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GROWTH AND YIELD RESPONSE OF FOOD BARLEY (*Hordeum vulgars* L.) VARIETIES TO SEEDING RATES IN CHEHA DISTRICT, GURAGE ZONE, CENTRAL ETHIOPIA

MSc THESIS

TIZAZU ANKTAWE GORAGA

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Growth and Yield Response of Food Barley *(Hordeum vulgars L.)* Varieties to Seeding Rate in Cheha District, Gurage Zone, Central Ethiopia

A Thesis Submitted to School of Graduate Studies in partial Fulfillment of the Requirements for the Degree of Master in Agronomy

Tizazu Anktawe Goraga

Major Advisor: Gizachew Woldesenbet (PhD)

Co-Advisor: Kifle Zerga (Assistant Professor)

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Wolkite, Ethiopia

APPROVAL SHEET

Wolkite University

School of Graduate Studies

We certify that we have read and evaluated this thesis titled **"Growth and Yield Responses of Food Barley (*Hordeum vulgars* L.) Varieties to Seeding Rate in Cheha District, Gurage Zone, Central Ethiopia",** prepared under our guidance by Tizazu Anktawe Goraga. We recommend that the Thesis shall be submitted fulfilling the requirements for the award of an MSc. degree in Agronomy

Gizachew W/Senbet (PhD)	__________________	_______________
Name of Major Advisor	Signature	Date
Kifle Zerga (Assistant Professor)	_____________	______________
Name of Co-Advisor	Signature	Date

As members of the board of the examiners of the Master of Science Thesis open defense examination, we have read and evaluated this thesis prepared by **Tizazu Anktawe** and examined the candidate. We here certify that the thesis has been accepted for fulfilling the requirements for the award of the degree of Master of Science (MSc) in Agronomy.

______________________	________________	______________
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Final approval and acceptance of the thesis is contingent upon the submission of its final copy to the School of Graduate Studies (SGS) through the candidate's Department or School Graduate Committee (DGC/SGC).

DEDICATION

I dedicate this thesis to my beloved wife Chewanesh Habte and all my lovely family for their smoothed and unrestricted support rendered to me for the betterment of my life.

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First, I would like to thank God, who helped me in each aspect of my life giving me strength and wisdom including this thesis work. I express my heartfelt and sustained genuine gratitude to my major advisor, Dr. Gizachew W/Senbet for his rational guidance, support constructive comments, and advices starting from proposal development to research write up. I wish to express my sincere gratitude to my Co-advisor Kifle Zerga (Asst· Prof) for his unreserved support, constructive comments and his fatherly advice during research write up. My special thanks go to Holletta Agricultural Research Center for providing me the seed of food barley varieties used for the experiment.

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STATEMENT OF THE AUTHOR

By my signature under, I announce and affirm that this thesis work is my own work. I have followed all ethical and technical values of scholarship in the preparation, data collection, and data analysis compilation of this thesis. Every scholarly matter that is incorporated in the thesis has been given all the way through citation.

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Name: Tizazu Anktawe Signature-----------------

Department: Plant Sciences Date of Submission-------------

BIOGRAPHICAL SKECH

The author, Tizazu Anktawe, was born at Yewezhe near to Emdebir town, Cheha District, Gurage Zone, SNNP Region, on August 16, 1983 G.C from his father, Anktawe Goraga, and his mother Tamechet Keraga. He attended his elementary and Secondary Education at Emdebir primary school and Emdebir secondary School respectively. Then, he attended college education at Mizan Agricultural Technical and Vocational Education Training College from 2003 up to 2005 G.C and graduated in Diploma. The author joined Dilla University from 2011 up to 2015 G.C and graduated with a BSc degree in Plant science on November 2015 G.C. He has been employed in the office of Cheha District Agricultural office and served at different position since. He joined the post graduate program at Wolkite University, Department of Plant Sciences in December 2021 G.C to pursue his studies for the degree of Master of Science in Agronomy.

LIST OF ABBREVATION AND ACRONOMY

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ANOVA	Analyses of Variance
ATA	Agricultural Transformation Agency
CHDAO	Cheha District Agricultural Office
CSA	Central Statistics Agency
ETB	Ethiopian Birr
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics
GFB	Gross Field Benefits
HARC	Holletta Agricultural Research Center
ICARDA	International Center for Agricultural Research in the Dry
LSD	Least Significance Difference
MRR	Marginal Rate of Return
RCBD	Random Complete Block Design
SAS	Statically Analysis' Soft ware
SNNPRS	South, Nation, Nationality, peoples, Regional, state
USDA	United States Department of Agriculture

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ABSTRACT

Barley (*Hordeum vulgare* L.) is an important food security and cash crop in Central Ethiopia. The productivity of the crop is very low in many parts of the Gurage zone, including the Cheha district. Several factors are responsible for the area's low crop yield. There is limited information on the response of various barley genotypes and seed rates for optimal production. Hence, a field experiment was conducted to evaluate the effects of seeding rate and genotypes on growth, yield, and yield components of barley in Cheha District. Factorial combinations of four food barley varieties, namely HB-1307, HB1966, HB1965, and Local genotype, and four seeding rates (75, 100, 125, and 150 kg ha^{-1}) were used. The experiment was laid out in a randomized complete block design with three replications. The result showed that seeding rate and varieties significantly affected the majority of food barley growth and yield parameters. The highest days to 50% heading (82 days), and days to physiological maturity (139 days), were recorded on 75 kg of seeding rate ha^{-1} with variety HB1966, while, the highest plant height (96 cm) was recorded with the use of 150 kg ha^{-1} of food barley seeding rate on HB1966 variety. The highest spike length (8 cm), total number of tillers (8), number of productive tillers (7), and number of kernels spike^{-} (66) were recorded on the use of a 75 kg ha^{-1} seeding rate with the HB-1307 variety. The highest biomass yield (13.18 t ha^{-1}) and straw yield (8.95 t ha^{-1}) were recorded on 150 kg of seeding rate ha^{-1} with variety HB-1307. The highest grain yield (4.89 t ha^{-1}), thousand seed weight (57g), and harvest index (43%) were recorded on variety HB-1307 with a 125 kg ha^{-1} seed rate. Net benefit of 129375.5 ETB ha^{-1} was obtained from the treatment combination of 125 kg ha^{-1} food barley seed rate with Variety HB-1307. The result indicated that the food barley variety HB-1307 with a seeding rate of 125 kg ha^{-1} is economically feasible and profitable for the study area. Since the present study was conducted only in a single season and location, it is necessary to conduct similar experiments further in different seasons and locations to come up with concrete and workable recommendation for varieties and seeding rates of food barley.

Key words: Food Barley, varieties, seed rate, yield, yield component

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) belongs to the grass family Poaceae and one of the world's most earliest food crop, believed to be first domesticated about 10,000 years ago from its wild relatives in the Near East and, Ethiopia is recognized as center of diversity (Hashash *et al.,*2019). It is one of the most important food crops in the world in general and Ethiopia in particular. In production wise, the crop is the fourth important cereal crop in the world, following wheat, rice and maize, and it accounts for both 9% in terms total area under cereal crops and total cereal production in Ethiopia (CSA, 2020). Nearly half of the world's total production of barley is produced in France, Germany, Canada, Ukraine, and Russia (Jemal *et al.,* 2021). In 2023, global food barley production accounted for a small share of the total 142.6 million metric tons, with yields averaging 3.1-4.2 t ha^{-1} across 47-50 million ha, while Africa produced 6-8 million tons, with Ethiopia leading at 2.1-2.5 million tons on 1 million ha at a yield of 1.9-2.2 t ha^{-1} (Ahmed *et al.,*2023). Ethiopia accounts for nearly 25% of the total production in Africa which out of the total area under cereals, barley covered 926,106.9 ha with the production and productivity of 23,391,098 qt and 25.26 qt respectively (CSA, 2020).

The southern Nation and Nationalities people Region (SNNPR) ranks 3rd in barley production, which covers an area of 93,643.58 ha with total production of 181,893.869 t and productivity of 1.94 t ha^{-1} (CSA 2018). Barely is a reliable source of food in the highland of the country as it is produced throughout the main and short rainy seasons, as well as under residual moisture (Asfaw *et al*., 2015). In Ethiopia, barley is an important crop that supports cultural values, economic growth, food security, and agricultural resilience (Tadesse *et al*., 2019). Gurage zone is one of producers of barley which covers the total area of 24756 ha, with average production and productivity 81694 t ha^{-1} and of 2.4 t ha^{-1} respectively (Gurage Agri office, 2021). Cheha district is one of the potential food barley producing areas of Gurage Zone. In the highlands of the district, the crop is produced as a supplementary food and cash crop.

Like any other crop, the productivity of barley is determined by genetic potential (variety), environmental and management factors. The use of improved variety in barley production is constrained by different factors like depletion of soil fertility, soil acidity, unbalanced fertilization, advanced agronomic management practices, soil erosion, poor seed quality, disease, pests, and weed infestation (Parashar *et al.* 2020). The significant influence of varieties and seeding rate on the growth and yield performances of food barley was reported (Kazimierz *et al*., 2010). Optimization of seeding rate is one of the most determining crop management factors for food barley production since it affects plant population, number of tillers per unit area, length of spikes, and number of grains spike$^{-1,}$ which in turn affect the grain yield productivity (Chandrasekaran *et al*., 2010). The use of a proper seeding rate encourages nutrient availability, proper sunlight penetration for photosynthesis, good soil environment for uptake of soil nutrients and water use efficiency, which all are necessary for crop vigor and consequently increase the production and productivity of the crop (Alemayehu, 2015). The higher seed rate leads to higher competition, shorter spike length, and lower number of grains spike$^{-1,}$ whereas; increases weed population in case of using low seed rates (Ejaz *et al.*, 2002).

In the Cheha district, barley food production and productivity are low. Improper use seeding rate is among the contributing factors for the optimum productivity of the crop. Although the nationally recommended rate is 100 kg ha^{-1}, farmers in the study area are planting at a rate of 75 to 150 kg ha^{-1}, because they are not convinced of the very general recommendation (personal observation). Moreover, the perception of the farmers towards improved varieties supplied by the Office of Agriculture is different. Some of the farmers are in favor of the variety *HB1307,* while others, *HB1966* or local (Jimua-Tikur) varieties. Research output in this regard is limited in the Gurage Zone in general and at the Cheha District in particular. Hence, it was found necessary to conduct a field experiment to identify productive, suitable varieties fitting the agroecology of the study area and the optimum seeding rate.

Thus, the research was initiated to achieve the following objectives:

General objective

To study the performance of food barley varieties under different seeding rates in Cheha district, Gurage Zone

Specific objectives

- To evaluate the growth and yield performance of food barley varieties at Cheha district
- To evaluate the effect of seed rate on the growth and yield of food barley varieties
- To evaluate the economic feasibility of different seeding rates in barley production in the area

2. LITERATURE REVIEW

2.1. Origin and Distribution of Food Barley

Barley (*Hordeum vulgare L.*) is an important cereal crop that has been cultivated for thousands of years, with its origins tracing back to the Fertile Crescent in the Middle East (Hashash *et al.,* 2019). It was domesticated from its wild relative, *Hordeum spontaneum C. Koch*, around 10,000 years ago, as evidenced by archaeological findings in the Fertile Crescent (Harlan, 1995). Although the barley crop is distributed landraces adapted to northern and western European environments and later to North American, Australian, and Southern African environments (Ellis, 2002). It is believed that the barley crop have distributed throughout the region of its origin after domestication.

Historically, Ethiopia is considered as the center of origin and barley diversity in the world having high level of morphological variations between landraces that has developed over time, through adaptation to varied climatic and soil conditions (Lakew *et al*., 1997). This diversity may have been likely contributed through long-term geographic isolation since barley is considered as a founder crop of old world agriculture and may have been cultivated in Ethiopia for the last 5,000 years (Endashaw, 1983). Ethiopia based on the diverse variation and concentrations of some characters including genes for disease resistance can be defined as a center of diversity and origin of barley (Daniel *et al.,* 2019). Evidences indicate that the crop is grown in all regions of the country (Wosen *et al.,* 2015). Archeological excavations have been identified barley in many pre-agricultural and incipient sites in the Near East, Southeast Asia and Ethiopia where it was one of the first crops cultivated for more than 10,000 years ago (Jose, 2012; Eric, 2011).

2.2. Botanical Description of Food Barley

Barley belongs to the genus *Hordeum*.in the tribe *Triticeae* of the family *Poaceae* also called *Gramineae* (OGTR 2008; Satish *et al.,* 2016). The genus *Hordeum* is unusual among the *Tritceae* as it contains both annual species such as *H. vulgare* and *H. marinum* and perennial species such as *H. bulbosum* (Blattner, 2018). The cultivated barleys are classified into three species based on the fertility of the lateral spikelets: *Hordeum vulgare* L. six-rowed type barley with all florets fertile, *H. distichum* L. a two-rowed type barley with only the central florets fertile and *H. irregular* has central florets and varying proportions of fertile and sterile lateral florets (Zhou, 2010).

Barley crop which grown now a day roots that has both seminal and permanent roots type contain main root and other lateral roots and has stem cylindrical in shape with the characteristic of wider in the lower beneath and with hollow internodes that contain 5 to 7 nodes and the leaves characterized by arranged alternately on opposite directions of the stem and arising at each node and the spike at the top of the stem consisting of the flowers arranged in spikelets (USDA, 1979).

2.3. Environmental and Agronomic Requirements of Food Barley

Food barley is a cool season crop that is suitable for high altitudes and cultivated in various agro-ecological regions under several production system Assefa *et al.,* 2021). Currently, producers cultivate the crop from altitudes ranging from 1,400 to over 4,000 meters above sea level under highly variable climatic and edaphic conditions (Asfaw, 2000). The yield potentialities of barley varieties are realized extent when they are grown under optimum agro-climatic environment (Singh *et al.*, 2009).

Ethiopia is renowned for having a wide variety of barley landraces and types that are well-suited to the various agro ecological zones within the nation. The recommended agro-ecology for food barley are altitude ranging from 2000 to 3500 meters above sea level, 15-20 °C temperature, with an annual rainfall of 500 mm to 1200 mm and well drained fertile soil can be taken as suitable (Asresie *et al*., 2015). It performs best in areas of relatively high rainfall, low relative humidity and cool temperature at maturity. Generally, it is a cool season crop that yield the best under conditions in which the vegetative and early reproductive growth coincide with moderate temperatures (Oser, 2015). Barley being a long day plant would prefer a photoperiod of 10-12 and 12-14 hours during vegetative and reproductive stages, respectively (Ahlawat, 2012). Soil texture is very essential to the performance of barley. Barley grows under a wide range of soil type however; it is best adapted to fertile and well drained silt to clay loam soils and can tolerate higher levels of soil salinity than most other crops. It is very tolerant of alkalinity and salinity but it is less tolerant to acidic soils, preferring a soil pH of 6.0 to 8.5. Soil pH levels of 5.5 or lower barley responds negatively and fields should be limed according to soil analysis results (Ashley *et al.,* 2014).

Agronomic practices also influence the growth, yield and yield parameters of barley as early planting reduces the risk from moisture stress, high temperatures later in the season, diseases, and insect infestations (McVay *et al*., 2008). Growing of different barley variety with wider adaptability and responsive to inputs has opened a new avenue for exploiting higher grain yield potential the identification of high yield responsive varieties is considered to be the first and the most important steep the development of production technology. By developing high-yielding and disease-resistant food barley varieties, farmers have been able to increase their productivity per unit of land (Bishnoi *et al*., 2022). Several a biotic and biotic factors have ensure to the low productivity, such as poor agronomic crop management practices; the use of low yielding cultivars; the inadequate availability of the few maintained cultivars released; diseases, insects and weed; and the inherently low yield potential of the prevalent local varieties (Bayeh; Stefania, 2011).

Barley requires essential nutrients for growth, such as nitrogen, phosphorus, and potassium to replenish soil nutrients and improve crop productivity (Timsina *et al*., 2018). Balanced fertilization practices help maintain soil fertility and support healthy plant growth. The regions where rainfall is insufficient, farmers may practice supplemental irrigation to meet the water requirements of barley plants (Savin *et al*., 2022).

2.4. Importance of Food Barley in Ethiopia

Barley is a highly important cereal crop in Ethiopia, ranking fifth in area, productivity, and total production among major cereals and serves as a staple food for many Ethiopians, particularly in the highlands, where it accounts for over 60% of the diet. In terms of utilization, barley is largely consumed as staple food and used for preparing the popular traditional foods and drinks prepared from barley grains include; *kolo, Dabo, genfo, kinche, beso, tela, borde,* and other types of food (Senite *et al*., 2020). Barley grain consists about 65-68% starch, 10-17% protein, 4-9% s-glucan, 2-3 free lipids and 1.5-2.5% minerals (Martin *et al.,* 2006). Barley is an important subsistence crop for smallholder farmers, often grown in areas where soil fertility, drainage conditions, and topography are not suitable for other crops (Teklemariam *et al*., 2022).

Barley has played an important role in providing better yield, seed quality and different agro-ecological adaptation that growing of different barley variety with wider adaptability and responsive to inputs has opened a new avenue for exploiting higher grain yield potential the identification of high yield responsive varieties is considered to be the first and the most important steep the development of production technology.

Barley is regarded as a drought-tolerant crop and its water-use efficiency is higher than that of other cereals; however, it is responsive to supplementary irrigation (Savin *et al*., 2022). Food barley can grow best on well-drained soil and can tolerate high levels of soil salinity (Berhanu *et al*., 2005).

2.5. Production Status of Food Barley in Ethiopia

Barley cultivation and consumption have since increased globally due to its adaptability to various agro ecologies and numerous uses. Ethiopia is a major producer of barley, ranking second in Africa after Morocco and accounting for about 25% of the continent's total barley production (Verma *et al*., 2018). Over the years, Ethiopia has shown positive trends in both production volume and yield of food barley (Araya *et al*., 2021). According to data from the Food and Agriculture Organization (FAO), Ethiopia produced ~4.5 million metric tons of food barley in 2020. The production status of food barley in Ethiopia can vary from year to year depending on factors such as weather conditions, agricultural practices, and market demand (Tadesse *et al*., 2020). Food barley in Ethiopia occupies about 811,782.08 ha of land annually with an estimated production of 48,380, 74.091 t (CSA 2019).

In Ethiopia by the year 2020 2,339,109.9 metric ton was harvested from the area of 926,106.90 ha with the productivity of 2.5 t ha^{-1} (CSA, 2020). In spite of its wide spread cultivation and uses, average yield of the crop in the country under farmer's condition is 2.56 t ha^{-1} (CSA, 2020), which is far below the average potential yield under improved management conditions (6 t ha^{-1}) (*Habtamu et al., 2014*).

Barley is grown in various regions of Ethiopia, with the highland areas particularly well-suited for its cultivation (Tesfaye *et al.,* 2023). The major barley-producing regions in

Ethiopia include Oromia, Amhara, Tigray, and Southern region, and its production in Ethiopia is primarily carried out by smallholder farmers who cultivate the crop for both food and feed purposes (Rashid *et al*., 2019). The highlands of Oromia, Amhara, Tigray and part of the Southern Nations, Nationalities and Peoples' Regional States are the major barley producing areas of the country (CSA, 2020). At the same time, in terms of the area coverage and production, Oromia regional State contributes 440,702.06 ha and 12,319 94.709 t respectively, to the nation with an average productivity of 2.8 t ha^{-1} (CSA, 2020). However, 554,571 farmers are involved with an area coverage of 81,161.32 ha and 1, 545, 04.718 t barley produced in the Southern Nations, Nationalities, and People's Region (CSA,18). Gurage zones in SNNPR State contribute 12.80% (10345.86 ha) with average zonal values of 2.68 tons ha^{-1} (Ferede et al., 2018).

2.6. Constraints of Food Barley Production in Ethiopia

Barley production is a problematic issue due to both biotic and abiotic factors such as low soil fertility, weeds, diseases, insect pests, poor management practices, in adjustable barley cultivars with durable resistance to diseases, inappropriate sowing patterns, shortage of improved variety, rate of fertilizers, climatic condition, and sowing time. Factors that are responsible for the low yield of food barley include the use of unbalanced rates of fertilizers, inappropriate use of variety, and use of inappropriate seeding rates are important agronomic practices, and research on these limiting factors will enhance yield (FAO,2017). Land degradation, soil erosion, and declining soil fertility can negatively impact barley production in Ethiopia (Aleminew *et al*., 2020). Barley food production in Ethiopia faces challenges from biotic stresses that are susceptible to various diseases and pests such as net blotch, scald, and leaf rust that can damage crops and reduce yields (Peng et al .,2019).

The productivity of food barley in Ethiopia has been constrained mainly by low-yielding capacity of farmers' varieties, inadequate number and poor supply of improved varieties adapted to the different production systems and different agro-ecological zones, and poor agronomic practices such as inappropriate seeding rate, sowing depth and planting methods (Kemelew; Alemayehu, 2011).

Seeding rate is one of the important yield production problems as higher barley grain yield with better quality requires applicable seeding rate for different cultivars and increased seed rate in appropriate level may only enhance production cost without any increase in grain yield (Rafique *et al*., 2010).

Ethiopia is highly vulnerable to the impacts of climate change, which can have a direct effect on barley production (Kassaye *et al*., 2021). According to (Bekele *et al*., 2019) climate change and its impact on food barley increasing trend in temperature and significant variation of seasonal rainfall from the historical period which adversely affected food barley yield. Climate change adaptation strategies, such as developing drought-tolerant barley varieties, implementing water management practices, and promoting sustainable farming techniques, are essential to mitigate the impact of climate change on food barley production (Amare *et al*., 2019).

2.7. Effect of Seeding Rate on Yield and Yield Components of Food Barley

Seeding rate is among the vital agronomic attributes to determine food barley productivity and has an influence on tiller dynamics, whereby tillering begins earlier and happens at lower planting densities than at higher rates (Shane, 2015). The required plant density is controlled by different agronomic and other factors; importantly, most of these are include, growth period duration, planting time, methods, soil fertility, plant size, available moisture, sunshine and situation of weeds (Shirtliffc, 2002). Rahim *et al*., (2012) confirmed that plant height is controlled by plant density as compute for light absorption which suited for the performance of crop stand.

Maximizing seeding rates hasten phenological behaviours, such as days to heading and maturity and are related with higher tiller and spike numbers m^2 but lower tiller and spike numbers $plant^{-1}$ (Seleiman *et al.,* 2010). The use of properly managed seed rate boosts nutrient availability, avoids interference of sunlight penetration for photosynthesis, good soil nutrients uptake and water use efficiency; and all other necessary for crop vigour and consequently increases the production and productivity of the crop (Alemayehu, 2015).

Inherently tiller production out shine directly governed with genotype features but it is limited by seed rate, which could be accompanying with resource sharing. Gomez (2001) suggested that that number of tillers plant^{-1} is influenced by seed rate, nature of the cultivar and environmental factors by Dereje *et al*., (2019) confirmed that number of effective tillers plant^{-1} significantly varied among different food barley varieties evaluated for their performances.

The finding by Rahel and Fekadu (2016) indicated that plant height; number of tiller plant^{-1}, number of grains spike^{-1}, biological yield, grain yield and straw yield were significantly affected by different seeding rates. A study in North Dacota indicated that cultivars that have high tillering capacity can reach maximum yield at a lower seeding rate than cultivars with less tillering capacity (Grant, 2016). Zenebe, (2019) found that seeding rate difference existed and significantly influenced on days to 50% heading, plant height, and spike length, number of kernels spike^{-1} and thousand-kernel weight of malt barley. Tiller numbers plant^{-1} is influenced by seed rate, nature of the cultivar and environmental factors (Otteson, 2007).

The maximum thousand seed weight obtained when seed applied at low seed, and although, minimum weight of thousand seeds obtained in plots at high seed applied (Lake, 2018). Maximum thousand seed weight (41.3 g) was reported from a seed rate of 100 kg ha^{-1}, while minimum thousand seed weight was reported from a seed rate of 150 kg ha^{-1} which is (39 gm.) followed by 125 kg ha^{-1} which is (39.6) (Veselinka *et al*., 2014). Similar reports were also reported on the spike length by different authors (Ketema and Mulatu, 2018).

Lowing seeding rate reduce grain yield depending on the variety and the higher grain yield in the higher seeding rates connected with higher spike number or plant population ha^{-1} (Haile *et al*., 2013). A two year study in Jordan showed that barley seeding rate had a significant effect on all variables measured in both seasons. Grain weight spike^{-1}, 1000 grains weight, and number of grains spike^{-1}, spike length and fertile tillers plant^{-1} were negatively related to seeding rate (Munir, 2002). Baloch *et al*. (2010) reported that different seed rate had no significant effect on spike length. Furthermore, Zewdie *et al*. (2014) reported that plant height and spike length are negatively related.

2.8. Effect of Varietal Differences on Growth and Yield of Food Barley

Workineh (2016) who reported that among twenty malt barley varieties tested for their performances, significant differences were observed for days to heading, days to maturity, total tillers plant^{-1}, fertile tillers plant^{-1}, spike length, number of kernels spike^{-1}, grain yield and biomass yield. A two years study in South western Ethiopia showed that among the ten improved food barley varieties tested for their adaptability, there were significant differences in days to 50% heading, days to 95% Physiological maturity, thousand kernel weight and grain yield (Teshome, 2017).

A study conducted by Zeleke *et al*. (2018) indicated that among ten improved food barley varieties tested for their performances, highly significant differences were observed in days to maturity, plant height, spike length, number of grains spike^{-1} and grain yield. Selamawit and Tariku (2018) also reported that among 12 improved varieties and one standard check tested for their performances, days to 50% heading, days to 50% maturity, plant height, spike length and grain yield were significantly varied.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiment was conducted at Moche *kebele* of Cheha District, Central Ethiopia in the 2023 G.C main cropping season. Experimental site is located 201 km from Addis Ababa and 42 km from the capital city of Gurage Zone Wolkite. The area has an altitude of 2722 m.a.s.l and located between geographic coordinates of 08° 03' 31.3"N latitude and 038° 02' 10.4"E longitude (Cheha Agri office, 2022). The annual average rainfall is 1268 mm while, the mean average minimum and maximum temperatures of the site are 10.42° C and 24.55° C, respectively (NMA, 2021).The soil in the experimental area is characterized as silt loam texture. The District is bordered by Gummer District at the East, Enemore District at South, Ezahe District at North and Abeshge at the West direction. Cheha District has two agro-ecological zones, with 80% of the area classified as midland (*Weina Dega*) and 20% as highland (*Dega*) type. The specific *kebele* (administrative unit) where the study was conducted Moche *kebele*, is located 16 km east of Emdibr, the capital town of Cheha District. The major crops grown in the study area include Enset, Maize, wheat (*Triticum aestivum L.*), Potato, barley (*Hordeum Vulgare L.*) and Faba bean (Cheha Agri office, 2021).

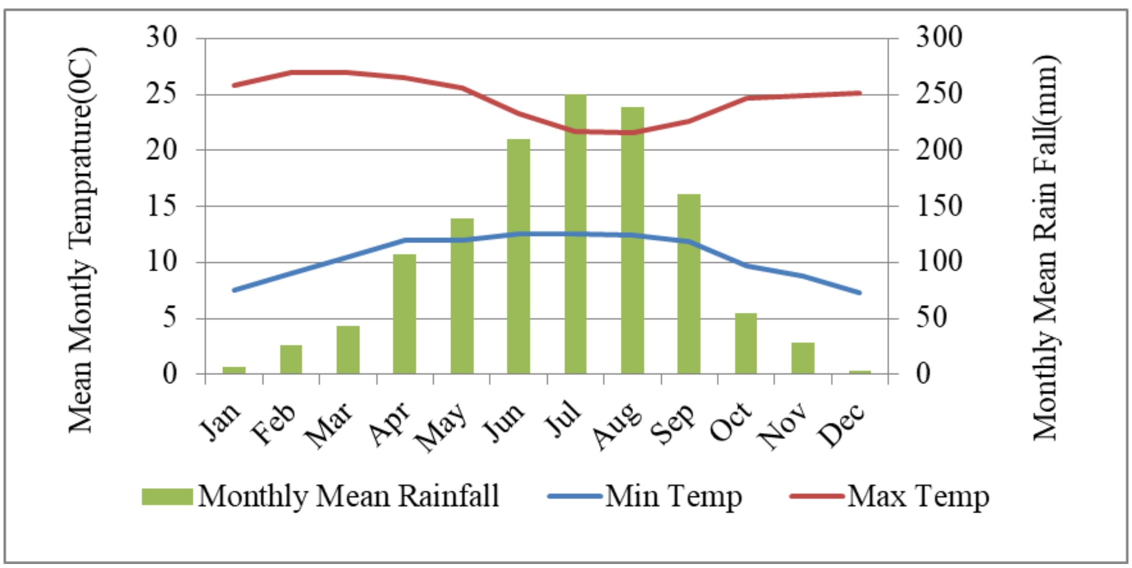

Figure 1: Temperature (^{0}C) and rainfall (mm) condition of experimental area (NMA, 2021).

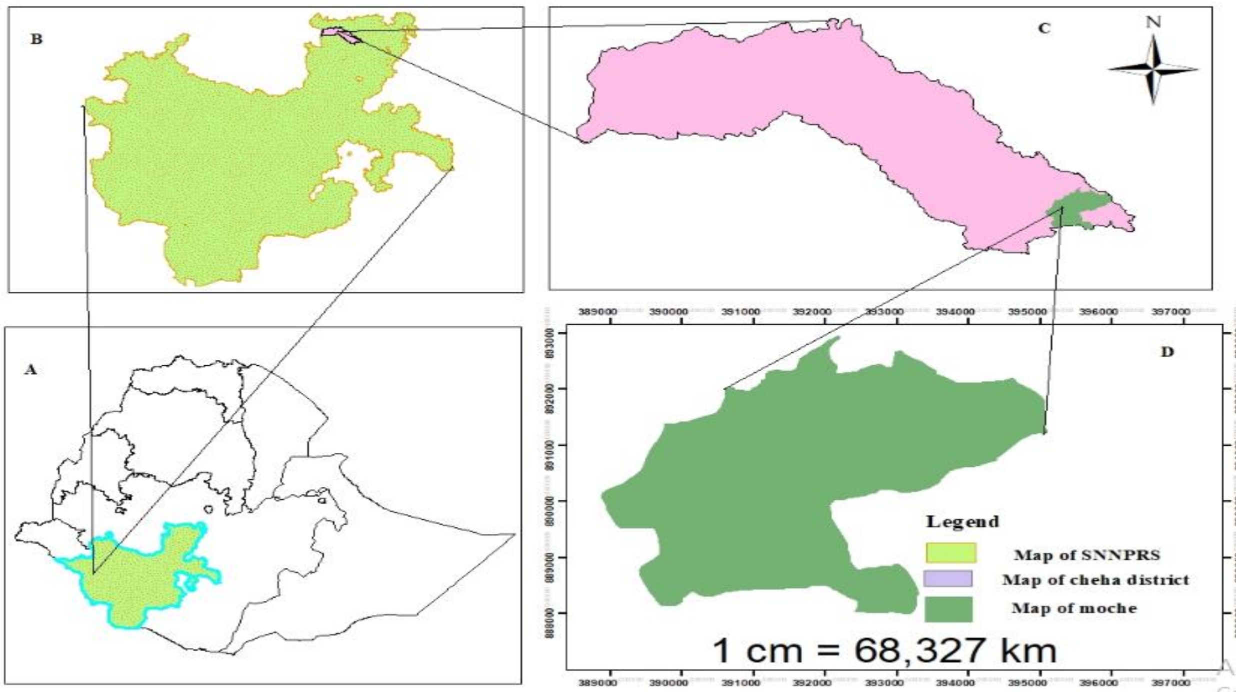

Figure 2: Map of the study site

3.2. Experimental Materials

3.2.1. Food barley varieties

Three white colored food barley varieties, (HB 1307, HB1966 and HB1965) were obtained from Holeta Agricultural Research Centre (HARC) and one local genotype locally called *Jimua-Tikur*, which is characterized by black color was obtained from Cheha District farmers' seed system. The details of the experimental plant material are as shown in **Table1.**

Table 1: General description of barley genotype used in the experiment

Varieties	Year of release	Breeder	Altitude	Rainfall	Days to Maturity	Yield t ha^{-1}	
						Farmers' Field	Research Site
HB1307	2006	HARC	2000-3000	700-1000	137	3.5	3.5-5.0
HB19966	2017	HARC	>2400	500-1000	137	3.0-4.0	3.5-5.4
HB1965	2017	HARC	2000-2800	500-700	132	2.5-3.5	3.0-5.0
Local (Juma-Tikur)	-	-	-	-	124	1.4-2.1	-

Source: HARC (2019) and Personal communication

3.2.2. Fertilizer materials

Blended NPSB fertilizer, that contains (18.9% N, 37.7% P_2O_5, 6.95%, S and 0.1% B) and Urea that contains 46% N were used based on the recommendation (ATA, 2016).

3.3. Treatments and Experimental Design

The experiment consisted of a factorial combination of four levels of food barley seeding rates (75, 100, 125 and 150 kg ha^{-1}) and four varieties of food barley genotypes namely HB1307, HB1966, HB1965 and local (Jimua-Tikur) variety resulting sixteen treatment combination. The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications. The gross size of each plot was 2m x3m (6m^2) while the net plot size was 1.6m x 2.6m (4.16m^2).The distances between adjacent plots and blocks were 0.5m and 1m, respectively. The outer most rows on both sides of each plot were considered to have border effect. The total area of the experimental size was 384m^2.

3.4. Experimental Procedures and Field Management

The experimental field was cleared from plant residues and unnecessary materials and ploughed to depth of 30 cm with oxen plough to affine filth 4-times and the plots were leveled manually. The experimental field was divided in to three blocks, with sixteen (16) plots in each replication. Based on the design, a field lay out was made and each treatment was assigned randomly based on Gomez and Gomez (1984) to the experimental units within a block. Seeds were sown as pre planned varieties on respective plots in rows of 20 cm spacing manually by drilling in July 11, 2023 G.C. Fertilizer was applied at the rate of 100 kg ha^{-1} of NPSB and 100 kg N ha^{-1} as the recommendation of Ethiopia Ministry Agriculture (EMA, 2011). Based on the experimental design total 100 kg ha^{-1} NPSB and 1/3 urea fertilizer were applied at sowing while, the remaining 2/3 urea was applied at mid-tiller stage (35 days after sowing) as a top dressing. The first weeding was done one month after planting and the second weeding done before flowering. All necessary agronomic management was carried out uniformly and properly for each plot at right time starting from the field preparation to harvesting. Harvesting was done manually when the crop reached at physiological maturity.

3.5. Data Collection

3.5.1. Crop phenologies

Days to 50% heading: 50% heading was determined by visual observation and, computed by counting the number of days from sowing to the time when 50% of plants were headed.

Days to 90% maturity: It was determined as the number of days from sowing to the time when 90% of the plant in the plots reached physiological maturity, and when straw is turned to yellow, no green color remained on glumes and panicles of the plant.

3.5.2. Growth parameters

Plant height (cm): plant height was determined by measuring from ground level to the top of the spike (excluding the awns) of ten randomly selected plants from the net plot area at physiological maturity.

3.5.3. Yield and yield components

Spike length (cm): spike length was measured from bottom of the spike to the tip of the spike (excluding the awns) of ten randomly selected plants from the net plot at physiological maturity.

Number of total tillers: The average number of total tillers $plant^{-1}$ was computed by counting the number of tillers of ten randomly selected plants during tillering stage at 45 days.

Number of productive tillers: The number of tillers bearing spikes was determined by counting the productive tillers from ten randomly selected plants in each net plot at physiological maturity.

Number of kernel spike^{-1}: Ten randomly selected plants were used from net plot area of each plot and number of kernels spike^{-1} was counted and then the average was determined.

Thousand kernels weight (g): Thousand grains weight of 1000 grains sampled from each net plot by counting using electronic seed counter and weighed with sensitive balance. Then, the weight was adjusted to 12.5% moisture content.

Above ground biological yield: The above ground dry biomass were harvested from the net plot area after sun drying to a constant weight and converted to t ha^{-1}.

Straw yield (t ha^{-1}):- After threshing and measuring the grain yield, the straw yield was measured by subtracting the grain yield from the total aboveground biological yield.

Grain yield (t ha^{-1}):- Grain yield was taken by harvesting and threshing the seed yield from net plot area. The grain yield was adjusted to 12.5% moisture content. Finally, yield per plot was converted to ha^{-1} basis and the average yield was determined into t ha^{-1}.

Harvest index (%): Harvest index was calculated as ratio of grain yield per plot to total above ground dry biomass yield per plot expressed as percent.

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

3.6. Data Analysis

The data collected were subjected to analysis of variance using software (SAS version 9.3) using ANOVA. The mean separation of significant treatment was carried out using the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

3.7. Partial Budget Analysis

The economic analysis was out by using the methodology described in CIMMYT (1988) in which prevailing market prices for input at planting and for outputs at harvesting was used. All costs and benefits were calculated on hectare basis in Etb. Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. Adjusted grain yield downward by10% to reflect the difference between the experimental yield and yield of farmers. Gross field benefit (GFB) (ETB) ha^{-1} was computed by multiplying field per farmer was gate price that farmers receive for the crop when they sell it as adjusted yield as GFB =AGY X field per farm gate price for the crop. Total variable cost (TVC) (ETB) the seed cost was considered as a variable cost. All the costs and benefits were calculated on hectare basis. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that vary (TCV) using the formula NB= (GYXP)-TVC) where GY x P= Gross field benefit (GFB), GY =Adjusted grain yield ha^{-1} and P =Field price per unit of the crop.

4. RESULTS AND DISCUSSION

4.1. Phenology of Food Barley as Influenced by Varieties and Seeding Rates

4.1.1. Days to 50% heading

The analysis of variance indicated that day to 50% heading was significantly ($p<0.001$) influenced by the main effects of seed rates and varieties while their interaction did not show significant effects (Appendix Table1).

Days to 50% heading of varieties ranged from 71.3 to 82.3 days with mean value of 76.8 days. Variety HB1966 took maximum days (82 days) to heading which is statistically at par to the value (78 days) recorded from HB1307 while, variety local took the minimum (71) number of days to heading (Table 2).The result showed that vegetative development for longer period of time before the beginning of reproductive phase which may have delayed heading. This prolonged period of heading could be due to the genetic difference of varieties for 50% heading. The current finding agrees with Teka and Atzeb (2018) confirmed that days to 50% heading of barely had been highly significantly ($P<0.001$) affected by the main effect of varieties. The result is supported by (Girma *et al.,* 2015) found that the differences in days to heading had been significant among ten improved food barley varieties tested for their performances.

The longest number of days (82) to heading was recorded from the seeding rate of 75 kg ha^{-1}, which was statistically at part with the value (78) recorded from seeding rate of 100 kg ha^{-1}, whereas the shortest days (71) to 50% heading was recorded from seeding rate of 150 kg ha^{-1} (Table 1). As the seeding rates increased from 75 kg ha^{-1} to 150 kg ha^{-1} days to 50% heading was decreased from 82 to 71 days. Days to 50% heading showed a decreasing tendency with increasing the seeding rate. This implies that promotion of vegetative growth before the beginning of reproductive phase at lowest seeding rate which may have delayed heading might be due to a presence of ample resources such as water, nutrients, space and sunlight, which helps crop plant partitioning dry matter but the productivity potential and other important characters depend on the varieties.

This finding is comparable with Senite *et al*., (2020) who stated that when the seeding rates increased from 100-175 kg ha^{-1} days to 50% heading decreased by 6% in malt barley. Chalachew, (2019) also reported that as compared to the seeding rate of 85 kg ha^{-1}, seeding rate of 150 kg ha^{-1} had significantly fastened days to 50% heading in food barley.

4.1.2. Days to 90% physiological maturity

The analysis of variance showed that the day to 90% physiological maturity was significantly ($p<0.001$) influenced by the main effects varieties and seeding rates, while their interaction was not shown significant effects (Appendix Table 1).

The highest days to physiological maturity (139 days) was recorded from HB1966 variety, which was statistically at part with the value recorded from the variety HB1307, whereas the least value of this treatment was scored from the local variety (Table 2).As viewed difference in days to physiological maturity among the barley varieties might be inherent-genotypic difference. The finding by Zenebe (2019) also indicated that, days to 90% maturity was significantly affected by main effect of varieties in malt barley.

The highest days to maturity of (139.1 days) was recorded from seeding rate of 75 kg ha^{-1} which was statistically at par to the value (134.5 days) recorded from seeding rate of 100 kg ha^{-1}, whereas the lowest value (125.8 days) recorded from seeding rate of 150 kg ha^{-1}, however it was not statistically different to the value (130.3 days) recorded from seeding rate of 125 kg ha^{-1} (Table 2). An increased in application of seed rates from 75 to 150 kg ha^{-1} decreased the days to 90% physiological maturity of food barley. This might be at highest seeding rate an increased plant population due to increased compete for nutrients, water space and light which make plants stay no extended in vegetative stage. The result of the current finding was in line with the finding of (Abiot, 2017) who report that days to 90% physiological maturity was significantly late by the lowest seeding rate.

4.2. Growth Parameters of Food Barley as Influenced by Varieties and Seeding Rates

4.2.1. Spike length (cm)

The analysis of variance showed that, the main effects varieties and seeding rate significantly ($P<0.01$) influenced spike length, whereas the interaction of varieties and seeding rate was not significant (Appendix Table 2).

Mean values of spike length for the main effect food barley varieties varied from 4.6 to 8.5 cm with mean value of 6.6 cm. The highest spike length (8.5 cm) was obtained from the variety HB1307; while the shortest spike length (4.6 cm) was recorded from the local variety (Table 2).This might be the variation in spike length among varieties due to the cultivars difference in their genetic make-up. The result in current study agrees with that of, (Jemal and Aliyi, 2021) reported that significant differences in spike length of twenty food barley varieties tested.

The maximum spike length (7.98 cm) was produced from the lowest level of seeding rate (75 kg ha^{-1}), whereas the minimum spike length (4.75 cm) was measured from 150 kg ha^{-1} seeding rate treatment (Table 2). An increased in application rate from 75 to 150 kg ha^{-1} has decreased the spike length of barley seed from 7.98 to 4.75 cm. The increase in spike length at minimum seeding rate might be more growing area between plants and resulted in higher spike length. In agreement with the current finding, significant decrease of spike length as a result of increased seeding density from 200-400 grains m^2 was reported by Gafaar, (2007). Another finding were also stated by different authors (Yahya, 2015; Senaite *et al*., 2020) who reported that raising the rate of seeding rate increased significant decrease spike length in wheat.

4.2.2. Plant height (cm)

The analysis of variance showed that the main effects of seed rates and varieties highly significantly influenced ($P < 0.01$) plant height of food barley whereas the interaction of varieties and food barley seed rate did not significantly influenced plant height (Appendix Table 2).

Accordingly the mean values of plant height were affected by the varieties and it ranged from 77.5 to 96.4 cm with the overall mean value of 86.95 cm. The longest plant height (96.4 cm) was recorded from variety HB1966, whereas the shortest plant height (77.5 cm) was recorded from local variety (Table 2).

The result showed that Plant height difference among the barley Varieties might be a genetic makeup character which helped in the maximum vegetative growth. This study are in line with the findings of, (Wegayehu *et al.,* 2019) reported that plant height difference among the varieties could be due to the difference in their genotypic character in malt barley.

The mean values of plant height varied from 79.12 to 91.6 cm with average value of 85.4 cm. The highest (91.6 cm) plant height was measured from seed rate 150 kg ha^{-1} whereas the shortest (79.1cm) plant height was recorded from 75 kg ha^{-1} seed rate (Table 2). This might be the increased plant height with increased seeding rate could be due to strong competition for water, nutrient, space and interfere for light interception at denser condition which results decrease in horizontal growth, increased inter node length, reduced stem thickness, thereby increase plant height.

The current finding line with (Lake, 2018), higher seeding rate (175 kg ha^{-1}) develop longer plant height than the lower (125 kg ha^{-1}) in wheat. Comparable results line with (Tewodros *et al.,* 2017) also found that as seeding rate increased from 100 kg ha^{-1} to 175 kg ha^{-1} plant height increased from 66.47cm to 73.27 cm in barley.

Table 2: Main effect of varieties and seed rates on days to 50% heading, physiological maturity, spike length and plant height during 2023 main cropping season

Varieties	Days to 50% heading	Days to 90% physiological maturity	Spike length (cm)	Plant height (cm)
HB1966	82.3^{a}	139.6^{a}	6.8^{b}	96.4^{a}
HB1307	78.5^{ab}	135.8^{ab}	8.5^{a}	85.02^{b}
HB1965	74.8^{bc}	130.3^{bc}	5.6^{c}	81.02^{bc}
Local	71.3^{c}	124^{c}	4.6^{d}	77.5^{c}
LSD$^{(0.05)}$	5.19	8.3	0.49	5.3
		Seed rate (kg ha^{-1})		
75	82.3^{a}	139.1^{a}	7.98^{a}	79.12^{c}
100	77.8^{ab}	134.5^{ab}	6.9^{b}	82.7^{bc}
125	74.8^{bc}	130.3^{bc}	5.87^{c}	86.5^{ab}
150	71.8^{c}	125.8^{c}	4.75^{d}	91.6^{a}
LSD$^{(0.05)}$	5.19	8.3	0.49	5.3
CV$^{(\%)}$	8.11	7.5	9.25	7.52

Means follow by the same letter in each column are not significantly different at the 5% probability level CV (%): Coefficient of variation LSD (0.05): List significant difference at 5%

4.3. Yield and Yield Related Parameters of Food Barley as Affected by Variety and Seeding Rate

4.3.1. Total number of tillers

Total number of tiller was significantly ($p < 0.01$) influenced by the main effects, food barley varieties and seeding rates, in addition to their interaction (Appendix Table 3).

The highest number of total tillers plant^{-1} (8 tillers) was recorded from HB1307 barley variety sown at the lowest seeding rate (75 kg ha^{-1}) which was statistically similar to the value (7.7 tillers) recorded from HB1966 at the same seeding rate (75 kg ha^{-1}).Whereas the lowest number of total tillers (3 tillers) was acquired from both the local and HB1965 varieties sown at 150 kg ha^{-1} of seed rate (Table 3).This decrement in total tiller number with an increased seeding rate of the barley varieties might be due to growth resource limitation.

The lower number of tillers plant^{-1} under increased seeding rates might be the result of high resource competition between plants in the growing season and inherent characteristics of the cultivars as well.

The current finding is in agreement with the result of Tefferi, (2019) who reported increased number of tillers with low seeding rate (75 kg ha^{-1}) than high seeding rate 150 kg ha^{-1} in food barley. Otteson (2007) reported that number of tillers plant^{-1} is controlled by seed rate, nature of the variety and growing condition of environment. Gomez (2001) confirmed that the number of tillers plant^{-1} is managed by seeding rate, types of cultivar and growing condition of environment.

Table 3: Interaction effect of varieties and seeding rates on number of total tillers during 2023 main cropping season

	Seed rate (kg ha^{-1})			
Variety	75	100	125	150
HB1307	8.00^{a}	7.00^{b}	6.67^{b}	4.33^{de}
HB1966	7.67^{a}	6.67^{b}	4.67^{d}	3.67^{f}
HB1965	6.67^{b}	5.67^{c}	4.33^{de}	3.00^{g}
Local	4.67^{d}	4.00^{ef}	3.00^{g}	3.00^{g}
LSD$^{(0.05)}$	0.6			
CV$^{(\%)}$	7.29			

Means followed by the same letter in each column are not significantly different at the 5% probability level. LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

4.3.2. Number of productive tiller

Seed rates and varieties and their interaction significantly ($p < 0.01$) influenced number of productive tiller of food barley (Appendix Table3). The number of effective tillers recorded from different treatment combinations varied from 2.67 to 7.00 tillers with an average mean value of 4.84 tillers. Significantly highest mean value of effective tillers (7 tillers plant^{-1}) was obtained from the variety HB1307 sown at a rate 75 kg ha^{-1}, while the lowest mean value of effective tillers (2.67 tillers plant^{-1}) was obtained from the local variety all other three varieties sown at higher seeding rate (150 kg ha^{-1}), which was statistically not different from the value (3 tillers plant^{-1}) obtained from varieties HB1966 and HB1965 sown at the same seeding rate, and local variety at seeding rate of 125 kg ha^{-1} (Table 4).

This might be due to that the highest effective tillers in decrease seeding rate could be the encouraged to the tillering capacity of variety combined with normally for the available growth resources at lowest seeding rate, in contrast at maximum seeding rate that led to higher plant number might have resulted in more competition for inadequate resources. Thus late growing tillers might be died because of high competition and resulted in low number of productive tillers.

The current finding is in line with the finding of Bereket, (2019), who reported the highest number of productive tillers for variety HB1307 at seeding rate of 75 kg ha^{-1}, and the lowest productive tillers at higher seeding rate.

Table 4: Interaction effect of varieties and seeding rates on number of productive tillers during 2023 main cropping season

	Seed rate (kg ha^{-1})			
Variety	75	100	125	150
HB1307	7.00^{a}	6.33^{b}	5.67^{c}	3.67^{e}
HB1966	6.33^{b}	5.67^{c}	3.67^{e}	3.00^{f}
HB1965	5.67^{c}	4.67^{d}	3.67^{e}	3.00^{f}
Local	4.00^{e}	3.67^{e}	3.00^{f}	2.67^{f}
LSD $^{(0.05)}$	0.6			
CV$^{(\%)}$	8.19			

Means followed by the same letter in each column are not significantly different at the 5% probability level. LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

4.3.3. Number of kernels spike^{-1}

Number of kernels spike^{-1} significantly ($P < 0.01$) influenced by the main effects food barley varieties and seeding rate and their interaction (Appendix Table3).

The mean grain numbers spike^{-1} varied from 30.33 to 66.33 grain spike^{-1} with average mean value of 48.33.The maximum kernels number spike^{-1} (66.33) of food barley was observed from HB1307 variety sown at seeding rate of 75 kg ha^{-1}, which was followed by the values recorded from HB1307 variety at 100 kg ha^{-1} and HB1966 variety at 75 kg ha^{-1} while, the lowest number of kernels spike^{-1} (30.33) was obtained from local cultivar sown at seeding rate of 150 kg ha^{-1},which was statistically not different from the values recorded from all varieties at highest seeding rate (Table 5).

The increased number of kernel spike^{-1} with a decreased seeding rate could be due to the ample amount of available nutrients, moisture and light which have ensured in increase in chlorophyll which resulted in higher photosynthetic rate and eventually grain formation.

The current result in lined with the findings of (Amare 2017; Senite *et al*., 2020) reported that as the seed rate was increased from 100 kg ha^{-1} to 150 kg ha^{-1}, the number of kernels spike^{-1} decreased by 10.42%. Moreover, Gaffar (2007) conclude that increasing seeding density from 200-400 grains m^{-2} significantly reduced the number of spikelet and number of kernels spike^{-1}.

Table 5: Interaction effect of varieties and seeding rates on number of kernel spike^{-1} during 2023 main cropping season

	Seed rate (kg ha^{-1})			
Variety	75	100	125	150
HB 1307	66.33^{a}	53.67^{b}	40.67^{cde}	31.67^{fg}
HB1966	48.00^{bc}	43.67^{cde}	38.67^{def}	36.67^{defg}
HB1965	44.00^{cd}	41.00^{cde}	37.33^{defg}	32.33^{fg}
Local	38.67^{def}	36.67^{defg}	36.33^{efg}	30.33^{g}
LSD $^{(0.05)}$	7.45			
CV $^{(\%)}$	10.90			

Means followed by the same letter in each column are not significantly different at the 5% probability level. LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

4.3.4. Thousand grains weight (g)

Analysis of variance showed that varieties and seeding rate as well as their interaction significantly ($P < 0.01$) affected thousand grain weight of food barley (Appendix Table 4).

The mean values of thousand grain weight ranged from 26.00 to 57.33 g, with average mean value 41.67g. The highest thousand grain weight (57.33 g) was obtained from HB1307 variety with seeding rate of 125 kg ha^{-1}, whereas the lowest thousand grain weight (26.00 g) was recorded from local variety at seeding rate of 150 kg ha^{-1} (Table 6).

This might be the highest thousand kernels weight from HB1307 variety at seeding rate of 125 kg ha^{-1} due to the genetic potential of the varieties combined with efficient utilization of resource as nutrient, water space and light. The lowest kernels weight was recorded from the maximum seeding rate and this could be due to higher plant population density, which resulted in higher competition for plant nutrients moisture, space and sun light during growing season.

The current result is in harmony with Senait *et al*., (2020) also reported that increasing seed rate resulted in decreased thousand grain weight when seeding rate increased from 100-175 kg ha^{-1} resulted in decreased thousand kernels weight by 23.51% in malt barley. The current result is in harmony with Ketema and Mulatu (2018). Also, Fani *et al*., (2014) reported that at high densities at 250 and 300 kg ha^{-1} of seed, the thousand seeds weight was reduced, whereas in low densities of 50 and 100 kg ha^{-1}, thousand seed weights was increased.

4.3.5. Above ground biomass yield (t ha^{-1})

Analysis of variance show that the above ground biomass yield was significantly ($P < 0.01$) affected by the main effects of food barley variety and the seeding rate, and their interaction (Appendix Table 4).

The highest mean total biomass yield (13.3 t ha^{-1}) was obtained from HB1307 variety at 150 kg ha^{-1} seeding rate, which was not statistically not different from the value (12.7 t ha^{-1}) recorded from HB1966 variety at seeding rate of 150 kg ha^{-1}, while the lowest (7.1 t ha^{-1})

Table 6: Interaction effect of varieties and seed rate on thousand grains weight (g) during 2023 main cropping season

	Seed rate (kg ha^{-1})			
Variety	75	100	125	150
HB 1307	39.33^{de}	48.67^{b}	57.33^{a}	32.67^{g}
HB1966	37.33^{defg}	40.00^{cd}	44.33^{bc}	35.00^{efg}
HB1965	34.00^{fg}	37.33^{defg}	40.67^{cd}	27.67^{h}
Local	37.97^{def}	38.67^{def}	40.00^{cd}	26.00^{h}
LSD $^{(0.05)}$	4.9			
CV $^{(\%)}$	7.55			

Means followed by the same letter in each column are not significantly different at the 5% probability level. LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

from local variety at seeding rate of 75 kg ha^{-1}, but statistically similar with the values recorded from most of other treatments (Table 7).

The higher biomass yield with increased seeding rate this might be due to that an increased in straw yield and plant height in variety HB1307 at 150 kg ha^{-1} seeding rate and generally increases biological yield with increases in plant density up to a point and reaches a plateau with further increase in density, thus no additional biological yield can be obtained.

The present finding is in agreement with Tsegalem, (2020) who reported that the positive association between biomass yield and plant height, in which the taller plants resulted higher biomass yield as significantly highest biomass yield was recorded for the seeding rate 150 kg ha^{-1} On the other hand, significantly lowest biomass yield was recorded for the seeding rate 175 kg ha^{-1}. In harmony with the current result the finding by Intsar *et al*., (2017) confirmed that the interaction effects of seeding rates and cultivars had been significantly affected biological yield of bread wheat.

Table 7: Interaction effect of varieties and seeding rate on above ground biomass yield during 2023 main cropping season

		Seed rate (t ha^{-1})		
Variety	75	100	125	150
HB 1307	7.8^{gh}	9.6^{def}	11.4^{bc}	13.2^{a}
HB1966	8.6^{efg}	9.4^{def}	9.7^{de}	12.7^{ab}
HB1965	8.1^{fgh}	9.2^{defg}	10.4^{cd}	8.2^{fgh}
Local	7.1^{h}	8.2^{fgh}	11.3^{bc}	8.2^{fgh}
LSD $^{(0.05)}$		1419		
CV $^{(\%)}$		8.91		

Means followed by the same letter in each column are not significantly different at the 5% probability level. LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

4.3.6. Grain yield (t ha^{-1})

The analysis of variance revealed that, the grain yield was significantly ($p < 0.01$) influenced by main effects variety and seeding rate, as well as their interaction (Appendix Table 10).

The highest grain yield (4.89 t ha^{-1}) was obtained from HB1307 variety with the application of 125 kg ha^{-1} seeding rates while, the lowest (2.1 t ha^{-1}) from local variety at seeding rate of 75 kg ha^{-1} (Table 8). The higher grain yield in the higher seeding rates might be attributed due to the production of higher thousand kernel weight and harvest index. The higher grain yield in the higher seeding rates was associated with higher spike number or plant population ha^{-1}. Furthermore, the highest number of productive tillers m^{2} was obtained from this variety with combination of 125 kg ha^{-1} seeding rate. Hence, productive tillers are very important because the final yield is mainly a function of the number of spike bearing tillers^{-1} unit area. The use of 125 kg ha^{-1} seeding rate gave higher grain yield than the lowest (75 kg ha^{-1}) and the highest (150 kg ha^{-1}) seeding rate treatments indicating that both very low and very high seeding rates were not favorable on the grain yield of food barley.

The current finding agree with (Tefferi *et al.*, 2019) that the interactive effect indicated that the maximum grain yield was observed when seed rate of 125 kg ha^{-1}, whereas minimum grain yield was recorded with 75 kg seed rate kg ha^{-1}. Grain yield did not increase with an increase in seed rate consistently, treatments indicated that both very low and very high seeding rates were not favorable on the grain yield of food barley as the use of 100 kg ha^{-1} seeding rate gave higher grain yield than the lowest (85 kg ha^{-1}) and the highest (150 kg ha^{-1}) seeding rate (Chalachew, 2019).

Table 8: Interaction effect of varieties and seeding rate on grain yield during 2023 main cropping season

		Grain yield (t ha^{-1})		
Variety	75	100	125	150
HB 1307	2.8^{h}	3.8^{cd}	4.9^{a}	4.2^{b}
HB1966	3.1^{fgh}	3.5^{def}	4.1^{bc}	3.7^{cd}
HB1965	2.9^{h}	3.3^{efg}	3.6^{de}	2.9^{gh}
Local	2.1^{i}	2.9^{gh}	3.5^{def}	2.9^{gh}
LSD $^{(0.05)}$		397.20		
CV $^{(\%)}$		7.04		

Means followed by the same letter with in row and columns are not significantly different at the 5% probability level**.** LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

4.3.7. Straw yield (t ha^{-1})

Straw yield was highly significantly ($P < 0.01$) affected by the main effect of seed rate and varieties. The interaction effect of variety with seed rate was also significant ($P < 0.01$) (Appendix Table 4).

Significantly highest (8.95 t ha^{-1}) mean straw yield value was recorded from the combined treatment HB1307 *150 kg ha^{-1} on the other hand, significantly lowest mean straw yield value was recorded from the combined treatment local*75 kg ha^{-1} (4.98 t ha^{-1}).

The increased in straw yield within 150 kg ha^{-1} seeding rate might be due to the fact that higher seeding rates resulted in more plant population and plant height which resulted in higher straw yield.

In line with the current result the finding by Tefferi *et al*., (2019) also confirmed that the straw yield of food barley was significantly affected by the interaction of varieties and seeding rates as there was a linear increase in straw yield as the seeding rate increased from the 75 to 150 kg ha^{-1}. The finding agree with the finding of Intsar *et al*., (2017) indicated that the interaction effects of varieties of bread wheat seeding rates had been significant on straw yield as the seeding rate increased.

Table 9: Interaction effect of varieties and seed rate on straw yield during 2023 main cropping season

		Seed rate (t ha^{-1})		
Variety	75	100	125	150
HB 1307	4.9^{e}	5.8^{cde}	6.6^{bcd}	8.9^{a}
HB1966	5.5^{cde}	6^{cde}	5.6^{cde}	8.9^{a}
HB1965	5.3^{de}	5.9^{cde}	6.8^{bc}	5.3^{de}
Local	4.9^{e}	5.3^{de}	7.7^{ab}	5.3^{de}
LSD $^{(0.05)}$		1380.5		
CV $^{(\%)}$		13.39		

Means followed by the same letter with in row and columns are not significantly different at the 5% probability level**.** LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

4.3.8. Harvest Index (HI)

A crop plant that converts proportion of dry matter into yield is measured in terms of harvest index. The result indicated that the main and interaction effect of variety and seeding rate had highly significant ($P < 0.01$) on the harvest index (Appendix Table 4).

The mean values of the combined harvest index for food barley were varied from 29.67 to 43.18% with average mean value of 36.43%. Significantly highest (43.18%) harvest index value was recorded from HB1307 with 125 kg ha^{-1} On the other hand; significantly lowest harvest index value (29.67%) was recorded from local genotype with 75 kg ha^{-1} (Table13).

This might be attributed to greater photo assimilate production and its ultimate partitioning into grains compared to partitioning in to straw, i.e. proportionally higher grain yield than vegetative biomass yield. The highest harvest index in variety HB1307 revealed its capacity to efficiently distribute the dry matter produced from source to seed compared to other varieties.

The current finding agrees with the result of Harmeet and Rash pal (2022) reported that the higher harvest index recorded significantly in 112.5 kg seed rate ha^{-1} over 75 kg seed rate ha^{-1} but at par with 100 kg seed rate ha^{-1} and 87.5 kg seed rate ha^{-1} in food barley. In line with this finding, Donald *et al.*, (1976) reported that grain yield is proportional to harvest index and factors which make up grain yields such as grain weight and grains $spikelet^{-1}$ have a relatively high effect on harvest index. The finding by Haile *et al.*, (2013) also indicated that harvest index of wheat was significantly affected by interaction effects of varieties and seeding rates.

Table 10: Interaction effect of varieties and seed rate on harvest index during 2023 main cropping season

	Seed rate (kg ha^{-1})			
Variety	75	100	125	150
HB1307	36.03^{cde}	39.49^{abc}	43.18^{a}	32.1^{def}
HB1966	36.57^{bcde}	37.33^{bcd}	41.83^{ab}	29.73^{f}
HB1965	35.03^{cdef}	35.59^{cde}	34.68^{cdef}	35.64^{cde}
Local	29.67^{f}	35.52^{cde}	31.27^{ef}	35.58^{cde}
$LSD^{(0.05)}$	5.77			
$CV^{(\%)}$	9.72			

Means followed by the same letter with in row and columns are not significantly different at the 5% probability level**.** LSD (0.05) = Least Significant Difference at 5%; CV= Coefficient of variation

4.4 Partial Budget Analysis

The result indicated that the use of improved food barley varieties and optimum seeding rate resulted in higher benefits than Control treatment (Table 11).

Table 11: Partial budget analysis of food barley as influenced by variety and seeding rate during 2023 main cropping season

Varieties	Seed rate Kg ha^{-1}	Average Yield t ha^{-1}	Adjusted GY t ha^{-1}	Adjusted SY t ha^{-1}	GY Etb ha^{-1}	SY Etb ha^{-1}	GFB Etb ha^{-1}	TVC Etb h^{-1}	NB Etb ha^{-1}
HB1307	75	2.8	2.53	4.49	75900	1573	77473	2812.5	74660.5
	100	3.77	3.39	5.21	101700	1823	103523	3750	99773
	125	4.89	4.40	5.89	132000	2063	134063	4687.5	129375.5
	150	4.23	3.80	8.06	114000	2820	116820	5625	111195
HB1966	75	3.13	2.82	4.94	84600	1727	86327	2812.5	83514.5
	100	3.48	3.13	5.43	93900	1901	95801	3750	92051
	125	4.07	3.67	5.06	110100	1771	111871	4687.5	107183.5
	150	3.73	3.35	8.06	100500	2819	103319	5625	97694
HB1965	75	2.85	2.57	4.76	77100	1664	78764	2812.5	75951.5
	100	3.27	2.94	5.33	88200	1864	90064	3750	86314
	125	3.62	3.26	6.13	97800	2145	99945	4687.5	95257.5
	150	2.90	2.71	4.75	81300	2374	83674	5625	78049
LOCAL	75	2.10	1.89	4.48	56700	1569	58269	2250	56019
	100	2.89	2.61	4.74	78300	1658	79958	3000	76958
	125	3.53	3.18	6.97	95400	2438	97838	3750	94088
	150	2.88	2.59	4.75	77700	1662	79362	4500	74862

Cost of improved seed (37.5 Etb kg^{-1}), local seed (30 Etb kg^{-1}) and 30 Etb kg^{-1} was the value of barley at harvesting on local markets.

The partial budget analysis resulted that the maximum net benefit of 129375.5 Etb ha^{-1} was obtained from the treatment combination of 125 kg ha^{-1} barley seeding rate for variety HB1307 followed by HB1307 treatment combination of 150 kg ha^{-1} 111195 Etb ha^{-1} whereas, the lowest net benefit 56019 Etb ha^{-1} was obtained from variety local with 75 kg ha^{-1} seeding rate. As indicated in Table 11, the partial budget analysis showed that the highest net benefit (129375.5 Etb ha^{-1}) was recorded at the seed rate of 125 kg ha^{-1} combined with variety HB1307, whereas the lowest net benefit (56019 Etb ha^{-1}) was obtained from variety local with 75 kg ha^{-1} seeding rate. As a result, variety HB1307 with the use of 125 kg ha^{-1}

seed rate gave the maximum economic benefit (129375.5 Etb ha^{-1}) and economical for production of barley in the study area and other areas with similar agro-ecological conditions. In lined with this finding (Tsegalem, 2020) obtained the highest net benefit of 103018 Etb with the application of 150 kg ha^{-1} seeding rate of food barley.

5. CONCLUSSION AND RECOMUNDATION

Barley (*Hordeum vulgare L.*) is one of the major cereal crops grown in Ethiopia including Gurage Zone, Cheha district. Farmers in the study area produced barley both as food and cash crop under rain fed conditions. The existing barley productivity in Cheha district was very low despite the high potential for increased production and yield of the crop. From the major constraints in the study area was soil acidity problem, unbalanced use of fertilizer, poor soil fertility management system, shortage of information on varying response of genotypes and recommended optimal seed rates for the varieties, poor cultural practices, diseases and pests are the problems observed in the study area. Among the several factors responsible for low yield, shortage of information on varying response of genotypes and recommended optimal seed rates for the varieties are crucial to come up with profitable and sustainable barley production in cheha district. The results indicated that interaction affected by interaction effect of seeding rate and varieties were, number of total tillers, number of productive tillers, number of kernel spike^{-1}, thousand seed weight, above ground biomass yield, straw yield grain yield and harvest index significantly ($P < 0.01$) affected due to the interaction of both factors while on days to heading, day to maturity, spike length and plant height were not significant interaction effect. Maximum number of total tillers (8), productive tillers (7), number of kernel spike^{-1} (66) were recorded for variety HB1307 with the use of 75 kg ha^{-1}.The maximum above ground biomass yield (13.2 t) and straw yield (8.9 t) were recorded for variety HB1307 with the use of 150 kg ha^{-1}. Grain yield (4.9 t), thousand grain weights (57g), and harvesting index (43%) were recorded from variety HB1307 with 125 kg ha^{-1} seeding rates. The partial budget analysis indicated that use of 125 kg ha^{-1} seed rate on variety HB1307 were resulted in the highest net benefit of (129375.5 ETB ha^{-1}) economical for production of barley. From the current investigation, the use of 125 kg ha^{-1} seed rate with variety HB1307 responded well in terms of yield parameter of barley. Based on the present study, therefore, food barley variety HB1307 at the seeding rate of 125 kg ha^{-1} is recommendable for the study area. However, since the present study was conducted only in a single season and one site, it is necessary to conducted similar experiments further in different seasons and locations to come up with concrete and workable recommendation for varieties and seeding rates of food barley.

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7. APPENDIX TABLE

Appendix Table 1. Mean squares of analysis of variance for phenology of food barley as influenced by varieties and seeding rates

		Mean squares	
Sources of variation	DF	DH	DPM
Replication	2	319.19	526.02
Variety	3	270.19*	550.61*
Food barley seed rates	3	237.02*	390.28*
Variety x FBS rates	9	6.67 ns	4.04ns
Error	30	38.68	98.69
CV (%)		8.11	7.52

DF=degree of freedom, ns=non-significant, *significant at 5% level of significance, e**=significant at 1% level of significance, DH=days to 50% heading DPM= Days to 90% physiological maturity, SL= spike length PH=plant height

Appendix Table 2. **Mean squares of analysis of variance for growth parameters of food barley as influenced by varieties and seeding rates**

		Mean squares	
Sources of variation	DF	SL	PH
Replication	2	9.45	800.3
Variety	3	33.02**	806.02**
Food barley seed rates	3	22.96**	344.61**
Variety x FBS rates	9	0.6^{ns}	3.2^{ns}
Error	30	0.35	40.82
CV (%)		9.25	7.52

DF=degree of freedom, ns=non-significant, *significant at 5% level of significance, e**=significant at 1% level of significance, SL= spike length PH=plant height

Appendix Table 3. Mean squares of analysis of variance for yield and yield related parameters of food barley as affected by variety and seeding rate

		Mean squares			
Sources of variation	DF	NTT	NPT	NKPS	TSW
Replication	2	1.19	1.65	119.15	199.26
Variety	3	17.35**	11.24**	229.38**	186.02**
FBS rates	3	23.91**	16.63**	503.06**	440.87**
Variety x FBS rate	9	0.98**	0.78**	37.55**	43.53*
Error	30	0.14	0.13	8.48	12.21
CV (%)		7.29	8.19	7.55	8.95

DF=degree of freedom, ns=non-significant, *significant at 5% level of significance, e**=significant at 1% level of significance, NTT=number of total tillers, NPT= number of productive tillers, NKPS =number of kernel spike^{-1}, THW= thousand grain weight.

Appendix Table 4. Mean squares of analysis of variance for yield components of food barley affected by FBSR and varieties

		Mean squares			
Sources of variation	DF	GY	AGBY	STY	HI
Replication	2	570044	1150240	263985	21.54
Variety	3	2701685**	9189438*	2127467*	47.22*
FBS rates	3	3403849**	2.09**	9189444**	54.37*
Variety x FBS rate	9	250799*	5996791**	4728330**	38.59*
Error	30	56740	724944	685382	11.97
CV (%)		7.04	8.91	13.39	9.72

DF=degree of freedom, ns=non-significant, *significant at 5% level of significance, e**=significant at 1% level of significance, GY=grain yield, ST= straw yield, AGBY= above ground biomass yield, HI= harvest index.