.95
Varieties	
Holker	27.37^{a}
IBON-173/04	25.85^{b}
LSD (0.05)	0.64**
SE±	0.95
Mean	26.61
CV (%)	4.36

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing; 1/3 at mid tillering 1/3 at anthesis

4.3.4 Above ground biomass

The result of the analysis of variance indicated that above ground biomass was very highly significantly (P<0.001) affected by the main effects of variety, N rates with its time of application. Moreover, it was also highly significantly (P<0.01) influenced by the combined effect of variety with rate of nitrogen and N rate and its time of application However, above ground biomass was not significantly (P>0.05) affected by the other interactions (Appendix Table 3)

Regarding the combined effect of variety with rate of nitrogen the highest above ground biomass yield (10.10 t ha^{-1}) was recorded when highest level of nitrogen was applied on IBON 174/03 variety. This was followed by the application of 69 kg N ha^{-1} on similar variety. On the other hand the minimum above ground biomass yield (6.60 kg ha^{-1}) was obtained when 34.5 kg ha^{-1} of N was applied on Holker variety (Table 4.9). The highest value of above ground biomass observed at application of high rate of nitrogen on IBON 174/03 variety might be due to the vital role of nitrogen for accelerating number of tillers and the genetic difference between the studied varieties in nitrogen use efficiency as well as tiller producing ability. Similar studies were reported by Demisse Egigu et al. (2015) Ketema Niguse and Mulatu Kassaye (2018) and Lake Mekonen (2018) who observed that increasing above ground with increasing nitrogen rate.

The current finding also showed that, above ground biomass exhibits a significant difference by the combined effect of nitrogen with its time of application. The highest above ground biomass yield (10.13 t ha^{-1}) was recorded when highest level of nitrogen was used in two applications 1/3 at sowing and 2/3 at mid-tillering, followed by 69 Kg N ha^{-1} with similar split applications. Whereas, the minimum (6.33 t ha^{-1}) above ground biomass yield was obtained when lower rate of N (34.5 kg ha^{-1}) was applied with two split application of 2/3 at sowing and 1/3 at mid-tillering (Table 4.10). Increasing above ground biomass at high rate of nitrogen in such split application might be due to the positive contribution of nitrogen which accelerates tillers and other growth parameters when high level of N was applied at the time of mid-tillering. In line with the present study, Tilahun Chibsa et al. (2016) reported that above ground biomass increases when high rate of nitrogen was applied at mid-tillering stage of durum wheat. Similarly, Legesse Admassu and Sakatu Hunduma (2020) observed that above ground biomass of barley was increase when nitrogen was applied 1/3 at sowing and the remaining 2/3 after 21-30 days of emergence.

4.3.5 Grain yield

The result of analysis of variance showed that grain yield was very highly significantly ($P<0.001$) affected by the main effect of variety, nitrogen rate and its time of application. In addition, the result also revealed that grain yield was significantly ($P<0.05$) influenced by the combined effect of variety with nitrogen rate and nitrogen rate and its time of application. However, other interaction had non-significant ($P>0.05$) effect on the grain yield of malt barley (Appendix Table 3).

Concerning the interaction effect of variety with nitrogen, the highest grain yield (4.12 t ha^{-1}) was obtained from the combined effect of highest level of nitrogen (103.5 kg ha^{-1}) and IBON 174/03 variety followed by the application of 69 kg N ha^{-1} with similar variety. Whereas, the minimum grain yield (2.49 t ha^{-1}) was recorded when 34.5 kg N ha^{-1} applied on Holker variety (Table 4.9). IBON 174/03 variety gave the highest grain yield (4.12 t ha^{-1}) when it interacts with the highest level of nitrogen while Holker variety resulted better grain yield of 3.35 t ha^{-1} when it interacts with 69 kg N ha^{-1}. As compared to the highest grain yield obtained by the two varieties, IBON 174/03 scored 22.99 % additional grain yield than that of Holker. The variation in grain yield with increasing rate of nitrogen might be happened due to the contribution of high level of nitrogen for increasing effective tillers and the varietal difference to uptake and utilize the available nutrients. Similar findings were reported by (Minale Liben et al. 2011; Amare Alemnew, 2015; Ketema Niguse and Mulatu Kassaye, 2018; Melaku Tafese, 2019) who observed that significant increase in grain yield of barley with increasing rate of nitrogen. Similarly, Tilahun Chibsa et al. (2016) and Yohannes Erkeno (2019) observed increasing grain yield of wheat with increasing rate of nitrogen. This result was also in harmony with the study of Patel et al. (2004) who noted that grain yield of barley increases with increasing N from 60 to 100 kg ha^{-1} but the grain yield obtained 100 kg ha^{-1} was similar with 80 kg ha^{-1} application.

Regarding the interaction effect of nitrogen with its time of application, the maximum grain yield (4.26 t ha^{-1}) was obtained when 69 kg N ha^{-1} was added in two split applications of 1/3 at sowing and 2/3 at mid-tillering however, it was statistically on par with treatment received 103.5 kg N t ha^{-1} with similar split applications. On the other hand, the minimum grain yield (2.40 t ha^{-1}) was recorded when 34.5 kg N ha^{-1} was applied with two split applications 2/3 at sowing and 1/3 at mid-tillering. As indicated on Table 4. 10, grain yield was ranged from 2.40 t ha^{-1} to 4.26 t ha^{-1} as a result of different N rates and time of applications The highest grain yield obtained at 69 kg N ha^{-1} with such split application probably due to the combined effect of optimum level and its appropriate time of N application required by the plants to be efficiently utilized and increased photo assimilate production. In line with the present study, Alemayehu Assefa et al. (2013) observed that higher grain yield of rice was obtained when nitrogen was applied in two splits of 1/3 at sowing and 2/3 at tillering stage of the crop. Beside to this, the result obtained by Legesse Admassu and Sakatu Hunduma (2002) indicated that grain yield of malt barley increases with two split application of N 1/3 at sowing and 2/3 after 21-30 days of emergence. A similar effect of nitrogen application on bread wheat grain yield was reported by Hiroshi et al. (2008) who observed significant grain yield increases when higher rate of nitrogen was applied at active tillering stage. This result is also partly in harmony with the study of Anonymous (2001) and Singh (2005) who reported that two splits of N (1/3 at sowing and 2/3 at first irrigation results higher grain yield in barley. In contrary with the present result, Turk (2001) and Roy (2006) reported that higher grain yield of barley was obtained when nitrogen was applied in to three equal splits.

The present result was by far higher than the national average grain yield 2.50 t ha^{-1} (CSA, 2020). This indicated that there is great potential to increase malt barley production in Ethiopia through proper application of agronomic practices. The present result was also greater (10.36%) than the average grain yield (3.86 t ha^{-1}) obtained on a research conducted by participatory evaluation of malt barley varieties in barley-growing highland areas of northwestern Ethiopia (Misganaw Ferede and Zina Demise, 2020). Beside to this, the present result was greater (5.97%) than the average grain yield (4.02 t ha^{-1}) obtained under cluster-based improved malt barley technology demonstration in selected districts of West Arsi zones of Oromia Regional State (Sintayehu Abebe and Lemlem Abebe, 2021).

Table 49. The interaction effect of varieties and N rates on above ground biomass and grain yield of malt barley in 2020/2021 main cropping season in Farta district

	AGB (t ha^{-1})		GY(t ha^{-1})	
	Varieties			
N , rates (Kg ha^{-1})	Holker	IBON-174/03	Holker	IBON- 174/03
34.5	6.60^{c}	7.01^{c}	2.49^{c}	2.67^{c}
69	8.09^{b}	9.72^{a}	3.35^{b}	4.07^{a}
103.5	8.28^{b}	10.10^{a}	3.28^{b}	4.12^{a}
Mean	8.30		3.33	
LSD(0.05)	0.89**		0.61*	
SE±	0.76		0.41	
CV (%)	6.75		11.43	

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; AGB: above ground biomass; GY: grain yield

Table 410. Combined effect of N rate and its time of application on above ground biomass and grain yield of malt barley in 2020/2021 main cropping season in Farta district

Treatments	AGB (t ha^{-1})	GY (t ha^{-1})
34.5 kg N ha^{-1}+ T1	6.33^{f}	2.40^{g}
34.5 kg N ha^{-1} +T2	6.92^{ef}	2.60^{fg}
34.5 kg N ha^{-1}+ T3	7.16d^{ef}	2.74^{efg}
69 kg N ha^{-1} + T1	8.17^{cd}	3.30^{cde}
69 kg N ha^{-1} + T2	9.90^{a}	4.26^{a}
69 kg N ha^{-1}+ T3	8.64^{bc}	3.58^{bcd}
103.5 kg N ha^{-1}+ T1	8.08^{cde}	3.20^{def}
103.5 kg N ha^{-1}+ T2	10.13^{a}	4.08^{ab}
103.5 kg N ha^{-1}+ T3	9.37^{ab}	3.85^{abc}
Mean	8.30	3.33
LSD (0.05)	1.17**	0.61*
SE±	0.82	0.43
CV (%)	6.75	11.43

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing; 1/3 at mid tillering 1/3 at anthesis; AGB: above ground biomass; GY; grain yield

4.3.6 Harvest index

The results of analysis of variance indicated that harvest index was highly significantly (P<0.01) affected by the main effects of nitrogen rate. However, other main effects and all interactions had no significant effect on harvest index (Appendix Table 3). As indicated in Table 4.11, the maximum harvest index (41.55%) was observed from the treatment of 69 kg N ha^{-1} which is followed by the highest level of nitrogen. Whereas, the minimum harvest index (37.85%) was recording at the lowest level nitrogen (34.5 kg ha^{-1}) applications. Higher harvest index indicates higher proportion of dry matter transformed in to economic yield. In contrast with the current result, Derebe Terefe *et al.* (2018) observed higher harvested index at lower rate of nitrogen applications.

Table 4.11. Harvest index as influenced by main effect of N rates of malt barley in 2020/2021 main cropping season in Farta district

Treatments	Harvest Index (%)
N rates (kg ha^{-1})	
34.5	37.85^{b}
69	41.55^{a}
103.5	40.19^{a}
Mean	39.86
LSD (0.05)	1.73**
SE±	2.08
CV (%)	6.40

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent

4.4 Quality Traits

4.4.1 Thousands kernel weight

The analysis of variance revealed that thousands kernel weight was very highly significantly (P<0.001) influenced by the main effects of varieties and significantly (P<0.05) affected by the main effects of nitrogen rate and its time of application. However, non- significant effects (P>0.05) were observed by all interactions of varieties, nitrogen rate and its time of application (Appendix Table 4).

The highest thousands kernel weight (45.60 g) was recorded from IBON 147/03 variety whereas the lowest (41.14 g) was observed from Holker (Table 4.12). This might be happened due to the genetic variation between the studied varieties. Similar results were reported by Minale Liben et al. (2011); Biruk Gezahegn and Demelash Kefale (2016); Derebe Terefe et al. (2018); Ketema Niguse and Mulatu Kassaye (2018); Meharie Kassie and Kindie Tesfaye (2019) who observed significant differences on thousands kernel weight between the studied varieties. According to Verma et al. (2004) thousands kernel weight for two and six row varieties needs to be greater than 45g and 42g, respectively. However, the National Standard Authority of Ethiopia for thousands grain weight and test weight (hectoliter weight) specified within the range of 35 to 45 g and 60 to 65 kg hl^{-1}, respectively. While the acceptable (thousand-kernel weight) and test weight (hectoliter weight) settled in the range of 25, 35 g and 48, 62, respectively (EQSA, 2006).

Regarding rate of nitrogen, the maximum kernel weight (44.78 g) was obtained from the application of 69 kg N ha^{-1}). Whereas the lowest kernel weight (42.71 g) was recorded from the application minimum rate of N (34.5 kg ha^{-1}) (Table 4.12). The variation on thousands kernel weight might be due to proper utilization the given resource as per plant population and photosynthesis use efficiency. The current result was closely confirmed by the study of Biruk Gezahegn and Demelash Kefale (2016) who observed that highest value of thousands kernel weight of barley (44.87 g) was obtained from application of 87 kg N ha^{-1}) than using 98 kg N ha^{-1}. The current result was also supported by the previous studies of Paterson and Potts (1985), who reported that increasing nitrogen rate decreases grain weight of barley. However, different studies done on wheat and barley showed that thousand kernel weight increase with increase rate of nitrogen (Tilahun Chibsa et al., 2016; Ketema Niguse and Mulatu Kassaye, 2018); Meharie Kassie and Kindie Tesfaye, 2019).

Concerning, application time of nitrogen, the highest value (44.60 g) of thousands kernel weight was recorded from two split application of N 1/3 at sowing and 2/3 at mid-tillering followed by three split applications 1/3 at sowing, 1/3 at mid-tillering and 1/3 at antheses while the lowest (41.87 g) was obtained from two split application of N where 2/3 at sowing and 1/3 at mid-tillering (Table 4.12). The higher thousands kernel weight obtained probably due to sufficient availability of nutrients as per growth stages as a result of split application of nitrogen. The current result was in line with the study of Singh and Singh (2005) who reported that thousands kernel weight and other yield components was increase with two splits of nitrogen application that 1/3 at sowing and 2/3 at tillering. This result was also partly related with the study of Amani and Behzad (2020) who found that split application of nitrogen had a significant effect on thousand kernel weight of wheat and the highest value was attained when N was applied in two split application that 1/3 at sowing and 2/3 at flowering followed by three splits of N 33% N at basal + 33% N at tillering +33% N at flowering

4.4.2 Hectoliter weight

Based on the analysis of variance hectoliter weight was significantly ($P<0.05$) influenced by the main effects of nitrogen and its time of application. Moreover, the interaction effect of nitrogen rate and its time of application highly significantly ($P<0.01$) influenced this quality trait. However, the main effect of variety and other interaction effects had no significant ($P>0.05$) effect on hectoliter weight (Appendix Table 4).

The highest hectoliter weight (62.15 kg hl^{-1}) was observed from the application of 69 kg N ha^{-1}) with two splits of 1/3 at sowing and the remaining 2/3 at mid-tillering. Whereas the lowest (57.57 kg hl^{-1}) was recorded when 34.5 kg N ha^{-1}) was applied in two splits of 2/3 at sowing and 1/3 at mid-tillering (Table 4.13). The maximum hectoliter weight observed on respective treatment might be due to the combined effect of optimum nitrogen rate and proper time of application and thus results plump and uniform grain size. According to the study of Shewry and Morell (2001) barley with higher bulk density have a greater percentage of starch in the grain. In consistent with the present study (Biruk Gezahegn and Demelash Kefale, (2016); Derebe Terefe et al., (2018) observed slight increase in hectoliter weigh with increasing nitrogen. On the other hand, Meharie Kassie and Kindie Tesfaye (2019) observed no significant difference on hectoliter due to the application of different N rates. The present result was within the Ethiopian quality standard that the acceptable hectoliter weight ranged between 48-62 (EQSA, 2006).

4.4.3 Germination energy

The analysis of variance showed that germination energy was significantly (P<0.05) influenced by the main effects of variety. However, other main and interaction effects had non significant (P>0.05) effect on germination energy (Appendix Table 4). The highest germination energy (96.27%) was recorded from IBON 174/03 variety as compared to Holker (Table 4.11). This might be due to the genotypic difference between the studied varieties in response to dormancy. Based on the study of Han et al. (1999) barley grain dormancy can be affected by genotype. The present result was in line with the study of Derebe Terefe et al. (2018) and Melaku Tafes (2019) who observed a significant difference between varieties on germination energy.

Table 412. Main effect of varieties, N rates and its time of application on thousands kernel weight and germination energy of malt barley in 2020/2021 main cropping season in Farta district

Treatments	TKW (g)
N rates (kg ha^{-1})	
34.5	42.71^{b}
69	44.78^{a}
103.5	43.02^{b}
LSD (0.05)	1.72*
SE±	2.09
Time of N application	
T1	41.87^{b}
T2	44.60^{a}
T3	44.04^{a}
LSD (0.05)	1.72*
SE±	2.09
Varieties	
Holker	41.41^{b}
IBON-173/04	45.60^{a}
LSD (0.05)	1.41***
SE±	2.09
CV (%)	5.85

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing; 1/3 at mid tillering; 1/3 at anthesis. TKW: thousands kernel weight;

Table 413. Interaction effect of nitrogen rate and its time of application on hectoliter weight of malt barley in 2020/2021 main cropping season in Farta district

	Hectoliter weight		
N rates kg ha^{-1}	Time of N application		
	T1	T2	T3
34.5	57.57^{c}	57.59^{c}	59.56^{b}
69	58.03^{bc}	62.15^{a}	58.45^{bc}
103.5	58.28^{bc}	58.32^{bc}	58.42^{bc}
LSD (0.05)		1.77**	
SE±		1.33	
CV (%)		2.78	

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing; 1/3 at mid tillering; 1/3 at anthesis

Table 414. Main effect of varieties on germination energy of malt barley in 2020/2021 main cropping season in Farta district

Treatments	Germination energy (%)
Varieties	
Holker	95.23b
IBON 174/03	96.27^{a}
LSD (0.05)	0.82*
SE±	1.21
CV (%)	2.55

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent

4.4.4 Protein content

The results of analysis of variance showed that grain protein content was highly significantly (P<0.01) affected by the main effect of variety, N rate and its time of application. Furthermore, the combined effect of N rate with variety and variety with time of nitrogen application were significantly (P<0.05) influence protein content of barley grain. However, other interaction effects did not significantly influence the grain protein content (Appendix Table 4).

Regarding the interaction effect of variety with rate of nitrogen, the maximum grain protein content (12.19%) was observed from the application of highest rate of N (103.5 kg ha^{-1}) on IBON 174/03 variety. Whereas, the lowest value (9.50 %) was obtained when minimum level of N was applied on Holker variety (Table 4.15). The variation on grain protein content might be due to the effect of nitrogen which increases the level of protein content when it was applied at higher rate and the genetic difference between varieties. In line with the current study Minale Liben et al. (2011); Amare Alemnew and Adane Legas (2015); Derebe Trefe et al (2018); Meharie Kassie and Kindie Tesfaye (2019) observed that grain protein content increased with increasing nitrogen on the studied varieties. In contrast to the present result, the research done by Singh et al. (1978) revealed that increase in N supply from 0 to 40 kg N ha^{-1} has non-significant effect on protein content. However, nitrogen fertilization of malting barley carefully managed as it affects different malting quality characteristics often become unacceptable as fertilization is increased for maximum yield (Zubriski et al., 1970). Moreover, protein content and other quality traits of malt barley were also influenced by different agronomic practices (Singh et al., 2014).

The higher protein content in the grain the lower carbohydrate and malt extract content and thus further prolonging the malting process and affects the final beer quality (Zhang et al., 2001; Verma et al., 2003). On the other hand, lower protein content of a grain limit yeast growth during fermentation (Emebiri et al., 2005). According to the Ethiopian standards authority and Assela Malt factory, the raw barley quality standards for malt protein content ranged between (9-12 %). As shown in Table 4.15 the present result exhibits the standard range of protein content except the highest level of N 103.5 kg ha^{-1} interacts with IBON 174/03 variety.

Concerning the combined effect of variety with time of N application, the maximum level of protein content (12.10 %) was recorded when N was applied in three splits 1/3 at sowing, 1/3 at mid- tillering and 1/3 at anthesis on IBON 174/03 variety. On the other hand, the minimum protein content (10.20 %) was obtained when Holker variety receive N with two split application of 2/3 at sowing and 1/3 at mid-tillering. This was statistically on par with the application of 1/3 of N at sowing and 2/3 at mid-tillering on similar variety (Table 4.16). The protein content of the grain obtained from the interaction of varieties with different time of N application was with the range of Ethiopian quality standard authority except three split application of N on IBON 174/03 variety. The higher level of protein observed from three splits of N interacted with IBON 174/03 variety might be due to sequential supply of nitrogen in different growth stage and the varietal difference in nitrogen use efficiency that barley plants apparently continued to use available N even after yield requirements were met since grain protein increased, but yield did not (Mcguire et al., 1979). In harmony with the current study Singh and Singh (2005) revealed that protein content of malt grain increases with three split applications of nitrogen than two splits. Similarly Jurjescu and Paul (2010) reported that three split applications of higher rate of nitrogen increases the protein content beyond the recommended level.

Table 415. Combined effect of varieties and N rates on protein content of malt barley in 2020/2021 main cropping season in Farta district

	Protein content (%)	
N , rates (Kgha^{-1})	Varieties	
	Holker	IBON 174/03
34.5	9.56^{d}	10.76^{c}
69	10.89^{c}	11.60^{b}
103.5	11.08^{c}	12.19^{a}
Mean	11.01	
LSD(0.05)	0.48*	
SE±	0.41	
CV (%)	2.73	

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent

Table 416. Interaction effect of varieties and time of N applications on protein content of malt barley in 2020/2021 main cropping season in Farta district

Time of N application	Protein content (%)	
	Varieties	
	Holker	IBON 174/03
2/3 at sowing+1/3 at MT	10.20^{d}	10.93^{bc}
1/3 at sowing+2/3 at MT	10.51^{cd}	11.51^{ab}
1/3 at sow+1/3 at MT+1/3 at An	10.79^{cd}	12.10^{a}
Mean	11.01	
LSD(0.05)	0.71*	
SE±	0.62	
CV (%)	2.73	

Means with the same column followed by the same letter(s) are not significantly different at 5% significant level. Where NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent, MT: mid-tillering; An: anthesis

4.5 Correlation Analysis of Growth, Yield and Quality Traits of Malt Barley as Influenced by Variety, N rate and Time of Application

As indicated in Table 4.17 grain yield exhibited highly significantly ($P<0.001$) and strongly positively associated with total number of tillers (r= 0.83), effective number of tillers (r=0.84), above ground biomass (r= 0.97), thousands kernel weight (r= 0.63). This indicated that those traits play a positive contribution for the increment of grain yield. The present result was in line with the study of Meharie Kassie and Kindie Tesfaye (2019) and Melaku Tafese (2019) who observed that grain yield was significantly and positively correlated with most of the traits studied. The results from correlation analysis revealed that, grain yield was non-significantly and weakly positively correlated with plant height and spike length. This might be due to the genetic difference of the studied varieties that IBON 174/03 gave high yield but it is shorter than Holker. In contrast to the present study, Ketema Niguse and Mulatu Kassaye (2018) observed that plant height and spike length was significantly associated with grain yield in food barley. Protein content was positively and significantly correlated with total number of tillers (r= 0.74), effective number of tillers (r=0.79), above ground biomass (r= 0.74), grain yield (r = 70) and thousands kernel weight (r= 48). The increment of protein content with grain yield might be due to the role of nitrogen which increases such trait with similar trends when it is applied in less fertile soil.

Table 417. Simple correlation coefficient (r) among studied traits as influenced by varieties, N rates and its time application of malt barley in 2020/2021 main cropping season in Farta district

TRT	PH	SL	TNT	ENT	NKPSP	AGB	GY	STY	HI	TKW	PC	HCW
PH	1											
SL	0.25^{ns}	1										
TNT	0.10^{ns}	0.18^{ns}	1									
ENT	0.09^{ns}	0.17^{ns}	0.10***	1								
NKPSP	0.61***	0.39**	0.43**	0.43**	1							
AGB	0.05^{ns}	0.07^{ns}	0.89***	0.89***	0.36**	1						
GY	0.01^{ns}	0.12^{ns}	0.83***	0.84***	0.33*	0.97***	1					
STY	0.09^{ns}	0.03^{ns}	0.88***	0.88***	0.37**	0.97***	0.86**	1				
HI	0.14^{ns}	0.23^{ns}	0.48**	0.48***	0.15^{ns}	0.58***	0.77***	0.36**	1			
TKW	-0.39**	0.09^{ns}	0.44**	0.47***	0.003^{ns}	0.62***	0.63***	0.58**	0.41**	1		
PC	-0.13^{ns}	0.14^{ns}	0.74***	0.79**	0.30*	0.74***	0.70***	0.72**	0.43**	0.48**	1	
HCW	0.07^{ns}	-0.31*	0.37*	0.40**	0.10^{ns}	0.51***	0.54***	0.45**	0.42**	0.59**	0.22^{ns}	1

Note: PH= Plant height, SL= Spike length, TNT=Total number of tillers, ETN= Effective number of tillers, NKPSP= Number of kernels per spike, AGB=Above ground biomass, GY=Grain yield, STY=Straw yield, HI=Harvest index, TKW=Thousands kernel weight, PC=Protein content, HCW=Hectoliter weight, ns=Non significant, *=significant, **= Highly significant, ***=Very highly significant

4.6 Economic Analysis

The result of partial budget analysis showed that application of 69 kg N ha^{-1} with two splits 1/3 at sowing and 2/3 at mid-tillering gave the highest net return ETB (Ethiopian birr) 82,627.50 with acceptable marginal rate of return (1824.20%) (Table 4.19). In case of nitrogen rate with variety, the highest net benefit (ETB 80,894.00 ha^{-1}) with an acceptable level of MRR (2513.57%) was observed when 69 kg N ha^{-1} was applied on IBON 174/03 variety (Table 4.20). Application of 69 kg N ha^{-1} with two splits 1/3 at sowing and 2/3 at mid-tillering resulted better net benefit advantage of Birr 1,733.5 over the results obtained from the application of 69 kg N ha^{-1} on IBON 174/03 variety. This might be due to optimum level and its appropriate time of N application required by the plants to be efficiently utilized, increased photo assimilate production and this resulted proper and uniform grains. Similar to the present result, Legesse Admassu and Sakatu Hunduma (2020) observed the highest net economic benefit when nitrogen was applied in two splits 1/3 at sowing and 2/3 at mid-tillering on malt barley.

Table 418. Partial budget analysis of malt barley as influenced by N rates and its time application in 2020/2021 main cropping season in Farta district

Treatment combination	Mean grain yield (t ha^{-1})	Mean straw yield (t ha^{-1})	Adjusted gain yield (t ha^{-1})	Adjusted straw yield (t ha^{-1})	Total sales price (ETB ha^{-1})		Gross benefit ETB ha^{-1}
					GY	SY	
N1T1	2.40	3.94	2.16	3.55	47520.00	1773.00	49293.00
N1T2	2.60	4.32	2.34	3.89	51480.00	1944.00	53424.00
N1T3	2.74	4.43	2.47	3.99	54340.00	1993.50	56333.50
N2T1	3.30	4.88	2.97	4.39	65340.00	2196.00	67536.00
N2T2	4.26	5.63	3.83	5.07	84260.00	2533.50	8679350
N2T3	3.58	5.06	3.22	4.55	70840.00	2277.00	73117.00
N3T1	3.20	4.89	2.88	4.40	63360.00	2200.50	65560.50
N3T2	4.08	6.05	3.67	5.45	80740.00	2722.50	83462.50
N3T3	3.85	5.52	3.47	4.97	76340.00	2484.00	78824.00

Note: N1= 34.5kg N ha^{-1}, N2= 69 kg N ha^{-1}., N3= 103.5 kg N ha^{-1}, T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing; 1/3 at mid tillering; 1/3 at anthesis; GY: grain yield; SY straw yield; ETB ha^{-1}=Ethiopian Birr per hectare

Table 419. Total variable cost, gross and net benefit of malt barley under the effect of N rates and its time application in 2020/2021 main cropping season in Farta district

Treatments	GB (ETB ha^{-1})	Man power	Labor cost for urea app.n. (ETB Birr)	Cost of urea (ETB ha^{-1})	TVC (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Dominance analysis	MRR(%)
N1T1	49293.00	10	1000	1083	2083.00	47210.00	D	
N1T2	53424.00	10	1000	1083	2083.00	51341.00		-
N1T3	56333.50	15	1500	1083	2583.00	53750.50		481.90
N2T1	6753600	20	2000	2166	4166.00	63370.00	D	
N2T2	86793.50	20	2000	2166	4166.00	82627.50		1824.20
N2T3	73117.00	25	2500	2166	4666.00	68451.00	D	
N3T1	65560.50	25	2500	3249	5749.00	59811.50	D	
N3T2	83462.50	25	2500	3249	5749.00	77713.50	D	
N3T3	78824.00	30	3000	3249	6249.00	72575.00	D	

Note: N1= 34.5 kg N ha^{-1}, N2= 69 kg N ha^{-1}., N3= 103.5 kg N ha^{-1}, T1: 2/3 at sowing and 1/3 at mid tillering; T2: 1/3 at sowing and 2/3 at mid tillering; T3: 1/3 at sowing; 1/3 at mid tillering; 1/3 at anthesis; GB: gross benefit; TVC: total variable cost; NB: net benefit; MRR: marginal rate of return%; ETB ha^{-1}: Ethiopian Bir per hectarer; D: dominated

Table 4.20. Partial budget analysis of malt barley as influenced by variety and nitrogen rates in 2020/2021 main cropping season in Farta district

TRT	Mean GY t ha^{-1}	Mean STY t ha^{-1}	Ag GY t ha^{-1}	Ag STY tha^{-1}	GB (ETB ha^{-1})	C. Urea	TVC(ETB ha^{-1})	NB (ETB ha^{-1})	DA	MRR%
N1V1	2.49	4.11	2.24	3.70	51130.00	1083	1083	50047.00	D	
N1V2	2.67	4.34	2.40	3.91	54755.00	1083	1083	53672.00		-
N2V1	3.35	4.74	3.02	4.27	68575.00	2166	2166	66409.00	D	
N2V2	4.07	5.64	3.66	5.08	83060.00	2166	2166	80894.00		2513.57
N3V1	3.28	4.99	2.95	4.49	67145.00	3249	3249	63896.00	D	
N3V2	4.12	5.98	3.71	5.38	84310.00	3249	3249	81061.00		15.42

Note: N1= 34.5 kg N ha^{-1}, N2= 69 kg N ha^{-1}., N3= 103.5 kg N ha^{-1}, V1=Holker, V2= IBON 174/03; GY: grain yield; SY straw yield; Ag GY t ha^{-1}: adjusted grain yield ton per hectare; Ag STY t ha^{-1}; adjusted straw yield ton per hectare; GB: gross benefit; C.Urea: cost for urea (ETB ha^{-1}); TVC: total variable cost; NB: net benefit; MRR: marginal rate of return%; ETB ha^{-1}: Ethiopian Birr per hectare; DA: dominance analysis; D: dominated

Chapter 5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results of the present finding indicated that most of phonological, growth, yield and quality parameters were significantly affected by the main and interaction effects of variety, nitrogen rate and its time of application. Both varieties tend to delay to 50% heading and 90% physiological maturity when nitrogen rate increases. Similarly, both plant height and spike length increases with increasing nitrogen rate.

Regarding yield and yield related parameters, most of them were significantly affected by both the main and interaction effects. Both total and effective number of tillers m^{-2} increases with increasing nitrogen rate at applications of 1/3 at sowing and 2/3 at mid tillering. More number of tillers was counted with IBON 174/03 variety than Holker. The maximum grain yield (4.26 t ha^{-1}) was obtained when 69 kg N ha^{-1} was used in two split applications 1/3 at sowing and 2/3 at mid-tillering followed by the application of 103.5 kg N ha^{-1} on IBON variety with respective grain yield (4.12 t ha^{-1}). Variety IBON 174/03 was high yielder than that of Holker.

Thousands kernel weight was decreased both at highest and lowest level of nitrogen applications. Protein content increased in both varieties as they were treated from the lowest to the highest nitrogen rates. Indeed, Holker scored lower protein content as compared to IBON 174/03 variety. Beside to this, late applications of N increase the total protein content of the grain.

The overall result of the present finding indicated that, further increasing nitrogen rate slightly increase the grain yield but greatly reduces the quality traits. Moreover, application of higher rate of nitrogen at the time of sowing had minimum contribution on the grain yield as compared to other application times. The results obtained from economic analysis indicated that the highest net benefit 82.627.50 and 80,894.00 (ETB ha^{-1}) with acceptable MRR was obtained when 69 kg N ha^{-1} was applied with two splits 1/3 at sowing and 2/3 at mid-tillering and application of 69 kg N ha^{-1} on IBON 174/03 variety, respectively. Application of 69 kg N ha^{-1} with two splits 1/3 at sowing and 2/3 at mid-tillering gave the maximum grain yield and the highest net economic return. Therefore, application of optimum level of nitrogen with proper splits reduces production cost and resulted optimum grain yield with acceptable protein content.

5.2 Recommendation

Based on the results obtained in the present research, application of 69 Kg N ha^{-1} with two splits 1/3 at sowing and 2/3 at mid-tillering gave the maximum grain yield (4.26 t ha^{-1}) and the highest net return of ETB 82, 627.50 with acceptable marginal rate of return (1824.20%). So, this treatment combination is found to be economically feasible and can be recommended to the producers in the study area and similar agro ecologies. Since the present research was conducted only in one year and single location, the experiment should be repeated over years and locations to come up a conclusive and well defined recommendation. Beyond this recommendation, future works should include the newly released varieties to identify their response to different nitrogen rates and timing under diversified locations.

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7. APPENDICES

Appendix Table 1. Mean squares analysis of variance (ANOVA) for phenology traits of malt barley varieties as influenced by rates and time of nitrogen fertilizer application during 2020 cropping season

Source of variation	DF	DH	DM
Rep	2	15.72*	20.06*
N	2	184.72***	154.17**
T	2	68.17***	83.39**
V	1	979.63***	785.85***
N*T	4	9.81**	14.72*
N*V	2	8.69**	5.57*
T*V	2	0.91ns	1.69ns
N*V*T	4	0.55ns	3.41*
Error	34	1.11	1.09

Where, DF=degree of freedom, DH= days to 50% heading, DM= days to 90% physiological maturity *,**,*** significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively, NS= non significant

Appendix Table 2. Mean squares analysis of variance (ANOVA) for agronomic traits (PH, SL, TTN, ENT) of malt barley varieties as influenced by rates and time of nitrogen fertilizer application during 2020 cropping season

Source of variation	DF	PH	SL	TNT	ETN
Rep	2	23.92ns	0.18ns	2938.07**	2816.16**
N	2	321.37*	0.39*	50918.69***	53258.39***
T	2	210.46*	0.02ns	22929.13***	27054.22***
V	1	4125.63**	0.23ns	46816.67***	52640.67***
N*T	4	2.11ns	0.36ns	4200.52**	3950.78**
N*V	2	19.94ns	0.03ns	6033.39**	6034.72**
T*V	2	16.19ns	0.10ns	1684.50ns	1194.00ns
N*V*T	4	1.91ns	0.14ns	1437.22ns	1404.39ns
Error	34	18.77	0.11	33.96	31.05

DF=degree of freedom, PH=plant height, SL= Spike length TNT= Total number of tillers, ETN= effective number of tillers, *, **,***significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively, NS= non significant

Appendix Table 3. Mean squares analysis of variance (ANOVA) for NKPS, AGB, GY and HI of malt barley varieties as influenced by rates and time of nitrogen fertilizer application during 2020 cropping season

SV	DF	NKPS	AGB	GY	HI
Rep	2	0.167ns	0.33ns	0.22ns	9.49ns
N	2	24.39**	30.59***	7.69***	63.07**
T	2	18.67**	9.64***	2.12***	4.58ns
V	1	31.13**	22.31***	4.54***	4.97ns
N*T	4	2.56ns	1.34**	0.39*	4.73ns
N*V	2	1.79ns	2.66**	0.57*	0.62ns
T*V	2	1.19ns	0.46ns	0.15ns	2.38ns
N*V*T	4	2.35ns	0.97ns	0.24ns	4.98ns
Error	34	1.34	0.31	0.15	6.51

SV=source of variation, DF=degree of freedom, NKPS=Number of kernels per spike, AGB= aboveground biomass, GY=grain yield, HI= harvested index, *, **,*** significant at P€0.05, p€0.01 and p€0.001 probability levels respectively, NS= non significant

Appendix Table 4. Mean squares analysis of variance (ANOVA) for quality traits (TKW, PC, HCLW and GE) of malt barley varieties

SV	DF	TKW	PC (%)	HCLW	GE (%)
Rep	2	9.40ns	0.71*	0.28ns	1.95ns
N	2	22.56*	10.73**	9.48*	2.2ns
T	2	37.47*	3.47**	8.93*	5.4ns
V	1	237.47***	13.90**	0.5ns	14.50*
N*T	4	9.19ns	0.03ns	15**	1.33ns
N*V	2	5.36ns	0.33*	1.11ns	1.73ns
T*V	2	3.04ns	0.38*	0.22ns	1.29ns
N*V*T	4	1.39ns	0.18ns	1.54ns	1.49ns
Error	34	6.47	0.09	2.65	2.19

SV=source of variation, DF=degree of freedom, TKW=Thousands kernel weight, PC=protein content (%), HCLW=hectoliter weight, GE= germination energy, *, **,*** significant at P€0.05, p€0.01 and p€0.001 probability levels respectively, NS= non significant,

Appendix Figure 1. Field lay out preparation and sowing of malt barley

Appendix Figure 2. Pictures taken during data collection of agronomic traits of malt barley

Appendix Figure 3 Pictures taken during threshing and winnowing of malt barley

8. BIOGRAPHY OF THE AUTHOR

The authorwas born on August 16, 1991 in Guagusa shikudad woreda, Awi Zone of Amhara Region, Ethiopia. He attended his elementary education (1-8) at Tillili Primary school from 1999-2006. He also attended his secondary and preparatory education at Tillili Secondary and preparatory School from 2007 to 2010. After completing his secondary and preparatory School, he joined Debre Markos University College of Agriculture and Natural Resource in 2011 and graduated in Bachelor of Science Degree in Plant Science in July 2013. Up on graduation, he became employed at Dangila woreda as crop production and management expert in December 2013 and served two and half years. Then he joined Mehoni Agricultural Research Center in September 2016 and he served up to September 2019. Then the author joined Bahir Dar University College of Agriculture and Environmental Sciences to pursue his M.Sc. degree in Agronomy in October 2019.