EFFECT OF SEED SOURCES AND RATES OF NITROGEN FERTILIZER ON SEED QUALITY, YIELD AND YIELD RELATED TRAITS OF MALT BARLEY (*Hordeum vulgare* L.) AT KULUMSA, ARSI ZONE, ETHIOPIA

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Effect of Seed Sources and Rates of Nitrogen Fertilizer on Seed Quality, Yield and Yield Related Traits of Malt Barley (*Hordeum vulgare* L.) at Kulumsa, Arsi Zone, Ethiopia

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As thesis research advisors, we hereby certify that I have read and evaluated the thesis under our guidance by Nure Kemal, entitled **"Effect of Seed Sources and Rates of Nitrogen Fertilizer on Seed Quality, Yield and Yield Related Traits of Malt Barley** (*Hordeum vulgare* L.) **at Kulumsa, Arsi Zone, Ethiopia"** prepared by **Nure Kemal**. We recommend that it be submitted as it fulfils the Thesis requirement.

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As members of the Board of Examiners of the open MSc thesis Open Défense examination of **Nure Kemal**, I certify that I have read and evaluated the thesis and examined the candidate. I recommend that the thesis be accepted as it fulfils the requirement for the degree of Master of Science in Agriculture (Seed Science and Technology).

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External examiner	Signature	Date

Final approval and acceptance of the thesis is contingent up on the submission of its final copy to the council of Post graduate Program Directorate through the Graduate Council of the school of plant sciences.

DEDICATION

This thesis work is dedicated to my mother Mrs. Hassie H/Hussein, my father Kemal haji my Wife Beshu Kiniso, and esteemed family.

STATEMENT OF THE AUTHOR

I declare that this thesis, which is titled "Effect of Seed Sources and Rates of Nitrogen Fertilizer on Seed Quality, Yield and Yield Related Traits of Malt Barley (*Hordeum Vulgare* L.) At Kulumsa, Arsi Zone, Ethiopia" is a result of my genuine work, and that all sources of materials used for this thesis have been profoundly acknowledged.

I submit this thesis to the school of graduate studies of Haramaya University in partial fulfilment of the requirements governing the award of the Degree of *Master of Science in Seed Science and Technology*. The thesis is deposited at the Library of the University to be made available to borrowers for reference. I solemnly declare that I have not so far submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHY SKECH

The author was born on September 12, 1988 at Shirka, Arsi Zone of Oromia Regional State, Ethiopia from his father Kemal H/Haji and his mother Hasia H/Hussein. He completed elementary (1995-2002) and secondary education (2003-2004) at Shirka Elementary and Shirka Secondary Schools, respectively. He joined Chiro Agricultural Technical Vocational Education and Training College (ATVET) in 2005 and at Asela ATVET in 2nd year (2006-2007) and graduated with Diploma in 2007. Thereafter, he was recruited by Oromia Agricultural and Natural Resource Development Bureau and served as Development Agent until 2014. He joined Adama Science and Technology University Asela branch in regular program and graduated with B.Sc. degree in Plant Sciences in 2017. Upon graduation, he was employed by the bureau of Agriculture and Natural Resource Development of Arsi zone, and served Shirka woreda as Agricultural Supervisor, Plant Protection, Coffee and Tea expert in 2018, 2019 and 2020, respectively. In 2021 he joined Oromia Agricultural Inputs and Product Regulatory Authority Asela office served as seed certification expert. He joined the School of Graduate Studies of Haramaya University in 2021 to pursue a study leading to the degree Master of Sciences in Agriculture (Seed Science and Technology).

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ABBREVIATIONS AND ACRONYMS

AACC	American Association Cereal Chemists
BIF	Business Innovation Facility
CGR	Crop Growth Rate
CSA	Central Statistical Agency
ERCA	Ethiopian Revenues and Customs Authority
ESA	Ethiopian Standard Agency
FAO	Food and Agriculture organization of the united nation
IFPRI	International Food Policy Research Institute
ISTA	International Seed Testing Association
KARC	Kulumsa Agricultural Research Center
MoA	Ministry of Agriculture
NBE	National Bank of Ethiopia
NUE	Nitrogen Use Efficiency
RGR	Relative Growth Rate
USDA	United States Department of Agriculture

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ABSTRACT

Malt barley is cultivated for both home consumption and market purposes in Arsi. However, limited availability of quality seeds and information on rate of nitrogen fertilizer for quality seed and malt quality of grain are among the constrains to boost the productivity of the crop. Thus, this study was carried out to evaluate the effect of seed sources and rates of nitrogen fertilizer on seed quality, yield related traits, yield and malt quality and estimate cost-benefit of seed sources and rates of nitrogen fertilizer for quality seed yield production of barley variety. Six seed samples of 'Traveler' malt barley variety from six seed sources (Gelema Union, Hunde gudena Cooperative, Lemu dima Cooperative, Oromia Seed Enterprise, Souflet Malt Ethiopia Plc., and Tuka ketar Cooperative) and four rates of Urea fertilizer (0, 75, 150, and 225 kg ha^{-1}) in factorial combinations were evaluated at Kulumsa Agricultural Research Center in Randomized Complete Design with three replications. The seed quality test was conducted at Asela Agricultural Inputs and Production Regulatory Authority Asela branch in Completely Randomized Design with four replications. The seed samples of the variety collected from six seed suppliers had 97.75,13.43, 93.17% and 40.82g mean physical purity, moisture content, germination and Thousand seeds weight respectively. The seed samples also had 63.07, 9.87 and 97.32% mean starch, protein contents and sieve test of grain, respectively. The seed sources and rates of nitrogen fertilizer significantly influenced most of the phenology, growth traits, yield components seed yield, seed quality and grain malt quality parameters of the variety. Interaction of seed source and rate of nitrogen fertilizer had significant effect on seed moisture content, percentages of dead seedlings, sieve test and grain starch content of the variety. The seeds obtained from Tuka ketar Cooperative produced highest seed yield (3154.17 kg ha^{-1}) while the lowest seed yield (2773.42 kg ha^{-1}) was produced from seeds obtained from Lemu dima Cooperative. The lowest (2519.61 kg ha^{-1}) and highest (3426.89 kg ha^{-1}) seed yield produced without fertilizer and 225 kg ha^{-1} Urea fertilizer application, respectively. The variety had lowest and highest grain protein content of 10.03 and 12.20% 'without fertilizer and 225 kg ha^{-1} Urea fertilizer application, respectively, and seeds obtained from Gelema Union. the lower (55.37) and higher (58.9%) starch contents measured for grain produced with 225kg ha^{-1} and without nitrogen fertilizer application respectively. The economic analysis indicated that the highest net benefit of 120158.5 Birr with marginal rate of return (MRR %) of 255% was obtained from seeds obtained from Tuka ketar Cooperative with 225 kg ha^{-1} Nitrogen fertilizer application whereas the highest MRR (%) of 911.3% was estimated for seeds obtained Gelema Union with 75 kg ha^{-1} Urea fertilizer application. It is concluded that the rates of fertilizer is better to be determined separately for seed yield and quality and grain yield and malt quality.

Keywords: Germination, Growth traits, Marginal rate of return, Protein and Starch contents.

1.INTRODUCTION

Ethiopia is recognized as a center of diversity for barley (Gadissa and Bekele, 2021) with a high level of morphological variation between landraces that resulted from adaptation to diverse climatic conditions and soil types. The country is one of the major producers of barley in Sub-Saharan Africa and the second largest producer in Africa next to Morocco, accounting for about 26% of the total barley production in the continent (Shahidur *et al*., 2015). In 2019/20 *Meher* season,3,915,584 smallholders' farmers grew barley on 950,742.01 hectares of land and produce 2,378,010.29 tons with the average yield of 2.501 t ha^{-1} (CSA, 2020).

Ethiopia has large suitable cultivated land for barley production, and farmers in the highland areas of Ethiopia have produced barley for food security and local markets (Berhanu, 2013). There is also high demand for malt barley products by malt and brewery factories in Ethiopia. This high demand for raw malt barley products is due to the older established and new emerging malt and brewery factories. It has a total of four malt and 12 brewery factories (Asokoinsight, 2019). As the result, Ethiopia has established a malt barley market value chain from the farmers to malt and brewery factories (Addisu, 2018; NBE, 2017). However, the supply of malt barley does not meet the demand of emergence of malt and brewery factories which covers only about 50% of it (NBE, 2017; Addisu, 2018; Business innovation facility BIF, 2018). As a result, the country imports malt barley that cost 40 million US dollar in 2014 and projected to reach as high as 420 million US dollar by 2025 (Rashid et al., 2015). Given the country's balance of payment situation in recent years, this is an alarming trend and not sustainable.

The yield of barley (2.501 t ha^{-1} in 2019/20 Meher cropping season) is also low as compared the achievable potential yield is 3-6 t ha^{-1} of different malt barley varieties under the optimum management and environmental condition of the research system of Ethiopia (Zewdie and Adamu, 2020). This is due to many environmental and socio-economic constraints the smallholder farmers faced. Soil acidity and waterlogging, soil degradation through erosion, frost, and low input use by subsistent smallholder farmers due to high price of inputs are among the major factors contributing to low productivity (Tesfaye and Assefa,2020).

Selection of variety is the first step in the successful production and marketing of malting barley. A good way to start malting barley production is by planting Certified seed.
The seed selected for planting should be true to variety, plump, free of weed seeds and diseases and also have high germination. Proper fertilizing is vital for producing good yields of an acceptable quality malting barley. Yield and/or quality will be lowered when nutrients are lacking. Many producers are reluctant to apply nitrogen fertilizer to malting barley crops because of concerns that nitrogen will produce a higher protein content. As a result, malting barley yields are often lower than optimal. Desirable protein levels are 10.5 to 13% for six-row and 10.5 to 12.5% for two-row malting barley. Protein content and yield will increase with increased rates of nitrogen application; however, protein content increases at a slower rate. For instance, where nitrogen application doubles yield, protein content may only increase by 1 to 2% (Agri-facts, 2009). Therefore, selection of variety, the use of quality seed and appropriate nitrogen fertilizer rate is critical for malt barley production to obtain high yield without affecting the quality of the product for industrial use.

The productivity of barley is low in Ethiopia. This is due to the lack of improved varieties, quality seed sources, poor agronomic practice (Inappropriate fertilizer rate and row spacing), diseases, weeds and low soil fertility in Ethiopia in general (Tesfaye and Assefa, 2020). Availability, access and use of quality seed of well adapted and preferred varieties remain a challenge for many crops in Ethiopia including malt barley. Efforts have been made to overcome the access of improved varieties and availability of quality seeds. The efforts include seed production through farmer cooperatives or farmer groups and some of the farmers are organized into seed producers' cooperatives linked to unions and public seed enterprises. The performance of farmer-based malt barley seed production proved to be feasible approach to improve timely access, low-cost deployment of technologies and scaling. The involvement of many actors (farmers groups, cooperatives, unions and public seed enterprises) also allows the supply of seeds for malt barley on time for producers (Zewdie and Adamu. 2020).

However, in addition to the seed supply, the seed quality supplied by all actors is also an important factor to improve the malt barley and narrow the yield gaps between the potential and attained yield of the crop. The seed quality of malt barley produced and supplied to producers by different actors separately tested by seed quality test laboratories

to check the seeds are fulfilling the minimum quality requirements. Thus, it is vital to evaluate the seed quality of malt barley varieties supplied by various actors and assess the effect of seeds from different sources on seed yield and quality of malt barley to increase the yield of the crop in the country.

Grain yield and malt quality of barley are largely influenced by the specific variety, soil property and applied nitrogen fertilizer rates. Consequently, nitrogen fertilizer application could lead to trade-off between grain yield and malt quality and grain yield resulting in significant loss for beverage industries and farmers. Excessively higher protein content is undesirable, because of the strong inverse correlation between protein and carbohydrate content; thus, high protein content leads to low malt extract level (Fasil and Zenebe, 2021). On the other hand, grain yield is greatly influenced by the supply of available nutrients, particularly nitrogen, in the soil in relation to the minimum amount required for dry matter production (Demise *et al*., 2015). Malting barley breeders all over the world are challenged by the difficulty in producing barley with appropriate crude protein level (Wang *et al.,* 2001; McKenzie *et al*., 2005; Men gel *et al.,* 2006). This is because not only the variety but also the supply of nitrogen from fertilizer determines the acceptable crude protein content of grain (Petters son, 2007). In Arsi zone, malt barley varieties are produced with application of 100 kg ha^{-1} of NPS and 150 kg ha^{-1} of Urea mixed with the NPS at time of planting. Other researchers also reported about the effect of nitrogen fertilizer rates on productivity and grain quality of malt barley varieties in Arsi zone (Addis, 2018**;** Business innovation facility BIF, 2018; NBE, 2018). However, information is lacking about the effect of seed sources and rates of nitrogen fertilizer on seed yield and quality of malt barley varieties in Arsi zone. Therefore, this research is initiated to achieve the following objectives.

- To determine the effect of seed sources and rates of nitrogen fertilizer application on quality and seed yield of malt barley variety, and
- To estimate cost-benefit of seed sources and rates of nitrogen fertilizer application for quality seed yield production of malt barley.

2.LITERATURE REVIEW

2.1 Botany, Center of Origin and Description of Barley

Barley *(Hordeum vulgare* L.) is a grass of the family Poaceae. It is one of the most important cereal crops in the world, ranking fourth in the production area next to wheat, maize, and rice. Barley with its long history of cultivation it's deeply rooted in the consumption habit of the population for utilized in more diverse forms than any other cereals (Tehulie, 2021). Cultivated barley *(Hordeum vulgare* L.) is one of the world's important cereal crops. Ethiopia is claimed to be the center of origin due to its high phenotypic diversity and flavonoid patterns. It is widely cultivated on subsistence bases and important in supporting the livelihood of local poor. However, the local landraces are currently under threat of severing genetic erosion. Hence, assessing the extents of its genetic diversity is timely in improvement and conservation (Gadissa and Bekele, 2021).

Ethiopia is a center of origin and diversity of many cultivated crops and their wild relatives including barley. The richness and range of genetic diversity in Ethiopia, particularly of landraces, is currently subject to serious genetic erosion and irreversible losses due to the changing nature of agricultural production (Tesfaye and Sime, 2022).

Seeds are complex biological systems comprising three genetically distinct tissues: embryo, endosperm, and maternal tissues (including seed coats and pericarp) nested inside one another. Cereal grains represent a special type of seeds, with the largest part formed by the endosperm, a specialized triploid tissue ensuring embryo protection and nourishment (Nowicki *et al.*, 2021).

2.2 Ecological Requirement of Barley Production

Ethiopia is a center of origin and diversity for many cultivated crops and their wild relatives. Due to altitudinal variation, it experiences a temperate climate, especially at altitudes of more than 2000 meters above sea level. In addition, soil variation, ecological diversity, substantial temperature and rainfall variations, and diverse social and cultural conditions have produced suitable environments for genetic variation of crop varieties (Tesfaye and Sime, 2022).

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. Malt barley requires a favorable environment to produce a plump and mealy grain. The malt barley varieties adapted to Ethiopian conditions require a longer period of ripening. They tend to grow in a relatively cooler climate with uniform rainfall distribution (700-1000 mm). It grows best at altitudes ranging from 2300 to 3000 m.a.s.l. in well-drained soils with pH of 5.5–7.3. In the barley-based farming systems of the highlands of Ethiopia, smallholder farmers have very few alternative cash crops. Barley grows best on well-drained soils and can tolerate higher levels of soil salinity than most other crops (Bayeh & Stefania, 2011). Food barley is commonly cultivated in stressed areas were soil erosion, occasional drought or frost limits the ability to grow other crops. Malting barley, however, requires a favourable environment to produce a plump and mealy grain. The diversity of barley ecologies is high, with a large number of folk varieties and traditional practices existing in Ethiopia, which enables the crop to be more adaptable in the highlands (Tsige, 2020)

2.3 Importance of Barley

Barley is one of the most important cereal crops in the world, ranking fourth in the production area next to wheat, maize, and rice. Barley with its long history of cultivation it’s deeply rooted in the consumption habit of the population for utilized in more diverse forms than any other cereals. Its grain is used as human food in the form of bread, dehulled and roasted barley grain, porridge, soup, and for malting purposes (Tehulie, 2021).

Malt barley is becoming a major income source to smallholder farmers in the highland areas of Ethiopia, particularly where the agro-ecologies are not more productive to other cereal crops (Ministry of Agriculture [MoA], 2018). despite by products from the brewing process and malt sprouts are also used in livestock feed. It is found that two-rowed barley is most often used for animal feed because it produces higher weight and superior kernel production. Barley is also used in the production of beer and some wines. About 25% of the cultivated barley in the United States is used for malting, with about 80% being used in beer production, 14% used in distilled alcohol production, and 6% used for malt syrup, malted milk, and breakfast foods. A small amount of the produced barley is used for human food in the form of pearl barley or in the form of flour for porridge.

Barley is one of the cereal crops which are an important crop in the world, mainly used for animal feed and malt. It is the fourth cereal crop in the world, and the most adaptable crop. It is also one of the most important staple food crops produced in the highland areas of

Ethiopia. Its grain is used for the preparation of different foodstuffs, such as injera, Kolo, and local drinks, such as Tela, borde and beer. The straw is used as animal feed, especially during the dry season. Besides its use as food, feed and beverage barely has many important features. It is adapted to wide environmental condition, matures soon and has high yield potential (Kaftamu Hunde, 2017).

2.4 Barley Production in Ethiopia

In Ethiopia, Barley production started long years ago and is largely grown as a food crop in the central and northern parts of Ethiopia, with Oromia, Amhara, Tigray, and Southern Nations, Nationalities, and People's Region (SNPPR) as the main areas of production and 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 (Wang *et al*., 2001; McKenzie *et al*., 2005; Men gel *et al*., 2021).

Barley is a cool-season crop that is adapted to high altitudes. It is grown in a wide range of agroclimatic regions under several production systems. At altitudes of about 3000 masl or above, it may be the only crop grown that provides food, beverages and other necessities to many millions of people. Barley grows best on well-drained soils and can tolerate higher levels of soil salinity than most other crops. Food barley is commonly cultivated in stressed areas where soil erosion, occasional drought or frost limits the ability to grow other crops. Malting barley, however, requires a favourable environment to produce a plump and mealy grain. The diversity of barley ecologies is high, with a large number of folk varieties and traditional practices existing in Ethiopia, which enables the crop to be more adaptable in the highlands (Bayeh and Stefania, 2011).

Malt barley is a high-opportunity cash crop, with great room for profitable expansion, particularly when connected to growing breweries. However, there is a shortage of quality malt barley varieties to meet the demand of the local breweries that forced the malt factories to import large quantity of malt barley from abroad. The gap between domestic supply and demand indicates an opportunity to enhance local production and substitute import through huge untapped malt barley potential in the country. Malt imports has grown tremendously reaching over 75 thousand tons in 2017 covering about 70% of total annual demand and costing the country about 41.5 million USD (ERCA, 2017).

In Ethiopia, smallholder commercialization and integration into the market has been one of the policy directions. Though Ethiopia managed to raise economic growth recently, there is languished pace of agricultural commercialization. Malt barley commercialization process through contract farming scheme, and its experience, effect and prospects in Ethiopia. A systematic review system was employed. Now contract farming is evolving in Ethiopia, while the motives for promoting contract farming may vary by actor, the role of contract farming scheme in malt barley commercialization. Foreign investors took up the beer companies and upgraded their working capacity leading malt demand by 83%. Malt barley contract farming scheme was introduced by Heineken brewery to ensure local sourcing of malt. Recently, Heineken managed sourcing malt barley contracted farmers in Arsi Zone (Addis Bezabeh, 2018).

Barley is an important food grain and malting crop in the Ethiopian highlands with malting barley a major source of income for smallholder farmers. Despite a favorable biophysical environment, production and productivity of malt barley is low in the country. The malting quality of barley is one of the economically important traits, which are controlled by environmental factors and management practices such as variety, rate and time of nitrogen application. Arsi zone, barley is a major crop produced by small holder farmers. However, its production and productivity are low due to the use of inappropriate nitrogen fertilizer rate and local low yielding varieties (Shimels & Kef ale, 2021).

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

Barley (*Hordeum vulgare L.)* is one of the ancient cereal crops of agriculture in the world and one of the first domesticated cereals and fourth largest cereal crop next to maize, wheat and rice in the world. It contributes seven percent of the total cereal production. The production of barley in Ethiopia reduced by many factors from these biotic factors including rodents, pathogens, diseases, weed, pests, insects and abiotic stress like drought, flooding, temperature stress, salinity, poor management practice, low seed quality, frost, poor soil fertility, agronomic practice etc. among those the most important factors that reduce yield of barley in Ethiopia are the use of inappropriate organic fertilizers (Yimer, 2022).

Barley is an important food and beverage crop in the highlands of Ethiopia. Despite many importance of barley and its many useful characteristics, there are several factors affecting its production. Low Soil fertility is one of the major constraints affecting its production. Integrated nutrient management, where both natural and man-made sources of plant nutrients are used, is the best approach to supply adequate and balanced nutrients and increase barley productivity in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations. The basic concept underlying the combined applications of fertilizers is the adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining desired barley productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner. Therefore, increased attention should be being paid to developing an integrated soil fertility management that maintains or enhances soil productivity through balanced use of all sources of nutrients, including organic and inorganic fertilizers (Mistaught Adane, 2020).

Barley is the most important cereal crop in the world after wheat, maize, and rice, and is among the top ten crop plants in the world. However large numbers of farmers are not using improved technologies such as nitrogen fertilizer. It has been selected as one of the target crops in the strategic goal of attaining national food self-sufficiency, income generation, poverty alleviation, and achieving socio-economic growth of the county. However, its production and productivity are low due to the use of inappropriate nitrogen fertilizer rates. Nitrogen fertilizer is very important to the growth and improves yields of barley, so the farmers should use the appropriate rate of nitrogen fertilizer to increase plant height, spike length, number of fertile tiller grain weight, and grain yield of barley (Tehulie, 2021).

Barley is major staple grain which accounts for over 60% of the food of the people in the highlands of Ethiopia and cultivated by small holders in every region of the country. Even though it is able to grow at all elevations, but it performs best at the higher elevations in the northern and central regions of the country. Based on CSA and FAOSTAT official data of recent, the production and productivity of Barley shows nearly increasing pattern, but constrained by low rainfall, seed source and depilation of soil fertility which are the major causes of yield losses. In addition to these, Crop damage during planting, harvesting, and post-harvest handling is another major abiotic factor that causes significant barley yield losses in Ethiopia. Malt barley produced by the smallholders is constrained with lower quality. This is often due to farmers lacking the right inputs (seeds and fertilizers). The inputs that need to be targeted for improving malt barley quality and productivity should be improved seeds, fertilizers, credits and agricultural extension services. The capacity of smallholders to improve productivity as well quality depends on the interactions of factors including the availability of appropriate production technologies, the effectiveness of agricultural extension services and access to credits and finance (Bedada Begna1, 2020).

Generally, in the marketing activities, farmers gate the highest net margin (share) as compared to traders and processors due to the smaller cost they incur followed by Processors and traders. The major actors in the barley value chain are the input suppliers, farmers, rural assemblers, cooperative unions, grain wholesalers, processed food wholesalers, grain retailers, and retailers of processed food. The support actors that are currently providing support to the value chain are agriculture office of the woreda through supply of technical support through extension system; seed enterprises both the federal and regional enterprises that are providing seed to the farming communities through cooperatives, woreda administration, store service providers, transporters, universities and private chemical traders. The major constraints of Barley marketing involve poor storage and handling, poor value chain development, and low upgrading strategies to the commodity. Moreover, the major constraints identified as factors that affect Barley Value Chain are: Shortage of supply of disease resistant and high yield varieties, Weed and pest occurrence, Low soil fertility and low soil pH, Poor soil drainage, Frost and drought, Diseases, such as scald, net blotch, spot blotch and rusts, Rising costs of transport, Market price fluctuation and channel choice problems by producers (Samuel, 2016).

The malting industry in Ethiopia is often challenged by the availability of a barley variety, Seed source that meets the quality and quantity requirements set by the industry. Recently, the demand for malting barley has increased significantly in Ethiopia because of the increasing number of beer industries in the country, and more attention is now being given to meeting the demand for this crop. Selection of improved malt barley varieties in different locations is important to boost the grain yield and to fill the demand of malt barley for the users (Assefa *et al.*, 2021).

2.6 Role of Seed Quality on Seed Production

Seed quality describes the potential performance of a seed lot. Trueness to variety; the presence of inert matter, seed of other crops, or weed seed; germination percentage; vigour; appearance; and freedom from disease are important aspects of seed quality. High-quality seed lots should meet minimum standards for each of these characteristics. Trueness is usually determined by records of seed sources and by field inspections of the plants that produce the seed. It is also defined as a uniformed sum of seed features that after sowing lead to a rapid and uniform germination, forming of strong and healthy seedlings which will give the necessary number of plants in favorable and unfavourable environmental conditions (Kansiime *et al.*, 2021).

The seed quality is also reflected in the final growth, maturity of plants, their uniformity and stability of yield. Uses of quality seed of improved varieties has the potential to withstand stressful environmental conditions and significantly increase yield productivity per unit area (Amsalu, 2020).
Poorer quality seeds show low viability, reduced germination and emergence rates, poor tolerance to sub optimal conditions and low seedling growth rates (Sai Reddy *et al.*, 2021). The seed quality is also reflected in the final growth, maturity of plants, their uniformity and stability of yield (Alemu, 2019).

Seed and its quality among others are vital input in crop production. Crop response to other inputs largely depends on the quality of seed. It is estimated that good quality seeds of improved varieties alone can contribute about 18 to 20 per cent increase in crop yield keeping all the other inputs constant. Seed germination and vigour are important indicators of quality which are substantially reduced during storage. Seed aging and improper storage environment is recognized by some parameters like delay in germination and emergence, slow growth and increasing of susceptibility to environmental stresses in various periods of storage. Seed quality decreases under long storage conditions due to long seed storage period. It is the reason of declining in germination characteristics. Long seed storage period is manifested as reduction in germination percentage and those seeds that do germinate produce weak seedlings (Gadissa, 2019).

Therefore, the availability of quality seeds is one of production constraints. The production of seeds from improved variety from right seed source and stored for shortest possible duration period are among the requirements of quality seed production (Ofori *et al.*, 2020).
Generally, Seed quality is very important to optimum growth and yield production in farm which influenced by many factors such as genetic characteristics, viability, germination percent, vigour, moisture content, storage conditions, survival ability and seed health. High quality seed is important to ensure maximum seed germination and seedling vigour, which is turn is instrumental in achieving maximum yield. poorer quality seeds show low viability, reduced germination and emergence rates, poor tolerance to sub optimal conditions and low seedling growth rates.

The seed quality is also reflected in the final growth, maturity of plants, their uniformity and stability of yield. Seed size is an important physical indicator of seed related to yield, market grade factors and harvest efficiency. Seed size was the trait that was most consistently associated with yields. Seed size was the most consistent seed trait that influenced growth and yield (Gebeyehu, 2020).

The value of seed depends on its quality. Hence, evaluation of seed quality is of critical value in any seed production system. It is, therefore, desired that seed quality is tested for all essential parameters, following the standard procedures and performing the tests in such a manner that the results are consistent and are reproducible, within the permissible limits of tolerance. As the submitted sample is only a minute fraction of the whole seed lot, reproducibility and reliability of results will greatly depend on the precision of sampling (Dadlani and Yadava, 2023).

2.6.1 Seed physical quality parameters

Purity analysis is to determine the percentage composition by weight of pure seeds, seeds of other species and inert matters that make up the sum total of the sample. Seed samples can contain impurities such as weed seeds, seeds of other crop species, detached seed structures, leaf particles and other materials. Pure seed is defined as seeds of the cultivar stated by the sender or found to predominate in the purity; Seed cleaning and sizing is essential to remove straw, chaff, dirt stones, weed seeds, and broken, diseased or small shriveled kernels (ISTA, 2016).

Taking a germination test is essential to determine the seed viability. After seed germinability has been determined, the seeding rate can be determined. Seed to be used for planting should be above 85 percent germination. Using certified seed is an excellent way to ensure the quality of a seed lot. Certified seed is the grower’s best assurance of purchasing excellent quality seed (Mules a *et al.*, 2021).

Physical purity of crops is different in different varieties and seed sources (Singh *et al.*, 2021). it is maintained by field and seed inspections for maintaining standards, and adhering to the processing specifications. Hence, knowledge of seed morphology and identification of weed seeds are important. Purity testing and labelling are therefore, mandatory for quality seed (Dadlani and Yadava, 2023).

2.6.2 Determination of seed physiological quality

Seed quality is very important to optimum growth and yield production in farm and influenced by many factors such as genetic characteristics, viability, germination percent, vigour, moisture content, storage conditions, survival ability and seed health, but their most important is germination percent and vigour.
The aim of the seed germination test is to estimate the germination potential of a seed lot, which can then in turn be used to compare the quality of different lots and estimate the field planting value of all crops (ISTA.2001). Majid and Mohsen (2012) described that the difference in germination percentage is due to the factors such as varieties, environment and parental nutrition, maturity stage in harvest time, mechanical damages, seed storages, age and pathogens, affect seed germination and vigour. The crop sown with bolder seeds (large size seeds) had higher seed germination as compared to the crop sown with small size seeds. This shows that bolder seeds represent the seed quality that resulted in more germinated seedlings as compared to those sown with relatively low-quality seed (small size seed) (Abdul *et al.*, 2014). One of the important criteria in seed vigour is the amount of dry matter or the seed weight (Fouad *et al*., 2021).

Germination and seedling emergence requires a lot of energy that prepared through the oxidation of seed storages. Seed should have adequate food supply for seedling growing because seedling until enough growth is dependent to seed. In general, in seedling growth test, with increasing in thousand grain weight, increased significantly the traits of seedling length and seedling dry weight. More seedling weight and seedling length of the heavy seeds might be attributed to large food reserves of these seeds (Gharineh and Moshatati, 2012).

Germination can occur if three conditions exist: the embryo must be alive; seed dormancy must be overcome, and the proper environmental conditions must exist for germination. An alteration of any of these conditions will have an impact on the germination process. Abnormal seedlings are those seedlings with weak or unbalanced development of essential structures such as spirally twisted or stunted plumules, hypocotyls, or epicotyls, swollen shoots, stunted roots, split plumules, coleoptiles without primary leaves, watery seedlings or without further development after emergence of the cotyledons and normal development is prevented (ISTA,2004)
In seedling growth test, thousand kernel weight significantly affected seedling length so that with increasing in thousand grain weight, seedling length increased and the lowest seedling length related to lowest thousand grain weight, and the highest seedling length

belonged to highest thousand grain weight(Awulachew, 2019). Seed weights also significantly affected the seedling dry weight so that with increasing in thousand grain weight, seedling length increased and the lowest seedling dry weight related to lowest thousand grain weight, and the highest seedling dry weight belonged to highest thousand grain weight. In general, in seedling growth test, with increasing in thousand-grain weight, increased significantly the traits of seedling length and seedling dry weight. More seedling weight and seedling length of the heavy seeds might be attributed to large food reserves of these seeds. According to Agrawal (1980) vigour can also be measured by dry weight of seedling and germination percentages. Measuring the length of seedling and their weight is often used to determine physiological seed vigour.

Germination is the process of by which a dormant seed starts to sprout and become a seedling under favorable condition. Barley storage is an important character for its processing and to maintain its ability to germinate rapidly that helps to keep or improve its quality, Storage time and Storage Temperature were used as a factor for quality of malt barley variety. Storage time up to one year cannot affect the quality of malt barley variety but the storage Temperature significantly affect the quality of malt barley variety especially germination energy was improved up to 97%at the storage Temperature of twenty-five (25 ^{0}C) for variety under storage material (Abushu and Kef ale, 2018).

Barley must be alive in order to be processed into malt. Germination ability for malting is assessed using standardized tests develop by the malting industry. Storage in different sources one of the factors that influence the quality of malt barley quality and storage conditions determine the rate at which post-harvest maturation occurs. Storage of barley under appropriate environment condition removes and improves germination Technique's (Kef ale, 2019). when the storage time increases, the germination percentage and the nutritional values of barley crop were decreased for all nutritional values and total carbohydrate. Thus, it helps to profile the overall barley nutritional information and long-term storage effect for both consumption and research purpose (Sen beta and Dida, 2019).

Some malting barley varieties can exhibit dormancy, where live kernels fail to germinate under ideal conditions. In General, the storage time up to one year malt Barley samples stored under Jute bag and plastic bag (Fertilizer bag) the quality of malt barley remains unchanged (Abush and Kef ale, 2018).

2.7 Importance Quality Traits of Malt Barley

Barley (*Hordeum vulgare* L.) is an annual cereal crop that belongs to the grass family Poaceae of the tribe Triticeae. the contamination of barley with microorganisms is greatly influenced by various impurities that enter the grain mass during harvest. As well as various impurities in the grain mass of seed of malting barley, the grains of other plants wheat, rye and oats were found in some samples of seed sources in quantity of about 4%. There were also a lot of beaten barley grains, in some samples more than 2%. The moisture content of the grain mass also affects the seeding by microorganisms. Impurities had a higher humidity than grain, purified from impurities. To reduce the microbial contamination of seed barley grains, it is necessary to thoroughly clean and refine the grain mass immediately after harvesting (Belokurova *et al.*, 2020).

Barley is the fifth most important cereal crop after tef, wheat, maize and sorghum in area coverage in Ethiopia. Important malting barley quality characteristics depends upon various grain parameters as kernel shape, size, boldness, grain protein content, moisture content, germination capacity and etc., which affects the malt quality that is malt yield, friability, homogeneity (Assefa *et al.*, 2021).

The availability of barley for malting is not a problem, but whatever barley is available it is very poor interims of quality and not meeting the minimum standards of malting quality. So, that identification of malt barely varieties with different grain and malt parameters, which are desired for better malt production and quality improvement, needed for various products is very essential. Potential areas that boost the production, pertinent agronomic practice studies and strengthening micro malting laboratory and expert capacity are recommended to overcome the limitations of malt barley production and malt quality improvement. Generally high-quality malt barley variety has depended on, Pure lot of an acceptable variety, Germination is 95% or above, Protein content ranging between 9.5% to 12.5% (dry basis), Moisture content below 13.5%, Plump and uniform kernels, Free of disease and other contaminated agents, less than 5% peeled, broken and damaged kernels, Clean and free from any foreign material which is different from the original one (Gebeyaw Makonnen, 2020).

2.7.1 Grain Protein Content

Grain protein content (GPC) is the main quality trait of barley (Hordeum vulgare L.) because this parameter is a decisive component of seed quality for malt industry. Reaching the level of protein concentration required by the raw industry is very difficult, due to the negative correlation with the yield level (Vasilescu, Bude and Petco, 2019).

Grain protein content increased with increasing N rate in a linear fashion, indicating a direct impact of N fertilizer rate on malting barley grain quality. Increasing N rates to achieve maximum grain yields caused grain protein content to exceed the maximum acceptable value (11.5%) for malting, so that careful N fertilizer management is necessary for malting barley production (Kassie and Tesfaye, 2020).

The protein content of the barley grain affects the chemical composition and enzyme levels of the finished malt. If the protein is too high, this limits the starch content and amount of extract available to the brewer. High protein grain also takes up water slowly and is harder to modify in the Malthouse. On the other hand, if the protein to too low, there may be insufficient enzymatic activity to modify the barley kernel and break down starch for brewing. An ideal protein range is 9.5% to 12.5% (dry basis). Grain with a higher protein content can be suitable for producing malt for distilling. The protein level in the grain is determined both by agronomic practice, and by the environment. Hot, dry growing seasons tend to result in higher protein grain at harvest than cool, wet seasons. Excessive rates of nitrogen fertilization can also increase protein levels, although varieties can respond differently.

Grain protein content exceed from the recommended levels were undesirable for malt factory that increase the steeping time and cause uneven water uptake during steeping, create uneven germination during malting, and increase malt loss due to abnormal growth (Bekele and Ayalew, 2020).

2.7.2 Moisture content

Seeds are hygroscopic, meaning they exchange water with their surroundings until they reach equilibrium. The tendency of water to move into the tissues from the external environment is dependent upon the relative humidity (RH) of the atmosphere and the moisture content of the seed. It also depends on the chemical composition (oil content), size, and seed coat properties. Seeds with a higher oil content have a lower moisture content at a specific RH compared with lower oil content seeds (Whitehouse and Lusty, 2020).

To maintain quality on storage, moisture content of malting barley must be < 13.5%. This will reduce the risk of Mold growth and ensure long term preservation of germination ability. Barley should be stored in bins with good air circulation to prevent hot spots which can cause heat damage and Mold problems.

Thus, moisture content can affect the grain quality as well as its germinative capacity. Moisture levels need to be low enough to inactivate the enzymes involved in seed germination as well as to prevent heat damage and the growth of disease microorganisms. Quality and germination capacity may also significantly deteriorate (Lemma, 2019).

2.7.3 Kernel Plumpness

Barley grain used for malting should be uniform and plump to allow for consistent processing and for high yields of malt extract. One important factor affecting the size, shape and uniformity of barley kernels is the number of rows of kernels on the barley spike. Plump and uniform kernels are desirable as plump kernels contain higher levels of starch, which will produce more beer from a given weight of malt. Plumpness is assessed by sieving over a 6/64" slotted screen with greater than 80% kernel retention being ideal for a two rowed barley. Six rowed varieties are generally less plump than two rowed, overall increase in 1000-kernel weight and kernel plumpness with increased N rates (Kassie and Tesfaye, 2020).

2.7.4 Hectolitre Weight

Grain specific weight is measured in kg/hectolitre, and is an indication of the density of the grain. When available nitrogen is deficient, hectolitre weight will be lower. However, once nitrogen requirements are met, additional nitrogen has the potential to result in reduced test weight. Managing nitrogen carefully to meet, but not exceed yield goals maximizes the likelihood of a good hectolitre weight.

Hectolitre weight in small grains including wheat, oats and barley is an important component of crop quality and value. Several factors influence the hectolitre weight of small grains, including drought, nutrient deficiencies, quality of seed source, temperature extremes, plant lodging, insect damage and adverse weather events like frost and hail (Kassie and Tesfaye, 2019).

2.8 Role of Nitrogen in Crop Production

Nitrogen is the most important essential nutrient that comes under macronutrient category as it plays vital role in various physiological processes in plant as it produces rapid early growth, improve fruit quality, protein content in fodder crops, vegetative growth in plants, leaves, stem growth and imparts dark green colour to plants. When different level of nitrogen applied in Barley (*Hordeum vulgare L.*) at different sowing dates, it resulted in increased rate of growth parameters like plant height, number of tillers per hill, CGR (Crop Growth Rate), RGR (Relative Growth Rate), plant dry weight and yield attributes like grain yield, straw yield, number of effective tillers (Kumar, 2020).

Nitrogen deficiency in cereals results in restricted, poor tillering, thinner and smaller stems, premature ripening of grains are and the low number of ears per unit area and the low number of grains per ear. The Amount of N affects single spike weight and the spike weight increased as the amount of N increased. N application increased spike length, plant height, number of the tiller, grain weight, grain yield which increased the level of nitrogen and also increased grain yield with an increased level of nitrogen (Tehulie, 2021).

2.9 Effect of Nitrogen on Yield and Quality of Malt Barley

N affected leaf area, number of productive tillers per plant, number of spikes, grain per spike, plant height, straw yield, harvest index, thousand grain weight, grain size, grain protein content and germination energy were effects of N levels (Derebe Terefe, Temesgen Desalegn, 2018). Grain yield and malt quality of barley are largely influenced by the specific variety, soil property and applied nitrogen fertilizer rates. Consequently, nitrogen fertilizer application could lead to trade-off between grain yield and malt quality and grain yield resulting in significant loss for beverage industries and farmers, Malt extract content and germination energy were significantly affected by main effect of malt barley varieties, while grain protein content affected by nitrogen rate (Fasil and Zenebe, 2021).

The amount of nitrogen that a barley crop needs to maximize yield and quality will depend on the seasonal conditions, soil type, and rotational history of the soil as well as the potential yield of the crop. The rate of uptake and partition of N is largely determined by supply and demand during various stages of plant growth. Soil N supply, for example, must be high at tillering, stem elongation, booting, heading, and grain filling requiring a greater amount of the development and growth of its reproductive organs and for an enhanced and high accumulation of proteins in the kernel. Nitrogen is needed for the early tiller development of barley to set up the crop for high yield potential. Spilt N application had little effect on yield but decreased lodging and spike population with increased grain weight. Increased grain yield with increased in nitrogen level.

However, increasing N fertility beyond a certain limit induced lodging and ultimately decreased grain yield and its components (Tehulie, 2021). Barley yield tended to increase with N application rate while quality decreased due to increased protein concentration (Shrestha and Lindsey, 2021).

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

Information on crops response to N fertilizer rates, time of application and improved variety is very important to attain profitable and sustainable malt barley production with quality.
Excessive N causes excessive vegetative growth, resulting in greatly increased danger of lodging, delayed maturity and greater susceptibility to diseases and pests. N application at proper dose has the most important effect in terms of increasing crop production. N is a key factor in achieving an optimum yield in cereals and in their growing period requires lot amount of absorbed N. Proper dose of N increased leaf area, tillers formation, leaf area index and leaf area duration and this increase led to much greater production of dry matter and grain yield. In order to obtain greatest advantage from the fertilizer use the fertilizer should not only be applied in optimum quantity at recommended rate but also at right time as timely N application is one of the agronomic technique which has helped considerably in increasing the N use efficiency (NUE).It is now very well established that for most crops N must be applied in two or three split doses coinciding with the crop growth stages when its requirement is high therefore, it is high time to assess the effect of time of application of the recommended N fertilizer to increase the fertilizer use efficiency in barley. It is very important and crucial in crop production to nutrient supply is synchronized with plant demand in time and space throughout the growing season to get good yield and quality product acceptable along the value chain. Split applications reduce the exposure of N in saturated soils where the potential for losses such as leaching and denitrification are increased. Increasing fertilizer use efficiency is very important, particularly in developing countries where the fertilizer is very expensive driven mainly by increases in the price of natural gas. From the different research studies evident that time of split N applications generally improved grain yield of barley (Admasu, 2020)

2.11 Effect of Seed Source on Yield and Quality of Malt Barley

The major constraints in fulfilling the growing demand of malt barley in Ethiopia are limited as a result of the selection of a favourable production environment, long-time seed

storage for market, low quality of seed source advantages among others are few to mention, Besides, few research findings are available on evaluation of the potential differences across sites and crop management practices to meet malting and brewery industry quality standards (Bulli and Chofere, 2022).

Malt barley is the most important cereal crop grown in highland parts of Ethiopia. Even though Ethiopia has favorable environment and potential market opportunity, the share of malting barley production is quite low (about 15%) as compared to food barley. One reason for low production is the use of low yielding varieties and Seed source (Bizuneh and Abebe, 2019). The low yield per hectare is attributed to many factors, such as seed source, unavailability of quality seed, use of poor-quality seeds, inappropriate seed size and seed rate are some of the factors. Seed source influenced growth and yield during the growing season but the response depended on seed size and variety (Gadissa, 2019).

Moisture content below 13.5%, Plump and uniform kernels, Free of disease and other contaminated agents, less than 5% peeled, broken and damaged kernels, Clean and free from any foreign material which is different from the original one was affected by seed sources; rates of N fertilizer application and their interactions (Berhan Getie, 2017).

Sourcing certified seed can help ensure that the variety is pure (Not mixed with other varieties), meets germination targets, and is free of weed seed and seed-borne diseases. Grain that has been grown for feed or malt often will not meet these parameters and can negatively impact production from the start (Meints *et al*. 2021).

2.12 Nitrogen Use Efficiency of Malt Barley and Management

Nitrogen (N) fertilization plays an important role in crop production; however, excessive and inefficient use of fertilizer is a global issue that incurs high production costs, pollutes the environment and increases the emission of greenhouse gases. To overcome these negative consequences, improving nitrogen use efficiency (NUE) would be a key factor for profitable crop production either by increasing yield. It also has a worldwide economic impact due to the high production costs of N fertilizer and affects the protein content in barley, which is a major concern (Karunaratne *et al*., 2020).

2.13 Malting Barley Specific Quality Parameters

Different barley and malt quality parameters such as grain protein content, grain moisture content, water sensitivity, glassiness, germination energy, germination capacity, thousand kernel weight, hectolitre weight, malt protein content, extract, malt weight loss, malt moisture content, filtration time, saccharification time and wort viscosity were carried out. Briefly, a protein content between 10% and 12% is ideal; at these protein levels there is an optimal ratio of enzymes to starch, which is needed to efficiently convert starch to sugars and produce a high-quality malt extract. Excessive protein can result in lower malt extract production and hazy beers. Plump kernels of uniform size will germinate consistently during the malting process (Verhoeven *et al.*, 2019).

The greatest use of barley for malting purpose mostly for brewing industry. The quality of malt depends upon various grain parameters as kernel shape, size, boldness, grain protein content etc., which affects the malt quality that is malt yield, friability, homogeneity. The availability of barley for malting is not a problem, but whatever barley is available it is very poor interims of quality and not meeting the minimum standards of malting quality. So, that identification of malt barely varieties with different grain and malt parameters, which are desired for better malt production and quality improvement, needed for various products is very essential. Generally high-quality malt barley variety has its own characteristics: Pure lot of an acceptable variety, Germination is 95% or above, Protein content ranging between 9.5% to 12.5% (dry basis), Moisture content below 13.5%, Plump and uniform kernels, Free of disease and other contaminated agents, less than 5% peeled, broken and damaged (Kumar *et al.*, 2022)

3.MATERIALS AND METHODS

3.1 Description of the Study Area

The research consisted of two activities viz. 1) field experiment and 2) seed quality evaluation. The field study was conducted at Kulumsa Agricultural Research Center during 2022 cropping season and laboratory experiments were also conducted at Kulumsa Agricultural Research center (protein content, starch content and kernel sieve test) and other seed quality test was conducted at Oromia Agricultural Input and Production Regulatory Authority Asela Branch. The study site is located at 08° 01' 10" N and 39° 09'11E at an elevation of 2170 meters above sea level in Arsi Administrative Zone of Oromia Regional State, at 167 km southeast of Addis Ababa. The soil is deep to very deep (>100cm) and clayey in texture. The pH of the soil ranges from 6.593 to 6.786 and subsurface soils have higher pH values than surface soils (Abayneh *et al*., 2003). The agro-climatic condition of the area is wet and receives the annual mean rainfall of 809.15 mm from March to September; however, the peak season is from July to August. The average annual maximum and minimum mean temperatures are 23.08 and 9.9°C, respectively (Jemal *et al.,* 2015).

3.2 Experimental Materials

The six seed samples of 'Traveler' malt barley variety from six seed producers and sources (seed samples obtained from Gelema Union, Hunde Gudena, Lemu Dima, Oromia Seed Enterprise Arsi (OSEA), Souflet Plc. and Tuka Ketar) were collected. The description of 'Traveler' malt barley variety presented in Table 1.

Table 1. Description of 'Traveler' malt barley variety

Variable	Description
Altitude (m.a.s.l) (Adaptation)	2000–2600
Maintainer/breeder center	HEINKEN/ Holetta Agricultural Research center
Year of release	2013
Days to heading	79–93
Days to maturity	130–160
Yield at research station (q ha^{-1})	20–40
Protein content (%) during release	10–11.1
Disease reaction	Resistance to net blotch

Source: Abebe *et al*. (2021).

3.3 Treatments and Experimental Design

The six seed samples of 'Traveler' malt barley variety with the same seed class(C1) produced 2021 crop season from six seed sources were used for field and seed quality evaluation with the application of four rates of Urea fertilizer (0, 75, 150, and 225 kg ha^{-1}). The field experiment was conducted in Randomized Complete Block Design (RCBD) with three replications to evaluate a total of 24 treatments as 6 (seed sources) x 4 (rates of Urea fertilizer) factorial arrangement. The gross plot was prepared with 1.2 m x 2.4 m =2.88 m^2 consisting of six rows with the net plot size of 0.8 m × 1.9 m (1.52 $m^{2)}$ with four rows. The outermost one row on both sides of each plot and 25 cm of two ends was considered as border plants. The distance between adjacent plots and blocks were 0.5 m and 1 m apart, respectively.

The seeds of each treatment harvested at each replication were bulked and thoroughly mixed to obtain homogenized seed samples to deliver one kilogram of samples from each treatment for seed quality test at the laboratory was carried out in a Completely Randomized Design (CRD) with four replications. The 24 treatments combinations (6 seed sources x 4 rates of Urea fertilizer) in factorial combination were used. The International Seed Testing Association rules and procedures were applied for the evaluation of seed quality (ISTA, 2014).

3.4 Experimental Procedures and Management

Field experiment: The experimental plots were prepared following the conventional tillage practices. The seeds obtained from six seed sources were sown in rows at the recommended rate of 100 kg ha^{-1} in each row of plots by hand drilling method. The hand drilling sown seeds covered lightly with soil (at the depth of 3-5 cm) during the planting time. All plots were received blended NPS fertilizer (19% N, 38% P_2O_5, and 7% S) at the recommended rate of 100 kg ha^{-1} for the study area. The entire rate of NPS fertilizer was applied at sowing. The Urea fertilizer (46 kg N) at the rates of treatments (0, 75, 150, 225 kg ha^{-1} N) was applied into three splits (at sowing, mid-tillering and anthesis stage) as a source of nitrogen (Admasu, 2020). The plots were kept free of weeds by hand weeding at different growth stages of the crop. Fungicide (Rexduo and Tilt) at flowering 0.5 lit ha^{-1},1litha^{-1} respectively and insecticide (Karate) at tillering were applied at levels to prevent diseases from limiting yield.

All other agronomic practices were done as the recommendation made for barley seed production (Zewdie and Adamu, 2020). The trashing and seed conditioning (cleaning of seeds and other seed production practices at the farm level) were conducted as per the recommendation made for barley seed production (Buli and Chofere, 2022).

Seed quality test: The seeds of each treatment that harvested from each replication were bulked and thoroughly mixed to obtain homogenized seed samples to prepare one kilogram of seeds from each treatment for the seed quality test at the laboratory. The sub-sample of 400 seeds from one-kilogram seeds of each treatment was randomly taken and divided into four (100 seeds each) and each part (100 seeds) was assigned as one replication. Preliminary seed quality of seed samples was evaluated before planting for physical quality (seed purity, thousand seed weight and seed moisture content) and standard germination as per ISTA (2014) procedures for the crop. In addition, seed samples were evaluated for starch and total protein content as per malt factory procedures for malt barley. The seeds collected from the 24 treatments were evaluated for physical quality (seed purity, thousand seed weight and seed moisture content), and physiological quality (standard and speed of germination, seed vigour), to know physical purity and physiological purity according to ES (2012) and ISTA 2014).

3.5 Data Collection

3.5.1 Data Collection and Measurement from Field Experiment

3.5.1.1 Phenology and growth parameters

Days to 50% heading (DH): it was determined and registered as the number of days taken from the date of sowing to the date of 50% heading of the plants from each plot by visual observation (Shimels & Kef ale, 2021).

Days to 90% physiological maturity (DM): it was determined as the number of days from sowing to the date when 90% of the peduncle turned to yellow in straw colour when grain easily detached from glumes by pressing between thumb and forefinger and grains are difficult to break with thumb nail (Fasil and Zenebe, 2021).

Plant height (cm): it was measured from the soil surface to the tip of the spike of ten randomly selected plants from the net plot area at physiological maturity; the mean height of 10 plants was calculated and registered.

Spike length (cm): it was measured from the bottom of the spike to the tip of the spike excluding the awns from ten randomly selected spikes from the net plot and then the mean was calculated and registered.

Total tillers (m^2): total tillers (both effective and non-effective tillers) were determined at maturity by counting all the tillers in 0.5 m length row taken from each net plot area.

Number of productive tillers (m^2): The number of tillers bearing spikes was counted as productive tillers (effective tillers) at maturity in 0.5 m length row taken from each net plot area.

Number of kernels per spike (NKPS): Number of kernels per spike was calculated as an average of ten randomly taken spikes from the net plot area.

Biological yield (t ha^{-1}): it was measured and recorded by weighing the sun-dried total above ground plant biomass (straw + grain) at maturity from four central rows of the net plot size and converted to ton per hectare.

Seed yield per hectare (t ha^{-1}): it was determined from grain yield obtained from four central rows of the net plot size. The grain yield of each plot weighted then after it was cleaned and sorted carefully to make it free from other materials, shrivelled seeds, seeds with physical and pest damage, and other seeds that cannot be used for planting. The seeds obtained from grain yield after cleaning and sorting were weighted, adjusted to 12.5% moisture content, and registered as seeds yield per plot that was used to estimate seed yield tons per hectare.

Harvest index (%): Harvest index was calculated from ratio of grain yield per plot to total aboveground dry biomass yield per plot multiplied by 100.

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.5.2 Data Collected from Seed Quality Test

Thousand kernels weight (g): Thousand kernel weight was determined based on three samples of 1000 kernel weight took from the grain yield of each net plot by using electronic seed counter and weighed with sensitive balance. Finally, the mean was computed and the weight was adjusted to 12.5% moisture content.

Moisture Content (%): The grain moisture levels were measured by apparatus (grain analysis computer (GAC) 2100) as described in the AACC (2000) method.

Seed purity (%): it was determined based on International Seed Testing Authority (ISTA, 2014), purity analysis for each 'pure' seed of treatments, 200g seeds sample was separated from 1 kg working samples, sorted and categorized into four components including (i) pure seed, (ii) other crop seeds, (iii) inert mater and (iv) weeds seed. The percentage of each fraction was registered on a weight-by-weight basis. The percentage of each fraction was calculated on a weight-by-weight basis as follows.

$$\text{Seed purity (\%)} = \frac{\text{Weight of pure seed (g)}}{\text{Total weight of sample (g)}} \text{x } 100$$

Standard germination: Germination test was carried out according to ISTA (2014). For each treatment, 400 seeds were counted at random from the working seed sample. Then, 100 seeds were planted for each replication in sterilized sand media. The planted seeds germinated in a seed germinator at a temperature of 25°C for eight days. After eight days, normal, abnormal seedlings and ungerminated seeds will be sorted and counted. The proportion of normal seedlings will be calculated as germination percentage as follow.

$$\textbf{Standard Germination (\%)} = \frac{\text{Number of normal seedlings on day eigtht}}{\text{Total number of seeds}} \text{x } 100$$

The proportion of abnormal seedlings and ungerminated seeds will be estimated similarly to the germination percentage calculated.

Germination energy (%): it was evaluated according to the ISTA (2006) standard. Germination energy was tested simultaneously with germination ability and it was carried out on day four. The seeds that sprouted on day four after sowing were counted and the proportion of sprouted seeds was calculated as percentage as follow.

$$\textbf{Germination energy (\%)} = \frac{\text{Number of sprouted seeds on day four}}{\text{Total number of seeds}} \text{x } 100$$

Speed of germination (SPG): from each sample, 400 seeds were taken and divided into four replicates and seeds were planted for each replication in sterilized sand media kept at the temperature of 25°C for eight days in the seed germinator. The seeds were assessed for the presence of normal seedlings. The first count was made as soon as seeds started germination, seedlings were removed each day and the final count was done eight days after the start of the experiment. The number of newly developed normal seedlings was recorded daily at the same time from sowing (Mielezrski *et al.*, 2016). Then, the speed of germination (SPG) was calculated the following procedures described by Maguire (1962).

$$\text{SPG} = \frac{\text{Number of normal seeding}}{\text{Days of first count}} + \frac{\text{Number of normal seeding}}{\text{Days of final count}}$$

Seedling dry weight: The seedlings' dry weight was measured after the final count in the standard germination test. Ten seedlings were randomly taken from each treatment and each replication and cut free from their cotyledons weighed, placed in an envelope then dried in an oven at 80°C for 24 hours (ISTA, 2014). The dried seedlings were weighed to the nearest milligram and the average seedling dry weight was calculated.

Seedling length: Ten normal seedlings were randomly taken from each treatment and replication at the end of the standard germination test. The shoot and root length of each seedling will be measured and registered. The mean shoot and root length of the seedling will be calculated and it will be used to estimate vigor index I as follow.

Vigor index I: It was determined as the multiple of percent germination x the sum average of shoot and root length.

Vigor index II: It was determined as the multiple of percent germination x average seedling dry weight.

3.5.3 Grain Malt Quality Related Traits

Kernel size or Sieve Test (%): it was determined by sieving test which contains three different sieves size of 2.2, 2.5 and 2.8 mm and sum of kernels that remains on the top of a 2.2, 2.5, 2.8 mm size sieves registered. The kernel size above 2.2 mm is acceptable for malt barley (Deme, *et.al.,* 2020) and the percentage of sieve test was calculated on a weight-by-weight basis as follows.

Sieve test (%) = $\frac{\text{Weight of kernels >2.2 mm (g)}}{\text{Total weight of sample (g)}}$x 100

Hectolitre weight: it was determined by measuring kernels in1000ml by using sensitive balance then changed to kg/L.

Grain protein content (%): Protein content is the major quality parameter of malting barley and it is determined through the process of, one gram ground sample of malt barley measured and transferred into completely dry Kjeld Hal flask. Then the protein content of flour dry samples taken from the harvested grain yields of each treatment were calculated as, Percentage protein = percentage N*6.25; where: 6.25 is conversion factor (AACC, 2000).

3.5.4 Partial Budget Analysis

The economic analysis was carried with the prevailing market prices for inputs at planting and price of outputs at harvesting. All costs and benefits were calculated on ha basis in Birr. Total variable cost (TVC) (ETB ha^{-1}) was calculated by summing up the costs that vary, including the cost of Urea fertilizer ad its application costs. Cost of malt barley seed (50 Birr kg^{-1}) during sowing time (July 6, 2022). The partial budget analysis was generally carried out based on the formula developed by CIMMYT (1988) as follows.

Gross average grain yield (kg ha^{-1}) (AvY): This is the average yield of each treatment.

Adjusted marketable grain yield (AjY): The average yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield of farmers.

AjY = AvY- (AvY*0.1)

Gross field benefit (GFB): It was computed by multiplying the field/farm gate price that farmers receive for the crop when they sell it as adjusted yield.

GFB = AjY*field/farm gate price for the crop

Total cost: This is the cost of fertilizers and other costs of each treatment for the experiment. The costs of other inputs and production practices such as labour costs for land preparation, planting, weeding, and harvesting were considered to remain the same or considered insignificant among treatments.

Net Income (NI) or Net Benefit (NB): This was calculated as the amount of money left when the total variable costs for inputs (TVC) and other variables are subtracted from the gross field benefit (GFB).

NB = GFB – TVC.

Marginal rate of return (MRR %): it was calculated by dividing the change in net benefit by the change in total cost.

$$\text{MRR (\%)} = \frac{\Delta \text{NB}}{\Delta \text{TC}} * 100$$

Where; MRR = Marginal rate of return in percent, ΔNB, and ΔTC= change in net benefit and change in total cost, respectively.

3.6 Data Analysis

The data that were collected from field experiment subjected to analysis of variance (ANOVA) for RCBD while the data that was collected from seed quality test was subjected to ANOVA for CRD as suggested by Gomez and Gomez (1984) using GenStat 15th edition statistical software package. The mean values comparison was performed following the significance test results using least significant difference (LSD) at 5% level of probability.

4 RESULTS AND DISCUSSION

4.1 Seed Quality Test before Planting

The highest and the lowest seed purity were registered for seed samples obtained from Souflet Malt Ethiopia Plc. (99%) and Hunde gudena Union (95.5%), respectively. The highest seed moisture content (14.4%) was recorded for seed sample obtained from Lemu dima Union and the lowest seed moisture content (12.3%) was registered for seed sample obtained from Souflet Malt Ethiopia Plc, before planting. In this experiment, most of the seed samples had moisture content >13% except Oromia seed enterprise and Souflet Malt Barley Plc. (Table 2). The minimum requirement of pure seed for barley seed certification for certified seed C1 to C3 is 97% and seed moisture content is 12.5% (ESA, 2012). According to barley seed specification, all the seed samples obtained from suppliers except from Hunde gudena Cooperative had the standard percentages of pure seed for certified seed whereas the moisture content of seed samples except seeds obtained from Souflet Malt Ethiopia Plc. had higher than seed moisture content set for certified seed. Most of the seed samples had moisture content >12.5% except seed samples obtained from Souflet Malt Plc. Therefore, the seed samples are not expected to be more stable during storage and not more profitable to use for seed purpose. Similar result was reported by Strelec *et al*. (2010) that the increased seed moisture content decrease duration and germination rate with different storage temperatures and relative humidity of stored seeds.

The average germination of seeds was 93.17% with the lowest germination percentage (87%) registered for seeds obtained from Hunde Gudena Cooperative while the highest germination percentage (97%) was recorded for seeds obtained from Souflet Malt Ethiopia Plc. The seeds obtained from Oromia Seed Enterprise also had higher germination percentage (96%). The seed samples collected from Tuka ketar Cooperative, Lemu dima Cooperative and Gelema Union also had 92, 93 and 94% normal germinated seedlings, respectively (Table2). The minimum requirement of germination percentage is 85% for barley seed certification for certified seed C1 to C3 (ESA, 2012). The germination percentage of seeds from all suppliers had higher than the set minimum germination percentage for certified seed. High quality seed is the key factor in commercial seed production, although seed vigor is very important parameter of seed quality, germination of a seed lot is essential for seed trade (Na and Veka, 2022). One of the key qualities of malting barley is its ability to germinate rapidly and synchronously, and the failure of barley grain to germinate at an acceptable level (> 96%) could introduce problems during the malting process (Woonton et al., 2005).

The seeds obtained from Hunde gudena Cooperative had the heaver thousand kernels weight (49.15g) followed by seeds (44.76g) obtained from Lemu dima Cooperative whereas the lowest thousand kernels weight (36.52g) was registered for seeds obtained from Souflet Malt Ethiopia Plc. The seeds obtained from Hunde gudena Cooperative, Souflet Malt Ethiopia Plc., and Lemu dima Cooperative had sieve test of 99.4, 98.9 and 98.7%, respectively. The seeds obtained from Oromia Seed Enterprise and Tuka ketar Cooperative had sieve test of 95.7% and seeds obtained from Gelema Union had 95.7% sieve test (Table 2). According to ESA (2001), percent kernel sample which pass through sieve size < 2.2 mm should not be more than 4 to 6%. The seed samples had 0.6 to 4.5% kernel sample that pass-through sieve size < 2.2 mm, thus, the seed samples maintained the required quality standard in kernel plumpness (Wondimu et. al., 2013). The thousand grain weight and kernel plumpness are used to assess the desired shape and size of barley grains. Smaller grain generally has lower starch and higher protein levels, thus reducing the extract potential. Large grains generally have increased levels of starch and therefore more extract potential (Fox et al., 2003).

The percent protein content of samples seeds ranged from 9 to 11.2% while the starch content ranged from 60.9 to 65.1% (Table 2). The seed samples obtained from four suppliers (Gelema Union, Lemu Dima Cooperative, Oromia Seed Enterprise and Tuka Ketar Cooperative had 9 to 9.7% protein content and seeds obtained from Souflet Malt Ethiopia Plc. and Hunde gudena Cooperative had 11.2 and 10.2 9 % protein content with different moisture content, respectively (Table 2). According to the Ethiopian standard authority (EQSA, 2006), Asela malt factory (AMF, 2012) and Gondar Malt Factory (GMF, 2015) the protein level of raw barley for malt should be 9-12.5%, accordingly all seed samples obtained from six seed suppliers had grain protein within the acceptable standard range for malt purpose. Excessively higher protein content is undesirable, because of the strong inverse correlation between protein and carbohydrate content; thus, high protein content leads to a low malt extract level (Fox et al., 2003).

Table 2. Seed and malt quality of seed samples of 'Traveler' malt barley variety from six seed suppliers at Kulumsa in 2022

Seed source	PU (%)	ST (%)	Mo (%)	NG (%)	TKW (g)	Starch (%)	TPC (%)
Gelema Union	97.5	95.5	13.6	94	38.5	64.5	9
Hunde gudena Cooperative	95.5	99.4	13.9	87	49.15	62.1	10.2
Lemu dima Cooperative	98.5	98.7	14.4	93	44.76	65.1	9.5
Oromia Seed Enterprise	98.5	95.7	12.6	96	36.62	61.8	9.6
Souflet Malt Ethiopia Plc.	99	98.9	12.3	97	36.52	60.9	11.2
Tuka ketar Cooperative	97.5	95.7	13.8	92	39.36	64	9.7
Mean	97.75	97.32	13.43	93.17	40.82	63.07	9.87
SD	1.25	1.86	0.81	3.54	5.07	1.69	0.76
CV (%)	1.28	1.91	6.04	3.80	12.42	2.68	7.68

PU (%) = Percent of seed purity, ST (%) = Sieve test of grain, Mo (%) = Percent moisture content, NG (%) = Percentage of normal germinated seedlings, TKW (g) = Thousand seeds weight, TPC (%) = Percent total protein content, SD = Standard deviation and CV (%) = Percentage of coefficient of variation.

4.2 Field Experiment

4.2.1. Phenological and Growth Parameters

4.2.1.1. Days to heading and physiological maturity

Nitrogen rate had significant ($P<0.05$) effect on days to 50% heading and days to 90% physiological maturity of 'Traveler' malt barley variety, but the interaction of the two main factors (seed source and nitrogen rate) had nonsignificant effect on the two phenological parameters and the seed source had non-significance on the two phenological parameters (Appendix Table 1). The Traveler variety grown from seeds obtained from Gelema dima Union attained early 50% heading (79.66 days) and Hunde gudena coop. had shortest days to 90% physiological maturity (117.67 days). The plants grown from seeds obtained from Lemu Dima Coop., Tuka Ketar and Gelema Union had significant difference with plants grown from seeds obtained from Oromia Seed Enterprise Arsi with day of 50% heading. The plants grown from seeds obtained from Oromia Seed Enterprise Arsi, had delayed days to 50% heading (83.50 days) and seeds obtained from Tuka ketar had delayed days to 90%

physiological maturity (120.7 days). The plants grown from all six seed sources had not more than 3.34 and 4.92 days to 50% heading and days to 90%

physiological maturity differences, respectively (Table 3). This low difference of physiological maturity might be due to differences of production locations, seed processing and storage conditions implemented by seed suppliers. The three malt barley varieties had longest days to maturity in seed samples collected from Ethiopia Seed Enterprise (143 days) followed by samples collected from Debrebrhan Agricultural Research Centre, while the shortest duration to maturity were recorded in samples collected from Oromia Seed Enterprise (Nasser *et al*., 2017).

The plant that supplied highest rate of Urea fertilizer (225 kg ha^{-1}) had longest days heading (85.22 days) and days to physiological maturity (123.17 days) whereas plants grown without Urea fertilizer application had shortest days heading (73.72 days) and days physiological maturity (112.67 days). It was observed linear relationship between the rates of Urea fertilizer and days heading and physiological maturity (as the rates of Urea fertilizer increased the days to heading and maturity of variety were delayed) (Table 3). The earliness of plants to days to heading and maturity that grown without fertilizer application might be due to the higher competition to resources as the result plants no longer to stay in vegetative stage. In contrast, the delayed days to heading and maturity observed in plants that supplied highest rates of Urea fertilizer is the function of N nutrient that prolonged vegetative growth and delayed the reproductive stage of plants. Awulachew (2019) also reported similar result and suggested that the behavior of increased N fertilizer increases vegetative growth of crops thereby it delaying heading and maturity time. Rashid *et al*. (2007) also reported that N application significantly affected days to heading and maturity in barley. Nakano *et al.* (2008) reported that plants that received 8g N m^2 at active tillering headed slightly later than those that received 0g N m^2. The longer days of physiological maturity might be due to nitrogen fertilizer applied at tillering was used by the plant as the plant had developed roots to efficiently uptake the N applied at the stage which could result in extended vegetative growth and delayed physiological maturity (Fasil and Zenebe, 2021).

Table 3. Main Effect of Seed Source and Nitrogen Rate on Days To 50% Heading and Days To 90% Physiological Maturity at Kulumsa in 2022

Treatment		
Seed sources	DH	DM
Gelema Union	79.66^{bc}	117.75^{a}
Hunde gudena Union	80.25^{abc}	117.67^{a}
Lemu dima Union	79.0^{c}	119.25^{a}
Oromia Seed Enterprise	83.50^{a}	119.8^{a}
Souflet Malt Ethiopia Plc.	82.5^{ab}	120.17^{a}
Tuka ketar Cooperative	80.0^{bc}	120.7^{a}
LSD (5%)	3.34	4.92
Mean	**80.8**	120.64
Urea fertilizer (kg ha-1)		
N0	73.72^{c}	112.67^{b}
N75	81.278^{b}	119.67^{a}
N150	83.06^{ab}	121.44^{a}
N225	85.22^{a}	123.17^{a}
LSD (5%)	**2.73**	**4.02**
Mean	**80.8**	**119.2**
C.V	**5.03**	**5.02**

Means followed with the same letter(s) in the column of each treatment effect are not significantly different row each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level, C. V=Coefficient Variation.

4.2.1.2. Plant height and spike length

The two main factors viz. seed sources and Nitrogen fertilizer rates had significant effect on plant height of the variety. The spike length was significantly influenced by Nitrogen fertilizer rates. The plant height and spike length of the variety were not significantly influenced by the interaction of seed sources and Nitrogen fertilizer rates (Appendix Table 1). The tallest plants with 67.28 cm height were observed at plots where the seeds obtained from Tuka ketar Cooperative sown but had nonsignificant difference from plants that were grown from seeds obtained from Gelema Union and Lemu dima coop. The plants grown from seeds obtained from Hunde gudena coop, Oromia Seed Enterprise and Souflet Malt Ethiopia Plc. had nonsignificant difference for plant height (Table 4). The seeds obtained from Tuka ketar Cooperative, Gelema Union and Lemu dima coop and produced taller plants had higher starch content (64 to 64.5%) ad lower protein content (9 to 9.7%) as compared seeds obtained from three suppliers (Hunde gudena coop, Oromia Seed Enterprise and Souflet Malt Ethiopia Plc.) that produced shorter plants (Table 2). The lower protein content and higher starch content might help the seeds to germinate and establish plants earlier than seeds with higher protein content and lower starch content and this might Favor plants to utilize resources more and enhanced plant growth. The protein and carbohydrate content had strong inverse correlation and high protein content delayed seeds sprouting (Fox *et al*., 2003).

Tallest plants (69.2 cm) and longest spike (9.62 cm) were observed on plots that supplied with highest rate of Urea fertilizer (225 kg ha^{-1}) but the height of plants and spike length had nonsignificant difference with plants that received 150 kg ha^{-1} Urea fertilizer. The plants grown without fertilizer application had shortest plants and spike significantly different from plants that supplied fertilizer. The height of plants increased by 8.71, 15.17 and 18.62% due to application of 75, 150 and 225 Kg ha^{-1} Urea fertilizer, respectively, as compared plants grown without fertilizer application whereas spike length increased by 12.76, 26.89 and 31.96% in plants that received 75, 150 and 225 Kg ha^{-1} Urea fertilizer, respectively, then plants at control plot (Table 4). The increment of plant height with increasing of fertilizer rates might be directly related to the effects of nitrogen which promotes vegetative growth (Shimels and Kefale, 2021). Increasing levels of nitrogen significantly enhanced plant height of barley became higher at higher dose of N possibly due to higher availability of nitrogen (Kumar, 2020).

Table 4. Effect of seed source and Nitrogen rate on plant height and spike length of malt barley variety at Kulumsa in 2022

Treatment Seed sources	Plant height (cm)	
Gelema Union	65.12[ab]	
Hunde gudena coop.	62.11[b]	
Lemu dima coop.	64.72[ab]	
Oromia Seed Enterprise	63.89[b]	
Souflet Malt Ethiopia Plc.	64.12[b]	
Tuka ketar Cooperative	67.28[a]	
LSD (5%)	3.1	Spike length
Urea fertilizer (kg ha^{-1})		
N0	58.34[c]	7.29[c]
N75	63.42[b]	8.22[b]
N150	67.19[a]	9.25[a]
N225	69.2[a]	9.62[a]
LSD (5%)	2.53	0.87

Means followed with the same letter(s) in the column of each treatment effect are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

4.2.2. Yield Components and Seed Yield

4.2.2.1. Total and effective number of tillers

The number of total and effective tillers was highly significantly ($P<0.05$) influenced by the main factors seed sources and Nitrogen rates, however, the interaction of the two main factors had nonsignificant effect on number total and effective tillers (Appendix Table 1). The highest number of total number of tillers (388.34 m^2) registered from plots sown with seeds obtained from Tuka ketar Cooperative but had nonsignificant difference from number of total number of tillers at plots sown with seeds obtained from Gelema Union, Lemu dima Cooperative and Oromia Seed Enterprise. The number of effective tillers was highest (291.61) on plots sown with seeds obtained from Oromia Seed Enterprise but had nonsignificant difference at plots sown with Tuka ketar Cooperative Gelema Union and Lemu dima Cooperative. The lower number of total and effective tillers registered at plots sown with seeds obtained from Hunde gudena Cooperative and Souflet Malt Ethiopia Plc. (Table 5).

The highest number of total tillers (405.91 per 0.5 m^2) and effective tillers (325.27 per 0.5 m^2) registered from plots that supplied 225 kg ha^{-1} Urea fertilizer, but had nonsignificant difference with number of effective tillers counted at plots that received 150 kg ha^{-1} Urea fertilizer. The lowest number of total number of tillers (284.67 per 0.5 m^2) and effective tillers (203.27 per 0.5 m^2) registered from plots that did not supply fertilizer (Table 5). The number of tillers per 0.5 m^2 was significantly increased in response to increasing application rate of nitrogen. These may be due to nitrogen promotes activities essential for carbohydrate utilization and its most important function in plant promotion of rapid growth through increasing number of tillers (Awulachew, 2019). Shimels and Kefale (2021) also reported significantly increased number of total and productive tillers in response to increasing application rate of nitrogen and they suggested that nitrogen promotes carbohydrate utilization and rapid plant growth via increasing number of tillers per plant.

Table 5. Effect of seed source and Nitrogen rate on number of total tillers, number of effective tillers and kernels per spike of malt barley variety at Kulumsa in 2022

Treatment Seed sources	Total number of tillers	Number of effective tillers	Number of kernels per spike
Gelema Union	378.42^{ab}	273.18^{ab}	27.3167^{bc}
Hunde gudena Cooperative	332.52^{bc}	252.32^{b}	27.91^{ab}
Lemu dima Cooperative	370.34^{ab}	264.13^{ab}	26.93^{bc}
Oromia Seed Enterprise	351.91^{ab}	291.61^{a}	27.64^{b}
Souflet Malt Ethiopia Plc.	288.82^{c}	213.23^{c}	26.05^{c}
Tuka ketar Cooperative	388.34^{a}	288.37^{a}	29.07^{a}
LSD (5%)	53.12	32.77	1.37
Urea fertilizer (kg ha^{-1})			
N0	284.67^{c}	203.27^{d}	23.42^{d}
N75	340.04^{b}	244.57^{c}	27.04^{c}
N150	376.28^{ab}	282.13^{b}	29.12^{b}
N225	405.91^{a}	325.27^{a}	30.37^{a}
LSD (5%)	43.37	26.76	1.12

Means followed with the same letter(s) in the column of each treatment effect are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

4.2.2.2. Number of kernels per spike

The results from analysis of variance revealed that number of kernels per spike was highly significantly ($P < 0.05$) influenced seed sources and Nitrogen rates; however, the interaction of the two main factors had nonsignificant effect on number of kernels (Appendix Table 1). The highest number of kernels per spike (29.07) obtained from plants at plot sown with seeds obtained Tuka ketar Cooperative but it had nonsignificant difference from number of kernels per spike obtained from plants grown from seeds obtained from Hunde gudena Cooperative. The lowest number of kernels per spike (26.05) obtained from plants grown from the seeds obtained Souflet Malt Ethiopia Plc. but it had nonsignificant difference from number of kernels per spike obtained from plants grown from seeds obtained from Gelema Union and Lemu dima Cooperative. On the other hand, the highest number of kernels per spike (30.07) obtained from plants at plot that supplied 225kg ha^{-1} Urea fertilizer whereas the lowest number of kernels per spike (23.42) obtained from plants that did not receive fertilizer.

The number of kernels per spike increased with the application of Urea fertilizer as compared to the number of kernels per spike obtained from plants that did not receive fertilizer (table 5). This might be due to sufficient availability nitrogen that crops can uptake, assimilation nitrogen and remobilization of N for the synthesis and development of spikelet during anthesis phase. Demissie *et al*. (2015), Derebe *et al*. (2018) and Melaku (2019) also this might be reported that number of kernels per spike was significantly increased with increasing nitrogen. The reduced number of kernels per spike on plots that not received fertilizer was may due to deficiency of nitrogen in the soil had its own limitations. 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 components of yield and 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 increases components of yield and 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).

4.2.2.3. Seed yield

The seed yield of 'Traveler' malt barley variety was significantly influenced by seed source and nitrogen rate, but the two factors did not interact to influence yield (Appendix Table 1). The plots sown with seeds obtained from Oromia Seed Enterprise and Tuka ketar Cooperative produced higher seed yield (2918.75 to 3154.17 kg ha^{-1}) with nonsignificant difference among them than plots sown with seeds obtained from Lemu Dima Cooperative and Souflet Malt Ethiopia Plc. On the other hand, the plots that supplied with 225 kg ha^{-1} Urea fertilizer produced highest seed yield of 3426.89 kg ha^{-1} and the lowest seed yield was obtained from control plots. The application of 75, 150 and 225 kg ha^{-1} Urea fertilizer increased yield by 11.66, 22.96 and 35.01%, respectively, then growing plants without application of fertilizer (Table 6).

Nitrogen fertilizer application is the most important agronomic practice which determines grain yield of malting barley (McKenzie *et al*., 2004; Sainju *et al*., 2013). The observed difference of seed yield with increasing rate of nitrogen might be due to the contribution of high level of nitrogen for increasing effective tillers and to increase the uptake and utilization the available nutrients. Minale *et al*. (2011) also reported that grain yield was increased almost linearly as the N rate increased in malt barley varieties at mid- and high altitude of Northwest Ethiopia. Melaku (2019) and Shimels and Kefale (2021) also reported that the grain yield of malt barley was increased with increase nitrogen fertilizer level.

Table 6. Effect of seed source and Nitrogen rate on seed yield and biological yield, and harvest index of malt barley variety at Kulumsa in 2022

Treatment Seed source	Seed yield (Kg ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Gelema Union	3037.92^{ab}	14.21^{ab}	28.39^{a}
Hunde gudena Cooperative	3049.75^{ab}	11.21^{d}	26.68^{ab}
Lemu dima Cooperative	2773.42^{c}	12.99^{bc}	21.4^{c}
Oromia Seed Enterprise	2918.75^{abc}	14.2^{ab}	21.91^{bc}
Souflet Malt Ethiopia Plc.	2853.17^{bc}	11.98^{cd}	24.22^{abc}
Tuka ketar Cooperative	3154.17^{a}	15.14^{a}	21.48^{c}
LSD (5%)	255.57	1.6	4.99
Urea fertilizer (kg ha^{-1})			
N0	2519.61^{d}	10.39^{d}	25.27a
N75	2813.44^{c}	12.72^{c}	24.08^{a}
N150	3098.17^{b}	14.18^{b}	23.67^{a}
N225	3426.89^{a}	15.87^{a}	23.03^{a}
LSD (5%)	208.67	1.31	NS

Means followed with the same letter(s) in the column of each treatment effect are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

4.2.2.4 Biological yield and harvest index

The results from analysis of variance indicated that the two main factors (seed source and nitrogen rate) had significant effect on biological yield and seed source had significant effect on harvest index. The main factor on harvest index and the interaction of seed source and nitrogen rate had non-significant effect on biomass yield and harvest index (Appendix Table 1). The estimated biomass yield ranged from 11.21 to 15.14 t ha^{-1} from crop harvest grown from seeds of six suppliers. The higher biomass yield was obtained from plots sown with seeds obtained from Tuka ketar Cooperative, Gelema Union and Oromia Seed Enterprise with nonsignificant difference among the mean values of the plots whereas plots sown with seeds obtained from Hunde gudena Cooperative and Souflet Malt Ethiopia Plc produced lower biomass without significant difference between the two plots but had significant different from other plots. The harvest index was ranged from 21.4 to 28.39% estimated from crop harvest at plots sown with seeds of six suppliers. The higher harvest index was estimated at plots sown with seeds obtained from Gelema Union, Hunde gudena Cooperative and Souflet Malt Ethiopia Plc with nonsignificant among the mean values of the plots. The lower harvest index was estimated from plots sown with seeds obtained from Lemu dima Cooperative and Tuka ketar Cooperative with nonsignificant difference between the two but had significant different from estimated harvest index at other plots sown from other seed sources (Table 6).

The highest biomass yield (15.87 t ha^{-1}) was estimated for plots that supplied with 225 kg ha^{-1} Urea fertilizer which was significantly different from biomass yield produced from other plots that received lowest, medium rates of fertilizer and control plot. The lowest biomass yield (10.39 t ha^{-1}) was estimated from control plot followed by plots that supplied 75 and 150 kg ha^{-1} Urea fertilizer with statistically par each other. The application of 75, 150 and 225 kg ha^{-1} Urea fertilizer increased biomass yield by 22.43 ,36.48 and 52.74 %, respectively, then growing plants without application of fertilizer (Table 6).

The plots sown with seeds obtained from suppliers that produced higher biomass yield did not result higher estimate of harvest index and vice versa such as seeds obtained from Tuka ketar Cooperative and Hunde gudena Cooperative (Table 6). Harvest index is the ratio of grain yield to total biological yield. Biomass is the ability to produce and maintain an adequate quantity of vegetative material and dry biomass while harvest index is the physiological efficiency and ability of a crop for converting the total dry matter into economic yield (Sharifi *et al*., 2009). Thus, increasing harvest index accounted, in many instances, for the grain yield improvement in cereals, with little or no change in biological yield (Rosielle and Frey, 1975; Hanson *et al.,* 1985). The results of this research also indicated that the seeds that produced plants with good vegetative growth and dry biomass not necessarily had higher harvest index and vice versa. The result is in agreement with Awulachew (2019) that suggested high harvest index is an indicator of the presence of good partitioning of biological yield to economical yield.

The application of nitrogen fertilizer increased biomass yield from 22.43 to 52.74% over plants that did not receive fertilizer might be due to the increment of plant height and number of tillers directly related to the effects of nitrogen that promotes carbohydrate utilization and vegetative growth manifested with increasing plant height and number of tillers per plant

(Awulachew, 2019; Kumar, 2020; Shimels and Kefale, 2021). A positive association between biomass yield and plant height, thus taller plants resulted higher biomass yield (Zewdie *et al*., 2014). In this research, the highest biomass yield obtained from 225 kg ha^{-1} Urea fertilizer from the highest rates of fertilizer. This might indicate that this rate of fertilizer was sufficient to supply nitrogen to maximum plant growth and dry biomass, this rate might result the less competition of plants that does allow producing higher biomass. Mohammad *et al*. (2011) also reported barley variety produced the maximum tillers due to the application 60 kg N ha^{-1} when compared to higher and lower rates of nitrogen. The indicated that probable reason might be that optimum nitrogen availability plays an essential role in plant growth whereas low or very high dose of nitrogen caused reduction in above ground vegetative growth of plant.

4.3 Seed Quality Evaluation

4.3.1 Seed Physical Quality

Thousand kernels weight was significant influenced by seed source and rate of N application but not by the interaction of the two factors. Seed source and rate of N application and the interaction of the two main factors significant influenced moisture content of seeds and seed purity (Appendix Table 2). The plants grown from seeds obtained from Hunde gudena Cooperative and Gelema Union produced seeds with lower thousand kernels weight of 40.15 and 40.56g, respectively, than the plants grown from seeds obtained from other seed suppliers (Lemu dima Cooperative, Oromia Seed Enterprise, Souflet Malt Ethiopia Plc and Tuka ketar Cooperative) that produced seeds with 41.14 to 42.38g thousand kernels weight. On the other hand, heavier thousand kernels weight of 43.95g registered from plants that supplied225 kg ha^{-1} Urea fertilizer while the lowest thousand kernels weight (36.65g) was recorded from plants that did not receive fertilizer. The plants supplied highest rate of Urea fertilizer (225 kg ha^{-1}) produced seeds with higher thousand kernels weight than the plants received 75 and 150 kg ha^{-1} Urea fertilizer. The supply of 75, 150 and 225 kg ha^{-1} Urea fertilizer allowed plants to produce heavier seeds by 12.85,16.7 and 19.92% respectively, than plants at control plot (Table 7).

During account and weighted the thousand seed weight the moisture content of thousand seed weight also done. The plants grown from seeds obtained from all seed suppliers produced seeds with thousand kernels weight in the range between 40.15 and 42.38g. The National Standard Authority of Ethiopia for thousands grain weight specified within the range of 35 to 45g with acceptable thousand-kernel weight in the range of 25–35g (EQSA, 2006). Thus, thousand kernels weight registered from seeds produced by plants grown from seeds obtained from all seed suppliers had acceptable thousand-kernel weight. The increase of thousands grain weight due to the application of nitrogen containing fertilizer in wheat and barley varieties was reported by many authors (Tilahun *et al*., 2016; Ketema and Mulatu, 2018; Meharie and Kindie, 2019). Ketema and Mulatu (2018) reported that the average thousand kernels weight was ranged from 41.43 to 43.34g as the rate of nitrogen increase from zero to 69 kg ha^{-1}N. The heavier seeds were produced by plants supplied 225 kg ha^{-1} Urea fertilizer than plants received higher and lower rates of fertilizer. This might be due to the growth of plants and tillers produced allowed proper utilization of the available resource and photosynthesis use efficiency. Biruk and Demelash (2016) also observed heavier thousands kernel weight of barley (44.87g) at plots with application of 87 kg N ha^{-1} than using 98 kg N ha^{-1}. Paterson and Potts (1985) reported that increasing nitrogen rate decreases grain weight of barley.

Table 7. Effect of seed source and Nitrogen rate on thousand kernel weight of malt barley variety at Kulumsa in 2022

Treatment Seed source	Thousand kernels weight (g)
Gelema Union	40.56^{bc}
Hunde gudena Cooperative	40.15^{c}
Lemu dima Cooperative	42.38^{a}
Oromia Seed Enterprise	41.7^{ab}
Souflet Malt Ethiopia Plc.	41.16^{abc}
Tuka ketar Cooperative	41.14^{abc}
LSD (5%)	1.38
Urea fertilizer (kg ha^{-1})	
N0	36.65d
N75	41.36c
N150	42.77b
N225	43.95a
LSD (5%)	1.13

Means followed with the same letter(s) in the column of each treatment effect are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

The seed purity of 'Traveler' malt barley variety ranged from 97.96 to 99.9%. The plants grown from seeds obtained from Tuka Ketar Cooperative without fertilizer application and application of all rates of urea fertilizer produced seeds with higher seed purity ranged from 98.50 to 99.83 while plants grown from seeds obtained from Souflet Malt Ethiopia Plc. With supply of 0 to 225 kg ha^{-1} urea fertilizer produced seeds with lower seed purity ranged from 97.96 to 99.7%. The plants grown from seeds obtained from Gelema Union with the application of all rates of fertilizer also produced with higher percentages of seed purity, but plants without fertilizer application had seeds lower seed purity of 98.30%. The plants grown from seeds obtained from Oromia Seed Enterprise application of rates of fertilizer except without Urea fertilizer produced seeds with higher percentages of seed purity. The plants grown from seeds obtained from other seed suppliers (Hunde gudena Cooperative and Tuka ketar Cooperative) without fertilizer and with different rates of Urea fertilizer application produced seeds with low to high percentages of seed purity (Table 8). This showed that the initial seeds quality obtained from different sources interacted with rates of nitrogen rate to produce seeds with varied ranges of seed purity. According to ES 415:2012, Barley seed specification, the minimum pure seed for breeder/pre-basic and basic seeds is 98% (ESA, 2012). Therefore, all the seeds produced by all treatments combination (seed sources and rates of nitrogen fertilizer) had pure seed above the minimum pure seed for breeder/pre-basic and basic seeds.

Table 8. Interaction effect of seed source and Nitrogen rate on percentage of seed purity of 'Traveler' malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment	Seed source					
Urea fertilizer (kg ha^{-1})	GU	HG	LD	OSEA	Souflet	TK
N0	98.30^{ab}	98.3^{ab}	98.43^{ab}	98.86^{ab}	99.6^{ab}	98.50^{ab}
N75	99.9^{a}	99.90^{a}	99.86^{a}	99.8^{a}	97.96^{b}	99.70^{a}
N150	99.9^{a}	99.77^{a}	99.9^{a}	99.50^{ab}	99.70^{a}	99.6^{ab}
N225	99.86^{a}	99.9^{a}	99.80^{a}	99.9^{a}	99.3^{ab}	99.83^{a}
LSD (5%)			1.72			

Means followed with the same letter(s) in the columns and rows are not significantly different each other at 5% level of significance, GU = Gelema Union, HG = Hunde gudena Cooperative, LD = Lemu dima Cooperative, OSEA= Oromia Seed Enterprise, Souflet = Souflet Malt Ethiopia Plc., TK= Tuka ketar Cooperative and LSD (5%) = Least significant difference at 5% significance level.

The seed moisture content ranged from 10.5 to 11.57% to all seeds produced by application of all possible combination of treatments (six seed source and four rates of nitrogen fertilizer). The seeds collected from plots that received seeds from Gelema Union and 75 and 150 kg ha^{-1} Urea fertilizer seeds from Hunde gudena Cooperative and 150 kg ha^{-1} Urea fertilizer, seeds from Souflet Malt Ethiopia Plc and 75 kg ha^{-1} Urea fertilizer, and seeds from Tuka ketar Cooperative and 225 kg ha^{-1} Urea fertilizer had moisture content >11% while seeds obtained from other plots that received with all treatment's combination had moisture content <11% (Table 9). The results indicated that the initial seeds obtained from six seed suppliers and four rates of nitrogen fertilizer interacted to influence the moisture content of seeds though other pre-harvesting (uniformity of plants growth etc), harvesting and drying practices also had a potential to cause variation of seed moisture content among seed lots.

Seed moisture content indicate the physiological activities which are undergone within the seed while it was in the store or at harvest if the test was conducted within short period of time after harvest. According to "Rule of thumbs" of Harington (1973), 1% reduction of seed moisture content doubles the storage life of the seeds. Therefore, even if the temperature and humidity are kept constant every 1% reduction in moisture content has an advantage of doubling the seed longevity. In this experiment the difference between the lowest and highest seed moisture content was 1.07% and in most case the difference among seed samples was <1%. Therefore, the seed samples are expected to be more stable during storage. Moisture levels need to be low enough to inactivate the enzymes involved in seed germination as well as to prevent heat damage and the growth of disease microorganisms (Makonnen *et al*., 2017). However, the seed moisture content of all seed samples was <12.5% which is set for barley seed specification by Ethiopian Standard Agency (ESA, 2012).

Table 9. Interaction effect of seed source and Nitrogen rate on moisture content of seeds of 'Traveler' malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment	Seed source					
Urea fertilizer (kg ha^{-1})	GU	HG	LD	OSEA	Souflet	TK
N0	10.9^{c-f}	10.8^{d-h}	10.8^{d-h}	10.6igh	10.6^{igh}	10.5i
N75	11.1^{bcd}	10.7^{f-i}	10.7^{d-i}	10.6^{ih}	11.0^{c-e}	10.8^{d-h}
N150	11.57^{a}	11.13^{bc}	10.6^{igh}	10.9^{c-g}	10.8^{d-h}	10.9^{c-g}
N225	10.9 $^{c-f}$	10.9^{c-g}	10.6^{igh}	10.8^{c-h}	10.6^{ih}	11.2^{b}
LSD (5%)			0.27			

Means followed with the same letter(s) in the columns and rows are not significantly different each other at 5% level of significance, GU = Gelema Union, HG = Hunde gudena Cooperative, LD = Lemu dima Cooperative, OSEA= Oromia Seed Enterprise, Souflet = Souflet Malt Ethiopia Plc., TK= Tuka ketar Cooperative and LSD (5%) = Least significant difference at 5% significance level.

4.3.2 Standard Germination

Percentages of abnormal and dead seedlings estimated during standard germination test showed that the two parameters were significantly influenced by seed source and rate of nitrogen but not with the interaction effect of the two main factors. The highest abnormal was obtained from the seed produced with no application urea fertilizer rate and the lowest abnormal seedling obtained from seed produced with 225 kgha^{-1} urea fertilizer rates (table10). The dead seedling was also increase in seed produced without urea fertilizer and decreasing order in seed produced with urea application rate from 75,150,225 kgha^{-1} except seed produced with 150kgha^{-1} of Oromia Seed enterprise (table 11).
Germination percentages of normal seedlings were significantly influenced by seed source and rate of nitrogen (Appendix Table 2). The germination of normal seedling ranged from 93.27 to 96.47% for seed samples collected from plots as influenced by six seed sources and four rates of nitrogen fertilizer. Only the seeds produced by plants grown from seeds obtained Gelema Union had significantly higher normal seedlings germinations (96.47%) than the germination of normal seedlings computed for seeds produced by plants grown from Hunde gudena Cooperative. All other seeds produced from plants obtained seeds obtained from other suppliers had nonsignificant difference between each other, with seeds obtained Gelema Union and Hunde gudena Cooperative for germination of normal seedlings.

Similarly, only germination of normal seedlings was significantly lower than seeds produced by plants supplied with all rates of Urea fertilizer while seeds collected from plants supplied with fertilizer had nonsignificant difference (Table 12). This showed that the germination of normal seedlings only two treatments (seeds obtained Gelema Union and growing without fertilizer) had significant effect and results germination of normal seedlings significantly different from other treatments effect.

According to ES 415:2012, barley seed specification, the minimum germination for breeder/pre-basic and basic seeds is 90% (ESA, 2012). Therefore, all the seeds produced by all treatments (seed sources and rates of nitrogen fertilizer) had above the minimum pure seed for breeder/pre-basic and basic seeds. 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). The germination of seeds at laboratory might not be same at field condition, thus, as Gadissa (2019) suggested the practical seed vigor
test should give a good indication of field performance potential of the seed lot and the test results should be reproducible.

Table 10. Interaction effect of seed source and Nitrogen rate on percentages of abnormal seedlings of 'Traveler' malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment	Seed source					
Urea fertilizer (kg ha^{-1})	GU	HG	LD	OSEA	Souflet	TK
N0	3.0^{a}	3. 0^{a}	3.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}
N75	2.0^{b}	2.0^{b}	1.75^{c}	2.0^{b}	2.0^{b}	2.0^{b}
N150	1.0^{d}	1.0^{d}	1.0^{d}	1.0^{d}	1.0^{d}	1.0^{d}
N225	1.0^{d}	1.0^{d}	1.0^{d}	1.0^{d}	1.0^{d}	1.0^{d}
LSD (5%)			0.143			

Means followed with the same letter(s) in the columns and rows are not significantly different each other at 5% level of significance, GU = Gelema Union, HG = Hunde gudena Cooperative, LD = Lemu dima Cooperative, OSEA= Oromia Seed Enterprise, Souflet = Souflet Malt Ethiopia Plc., TK= Tuka ketar Cooperative and LSD (5%) = Least significant difference at 5% significance level.

Table 11. Interaction effect of seed source and Nitrogen rate on percentages of dead seedlings of ‘Traveler’ malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment	Seed source					
Urea fertilizer (kg ha^{-1})	GU	HG	LD	OSEA	Souflet	TK
N0	3.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}	3.0^{a}
N75	2.0^{c}	2.0^{c}	2.0^{c}	2.0^{c}	2.0^{c}	2.50^{b}
N150	2.0c	2.0c	2.0c	2.5b	2.0c	2.0c
N225	2.0^{c}	2.0^{c}	2.0^{c}	2.0^{c}	2.0^{c}	2.0^{c}
LSD (5%)			0.235			

Means followed with the same letter(s) in the columns and rows are not significantly different each other at 5% level of significance, GU = Gelema Union, HG = Hunde gudena Cooperative, LD = Lemu dima Cooperative, OSEA= Oromia Seed Enterprise, Souflet = Souflet Malt Ethiopia Plc., TK= Tuka ketar Cooperative and LSD (5%) = Least significant difference at 5% significance level

Table 12. Effect of seed source and Nitrogen rate on percentages of normal seedlings germination of seeds of ‘Traveler’ malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment Seed source	Germination of normal seedlings (%)
Gelema Union	96.47^{a}
Hunde gudena Cooperative	94.75^{b}
Lemu dima Cooperative	96^{ab}
Oromia Seed Enterprise	95.04^{ab}
Souflet Malt Ethiopia Plc.	95.13^{ab}
Tuka ketar Cooperative	95.08^{ab}
LSD (5%)	1.55
Urea fertilizer (kg ha^{-1})	
N0	93.27^{b}
N75	96.23^{a}
N150	96.47^{a}
N225	95.67^{a}
LSD (5%)	1.27

Means followed with the same letter(s) in the column of each treatment effect are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

4.3.3. Germination Energy and Speed of Germination

The application of nitrogen containing fertilizer (Urea) had highly significant ($P<0.05$) effect on germination energy and speed of germination of malt barley variety, however, seed source and interaction of seed source and Urea fertilizer had nonsignificant on these parameters (Appendix Table 2). Seeds germination energy was in the range between 89.96 and 95.08% with overall mean of 92.68%. The lowest germination energy was registered for seeds produced without fertilizer application while the highest germination energy was recorded for seeds produced from plants that supplied 225 kg ha^{-1} Urea fertilizer. The seeds produced from plants that supplied 75 and 150kg ha^{-1} Urea fertilizer had germination energy of 92.04 and 93.67 %, respectively. The seeds produced from plants that supplied 75, 150 and 225 kg ha^{-1} Urea fertilizer increased germination energy by 2.3, 4.12 and 5.12%, respectively, then seeds produced without application of fertilizer (Table 13).

Germination ability and germination energy are tested simultaneously. Germination capacity is the percentage of seeds that would normally germinate under optimal conditions for the species while germination energy is the number expressing the percentage of fast-germinating seeds. The assessment of the germination energy is carried out on day four and germination capacity on day eight following planting the sample (ISTA, 2006). The plants grown from seeds with high germination energy and capacity show steady development that restricts competition from weeds and allows for the maximum use of land under cultivation (Tang *et al*., 2010; Bhattacharya et al., 2012). In this research, only the seeds produced with 225 kgha^{-1} fertilizer application had >95% germination energy**.** Grains germination energy was significantly different among rates of nitrogen fertilizer but it increased as highest rates of nitrogen fertilizer. Derebe *et al*. (2018) reported the germination energy varied between 95-96.17% among four nitrogen levels for four malt barley varieties and germination energy was slightly decreased as N rates increase. In case of malt barley, is absolutely critical to the malting process and a minimum of 95% germination on a three-day germination test is an absolute requirement. The failure of barley grain to germinate at an acceptable level could introduce problems during the malting process (Woonton *et al*., 2005). In this regard, all seeds produced with application of nitrogen fertilizer had <95% germination energy except seed produced from225kg ha^{-1} and it was at acceptable level for malt quality.

The lowest speed of germination (21.83) was computed for seeds produced without fertilizer application whereas the highest speed of germination (23.75) was calculated for seeds produced from plants that supplied 225 kg ha^{-1} Urea fertilizer. The seeds produced from plants by application of 75 and 150 kg ha^{-1} Urea fertilizer had nonsignificant difference each other for speed of germination but had significant difference with seeds produced from plants that did not receive fertilizer and plants supplied 225 kg ha^{-1} Urea fertilizer. The speed of germination determines how the seeds germinate fast. The application of Urea fertilizer at the rate of 75, 150 and 225 kg ha^{-1} increased speed of germination by about 4.21,6.41 and 8.80 %, respectively, then seeds produced without fertilizer application (Table 13). Highly suited for malting is barley, which germinates rapidly and homogenously. The faster the rate of germination, the shorter the time needed to attain the desirable modifications during malting, the shorter the processing time, and the lower the cost of conversion. As a result, the germination vigor/rate of germination determines the time required for malting and hence the malting efficiency (Milford *et al.,* 2022).

Table 13. Effect of Nitrogen rate on germination energy and speed of germination for seeds of 'Traveler' malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment Urea fertilizer (kg ha^{-1})	Germination energy (%)	Speed of germination
N0	89.96^{d}	21.83^{c}
N75	92.04c	22.75^{b}
N150	93.67^{b}	23.23^{b}
N225	95.08^{a}	23.75^{a}
LSD (5%)	0.77	0.48

Means followed with the same letter(s) in the column of each parameter are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

4.3.4. Seedling Length and Dry Weight

The analysis of variance results indicated that shoot length of seedlings was significantly influenced by seed source and nitrogen fertilizer whereas root length of seedlings and seedlings dry weight were significantly influenced by nitrogen fertilizer. The interaction of seed source and nitrogen fertilizer had nonsignificant effect on all parameters (Appendix Table 2). The seeds collected from plants grown from seeds obtained from Tuka ketar Cooperative, Oromia Seed Enterprise and Souflet Malt Ethiopia Plc had seedlings shoot length of 14, 13.8 and 13.6 cm, respectively, with nonsignificant difference among means but significantly higher than seeds obtained from other seed suppliers. The longest shoot, root and seedlings length of 14.75, 12.34 and 27.05 cm were measured from seeds collected from plants that supplied 225 kg ha^{-1} Urea fertilizer. The shortest shoot, root and seedlings length of 12.47, 9.88 and 22.66cm respectively, measured from seeds collected from plants that did not receive fertilizer (Table 14). The difference observed for shoot, root and seedlings length among seed lots collected from plants grown from different seed suppliers might be the difference of locations, management practices, seed processing and storage conditions implemented by seed suppliers.

The application of 75, 150 and 225 kg ha^{-1} Urea fertilizer on plants increased the seedlings shoot length by 3.93,10.99 and 18.28 %, respectively, then seeds obtained from plants that did not supply fertilizer and seedlings root length by 8.40,17.71 and 24.89% as plants supplied 75, 150 and 225 kg ha^{-1} Urea fertilizer, respectively (Table 14). This implies that the growing of malt barley with nitrogen containing fertilizer much improved the growing of seedlings. This helps the seeds have to well-developed shoot and root systems that can withstand any adverse conditions and provide better seedling emergence and seedling establishment in the field. The effect of nitrogen on seedling length might be due to its effect on increasing seed size and weight. Seedling length from large size and heavy seeds might be attributed to large food reserves of the seeds (Gharineh and Moshatati, 2012).

Table 14. Effect of seed source and Nitrogen rate on seedling length and dry weight of 'Traveler' malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment Seed source	Shoot length	Root length	Seedling length	Seedling dry weight
Gelema Union	12.96[d]	10.9[c]	24.11[c]	14.76[a]
Hunde gudena Cooperative	13.4[bcd]	11.22[ab]	24.75[b]	14.36 [a]
Lemu dima Cooperative	13.2[cd]	11.25[ab]	24.66[b]	14.84 [a]
Oromia Seed Enterprise	13.84[ab]	10.98[bc]	24.9[ab]	14.39 [a]
Souflet Malt Ethiopia Plc.	13.59[abc]	11.11[abc]	24.86[b]	14.64 [a]
Tuka ketar Cooperative	14.03[a]	11.38[a]	25.42[a]	14.59 [a]
LSD (5%)	0.6	0.278	0.52	NS
Urea fertilizer (kg ha^{-1})				
N0	12.47[d]	9.88[d]	22.66[d]	13.45[c]
N75	12.96[c]	10.71[c]	23.94[c]	14.44[b]
N150	13.84[b]	11.63[b]	25.49[b]	15.05[a]
N225	14.75[a]	12.34[a]	27.05[a]	15.47[a]
LSD (5%)	0.49	0.23	0.43	0.0005

Means followed with the same letter(s) in the column of each treatment effect are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

The higher seedlings dry weight of 15.05 and 15.47 mg were measured from seeds produced by plants that supplied 150 and 225 kg ha^{-1} Urea fertilizer, respectively, whereas lower seedlings dry weight of 13.45mg from seeds collected from plants that did not receive fertilizer. The seedlings dry weight increased by 7.36,11.9 and 15.02 % as plants supplied 75, 150 and 225 kg ha^{-1} Urea fertilizer, respectively, as compared seeds produced from plants that did not receive fertilizer (Table 15). The seeds with heavier thousand seeds weight were produced from plants that supplied 75 and 150 kg ha^{-1} Urea fertilizer (Table 7) that might help to produce vigorous seedlings with higher dry weight. Zareian *et al*. (2013) reported that large seed size produces higher seedling dry weight in wheat varieties and it was noticed that seedling dry weight in large seed sizes was related to more seed food storage in their endosperms.

4.3.5. Seedling Vigor Index

Seedling Vigor index one was significantly influenced by rates of Nitrogen fertilizer whereas seedling Vigor index two was significantly influenced by rates of Nitrogen fertilizer and seed sources. The interaction of seed sources and rates of Nitrogen fertilizer had nonsignificant effect on both Vigor index (Appendix Table 2). The result indicated that seeds produced by plants grown from seeds obtained Tuka ketar Cooperative had significantly higher seed Vigor one (24.19) than seeds collected from plants grown from seeds obtained from others seed sources, but had nonsignificant difference with seed produced from plants that were grown from other three seed suppliers (Lemu dima Cooperative, Oromia Seed Enterprise and Souflet Malt Ethiopia Plc.). The higher seedling Vigor one **(**26.09) and two (14.58) were observed in seeds produced by plants that supplied 225 kg ha^{-1} Urea fertilizer, but the seedling Vigor two had nonsignificant difference in seeds produced from plants that supplied 150 kg ha^{-1} Urea fertilizer. The application of 75, 150 and 225 kg ha^{-1} urea fertilizer on plants increased the seedlings Vigor one by 8.37,16.04 and 23.47, respectively, then seeds obtained from plants that did not supply fertilizer and seedlings Vigor two increased by 10.66,16.03 and 19.63 % as plants supplied 75, 150 and 225 kg ha^{-1} Urea fertilizer, respectively (Table 15).

Seed vigour is defined as the potential of seeds for rapid and uniform germination and fast seedling growth under general field conditions. Seed vigour is the sum total of those properties of seed that determine the potential attributes of the seed express during the process of germination and seedling establishment that implies the sum of all seed aspects that result in rapid and uniform emergence and field establishment (Khare and Bhale, 2005). The increase of thousand grain weight result significantly increased seedling length and seedling dry weight and thereby seedlings vigor (Khan, 2003). Hasstrup *et al*. (1993) reported that wheat and barley yield would be decreased by increase of seed germination duration due to low seed vigor. This is in agreement with this study results that the supply of plants with nitrogen containing fertilizer produced seeds having heavier weight, fast germinated with long seedlings and higher dry weight. The increased vigor of growing plants implies better response of seedlings to adverse environmental conditions likely results increased yield (Basra, 2002).

Table 15. Effect of seed source and Nitrogen rate on seedling Vigor one and two of 'Traveler' malt barley variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Treatment Seed source	Seedling Vigor I	Seedling vigor II
Gelema Union	23.27[b]	14.06[a]
Hunde gudena Cooperative	23.46[b]	12.97[b]
Lemu dima Cooperative	23.69[ab]	14.26[a]
Oromia Seed Enterprise	23.68[ab]	13.65[a]
Souflet Malt Ethiopia Plc.	23.67[ab]	13.83[a]
Tuka ketar Cooperative	24.19[a]	13.88[a]
LSD (5%)	0.64	0.62
Urea fertilizer (kg ha^{-1})		
N0	21.13[d]	12.67[c]
N75	22.90[c]	13.64[b]
N150	24.52[b]	14.221[a]
N225	26.09[a]	14.58[a]
LSD (5%)	0.53	0.0005

Means followed with the same letter(s) in the column of each treatment effect are not significantly different each other at 5% level of significance and LSD (5%) = Least significant difference at 5% significance level.

4.4 Grain Quality Related Traits

4.4.1 Sieve Test and Hectolitre weight

The results of analysis of variance revealed that grain quality of malt barley variety in terms of sieve test (kernel size) and hectolitre weight was significantly influenced by seed source and rate of Nitrogen fertilizer. The interaction of seed sources and rates of Nitrogen fertilizer had significant effect on sieve test, but it had nonsignificant effect of hectolitre weight (Appendix Table 2). The seed test ranged from 88.50 to 98.86 % for grain produced by plants grown from seeds obtained from six seed suppliers. The lowest and highest seed test was measured for grain produced by plants grown from seeds obtained from Tuka ketar Cooperative and Hunde gudena Union, respectively. On the other hand, the grain produced by plants that supplied225 kg ha^{-1} Urea fertilizer and without fertilizer had highest (97.88%) and lowest (91.79%) seed test, respectively. However, plants influenced by the interaction of seeds obtained from 150 and 225kg ha^{-1} Urea fertilizer produced grain with highest seed test (96.5 %) followed by (96.2 %) measured from grain produced by plants influenced by interaction of seeds obtained from 225and 150 kg ha^{-1} Urea fertilizer kg ha-1 Urea fertilizer (Table 16). Moreover, the nitrogen rate and environmental effects in improving grain size, and uniformity of grain (Kassie and Tesfaye, 2019).

Table 16. Interaction effect of seed source and Nitrogen rate on sieve test (kernel size) of 'Traveler' malt barley variety at Kulumsa in 2022

Treatment	Seed source					
Urea fertilizer (kg ha^{-1})	GU	HG	LD	OSEA	Souflet	TK
N0	94.23^{hi}	94.13^{i}	92.40^{j}	91.166^{jk}	90.33^{k}	88.50^{l}
N75	95.43^{f-i}	95.82^{e-h}	94.66^{ghi}	94.50^{ghi}	94.10^{i}	91.38^{jk}
N150	97.53^{a-d}	97.27^{b-e}	96.40^{c-f}	96.43^{c-f}	96.03^{d-g}	95.3^{f-i}
N225	97.6^{abc}	98.86^{a}	98.400^{ab}	97.43^{a-d}	97.43^{a-d}	97.5^{a-d}
LSD (5%)			1.588			

Means followed with the same letter(s) in the columns and rows are not significantly different each other at 5% level of significance, GU = Gelema Union, HG = Hunde gudena Cooperative, LD = Lemu dima Cooperative, OSEA= Oromia Seed Enterprise, Souflet = Souflet Malt Ethiopia Plc., TK= Tuka ketar Cooperative and LSD (5%) = Least significant difference at 5% significance level.

Grain produced by plants grown from seeds obtained from Tuka ketar Cooperative, Gelema Union and Hunde gudena Union had hectolitre weight of 67.24, 66.79 and 65.72 kg/L, respectively, with nonsignificant difference among mean values but significantly different and higher than grain produced by plants grown from seeds obtained from other seed suppliers (Lemu dima Union, Oromia Seed Enterprise and Souflet Malt Ethiopia Plc.). The grain of the malt barley variety had highest hectolitre weight of 67.84 kg/L that was produced by plants supplied with 225 kg ha^{-1} Urea fertilizer, followed by hectolitre weight of 65.68 and 65.75 kg/L measured from grain produced by plants that supplied 75 and 150 kg ha^{-1} Urea fertilizer, respectively. The lowest hectolitre weight was measured from grain produced by plants that did not receive fertilizer. The grain produced by plants supplied with 75, 150 and 225 kg ha^{-1} Urea fertilizer increased grain hectolitre weight by 5.32, 5.44 and 8.79% respectively, as compared grain produced by plants without fertilizer application (Table 17). Hectolitre weight is a measure of grain sample density which can be an indicator of pre-harvest sprouting adversely affecting the grain. Based on the Ethiopian Quality Standard, the acceptable hectolitre weight for barley is in the range 48 to 62 kg/L (EQSA, 2006). The grain 'Traveler' malt barley variety produced as influenced by six seed sources and four rates of

Urea fertilizer ranged from 62.36 to 67.84 kg/L, thus, it was above the maximum limit of hectolitre weight for barley. The grain produced by plants supplied with Urea fertilizer increased grain hectolitre weight as compared grain produced by plants without fertilizer application which is in agreement with researcher findings. Hectolitre weight of barley was increased with increased nitrogen rates and the highest hectolitre weight was recorded from the highest applied N fertilizer rate (Minale *et al*., 2011; Biruk and Demelash, 2016; Derebe and Temesgen, 2018).

Table 17. Effect of seed source and Nitrogen rate on hectolitre weight of 'Traveler' malt barley variety at Kulumsa in 2022

Treatment Seed source	Hectolitre weight (kg/L)
Gelema Union	66.79^{ab}
Hunde gudena Union	65.72^{ab}
Lemu dima Union	63.77^{c}
Oromia Seed Enterprise	63.85^{c}
Souflet Malt Ethiopia Plc.	65.0917^{bc}
Tuka ketar Cooperative	67.24^{a}
LSD (5%)	1.76
Urea fertilizer (kg ha^{-1})	
N0	62.36^{c}
N75	65.68^{b}
N150	65.75^{b}
N225	67.84^{a}
LSD (5%)	1.43

LSD (5%) = Least significant difference at 5% significance level.

4.4.2. Grain Protein and Starch Contents

Grain protein was significantly influenced by rate of Nitrogen fertilizer and non-significance influenced by interaction of the two main factors; however, starch contents of 'Traveler' malt barley variety was significantly influenced by seed source and rate of Nitrogen fertilizer as well as with the interaction of the two main factors (Appendix Table 2). The grain protein content of 'Traveler' malt barley variety ranged from 10.03 to 12.20%. The plants grown from seeds obtained from Gelema Union, Hunde gudena Coop., and Tuka Ketar Coop., without fertilizer application produced grain with lower protein content of 10.03, 10.3 and 10.30%, respectively. than grain produced with urea application rate. The plants grown from seeds obtained from Tuka ketar Cooperative, Hunde gudena Coop, Gelema Union and Lemu dima Coop., Souflet Malt. Plc with the application of 150 and 225 kg ha^{-1} Urea fertilizer and plants grown from seeds obtained from Oromia Seed Enterprise with the application of 225 kg ha^{-1} Urea fertilizer produced grain with protein content ranged from 11.2 to 12.20% which was higher than the protein content of grain produced by plants with other treatments combination. The plants that received other treatments combination produced grain yield with varied protein contents (Table 18).

Grain produced with all combinations of seeds obtained from six suppliers and three rates of fertilizer combination with 75 kg ha^{-1} Urea fertilizer had higher protein content in the range from 1.9 to 21.64% than grain produced without fertilizer application**.** Among the seed sources and rates of fertilizer combination, grain produced from seeds obtained Gelama Union and three rates of fertilizer had higher protein increase of 11.37 to 21.64% than grain produced without fertilizer application and the lowest protein content observed in grain produced from seeds obtained from Souflet Plc and three rates of fertilizer ranged from 1.9 to 10.76%. In general, it was observed the tendency of higher protein content in grain produced from seeds of all suppliers with the application of 150 and 225 kg ha^{-1} Urea fertilizer (Table 18). Other researchers also reported as N fertilizer increase also increases grain protein content of malt barley evaluated at different parts of the country (Tadesse *et al.,* 2022; Fasil and Zenebe, 2021; Melaku, 2019; Biruk and Demelash, 2016; Minale *et al*., 2011).

The protein content of malt barley grain should be within a range of 9 to 12% as per the Ethiopian Standard Authority (EQSA, 2006). Zhang *et al*. (2001) indicated that malt gain having high protein content is associated with low carbohydrate and low malt extract that slows malting process and affects malt quality. On the other hand, low protein content has also its own limitations that it retards yeast growth during fermentation (Emebiri *et al*., 2005). In this research, the grain produced with all combinations of seeds obtained from six suppliers and four rates fertilizer including without fertilizer application had protein content in the range of set for malt barley grain by Ethiopian Standard Authority except Gelema seed source obtained from application rate of urea 225kgha^{-1}. Protein content is one of the important parameters in selecting malting barley, which is affected by genotype, cultural practices/crop management including the rate and time of nitrogen fertilizer application and growing environments (Riley *et al*., 1998; *Chen et al.,* 2006; Paynter and Van, 2014). Thus, it is necessary to identify the variety, rate and time of nitrogen fertilizer application in the target production area to produce optimum yield with acceptable level of protein content 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).

Table 18. Interaction effect of seed source and Nitrogen rate on grain protein content of 'Traveler' malt barley variety at Kulumsa in 2022

Treatment	Seed source					
Urea fertilizer (kg ha^{-1})	GU	HG	LD	OSEA	Soflet	TK
N0	10.03^{i}	10.3^{hi}	10.47^{f-i}	10.43^{hig}	10.50^{f-i}	10.30^{hi}
N75	11.17^{b-g}	10.90^{d-h}	10.93^{e-h}	11.0^{c-h}	10.70^{e-i}	10.90^{d-g}
N150	11.70^{abc}	11.20^{b-f}	11.43^{b-e}	11.57^{a-d}	11.47^{a-d}	11.27^{b-e}
N225	12.20^{a}	11.83^{ab}	11.83^{ab}	11.77^{ab}	11.63^{a-d}	11.83^{ab}
LSD (5%)			0.734			

Means followed with the same letter(s) in the columns and rows are not significantly different each other at 5% level of significance, GU = Gelema Union, HG = Hunde gudena Cooperative, LD = Lemu dima Cooperative, OSEA= Oromia Seed Enterprise, Souflet = Souflet Malt Ethiopia Plc., TK= Tuka ketar Cooperative and LSD (5%) = Least significant difference at 5% significance level.

the grain of 'Traveler' malt barley variety produced from all treatment's combination had grain starch content ranged from 55.37 to 58.97%. The higher starch content (57.8 to 58.9%) was measured from grain produced from the seeds obtained from Tuka ketar Cooperative, Oromia Seed Enterprise, Souflet Malt Ethiopia Plc., and Hunde gudena Union With application of 225 kg ha^{-1} Urea fertilizer without nonsignificant difference among the mean values. On the other hand, the lower starch content (55.37 to 56.37%) was measured for grain produced from the seeds obtained from all seed suppliers except Souflet Malt Ethiopia Plc., with the application of 150 and 225 kg ha^{-1} Urea fertilizer and seeds obtained from Gelema Union with 75 kg ha^{-1} Urea fertilizer. The grain of 'Traveler' malt barley variety produced from seeds obtained all suppliers with the application of the three rates (75, 150 and 225 kg ha^{-1}) Urea fertilizer had lower starch content in the range between 0.03 to 3.2% than grain produced without fertilizer application (Table 19). The results showed that protein content and starch content of grain have inverse relationship, as nitrogen rate increase starch content decrease and vise verse (Table 18 and 19).

In this research it was evident that the higher thousand grain weight, hectoliter weight, grain yield and grains protein content but lower starch content of grain as nitrogen fertilizer applied and mostly to the higher rates. This is in agreement with other research results that plump kernels contain higher starch levels and to the inverse relationship between protein and starch (Weston *et al.*, 1993). 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). Meharie and Kindie Tesfaye (2019) reported that grain protein content increased with increasing nitrogen rate in a linear fashion from the research conducted on malting barley grain quality and yield response to nitrogen fertilization in Arsi Highlands. They indicated increasing nitrogen rates to achieve maximum grain yields caused grain protein content to exceed the maximum acceptable value for malting. Fasil and Zenebe (2021) and Tadesse *et al.* (2022) also investigated the kernel protein concentration increased with increasing rate of nitrogen fertilizer rate and has a direct impact on the quality of malting barley. Thus, this research results suggested careful nitrogen fertilizer management for malting barley production as many authors indicated high protein is often associated with reduced malt extract levels, poorer endosperm modification, and problems with beer stability and viscosity (Edney *et al*., 2012; Mather *et al*., 1997). However, as many researchers suggested the improvement of malting barley yield and quality not only depend on strategic nitrogen fertilizer application but also it include proper cultivar selection, optimal seeding dates and rates, and appropriate crop rotations and tillage practices (McKenzie *et al*., 2005; Edney *et al.*, 2012; Turkington *et al*., 2012; Sainju *et al*., 2013; Carr *et al*., 2014; O'Donovan *et al*., 2015 and 2016).

Table 19. Interaction effect of seed source and Nitrogen rate on grain starch content of 'Traveler' malt barley variety at Kulumsa in 2022

Treatment		Seed source				
Urea fertilizer (kg ha^{-1})	GU	HG	LD	OSEA	Soflet	TK
N0	57.27^{b-f}	57.8^{a-d}	57.6^{b-d}	58.1^{ab}	58^{abc}	58.9^{a}
N75	56.07^{g-j}	57.1^{b-g}	56.7^{d-i}	56.97^{b-h}	56.9^{c-h}	57.07^{b-g}
N150	56.37^{f-j}	56.3^{f-j}	55.8^{hij}	56.17^{f-j}	57.17^{b-g}	56.17^{f-j}
N225	56.6^{e-i}	55.7^{ij}	55.37^{j}	55.67^{ij}	57.97^{abc}	55.7^{ij}
LSD (5%)			1.1804			

Means followed with the same letter(s) in the columns and rows are not significantly different each other at 5% level of significance, GU = Gelema Union, HG = Hunde gudena Cooperative, LD = Lemu dima Cooperative, OSEA= Oromia Seed Enterprise, Souflet = Souflet

Malt Ethiopia Plc., TK= Tuka ketar Cooperative and LSD (5%) = Least significant difference at 5% significance level.

4.5. Economic Analysis

Partial budget analysis used to analyse costs and benefits of treatments for further recommendations under seed producer. Partial budget analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 20. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation for seed producers. The partial budget analysis of the study indicates that the application rate of recommended urea and combined with a seed source was resulted in higher net benefit of birr 120158.5 ha^{-1}

Table 20. Partial budget analysis for seeds obtained from six suppliers and four Nitrogen rates on for grain yield of 'Traveler' malt barley variety at Kulumsa in 2022

Treatments combination	GY (Kg ha^{-1})	Adjusted yield (kg ha^{-1})	Total revenue (Birr)	TVC (Birr)	Net benefit (Birr)	MRR (%)
GUN0	2497	2247.3	101128.5	16550	84578.5	
GUN1	2923	2630.7	118,381.50	18256	100125.5	911.3
GUN2	3163	2846.7	128,101.50	22352	105749.5	137.3
GUN3	3568	3211.2	144504	25763	118741	380.9
HGN0	2626	2363.4	106353	16550	89803	
HGN1	2978	2680.2	120609	18256	102353	735.6
HGN2	3180	2862	128790	22352	106438	99.7
HGN3	3415	3073.5	138307.5	25763	112544.5	179.02
LDNO	2351	2115.9	95215.5	16550	78,665.50	
LDN1	2614	2352.6	105867	18256	87611	524.4
LDN2	2953	2657.7	119596.5	22352	97244.5	235.2
LDN3	3176	2858.4	128628	25763	102865	164.8
OSEAN0	2587	2328.3	104773.5	16550	88223.5	
OSEAN1	2748	2473.2	111294	18256	93038	282.2
OSEAN2	2968	2671.2	120204	22352	97852	117.5
OSEAN3	3372	3034.8	136566	25763	110803	379.7
SFN0	2360	2124	95580	16550	79030	
SFN1	2604	2343.6	105462	18256	87206	479.2
SFN2	3021	2718.9	122350.5	22352	99998.5	312.3
SFN3	3428	3085.2	138834	25763	113071	383.25
TKN0	2696	2426.4	109188	16550	92638	
TKN1	3014	2712.6	122067	18256	103811	654.9
TKN2	3304	2973.6	133812	22352	111460	186.74
TKN3	3603	3242.7	145921.5	25763	120158.5	255

GY = Grain yield, TVC = Total variable cost, MRR (%) = Percentage of marginal rate of return, GU=Gelema Union, HG = Hunde Gudena, LD= Lemu Dima, OSEA=Oromia Seed

Enterprise Arsi, SF =Souflet malt barley plc and TK =tuka ketar coop.NO=nil nitrogen kg ha^{-1}, N1=nitrogen 75k gha^{-1}, N2=Nitrogen 150 kg ha^{-1} and N3 =Nitrogen 225 kg ha^{-1}. The labour cost for application of Urea (persons ha^{-1}, each 200 ETB day, Market price of Malt barley seed = 45Birr kg^{-1} at Asela town at harvesting time in December 2023.

According to CIMMYT (1988) suggestion, the minimum acceptable marginal rate of return should be more than 100%. In this experiment, application of urea rate 225 kg ha^{-1} and combined with a quality seed source resulted the maximum net benefit (Birr 120158.5 ha^{-1}), with acceptable marginal rate of return of (911.3%). Thus, using quality and known seed source with application of 225 kg ha^{-1} of urea is economically beneficial as compared to the other treatments in the study area because the highest net benefit and the marginal rate of return was above the minimum level (100%).

5.SUMMARY AND CONCLUSIONS

Barley is an important food grain and malting crop in the Ethiopian highlands with malting barley a major source of income for smallholder farmers. However large numbers of farmers and some seed producers are not using improved technologies such as nitrogen fertilizer. It has been selected as one of the target crops in the strategic goal of attaining national food self-sufficiency, income generation, poverty alleviation, and achieving socio-economic growth of the county. However, its production and productivity are low due to the use of quality seed source and inappropriate nitrogen fertilizer rates. Nitrogen fertilizer is very important to the growth and improves yields of barley, so the farmers and seed producers should use the appropriate rate of nitrogen fertilizer to increase plant height, spike length, number of fertile tiller grain weight, and grain yield of barley.

Six seed samples of 'Traveler' malt barley variety from six seed sources (Gelema Union, Hunde gudena Cooperative, Lemu dima Cooperative, Oromia Seed Enterprise, Souflet Malt Ethiopia Plc., and Tuka ketar Cooperative) and four rates of Urea fertilizer (0, 75, 150, and 225 kg ha^{-1}) in factorial combinations were evaluated at Kulumsa Agricultural Research Center in Randomized Complete Design with three replications and the malt barley grain quality(protein content, sieve test and starch content) were conducted at Kulumsa Agricultural Research Center in Completely Randomized Design with four replications . The seed quality test (physical purity, physiological purity and seedling vigour index) was conducted at Asela Agricultural Inputs and Production Regulatory Authority Asela branch in Completely Randomized Design with four replications.

Thus, the present study was conducted to assess the yield and quality response of malt barley to different seed source and nitrogen fertilizer application in the study area. The two experiments results showed that the presence of significance difference among seeds of different sources for seed quality which consequently resulted significance difference in crop phenology, growth, yield and yield components of the six seed sources of malt barley variety. Nitrogen plays a crucial role in plants as plant depends on this nutrient for many of its processes and it affect plant at different stages of its life cycle differently mainly at vegetative stage, if at this stage availability of nitrogen declines then plant remain stunted and photosynthetic activity reduce and it directly affect the green fodder yield and grain yield as well. The seed samples of the variety collected from six seed suppliers before planting had 97.75,13.43, 93.17% and 40.82g mean physical purity, moisture content, germination and

Thousand seeds weight respectively. The seed samples also had 63.07, 9.87 and 97.32% mean starch, protein contents and sieve test of grain, respectively. Number of tillers, plant height, number of grains per spike, hectolitre weight and thousand kernel weight of malt barley were increased with N fertilizer rates increased. Grain yield and protein content of malt barley were increase with increasing N fertilizers rates. However, high nitrogen rate leads to high grain protein content while low nitrogen rates lead to optimum grain yield with acceptable quality and vice versa for starch content. the results revealed that days to 50% heading and 90% physiological maturity were significantly influenced by urea application rate. Total number of total tillers, number of kernels per spike, biological yield, seed yield, effective tillers, was significantly influenced with two main (seed source and nitrogen rate) factors studied, but not significant to interaction of seed source and urea application rate. Thousand kernel weight, moisture content, seed germination, abnormal seedling, dead seedling, germination energy, seedling shoot length, seedling length, vigour index two, sieve test, hectolitre weight and starch content were significantly affected by N application rate, and seed source. Sieve test, starch content, moisture content and dead seedling were influenced by interaction of nitrogen and seed source. Higher seed yield was scored by high urea application (225 $kgha^{-1}$) 3426.89 $kgha^{-1}$). Harvest index was significantly different to Seed source. Maximum plant height, spike length, total tillering number, productive tiller, seed yield and standard germination was increased when nitrogen rate increased, Grain protein content was only influenced by N application rate and no significance with seed sources and with their interaction. The economic analysis indicated that the highest net benefit of 120158.5 Birr with marginal rate of return (MRR %) of 255% was obtained from seeds obtained from Tuka ketar Cooperative with 225 kg ha^{-1} Urea fertilizer application whereas the highest MRR (%) of 911.3% was estimated for seeds obtained Gelema Union with 75 kg ha^{-1} Urea fertilizer application.

Generally, these results suggested that the importance of using appropriate nitrogen rate and quality seeds from reliable sources of improved variety to increase yield of malt barley in the study area. However, it is concluded that the rates of nitrogen fertilizer better to be determined separately for seed yield quality and grain yield of malt quality.

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APPENDICES

Appendix 1. Mean squares from analysis of variance for phenology, growth, yield components and seed yield of traveller malt barley variety at Kulumsa in 2022

treatment	Rep (2)	seed source (5)	Nitrogen (3)	SS * N (15)	Error (46)	CV (%)
Days to 50% heading	194.38	37.54ns	449.79**	27.84ns	16.54	5.03
Days to 90% maturity	62.72	19.65ns	382.01**	10.23ns	35.86	5.02
Plant height (cm)	1257.1	34.58*	410.38**	6.16ns	14.21	5.84
Spike length (cm)	4.84	3.76ns	19.97**	1.12ns	1.67	15.05
Total tillers (m-2)	23774.59	16140.50**	49027.71**	1208.75ns	4178.75	18.38
Productive tillers (m-2)	95602.01	9968.75**	48893.68**	1187.82ns	1590.02	15.12
No. of kernels per spike	5.74	12.25**	166.29**	0.86ns	2.77	6.06
Biological yield	227.87	26.95**	96.99**	1.40ns	3.8	14.67
Seed yield (ha-1)	4245206.35	239116.86*	2714484.98**	16936.05ns	96723.77	10.49
Harvest index	212.85	105.60*	15.92ns	24.86ns	35.5	14.81

Appendix 2. Mean squares from analysis of variance for seed quality and grain malt quality related parameters of Traveler' variety at Oromia Agricultural Inputs and Production Regulatory Authority Asela branch in 2022

Trait	Seed source (SS) (5)	Nitrogen (N) (3)	SS * N (15)	Error (69)	CV (%)
Thousand kernels weight (g)	7.60*	184.49**	3.01ns	2.81	4.07
Moisture content (%)	0.25**	0.25**	0.10**	0.03	1.5
Seed purity (%)	0.24ns	4.764**	0.84ns	1.1	1.05
Seed germination (%)	7.16*	51.49**	1.60ns	4.87	2.31
Abnormal seedlings (%)	0.010*	21.8 **	0.010ns	0.01	5.9
Dead seedlings (%)	0.07*	5.38 **	0.09 **	0.027	7.27
Germination energy (%)	7.025*	116.51**	1.863ns	2.8	1.81
Speed of germination	0.43ns	15.99**	0.31ns	0.71	3.68
Seedling dry weight (mg)	2.14ns	30.32**	0.91ns	1.92	9.55
Seedling root length (cm)	0.51ns	27.68**	0.07ns	0.15	3.54
Seedling shoot length (cm)	4.54**	39.2**	0.25ns	1.36	8.8
Seedling length (cm)	2.86**	86.938**	0.139ns	0.55	2.99
Vigor index I	1.54ns	109.24**	0.28ns	0.83	3.86
Vigor index Il	3.17**	16.74**	0.69ns	0.78	6.4
Sieve test (%)	18.03**	127.39**	2.5**	0.93	1.02
Hectolitre weight (kg/L)	25.38**	92.14*	4.71ns	4.59	3.27
Grain protein content (%)	0.09ns	7.67**	0.09ns	0.199	4.01
Starch content (%)	1.83**	11.78**	1.01*	0.52	1.26