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EFFECT of SEED and NITROGEN RATE on YIELD and YIELD COMPONENT of BREAD WHEAT (Triticum Aestivum L.) in MENZ MAMA DISTRICT, NORTH SHEWA, ETHIOPIA

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DEPARTMENT OF PLANT SCIENCES

POSTGRADUATE PROGRAM IN FILED OF AGRONOMY

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MSc THESIS

BY

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JUNE 2024

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BY

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JUNE 2024

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THESIS APPROVAL SHEET

We hereby certify that we have read and evaluated this thesis entitled "Effect of Seed and Nitrogen Fertilizer Rates on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) in Menz mama District, North Shewa, Ethiopia" prepared under our guidance by Kidane Menkore. We recommend that it be submitted as fulfilling the thesis requirement.

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BIOGRAPHICAL SKETCH

Mr. Kidane Menkore was born in 1995 and raised in a rural community in Astoya Kebele in Menz Mama district, north Shewa, in Amhara region, Ethiopia. Growing up in close proximity to agricultural activities sparked their interest in farming and environmental conservation from a young age. He attended his elementary education at Astoya Primary School from 2003 to 2010 and Senior Secondary and Preparatory High School from 2011 to 2014 G.C. at Molale Senior Secondary and Preparatory High School. They pursued their bachelor's degree in plant science at DebreBirehan University in 2017 G.C.

Following their undergraduate studies, Kidane gained valuable experience working as an irrigation agronomist at the Menz Gera Agricultural Office and after that he joined as an agronomist at the Ministry of Agriculture until he joined Bahir Dar University. The individual has participated in field trials and experimentation to evaluate crop management practices, including planting techniques, irrigation methods, and fertilizer applications. They have also been involved in harvesting operations and post-harvest management to maximize yields and quality.

Mr. Kidane got the best undergraduate research award from the University of Debre Birehan College of Agriculture for his outstanding research work on "Evaluation of faba bean (Vicia *faba*) varities under irrigation conditions at Debre Berhan." This recognition highlighted the significance of his research contributions to the field of agronomy, and He have gotten two online training certificates from Chania (the Ministry of Commerce) for completing the "Seminar on Agricultural Mechanization and the Excellence Award for Essay in Caams Award. I aspire to pursue a career in agricultural research, where I can continue to explore innovative solutions to enhance crop productivity and sustainability. My ultimate goal is to contribute to the development of resilient agricultural systems that address the challenges of food security and climate change on a global scale.

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DEDICATION

This thesis is dedicated to my mother, Amele sahile; hers unwavering support, encouragement, and sacrifices have been the cornerstone of my academic journey. Her belief in me has been my source of strength through the challenges and triumphs of this research endeavour. I am forever grateful for her love, guidance, and belief in my dreams.

LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CSA	Central Statistical Agency
FTC	Farmers’ Training Center
MoA	Ministry of Agriculture
RCBD	Randomized Complete Block Design
DMRT	Duncan Multiple Range Test
MRR	Marginal Rate of Return
CEC	Cation Exchange Capacity
ppm	parts per Million
DARC	DebreBirehan Agricultural Research Center
CV	Coefficient of variation
SAS	Statistical Analysis System
TVC	Total variable cost
OC	Organic Carbon
GFB	Gross Field Benefit
ETB	Ethiopian birr
OM	Organic matter

Effect Of Seed and Nitrogen Rate on Yield and Yield Component of Bread Wheat (*Triticum aestivum* L.) In Menz Mama, North Shewa, Ethiopia

Kidane Menkore, Dr. Dereje Ayalew

ABSTRACT

Wheat production plays a crucial role in global food security in Ethiopia. Understanding the influence of seed and nitrogen rates on bread wheat yield and its components is essential for improving agricultural productivity in such areas. The yield potential of bread wheat study area was 35-55 Qt per Ha, however due to the use of un optimal seed and nitrogen rate current productivity where 2.8 Qt. The experiment was conducted in Menz Mama district, north Shewa, in the 2023 cropping season, using a randomized complete block design (RCBD) with sixteen treatments. These treatments included seed rate of (125, 150,175 and 200 kg ha^{-1} and nitrogen fertilizer rates (150, 200, 250 and 300 kg ha^{-1}). Data on yield and yield components, such as grain yield, spike length, number of tillers per plant, and thousand kernel weights, were collected and analyzed using SAS statistical methods. The results revealed that spike length, number of tillers, thousand seed weight, biomass yield, lodging, and plant height were significantly influenced by the main effects of nitrogen and seed rate ($p<0.01$), while days of heading and days of physiological maturity were only influenced by the main effect of nitrogen. The interaction between seeding rates and nitrogen levels significantly influenced the number of grains per spike, grain yield, number of productive tillers, straw yield, and harvest index. The study revealed that the combination of 250 kg N ha^{-1} fertilizer with a seed rate of 175 kg ha^{-1} provided the highest number of productive tillers, kernel weight, and harvest index. These findings suggest that a seed rate of 175 kg ha^{-1} demonstrated superior performance in terms of productive tillers, kernel number, thousand kernel weight, and yield under nitrogen fertilizer rates of 250 and 300 kg ha^{-1}. Overall, the combination of 250 kg N fertilizer with a seed rate of 175 kg ha^{-1} provided the greatest economic advantage (256284.1ETB) and yield. Since the current study was conducted at single location and only one year, it is better to repeat this experiment on multi-locations and over seasons to come up with reliable recommendation.

Key words: bread wheat, grain yield, nitrogen rate, seed rate, yield component,

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1. INTRODUCTION

1.1. **B**ackground and **J**ustification

Bread wheat (*Triticum aestivum* L.) is a key annual crop in the Poaceae family, originating from the Mediterranean region and southwest Asia (Levy & Feldman, 2022). It serves as a staple food globally, contributing significantly to food security and income generation, with a production of 750 million tons across 220 million hectares (Wuletaw Tadesse and Zewdie Bishaw, 2019). Ethiopia, particularly its highlands ranging from 1500 to 3000 meters above sea level, plays a significant role in wheat cultivation, with ideal agro-ecological zones situated between 1900 and 2700 meters (Berhanu Sime & Shimelis Tesfaye, 2017).

Ethiopia stands as the largest wheat producer in Sub-Saharan Africa, with 1.89 million hectares under cultivation, making it the second-largest crop in terms of area coverage and production within the country (CSA, 2021). The Amhara Regional National State, known for its diverse crop cultivation, shows promise in wheat production, particularly bread wheat, which holds significance in bread-making and income generation (Amare Aleminew and Mekonen Misganaw, 2015). The North Shewa Zone, encompassing 130,442.10 hectares, is a notable wheat-producing region in Amhara (CSA, 2021). Despite its potential, Ethiopia faces challenges such as using uniform seed and nitrogen rates across diverse soil properties and agroecological conditions, resulting in relatively low productivity compared to other nations.

Wheat yield in Amhara region and particular in the study woreda is low (2.8 ton) as compared to the attainable yield of 5 t ha^{-1} and even when compared to Oromia region 3.3-ton (CSA, 2021). This is mainly due to the production of wheat is surrounded by different constraints it includes poor agronomic practice (inappropriate seed rate and N rate), poor soil fertility, weed, and biotic constraint (diseases and insect pests) (Girma Dawit, 2018).

However, global demand for wheat is expected to increase over the next few decades, which will require the development of new varieties and cultivation practices to meet this demand (FAO, 2014). Among the management practices Seed rate and nitrogen rate are two key factors that significantly impact wheat yield and quality (Wuletaw Tadesse, 2022). Therefore, it is essential to evaluate and optimize crop management practices to maximize wheat yields. Nitrogen rate is the key element in increasing productivity and the increase of agricultural food production worldwide. Adoption of appropriate N fertilizer management practices is reported to increase yield of wheat (Belete Dechassa, 2018). Consequently, to get more crop production, nitrogen availability is essential in the form of chemical fertilizers and Proper use of nitrogen is also considered for farm profitability and environment protection. Among all the essential nutrients applied in the field, nitrogen is the most important for vegetative crop growth, plant productivity and grain quality but optimum application (Iqbal *et al*., 2012a)

The optimization of seed and nitrogen rates is vital for enhancing wheat yields and ensuring food security (Markad, 2024). Understanding the interaction between these factors can lead to increased productivity and sustainable agricultural practices. Previous research underscores the significant impact of nitrogen and seeding rates on bread wheat yield and components, emphasizing the need for tailored recommendations based on specific agroecological conditions (Iqbal *et al*., 2012a). Addressing these gaps through comprehensive research can provide valuable insights for farmers and policymakers in North Shewa, Ethiopia.

The maximum yield of bread wheat is not only achieved through the yield potential of the crop, rather equally important are the agronomic practices, which play a pivotal role in exploiting the genetic potential of the crop or variety (Belete Dechassa, 2018). The application rate of nitrogen and seed significantly influences bread wheat output, particularly in the study area. Overly dense stands may not produce more, promoting disease, plant height, and lodging (Iqbal *et al.*, 2012). However, there is still a significant knowledge gap regarding fixing location (or area), specific optimal levels of nitrogen, and an appropriate seeding rate. The decline in soil fertility and inappropriate fertilizer application are among the key factors limiting wheat yields in the North Shewa region of Ethiopia (Abebual Woldetsadik, 2019).

1.2. **S**tatement of the **P**roblem

The yield potential of bread wheat study area was 35-55 Qt ha^{-1}, however due to the use of un optimal seed and nitrogen rate current productivity where 2.8 Qt. There is room for improvement in wheat yield, especially in the studied woreda, where the current production falls below its potential and lags behind other regions. As per the information from Menz Mama woreda agricultural office, farmers in the woreda used different rates of nitrogen for wheat production; blanketly recommended rate by woreda Agri office is 275 kg N ha^{-1}, and what farmers usually used based on their experiences is 200 kg N rates ha^{-1}. The same is true for seeding rate, farmers used different seeding rates; blanketly recommended rate by woreda Agri office from 125 kg ha^{-1}, up to 150 kg ha^{-1}. Hence there is a need to evaluate these practices and add some and evaluate which nitrogen and seeding rates can help to maximize wheat production in the study area.

Further, there is no information also about the interaction effect of the two most important agronomic practices, which should be increased while the other is decreased or vis-à-vis in order to properly exploit the potential of the varieties/crops and benefit the farmers. Therefore, there is a need to investigate the impact of seed and nitrogen rates on bread wheat production to optimize yield and quality in North Shewa, Ethiopia (Feyisa and Mengistu, 2023).

Maximizing bread wheat yield and its components is essential for food security and economic stability in the region. However, achieving optimal yields requires a thorough understanding of how seed and nitrogen rates influence crop performance. Investigating the effects of seed and nitrogen rates on bread wheat yield and yield components can contribute to the development of sustainable farming strategies. The agroecological conditions and farming practices in the North Shewa Zone may vary from other regions, necessitating region-specific research to provide actionable insights for local farmers.

Therefore, there is a need to investigate the effect of seed and nitrogen rates on bread wheat production to optimize yield and quality in Menz, Mama, North Shewa, Ethiopia (Hailu Feyisa and Girma Mengistu, 2023). By unraveling the effects of these agronomic practices on wheat cultivation, we can develop targeted strategies to enhance crop performance and support sustainable farming practices tailored to the unique conditions of the Menz Mama District.

1.3. Objective

1.3.1. General objective

The General objective of this study was to examine the effect of seeding and nitrogen rates on the yield and yield components of bread wheat and contribute to the enhancement of bread wheat production practices by determining optimal seed and nitrogen rate combinations for maximizing yield in the study area.

1.3.2. Specific objective

- ✓ To examine the effect of seed and N rates on the yield and yield components of bread wheat in Menz Mama, North Shewa, Ethiopia.
- ✓ To determine the optimal combination of seed and nitrogen rates that maximizes the yield and profitability of bread wheat in Menz Mama, North Shewa, Ethiopia.

2. LITERATURE REVIEW

2.1. **O**rigin, **E**volution, **D**omestication and **T**axonomy of **W**heat

The origin of wheat traces back thousands of years to the fertile crescent, an area in the Middle East and southern Asia that includes present-day Iraq, Syria, Lebanon, Jordan, Israel, Palestine, Pakistan, and India (Levy & Feldman, 2022). It is believed that wheat was first domesticated around 10,000 years ago by early agricultural societies in this region (Gustafson *et al*., 2011.). Wild grasses Einkorn and Emmer were among the earliest cultivated forms of wheat. Over time, through selective breeding, these wild grasses were transformed into the domesticated varieties of wheat that we know today (Betts *et al*., 2014). The domestication of wheat around 10,000 years ago marked a dramatic turn in the development and evolution of human civilization, as it enabled the transition from a hunter-gatherer and nomadic pastoral society to a more sedentary agrarian one (Levy & Feldman, 2022).

These earliest cultivated forms were diploid (genome AA) (einkorn) and tetraploid (genome AABB) (emmer) wheat, and their genetic relationships indicate that they originated from the south-eastern part of Turkey (Brandolini *et al*., 2002). The earliest cultivated forms of wheat were essentially landraces selected by farmers from wild populations, presumably because of their superior yield and other characteristics, an early and clearly non-scientific form of plant breeding (Misganaw Ferede *et al*. 2015). However, domestication was also associated with the selection of genetic traits that separated them from their wild relatives (Gustafson *et al.*, 2011). The first is the loss of shattering of the spike at maturity, which results in seed loss at harvesting. This is clearly an important trait for ensuring seed dispersal in natural populations, and the non-shattering trait is determined by mutations at the Br (brittle rachis) locus (Brandolini *et al*., 2002).

The second important trait is the change from hulled forms, in which the glumes adhere tightly to the grain, to free-threshing naked forms (Levy & Feldman, 2022). Wheat was one of the first crops that could be easily cultivated on a large scale and had the additional advantage of yielding a harvest that provided long-term storage of food (Gustafson *et al*., 2011). Two of the most important traits in the evolution of bread wheat and other cultivated grasses were an increase in grain size and the development of non-shattering seed (Shewry, 2009). The former has been associated with successful germination and growth of seedlings in cultivated fields, whereas the latter trait (a hallmark of domestication) prevents natural seed dispersal and allows humans to harvest and collect the seed with optimal timing (Gustafson *et al*., 2011).

Ethiopia is one of the principal producers and importers of wheat in East, Central, and Southern Africa (CSA, 2021). The two economically important wheat species grown in Ethiopia are tetraploid durum (Triticum durum) and hexaploidy bread wheat (*T. aestivum* L). The production of bread wheat is increasing rapidly (Padmanaban *et al*., 2017) due to both a high local demand and the availability of high-yielding, input-responsive cultivars adapted to heterogeneous environmental conditions.

Wheat is in the grass family Poaceae (Gramineae). Triticeae is one of the tribes containing more than 15 genera and 300 species, including wheat and barley (Levy & Feldman, 2022). Wheat belongs to the tribe Triticeae (= Hordeum) in the grass family Poaceae (Gramineae), in which the one to several flowered spikelets are sessile and alternate on opposite sides of the rachis, forming a true spike (Gustafson *et al*., 2011; Levy & Feldman, 2022). Wheat (Triticum) and ryes (Secale), together with Aegilops, Agropyron, Eremopyron, and Haynalidia, form the subtribe Triticeae (Betts *et al*., 2014; Gustafson *et al*., 2011).

Wheat taxonomy

Kingdom	Plantae
Division	Magnoliophyta
Class	Lilliopsida
Order	Cyperales
Family	Poaceae
Genus	*Triticum* L.
Species	*Triticum aestivum* L.

According to CSA (2021), wheat in Ethiopia is grown annually on 1.89 million ha with a total production of 5,780,130.59 million tons, and the country is considered the largest wheat producer in sub-Saharan African countries.

2.2. **O**verview of **B**read **W**heat **C**ultivation in **E**thiopia

The cultivation of bread wheat (*Triticum aestivum* L.) in Ethiopia has a long and rich historical background, dating back thousands of years (Asnake Fikre *et al*., 2016). Archaeological evidence indicates that bread wheat cultivation in Ethiopia dates back to ancient civilizations such as the Aksumite Kingdom, which flourished around the first millennium BCE (Brandolini *et al*., 2002). Mulu Nigus *et al*. (2022) and Zewdie Bishaw *et al*. (2010) studied that the Ethiopian highlands, characterized by fertile soils and suitable agroecological conditions, provided favorable environments for wheat cultivation by early agricultural communities. Bread wheat cultivation likely spread into Ethiopia through trade and exchange with neighboring regions, as well as through migration and cultural interactions (Adugna Anteneh & Dagninet Asrat, 2020). According to Zewdie Bishaw *et al*. (2010) and Wuletaw Tadesse (2022), it has been introduced to Ethiopia by ancient civilizations such as the Egyptians or the Sabeans from the Arabian Peninsula.

Based on the findings of Adugna Anteneh and Dagninet Asrat (2020); Wuletaw Tadesse (2022), Arsi Zone, Amhara Region, particularly the North Shewa and North Gondar, Tigray Region in Ethiopia is a significant wheat producer, contributing significantly to the country's overall wheat output. The Ethiopian highlands are significant bread wheat-growing regions with favorable agroclimatic conditions (Mulu Nigus *et al*., 2022). The crop is grown at an altitude ranging from 1500 to 3000 meters above sea level, between 6–16° N latitude and 35–42°E longitudes (Bekele Gemechu *et al*., 2019). Sandy soils and soils with problems of waterlogging are unsuitable for wheat production (Landon, 2011). They are growing with an average rainfall of 400–1200 mm.

Ethiopia is the second largest producer of wheat in sub-Saharan Africa, following South Africa, and about 1.89 million hectares of land are cultivated in the 202/2021 cropping season for both bread and durum wheat production (CSA, 2021). Bread wheat yields in Ethiopia are often constrained by limited access to fertilizers and improved seeds, land degradation, pests and diseases, and climate variability (Tomas Solomon, 2022). Out of the total cereal crop, wheat took up 22.56% of production (CSA, 2021). Again, with regard to the estimated yield, the report by CSA (2021) also mentioned that bread wheat has shown an increasing range from 26.75 to 30.46 quintals per hectare for the last 5 years (2017–2021).

2.3. Production Trends of Bread Wheat in Ethiopia

According to the Central Statistical Agency (CSA) of Ethiopia, wheat production has shown increasing trends over the past five years. Study by Tesfaye *et al*. (2020), conducted a study that reported an overall increase in wheat production in Ethiopia in recent years. Access to agricultural inputs such as seeds, fertilizers, and pesticides plays a crucial role in wheat production (CSA, 2021). Adoption of improved agronomic practices, including better soil management, integrated pest management, and efficient water use, has contributed to enhanced wheat yields (Tesfaye Andualem *et al*., 2020). Government policies and interventions, such as subsidies on inputs or investments in agricultural infrastructure, can impact wheat production positively by supporting farmers or improving farming practices (CSA, 2021). The Ethiopian government has implemented various policies and programs to support wheat farmers, including subsidies on agricultural inputs and investments in irrigation infrastructure (Asefa Ayele *et al*., 2018). Extension services have been expanded to disseminate improved agronomic practices and technologies among smallholder farmers (Alemu *et al*., 2019). Wheat in Ethiopia faces threats from pests and diseases, such as wheat rusts, which can cause significant yield losses if not effectively managed (Woldeamanuel et al., 2019).

Table 2. 1 Production Trained of Bread wheat in Ethiopia (2017-2021 G.C)

Year	2017	2018	2019	2020	2021
Production (million/ton)	4.5 million ton	4.6 million ton	4.8 million ton	5.3 million ton	5. 7 million ton

Source: - CSA

2.4. Importance of Bread Wheat

Regasa Dibaba (2019) states that bread wheat is a primary source of dietary energy and nutrition for millions of people in Ethiopia. It serves as a staple food, providing carbohydrates, proteins, vitamins, and minerals essential for human health and well-being (Noort *et al*., 2022). Bread wheat ensures food security and mitigates the risk of hunger and malnutrition, particularly in rural areas where access to diverse food sources may be limited (Mbow *et al*., 2020).

Bread wheat holds cultural significance in Ethiopian cuisine and traditions (Lyons & Catherine D'Andrea, 2003). It is a key ingredient in traditional dishes like injera and various breads consumed across the country (Regasa Dibaba, 2019). The consumption of wheat-based products is deeply ingrained in Ethiopian culinary heritage and is integral to social and religious gatherings, festivals, and ceremonies (Adugna Anteneh & Dagninet Asrat, 2020).

Bread wheat cultivation provides a source of income and livelihood for millions of smallholder farmers in Ethiopia (Regasa Dibaba, 2019). According to Asnake Fikre *et al*. (2016), it contributes significantly to rural economies by generating employment opportunities, income diversification, and market integration for farmers and rural communities. Bread wheat cultivation contributes to the diversification of agricultural production systems in Ethiopia (Minot *et al*., 2015). It complements other staple crops such as teff, maize, barley, and pulses, providing farmers with options for crop rotation, risk management, and income stability (Kihara *et al*., 2022). The findings of Adhikari *et al*. (2018) indicate that the cultivation of bread wheat helps optimize land use and resource allocation, contributing to overall agricultural productivity and resilience.

Bread wheat serves as a raw material for various industrial and commercial activities in Ethiopia (Lyons & Catherine D'Andrea, 2003). It is used in the production of flour, baked goods, pasta, noodles, snacks, and animal feed, supporting the development of agro-processing industries, food manufacturing, and value-added enterprises (Labuschagne *et al*., 2009).

According to the report by Regasa Dibaba (2019), bread wheat produced in Ethiopia is used mainly for domestic food consumption, seed, and industrial use. Wheat accounts for about 10–15 percent of all the calories consumed in the country (Minot *et al*., 2015). Based on reports by Adugna Anteneh and Dagninet Asrat (2020b), total wheat consumption (for food, seed, and industrial use) is rapidly increasing at the national level. Annual wheat consumption in Ethiopia reached 4.2 million metric tons in 2020/21, up from two million metric tons in 1995/96 (CSA, 2021).

2.5. **F**actors **I**nfluencing **B**read **W**heat **Y**ield and **Q**uality

Bread wheat production in North Shewa, Ethiopia, faces several challenges related to seed and nitrogen management (Amare Assefa & Mulatu Kassaye, 2017b). Tillering capacity, spike architecture, grain size, and protein content are genetically controlled and influence wheat yield and quality characteristics (Reynolds *et al*., 2007). Bread wheat growth and development are influenced by temperature, with optimal ranges varying depending on the wheat variety and growth stage (Challinor *et al*., 2010). Extreme temperatures, both high and low, can adversely affect yield and quality (Randall, 1990). Farooq *et al*. (2014) stated that adequate moisture availability during tillering, flowering, and grain filling is essential for achieving high yields and quality grains.

According to Steinfort *et al*. (2017), wheat is a photoperiod-sensitive crop, and adequate light intensity and duration are necessary for optimal growth, development, and grain filling. Soil fertility, pH, texture, and nutrient availability significantly impact wheat growth, nutrient uptake, and ultimately yield and quality (M. P. Reynolds *et al*., 2007). Biotic and abiotic stressors are known factors leading to the deterioration of wheat grain quality and crop yield reduction (Filip *et al*., 2023). An estimation of the phenotypic correlation coefficient among traits at Adet indicated that there was a significant correlation between thousand seed weight (r = 0.33) and grain yield (Birhanu Bayeh, 2010).

Optimal plant population per unit area affects tillering, competition for resources, and ultimately grain yield and quality (Rehberger *et al*., 2023). Proper application of fertilizers, such as nitrogen, phosphorus, and potassium, influences wheat yield, protein content, and other quality parameters (Bhatta *et al*., 2017). Controlled irrigation practices can help mitigate the effects of water stress and optimize yield and quality (Kihara *et al*., 2022). Effective control measures against weeds, pests, and diseases are essential to prevent yield losses and maintain grain quality. Rotating wheat with other crops helps break disease cycles, manage pests, and improve soil fertility, leading to better wheat yields and quality in subsequent seasons (Staggenborg *et al*., 2003). Seed and nitrogen rates have provided valuable insights into the management practices that can optimize wheat yield and quality while ensuring sustainable production systems (Bogale Ayana, 2019). Cropping systems and environmental conditions ultimately contribute to improved wheat productivity and profitability worldwide (Gebrekidan, 2016).

2.6. Effect of Nitrogen Fertilizer Rate on Bread Wheat Production

According to Fresew Belete *et al*. (2018), nitrogen fertilization plays a crucial role in bread wheat production, influencing crop growth, yield, and grain quality. Nitrogen is a fundamental nutrient required for wheat growth (J. Iqbal *et al*., 2012a). According to Ali *et al*. (2011.b), adequate nitrogen availability promotes vegetative growth, enhances tillering, increases the number of grains per spike, and improves grain filling, ultimately leading to higher grain yields. The N rate significantly influenced grain yield, protein content, N uptake efficiency, and N biomass production efficiency (Haile, Tamiru *et al*., 2012). Nitrogen deficiency can result in stunted growth, reduced tillering, poor grain development, and lower yields (Lawlor *et al*., 2011). Nitrogen rate influences wheat yield, grain quality, and nutrient uptake (Krapp, 2015). The findings of Abebe Bekalu and Manchore Mamo (2016) state that fertilizer applied at a rate of 46 kg ha^{-1} contributed to a 27.12% increment in spike length compared with N applied at 92 kg ha^{-1}.

Findings of Iqbal *et al*. (2012) on the effects of nitrogen fertilization rate on the physical properties of wheat grain indicated that an increase in nitrogen rate was met by a decrease in the thousand kernel weight (from 38.03 to 36.87) and an increase in the test-weight (from 82.5 to 84.2). According to Guerrini *et al*. (2020), kernel yield was significantly and positively related to nitrogen fertilization. Numerous studies have investigated the effects of different nitrogen rates on wheat yield, grain quality, and nutrient uptake across various environments and management practices (Duressa & Geleta Ayana, 2020; Iqbal *et al*., 2012). Optimal nitrogen rates vary depending on soil fertility, wheat variety, and management practices (Bayenesh Zemichael *et al*., 2017). Similarly, Duressa and Geleta Ayana (2020b) reported that with an increasing dose of fertilizer up to 100 kg ha-1 urea, mean plant height increased significantly. These results are in conformity with those of Ali *et al*. (2011a), who observed an increase in plant height due to nitrogen fertilization.

Nitrogen is present in many essential compounds; it is not surprising that growth without added nitrogen is slow (Ohyama & Sueyoshi, 2010). Dordas (2009) states that nitrogen makes up 1–7% of the dry matter of plants. Being the essential constituent of protein, it is involved in all the major processes of development, and a good supply of nitrogen to the plant stimulates root growth and development (Khan *et al*., 2008). Findings from Teketel Molla (2019) indicated that the tallest plant (93.64 cm) was recorded at 69 kg N ha^{-1}, while the shortest plant (80.45cm) was obtained at 23kg N ha^{-1}. The findings of Iqbal *et al*. (2012) indicate that a maximum grain yield of 4626 kg h^{-1}a was observed when nitrogen fertilizer increased from 100 kg to 125 kg ha^{-1}, while the lowest grain yield of 3193 kg ha^{-1} was recorded at zero levels of nitrogen. According to Xu *et al*. (2020), N fertilizer application could significantly increase the GY of spring wheat.

The rise of nitrogen increases the durability of the leaf area and biomass (Bhatta *et al*., 2017) . Nitrogen is important for rapid growth through an increase in height, tiller number, size of leaves, and length of roots in wheat (Amare Assefa & Mulatu Kassaye, 2017a). Nitrogen deficiency causes stunted plant growth, development of thin and spindle systems (Khalil *et al*., 2011). On the other hand, the finding of Wang *et al*. (2011) indicates excess nitrogen supply causes higher photosynthetic activities, vigorous growth, weak stems, dark green color, reduced product quality, delayed maturity, an increase in susceptibility to insect pests and diseases, and the building up of nitrate in foliage, which is harmful to animals. The findings of Duressa and Geleta Ayana (2020) showed that the harvest index of wheat an increase with increase in fertilizer rate up to a certain level. Adequate nitrogen fertilization significantly increases wheat yield by promoting tillering, increasing grain number per spike, and improving grain size and weight (Kassaye, 2017a). Nitrogen rates also influence grain protein content, with higher nitrogen levels generally resulting in higher protein content (Tekletsadik Degu *et al*., 2017). The highest biomass (13994.0 kg ha^{-1}) and grain yields (6990.6 kg ha^{-1}) were obtained with 250 kg ha^{-1} urea (Kebede *et al*., 2017). Grain volume weight (GVW) and thousand kernel weights (TKW) decreased with increasing N levels and were influenced by genotype (Otteson *et al*., 2007). The findings of Zewudu Berhanu *et al*. (2023) indicate that tef heights increased along the rates of fertilizer applied; the longest heights were recorded from plots fertilized with 150 and 200 kg ha^{-1}.

According to the findings of Iqbal *et al*. (2012), maximum grain weights were observed at a nitrogen level of 125 kg ha^{-1}, followed by 100 kg ha^{-1} and 150 kg ha^{-1}. Hailu Feyisa and Girma Mengistu (2023) state that the maximum grain yield of bread wheat was attained through the use of maximum N levels. According to Fresew Belete *et al*. (2018) and Birhanu Tilahun (2022), the role of N in wheat production in the highlands has been affected by substantial changes in yield and yield components affected by the application of N. Increasing N up to 75 kg/fad increased yield and the attributes of wheat in both growing seasons (Noureldin *et al*., 2013). Fresew Belete *et al*. (2018) indicate that application of up to 120 kg ha^{-1} N significantly increased plant height, biological yield, number of grain $spike^{-1}$, grain yield, harvest index, and protein content. Adequate nitrogen fertilization promotes tiller development and increases the number of productive tillers (Wang *et al*., 2011). Nitrogen deficiency can result in fewer tillers and reduced tiller size (Lawlor *et al*., 2001). The maximum spikes m^{-2} 332.95, grains $spike^{-1}$ 63.90 were noted from the plots fertilized with 120 kg N ha^{-1} (Ali Shah *et al*., 2011a).

2.7. Effect of Seed Rate on Bread Wheat Yield

Seed is the most vital agricultural input, and it is the basic unit for the distribution and maintenance of plant populations (Gooding *et al*., 2002). According to Šarauskis *et al*. (2022), optimal seeding rates vary depending on soil type, climate, wheat variety, and management practices. Adjusting seeding rates can help optimize yield and quality while minimizing input costs (Lafond, 2010). The effects of seed rate on grain specific weight and thousand grain weight were small and inconsistent (Gooding *et al*., 2002). However, Hag (2016), states that excessively high seeding rates may also increase competition among plants, leading to lodging, reduced grain size, and a lower overall yield. A higher number of tillers (503.40) was observed at a seeding rate of 175 kg ha^{-1}, while a smaller number of tillers (404.40) was recorded at a seeding rate of 125 kg ha (J. Iqbal *et al*., 2012).

The findings of Teketel Molla (2019) indicate that the maximum grain yield of 4544 kg ha^{-1} was recorded at a seeding rate of 175 kg ha^{-1}, while the lowest grain yield of 4118 kg ha^{-1} was recorded at a seed rate of 100 kg ha-1. According to the findings of Otteson *et al*. (2007), increasing the seeding rate failed to increase the grain yield of the three cultivars, but ND 740 was most productive at the lowest seeding rate. Based on the result of Mekonnen (2017), using a seeding rate of 150 kg ha^{-1} performed better, gave a higher grain yield of 4462.10 kg ha^{-1}, and had a 34.55% grain yield advantage on average over the remaining three seeding rates.

Other studies also show that the use of a 150 kg ha^{-1} seeding rate attained earlier heading than seed rates of 100 kg ha^{-1} and 125 kg ha^{-1} (J. Iqbal *et al*., 2012). Amare Assefa and Mulatu Kassaye (2017a) also conclude that a seed rate of 150 kg ha^{-1} performed better for late sowing of wheat up to November 28th. However, other studies conclude that yield is not increased by increasing the seed rate to produce greater yields at a lower seeding rate (Otteson *et al*., 2007). The shortest and highest spike lengths were recorded by using the highest and lowest seeding rates, respectively (Bhatta *et al*., 2017; J. Iqbal *et al*., 2012a). The findings of Girma Dawit (2018) also show that when seed rates increase from 100 kg to 150 kg ha^{-1}, the number of kernels per spike decreases from 56.85 to 51.96. Higher seed rates can increase tiller density and the overall number of tillers per unit area (Hag, 2016). Excessively high seed rates, competition for resources, and ultimately reduced tiller number and tiller size (Gebre-mariam & Larter, 2011).

High seed rates are required for poor seedbeds, for grains with reduced germination capacity, and vice versa (J. Iqbal *et al*., 2012a). Faurès *et al*. (2012) also explained that the establishment of an optimum population per unit area of the field is essential to achieving maximum yield. Seeding rate can impact wheat tillering, grain yield (Otteson *et al*., 2007). It was reported that, in a dense wheat population, grain yield decreased due to competition between plants that induced self-regulation (Abiot Makonnen, 2017). In cultivars that produce fewer tillers, higher seeding rates compensate for the reduced tillers and promote more main stem spikes (Birhanu Gebeyehu, 2020). Gooding *et al*. (2002) reported that higher seed rates significantly decreased the number of grains per spike and 1000 grain weight. The optimum seed rate is one of the most important agronomic practices for maximum crop yield. Less seed rate is used, and yield will be lower due to the lesser number of plants per unit area (Haider *et al*., 2016). The number of spikes per square meter was significantly ($P < 0.05$) lower at a seeding rate of 50 than 150 seeds per m^{-2} (Nakano & Morita, 2009).

On the other hand, research results indicated that the use of a proper seed rate encourages nutrient availability, proper sun light penetration for photosynthesis, and a good soil environment (Hag, 2016; Teketel Molla, 2019).

It was reported that, in a dense wheat population, grain yield decreased due to competition between plants that induced self-regulation (Jennifer *et al*., 2006). Asefa Workineh & Chavhan (2020) reported that the highest grain yield (5210 kg ha^{-1}) of wheat was observed with a seed rate of 177 kg ha^{-1} while the lowest grain yield (3500 kg ha^{-1}) was recorded with a seed rate of 66 kg ha^{-1}. Rahel Tigabu and Fikadu Asfaw (2016) also reported that when the seeding rate increased from 75 kg ha^{-1} to 150 kg ha^{-1}, the grain yield increased from 2220 kg ha^{-1} to 2450 kg ha^{-1}.

Using an optimum seeding density can provide suppression of weeds in wheat crops (Birhanu Gebeyehu, 2020). According to Gebre mariam & Larter (2017), the optimum plant density depends on planting time and methods, soil fertility, available moisture, sowing date, soil conditions, and cultivation intensity. According to the findings of J. Iqbal *et al*. (2012b), the tallest plants (98.33 cm) were observed at a seeding rate of 150 kg ha^{-1}, while the smallest plants (94.33 cm) were recorded at a seeding rate of 175 kg ha^{-1}. The findings of Amare Assefa and Mulatu Kassaye (2017b) indicate that the tallest spikes of the three varieties were attained at 100 kg ha^{-1}. According to Biri, Tadesse, *et al*. (2023b), a maximum spike length of 8.38cm was observed at a seeding rate of 150 kg ha^{-1} with 23 kg N ha^{-1}, followed by a minimum spike length of 8.35 cm at a seeding rate of 175kg ha^{-1} with 46kg N ha^{-1} 8.35cm, while a minimum spike length of 7.55cm was recorded at a seeding rate of 125 kg ha-1 with 23 kg N ha^{-1}. Seed rate influences grain weight by affecting tiller number and spike development (Šarauskis *et al*., 2022). Moderate seed rates promote optimal tiller density, and spike size tends to result in larger, heavier grains (Khalil *et al*., 2011).

Larger, heavier grains contribute more to overall grain yield and are desired for their higher market value and processing quality (Iqbal *et al*., 2012a). Grain weight is influenced by genetic factors, environmental conditions (temperature and moisture during grain filling), and nutrient availability (Nakano & Morita, 2009).

2.8. **I**nteractions **E**ffects **B**etween **S**eed and **N**itrogen **R**ates on **Y**ield and **Y**ield **C**omponents of **B**read **W**heat

The interactions between seed and nitrogen rates can significantly influence tiller number, grain number per spike, grain size, and overall grain yield (Staggenborg *et al*., 2003). According to Otteson (2007), Grain yield, biological yield and harvest index and were maximum at seeding rate of 150 kg ha^{-1} with nitrogen level of 125 kg ha^{-1}. Similarly, Iqbal *et al*. (2012a) states that a significant interaction was noted for number of grain/ spikes, grain yield, biological yield and harvest index and were maximum at seeding rate of 150 kg ha^{-1} with nitrogen level of 125 kg ha^{-1}. The application of 140 kg N ha^{-1} and 150 kg seed rate ha^{-1} was the best combination for getting higher seed yield with its better quality (Yadav, 2017). The results showed that the maximum grain yield and harvest index were recorded at a seeding rate of 150 kg ha-1 with nitrogen rates of 92 N ha^{-1}(Alemayehu Biri, 2023).

Sileshi, Workineh *et al*. (2015) reported that grain yield at the highest rate of nitrogen fertilization 138 kg N ha^{-1} with 177 kg ha-1 seed rate gave maximum grain yield of 5210 kg ha^{-1}. N fertilizer rate of 46 kg Nha^{-1} and seed rates of 125 kg ha^{-1} gave the optimum yield (Sisay, Gurmu, 2024). A seed rate of 150 kg ha^{-1} and 122 kg ha-1 nitrogen rate into the highest phenological and growth parameters (*Mohammed Hussen, 2021)*. Hailu Feyisa *et al*. (2023), also conclude that the maximum grain yield of bread wheat was attained through the use of maximum N levels and seeding rates. The interaction between seeding rates and nitrogen levels was found to be non-significant for plant height, number of tillers, spike length, and 1000 grain weight, while a significant interaction was noted for the number of grain spikes^{-1}, grain yield, biological yield, and harvest index, and was maximum at a seeding rate of 150 kg ha^{-1} with a nitrogen level of 125 kg ha^{-1} (J. Iqbal *et al*., 2012a).

The maximum genetic potential of high yielding wheat varieties cannot be harvested without ensuring a proper seeding rate and optimum nitrogen rate (Reynolds *et al*., 2009). As the plant density increases, the competition for resources, especially nitrogen, also increases, which reduces the ultimate grain yield (Otteson *et al*., 2007). Bhatta *et al*. (2017), reported that grain yield at the highest rate of nitrogen fertilization (N) with a seed rate of 177 kg ha^{-1} gave a maximum grain yield of 5210 kg ha^{-1}. Increasing the rate of nitrogen and seed rate application up to optimum significantly ($P< 0.01$) increased the total aboveground biomass and grain yields of the crop and decreased with further increase of applied N fertilizer (Otteson *et al*., 2007).

Moderate increases in both seed and nitrogen rates lead to higher tiller numbers, increased biomass accumulation, and ultimately higher grain yields compared to individual treatments (Fresew Belete *et al*., 2018; Hag, 2016; Bhatta *et al*., 2017). Excessively high seed rates reduce nitrogen uptake efficiency or increase lodging, negating the benefits of additional nitrogen application (Ali *et al*., 2011-a). Excessively high seed and N rate rates lead to overcrowding and lodging, resulting in reduced yield and quality (Teketel Molla, 2019a). Application of 92 kg N ha^{-1} with 75% SI increased tiller production by 94% (Bayenesh Zemichael *et al*., 2017).

2.9. **B**read **W**heat **P**roduction **C**hallenges in **N**orth **S**hewa, **E**thiopia

Poor seed quality can result in lower germination rates, reduced crop vigor, and susceptibility to diseases (Minot *et al*., 2015). Lack of access to improved wheat varieties adapted to the local agroecological conditions in North Shewa may hinder farmers from selecting the most suitable varieties (Abebual Woldetsadik, 2019). Growing inappropriate varieties can lead to suboptimal yields and susceptibility to pests and diseases (Tadesse *et al*., 2019).

Accessing and affording nitrogen fertilizers, which are crucial for optimizing wheat yield and quality (Biri, Tadesse, *et al*., 2023), with a limited knowledge, farmers apply nitrogen fertilizers ineffectively, leading to nutrient losses through leaching, volatilization, or denitrification (Minot *et al*., 2015). Inefficient nitrogen uses results in reduced nitrogen use efficiency, environmental pollution, and economic losses (Girma Assefa *et al*., 2022). Limited research efforts focused on determining the optimal seed rates for different wheat varieties and agroecological zones in North Shewa (Kihara *et al*., 2022). Knowledge gaps exist regarding the relationship between seed rates and wheat yield components, as well as the interaction with other agronomic practices (Fisseha Zegeye *et al*., 2020). Knowledge gaps exist regarding the optimum nitrogen rates to maximize wheat yield and quality while minimizing environmental impacts (Girma Assefa *et al*., 2022; Biri, Jifara, *et al*., 2023)

3. MATERIAL AND METHODS

3.1. Description Of the Study Area

The experiment was conducted at Astoya (Yedil Chora) Farmers' Training Centre (FTC), in Menz Mama District, north Shewa zone, during the meher rainy season of 2023. It was located in the Amhara region at 10°7'16.81''N latitude and 39°39'52.98''E longitude. Menz mama woreda was positioned in the northeastern part of the country. It was located about 70 km west of the main road from Addis Ababa to Dessie and 254 km from Addis Ababa. The borders of the woreda were Menz-Gera from the north, Kewot from the east, Moja from the south, and Menz-Lalo Districts from the west. The District had three agro-ecological Zones: kola/low land (5%), midland/weyna dega (24%), and highland/dega (71%). Astoya Kebele (Yedil Chora) Farmers' Training Centre (FTC) was located ten km from the Capital town of Menz Mama District. The elevation in the study area was 2758 m above sea level. There were two principal production seasons in the District, namely Maher (from mid-June to the end of August) and Belg (from mid-January to the end of March).

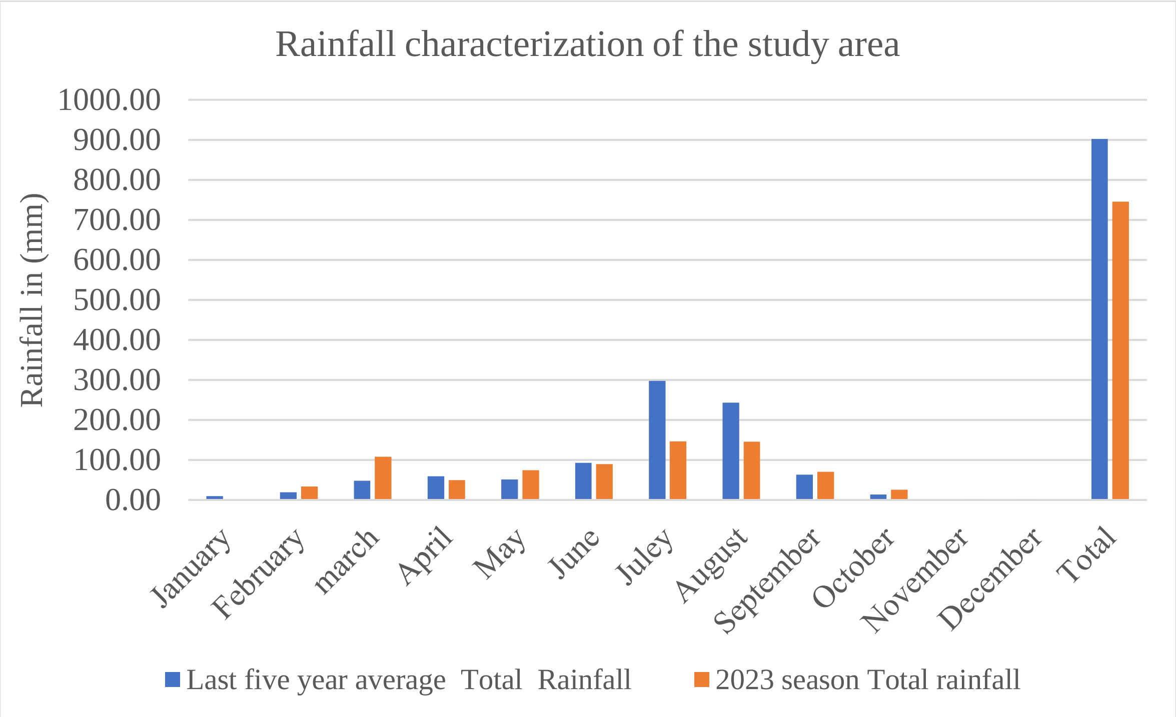

Figure 1. Rainfall characterization of the study area

Rainfall data was recorded at the National Meteorological Agency, Mehal Meda Branch. Average monthly 2023-year monthly during cropping season rainfall at the experimental site are presented in Appendix Table1. The area received an annual rainfall of 745.80 mm during the cropping season (January to December 2023). The mean maximum and minimum temperatures recorded at the station during the season were 18.76 °C and 8.12°C, respectively (Appendix Table 1). The area received a high amount of rainfall from March to September during the cropping season, with the highest amount (146.2 mm) obtained in July, followed by August (145.6 mm) (Appendix Table 1).

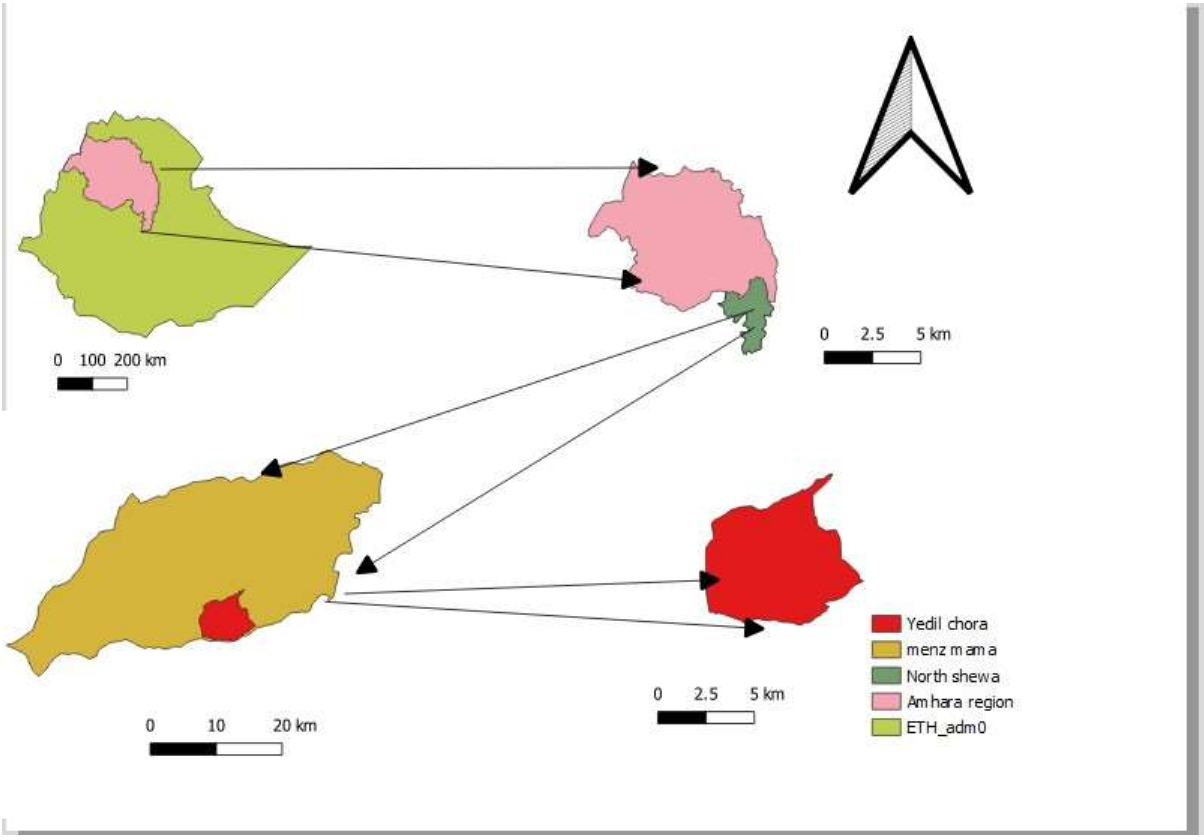

Figure 2. Study area Map

3.1.1. Soil Sampling and Analysis

Soil samples were taken in a zigzag method before planting at a depth of 0 - 30 cm using an auger and were composited. Then, the composite samples were air-dried at room temperature under shade, and the samples were mixed thoroughly to produce 1.0 kg of a representative composite sample. The composite sample was submitted to the DebreBirehan Agricultural Research center's (DARC) soil testing laboratory. Then, in the laboratory, it was ground to pass through a 2 mm sieve, whereas for organic carbon (OC) and nitrogen (N) determination, it was ground to pass through a 0.2 mm sieve. The soil sample was analyzed for selected Physico-chemical properties, namely soil texture, soil pH, cation exchange capacity (CEC), organic carbon, available P, and total available N, which determined at Debre Birhan agriculture Research Centre soil testing laboratory.

Total nitrogen was analyzed by the Kjeldhal method (Estefan *et al*., 2013). The pH of the soil was determined at a 1:2.5 soil-to-water dilution ratio using a glass electrode attached to a digital pH meter (Page, 1982). Cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH_4OAC) and displacing it with 1N NaOAC (Chapman,1965). Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Estefan et al., 2013). Available P was determined by Olsen's method (Olsen *et al*., 1954). Soil texture was analyzed by using a hydrometer. After 40 second all sand-sized particles (0.02 mm and larger) settled out of the suspension, and after 4 hour, particles larger than clay (0.002 mm) settle out of the suspension.

3.1.2 **S**oil **P**hysico-**C**hemical **P**roperties of **t**he **E**xperimental **S**ite

The findings of the laboratory examination of the soil's physico-chemical characteristics prior to planting are indicated below (Table 3. 1). The experimental soil's analytical results showed that the soil textural class was clay, with a distribution of particle sizes of 62 clay, 28 silt, and 10 sandy.

Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Landon (1991) classification of the soil have very high CEC of 60 .25 coml. (+)/kg soil indicating its best capacity to retain the cat ions (Table 3.1).

Organic matter content in soil is a critical component that influences soil fertility, structure, water holding capacity, and overall soil health. The organic matter content is typically expressed as a percentage of the soil's weight. According to Solomon *et al*. (2002), classified soil has organic matter content 2.81% (Table 3. 1) moderate organic matter content. They typically have better water retention capabilities and support a more diverse microbial community compared to soils with low organic matter content (Artifon *et al*., 2019). However, there is still room for improvement, and management practices should aim to maintain or increase organic matter levels.

Phosphorus is crucial for root development, flowering, and seed formation in bread wheat. The available phosphorus level of 31.98 ppm (Table 3.1) is essential for supporting bread wheat growth. Nitrogen is a vital nutrient for wheat, essential for its growth and protein synthesis. A total nitrogen content of 0.174% (Table 3.1) indicates a moderate level that should support bread wheat production, but nitrogen supplementation is necessary during specific growth stages (Lawlor, 2017).

Table 3.1 Selected Physico-chemical properties of the soil of the experimental site

No	Parameter	value	Rating	Reference
1	PH (1:2.5)	6.2	slightly acidic	Tekalign Tadese, (1991)
2	CEC/meq/100g	60.25	very high	Landon, (1991)
3	% OC	1.63	moderate	Tekalign Tadese, (1991)
4	% OM	2.81	moderate	Tekalign Tadese, (1991)
5	AV. p (ppm)	31.98	Medium	Olsen, (1954.)
6	T.N (%)	0.174	moderate	Tekalign Tadese, (1991)
7	C/N Ratio	9.37		
8	% Sand	10		
9	% Clay	62		
10	% Silt	28		
11	Textural class			clay

3.2. **E**xperimental **M**aterials

The widely grown bread wheat variety in the study area was called Danda', and it was used as the experimental crop. The variety was released by the kulmsa agricultural research center in the 2010 cropping season. The variety had a maturity period of 110-145 days with the yield potential of 35-55 t ha^{-1} in research fields (MOA, 2018). The variety was selected on the basis of its adaptation, better performance, and disease resistance in the area. Blended NPS (19% N, 38% P2O5, and 7% S) and urea were used as the sources of fertilizers.

3.3. **T**reatments and **E**xperimental **D**esign

The study evaluated four seed rates (125, 150, 175, and 200 kg ha^{-1}) and four nitrogen rates (150, 200, 250, and 300 kg ha^{-1}). The research employed a randomized complete block design (RCBD) in three replications. All treatment and treatment combinations were clearly indicated in Appendix Table 6. The gross size of each plot was 1.6 m × 2.4 m ($3.84m^2$), consisting of twelve rows, and the distance between adjacent plots and blocks was 0.5 m and 1 m apart, respectively. The outermost one row on both sides and 10 cm of two ends of the length of each plot were considered border plants and were not used for data collection to avoid border effects. The net plot was 1.4 m × 2 m ($2.8m^2$), consisting of ten rows with a total treatment of 16 (Appendix Table 6).

3.4. **E**xperimental **P**rocedures and **F**ield **M**anagement

The experimental field was ploughed with oxen to a fine tilt, and the plots were leveled manually. According to the design, a field layout was prepared, and each treatment was assigned randomly to the experimental units within a block. Bread wheat seeds were sown as per the rate in rows of 20 cm spacing manually by drilling during normal sowing time. The whole of NPS and 1/3 N fertilizers were applied at sowing, while the remaining 2/3 N fertilizer at the mid-tillering stage was applied as side dressings in the form of urea. Weeding was done as needed, and harvesting and threshing were done manually.

3.5. **D**ata **C**ollection

3.5.1. Crop phenology and growth parameters

Days to 50% heading (DH): days to spike heading were determined 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.

Days to 90% physiological maturity (DPM): days to physiological maturity was determined as the number of days from sowing to the date when 90% of the peduncle turned to yellow in straw color. *i.e.,* when grains were difficult to break with thumb nail.

Lodging percent: -The degree of lodging was assessed just before the time of harvest by visual observation by measuring the angle of inclination of the main stem from the vertical line to the base of the stem by visual observation.

Plant height (cm): plant height was measured from the soil surface to the tip of the spike (awns excluded) of 10 randomly selected plants from the net plot area at physiological maturity from the middle ten rows.

Spike length (cm): It was measured from the bottom of the spike to the tip of the spike excluding the awns from 10 randomly selected spikes from the net plot.

3.5.2. Yield and yield components

Number of tillers: the number of tillers per plant was determined from 10 randomly selected plant from middle ten rows.

Number of productive tillers: number of productive tillers per plant was determined from 10 randomly selected plants in the middle of ten rows.

Number of kernels per spike: the mean number of kernels per spike was computed as an average of 10 randomly taken spikes from the net plot area.

Thousand kernels weight (g): thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield with 12.5% moisture content and weighed with sensitive balance.

Aboveground dry biomass (kg ha^{-1}): the aboveground dry biomass was determined from plants harvested from the net plot area after sun drying to a constant weight and converted to kg per hectare.

Grain yield (kg ha^{-1}): The harvested wheat bundles of each plot were sun dried for five days and then was threshed and the grain yield was determined from the net plot area. The yield was adjusted to 12.5% moisture content. Finally, yield per plot was converted to kg ha^{-1}.

Straw yield (kg ha^{-1}): Straw yield was obtained as the difference of the total aboveground dry biomass and grain yield.

Harvest index (HI): harvest index was calculated as a ratio of grain yield per plot to total aboveground dry biomass yield per plot and expressed as percent.

3.6. **D**ata **A**nalysis

Data were subjected to analysis of variance (ANOVA) appropriate for randomized complete block design, to determine the significance of differences between treatments for each parameter measured. Statistical software using SAS (9.4 version) software packages were used to analyze the data. for the analysis PROC GLM (General Linear Model) were used. DMRT test was used for multiple comparisons between treatments at 5% level of significant. Summarize and describe the main features of a dataset. This includes measures such as mean, coefficient of variation for each yield components. Regression analysis can be used to assess the relationship between independent variables (seed rate and nitrogen rate) and the dependent variable (bread wheat yield). Use Pearson's correlation coefficient to assess the strength and direction of association between variables.

3.7. **P**artial **B**udget **A**nalysis

The CIMMYT (1988) was utilized to do the economic analysis, and the prices that were in effect at the time of planting and harvesting for inputs and outputs were taken from the market. In order to calculate the gross field benefit (GFB) (ETB ha^{-1}), farmers multiplied the field/farm gate price they received for the crop when they sold it by the adjusted yield (GFB = AGY × field/farm gate price). The total variable cost (TVC) (ETB ha^{-1}) was computed by adding up all of the variable costs, such as Price of seed 100 kg =5500-birr, Price of N fertilizer application costs 100 kg =3212-birr, and N costs. Planting and applying urea were projected to cost ETB 200 man/day in labor. Using the following formula, the net benefit (NB) was determined as the difference between the gross benefit and the total cost that varied (TCV); NB = (GY x P) – TCV, Where GY x P = Gross Field Benefit (GFB), GY = adjusted grain yield per hectare and P = field price per unit of the crop.

Marginal rate of return, which refers to net income obtained by incurring a unit cost of seed rate and fertilizer as MRR (%) = (Change in NB (NBb -NBa)) / (Change in TCV (TCVb - TCVa)) × 100, where NBa = NB with the immediate lower, NBb = NB with the next higher, TCVa = the immediate lower TCV and TCVb = the next highest TCV.

4. RESULTS AND DISCUSSION

4.1. **P**henological and **G**rowth **P**arameters

4.1.1. Days to 50% heading

The results of the analysis of variance showed that days to heading were highly significantly influenced by N fertilizer ($p<0.01$), but days to heading were not significantly affected by the main effect of seed rate or the interaction of two components (Appendix table 2). The maximum rate of N fertilizer (300 kg ha^{-1}), produced the longest days to heading (63.66 days), while the lowest rate of N fertilizers (150 kg ha^{-1}) produced the shortest days to heading (58.66 days) followed by 200 kg ha^{-1} N 60.12 days (Table 4.1).

The reason for delaying day to heading when applying a high nitrogen rate was that high nitrogen application rates in bread wheat plants stimulate vegetative growth, leading to a prolonged vegetative phase and delay in reproductive growth, including heading. This delay is due to the plant's focus on vegetative growth instead of reproductive structures. High nitrogen availability also encourages tiller development, further delaying the onset of heading. Nitrogen and photoperiod sensitivity can also affect the plant's time to reach the heading stage. Environmental conditions, such as temperature and moisture, also influence plant development.

The result is consistent with the findings of Teketel Molla (2019), who found that heading was significantly delayed at the highest (69 kg ha^{-1}) N rate compared to the lowest rate on bread wheat. Similarly, Endris *et al*. (2010) found that N rates up to 140 kg ha^{-1} significantly increased days to flowering and maturity of rice compared to the control, but Girma Dawit (2018b), concluded that days to 50% heading is statistically non-significant, this is in contrast to the findings of the present study.

4.1.2. Days to 90% physiological maturity

Regarding bread wheat's days to physiological maturity, the main effect of N was statistically highly significant ($p<0.01$). Conversely, days to physiological maturity were not substantially influenced by the main effect of seed rate and the interaction effect of two components (Appendix Table 2). Based on the result, it was found that the greatest rate of N fertilizer (300 kg ha^{-1}) had the longest days to physiological maturity (128 days), while the lowest rate (150 kg N fertilizer ha^{-1}) had the shortest days to physiological maturity (116 days) (Table 4. 1).

The reason for delaying physiological maturity when applying a high nitrogen rate was higher nitrogen availability in wheat crops leads to increased vegetative growth, delayed reproductive development, and a prolonged grain filling period. This can result in longer days to physiological maturity. Nitrogen also affects the crop canopy, affecting the microclimate around the grains. Genetic factors and environmental conditions can also influence the response of wheat crops to nitrogen fertilization.

According to Biri Tadesse *et al*. (2023), increased N levels led to longer days to maturity, sustained leaf photosynthesis, and delayed leaf senescence. A similar outcome was observed by Teketel Molla (2019) , who reported that the highest rate of N (69 kg N ha^{-1}) resulted in the longest days to physiological maturity (110.4 days), while the zero rate of N (0 kg ha^{-1}) produced the shortest days to physiological maturity (93.6 days).

Tigre (2014), reported a similar outcome barley took longer to mature when N rates were higher. The results of this investigation, however, did not agree with those of Adugna (2017), who found that when nitrogen rates rose from zero to 92 kg ha^{-1}, bread wheat's physiological maturity was accelerated from 158.75 to 152.96 days.

4.1.3. Lodging percent

The lodging percentage depends on environmental conditions, cultivar characteristics, and management practices. Seed rate and nitrogen application affect lodging percentages in wheat crops. Nitrogen rate affects lodging risk, with excess causing overly tall and weak-stemmed plants. Both the main effect of N fertilizer and seed rates had a highly significant ($P < 0.01$) influence on the lodging percent, while the interaction effect had no significant effect on the lodging % of bread wheat (Appendix Table 2).

The highest lodging percent (10.50 %) was recorded at the application of 300 kg N fertilizer, whereas the lowest lodging percent (2.75%) was recorded under the application of 150 kg N fertilizer (Table 4. 1). This result is due to the fact that when excessive nitrogen fertilizer is applied, it can lead to excessive vegetative growth in wheat plants. This lush, rapid growth can result in taller, weaker stems that are more prone to lodging, especially under adverse weather conditions such as wind or rain.

Therefore, the high lodging percentage observed at 300 kg N fertilizer application suggests that the plants might have experienced excessive vegetative growth, leading to weaker stems and increased susceptibility to lodging (Table.4.1). Conversely, the lower lodging percentage observed at 150 kg ha^{-1} N fertilizer application indicates that the plants received sufficient nitrogen for healthy growth without excessive vegetative development. As a result, they likely maintained stronger stems and were less prone to lodging.

The main factor of seed rate had a highly significant ($P<0.01$) effect on the lodging percentage of bread wheat. The highest lodging percentage (7.41%) was recorded from the highest seed rate of 200 kg ha^{-1}, while the lost lodging percentage (5.4 %) was measured from lowest seed rate 125 kg ha^{-1} (Table 4. 1). This indicates that increasing the seed rate resulted in a higher lodging percentage, while reducing the seed rate led to a lower lodging percentage. Seed rate directly influences plant density, affecting competition for resources such as light, water, and nutrients among individual wheat plants.

Higher seed rates can lead to increased competition, resulting in taller, thinner stems that are more prone to lodging due to reduced stem strength and increased susceptibility to environmental stresses such as wind and rain. Finding the optimal seed rate is crucial for maximizing wheat yield while minimizing lodging risk. While higher plant densities may initially seem advantageous for achieving higher yields, they can also increase lodging susceptibility. Conversely, lower seed rates may reduce lodging risk but could result in lower yields if plant density is too sparse.

Table 4. 1 Main effect of Nitrogen fertilizers and seed rate on days to 50% heading, days to 90% physiological maturity and lodging percentage

Treatment	Day to Heading	Days of 90% physiological	Lodging Percentage
		N fertilizer	
150	58.66^{D}	116.00^{D}	2.75^{D}
200	60.125^{C}	117.66^{C}	5.08^{C}
250	62.25^{B}	125.00^{B}	7.33^{B}
300	63.66^{A}	128.00^{A}	10.50^{A}
DMRT	**	**	**
		Seed rate	
125			5.41^{D}
150			6.08^{C}
175			6.75^{B}
200			7.41^{A}
DMRT			**
CV			8.7

*Means with the same letter (s) in the column are not significantly different at 5% level of significance; NS=non-significant; CV (%) = Coefficient of variation, DMRT= Duncan multiple range test at 5% level, *=significant at 5% level of significant, **=. significant at 1% level of significant*

4.1.4. Plant height (cm)

The analysis of the result shows that the main effect of N had a highly significant ($p<0.01$) influence, and the seed rate had a significant ($p<0.05$) effect. In contrast, the two-factor interaction had no discernible influence on this parameter (Appendix Table 3). The tallest plant, measuring 97.11 cm, was found to be at 300 kg ha^{-1} N fertilizer, while the smallest plant, measuring 73.54 cm, was found to be at 150 kg ha $^{-1}$ N fertilizer (Table 4. 2). The rate at which N fertilizer is applied has a considerable effect on bread wheat height, as indicated by this finding. Nitrogen is a vital component of amino acids, the building blocks of proteins, and is essential for plant growth and development. When plants receive adequate nitrogen, they can synthesize proteins more efficiently, leading to increased plant height. Nitrogen also plays a vital role in cell division and expansion, influencing enzyme activity and allowing plants to produce more cells and expand their tissues. It is also a key component of chlorophyll, the pigment responsible for photosynthesis, which converts light energy into chemical energy. Adequate nitrogen levels ensure sufficient chlorophyll production, maximizing the plant's ability to capture sunlight and produce growth energy. Additionally, nitrogen is closely associated with biomass production, allowing plants to accumulate more biomass, including structural components like stems, leaves, and roots, contributing to overall plant growth and height.

Findings of Teketel Molla (2019), in line with the current study, who reported that the tallest plant (93.64 cm) was recorded at the highest N rate (69 kg $ha^{-1)}$, while the shortest plant (80.45cm) was obtained at the lowest N rate (23 kg N ha $^{-1}$). Similarly, Duressa and Geleta Ayana (2020) reported that with an increasing dose of fertilizer up to 100 kg ha^{-1} urea, mean plant height increased significantly. These results are in conformity with those of Ali *et al*. (2011a), who observed an increase in plant height due to nitrogen fertilization.

The result also showed the main effect of seed rates significantly ($p<0.05$) increased the plant height, where the use of 200 kg ha^{-1} seed produced the tallest plants (87.66cm), followed by 175 kg ha^{-1} seed, which produced of 85.9 cm plant height, whereas the shortest plant recorded from the seed rate of 125 kg ha^{-1} (83.83 cm), followed by 150 kg ha^{-1} (85.02

cm), is statistically similar. Higher seed rates in wheat crops increase competition for resources like nutrients, water, and sunlight, leading to taller plants and denser stands. This competition can also result in the "tiller response" or "lodging response". In dense stands, nutrient availability may be lower per plant, causing individual plants to elongate their stems to access more nutrients. Overall, higher seed rates can lead to taller plants and denser stands.

This finding was in line with the finding of Abiot Mekonnen (2017), who reported that as the seeding rate increased from the lowest (100 kg ha^{-1}) to the highest (175 kg ha^{-1}), the height of the plant correspondingly increased from 76.86 to 81.76 cm. Biri Tadesse *et al*. (2023) also showed that the tallest plants (73.3 cm) were observed at a seeding rate of 175 kg ha^{-1}, while the smallest plants (68.9cm) were recorded at a seeding rate of 125 kg ha^{-1}. Similarly, Khalil *et al*. (2011) reported that a high seed rate of 150 kg ha^{-1} gave a maximum plant height of 80.6 cm as compared to 100 kg ha^{-1} of seed rate. Abiot Mekonnen (2017) reported that (higher seeding rate and lower light penetration) increase internode length, reduce stem thickness and increase plant height.

In contrast to the current study, Iqbal *et al*. (2012), reported those tallest plants (98.33 cm) were observed at seeding rate of 150 kg ha^{-1} while shortest plants (94.33 cm) were recorded at a seeding rate of 175 kg ha^{-1}. Rahel Tigabu and Fikadu Asfaw (2016), reported that the use of 75 kg seed ha^{-1} produced the tallest plants (83.87cm), followed by 100 kg seed ha^{-1} which produced a 79.72 cm plant height of wheat. The finding of Amare Assefa and Mulatu Kassaye (2017) is also in contrast to the current result, who reported that the highest plant height (80.07 cm) was recorded at 100 kg ha^{-1} seed rate, whereas the lowest plant height (74.92 and 72.92 cm) was recorded at a seed rate of 125 and 150 kg ha^{-1}, respectively.

4.1.5. Spike length (cm)

The main effects of N and seed rate had a highly significant ($p<0.01$) effect on bread wheat spike length, while the interaction effect of the two factors had no significant effect on this parameter (Appendix Table 4). The result shows that spike length increased when the rate of N was raised to the optimal range (Table 4. 2). At a seed rate of 250 kg ha^{-1}, the longest spike (9.19 cm) was obtained, and (9.01 cm) obtained at a seed rate of 300 kg N ha^{-1} with no statistically significant difference between them. On the other hand, the shortest spike (7.15 cm) was measured at 125 kg N ha^{-1}.

This finding clearly indicates that increasing the amount of N fertilizer applied beyond the optimum has no discernible influence on the length of the bread wheat spike. Nitrogen application does not directly increase yield or spike length in plants. It is less effective once the plant has received enough nitrogen for optimal growth. Other factors, like water availability, temperature, light intensity, and nutrient balance, may also limit growth. Excessive nitrogen application can disrupt nutrient balance, increase lodging risk, and delay plant maturity.

This result is in line with the findings of Teketel Molla (2019), who reported that as the N rate increased to the optimum spike length, the longest spike (9.09 cm) was obtained at a rate of 69 kg N ha^{-1}, while the shortest spike (8.13 cm) was recorded at a rate of 0 kg ha^{-1} N. In contrast, Bekalu Abebe and Mamo Manchore (2016) indicate that fertilizer applied at the rate of 46 kg ha^{-1} was contributed to a 27.12 % increment in spike length than N applied at 92 kg ha^{-1}, but resulted for 19.7 % reduction compared with N applied at 46 kg ha^{-1}.

The result also showed that the main effect of seed rate had a highly significant ($p<0.01$) effect on spike length. The longest spike length was measured from a seed rate of 125 kg ha^{-1} (7.00 cm), followed by 150 kg and 175 kg ha^{-1} there is no statistically significant difference between them, while the shortest spike length was measured from seed rate of 200 kg ha^{-1} (5.66 cm) Table.4. 2. This result indicates that as seed rates increase beyond the optimum spike length decrease. This was due to higher seed rates in bread wheat, which can lead to competition for nutrients, water, shading, resource allocation, and lodging risk. Nutrient uptake is reduced, limiting growth potential and spike length. Water competition can cause water stress, affecting growth rates and spike development. Denser plant populations result in increased shading, limiting light availability. Plants may prioritize traits like early vigour and tillering over spike development, resulting in shorter spikes.

This result is in line with the finding of Girma Dawit (2019), who showed that increasing the seed rates decreased spike length, the longest spikes (7.72) were produced at the lowest seed rate (100 kg ha^{-1}). Findings of Mekonnen (2017) also reported that a maximum spike length of 8.93 cm was recorded at those plots that received a seeding rate of 100 kg ha^{-1} while a minimum spike length of 7.33 cm was obtained from plots that received seed rate of 175 kg ha $^{-1}$. Biri, Tadesse *et al*. (2023) also reported the same result with the current study; maximum spike length (8.38cm) was observed at a seeding rate of 150 kg ha^{-1} followed by at seeding rate 175kg ha^{-1} (8.35cm).

In contrast to the current study finding of RahelTigabu and Fikadu Asfaw (2016), that spike length is genetic characters of a variety, which is less influenced by agronomic practices, Seed rate did not show significant effect on spike length.

4.2. **Y**ield and **Y**ield **C**omponents

4.2.1. Number of tillers per plant

The main effect of N and seed rate had a highly significant ($p<0.01$) effect on the number of tillers per plant of bread wheat (Appendix table 3). The number of tillers increased significantly across the increased rates of nitrogen. The highest number of tillers per plant (10.37) was recorded with the application of the highest rates of N rate (300 kg N ha^{-1} followed by 250 kg ha^{-1} N rate whereas the minimum number of tillers (6.66) was recorded with the 150 kg ha^{-1} N rate (Table 4. 2).

The reason for tiller number increase across N rate increase was nitrogen is crucial for plant growth, promoting vegetative growth and tiller development in bread wheat plants. It stimulates the formation of tiller primordia, enhances nutrient uptake, and regulates hormonal balance. Higher nitrogen levels also help maintain the proper hormonal balance for tiller initiation and growth.

The present result is also in line with the findings of Duressa and Geleta Ayana (2020b) and Adugna Weyesa, (2017), who reported an increase in the number of tillers produced in response to the increased rates of N. The finding of Abebual Woldetsadik *et al*. (2019) also reported that the application of blended fertilizer significantly increased the number of total and effective tiller per plant as compared to the control. Similarly, Keneni *et al*. (2022), reported that the highest total number of tillers per plant (6) was produced by plants treated with the highest rate of combined application of (150 kg ha^{-1}) NPSB and (69 kg ha^{-1}) N. In contrast to the current finding of J. Iqbal *et al*. (2012), which reported that when the N rate decreased from 92 kg ha^{-1} to 69 kg ha^{-1}, the number of tillers increased up to 60%.

The main effect of seed rates is also highly significant ($p<0.01$) for the number of tillers per plant (Appendix Table 3). As seed rates increase number of tillers per plant decrease. The maximum number of tillers (9.87) was recorded from a seed rate of 125 kg ha^{-1} followed by 150 kg ha^{-1}. However, the minimum tiller number (7.95) per plant was recorded from a seed rate of 200 kg ha^{-1}(Table 4.2). This is due to as bread wheat seed rate increase, competition for resources like nutrients, water, and light increases, leading to fewer tillers. Bread wheat plants have a sink-source relationship, acting as strong sinks for assimilates. The result was consistent with the findings of Rahel Tigabu and Fikadu Asfaw (2016), they found that when seed rate increase, the number of tillers decreased, the use of 75 kg ha^{-1} seed produced the highest number of tillers per hill (2.37), but 150 kg seed ha^{-1} produced the lowest number of tillers per plant (1.96).

In contrast to the current result, Amare Assefa and Mulatu Kassaye (2017), reported that higher seed rate produced many numbers of tillers. The finding of J. Iqbal *et al*. (2012), shows that neither the main effects nor the combined mean effects of nitrogen and seeding rate had a significant influence on total tiller per plant and productive tiller per plant of irrigated wheat.

Table. 4. 2 Main effect of N fertilizers and seed rate on Plant height spike length number of tillers, thousand Kerner weight and biomass yield on bread wheat. in Menz Mama midir district, north Shewa zone, during of 2023main cropping season

Treatment	Plant height (cm)	Spike Length (cm)	Number of Tiller per plant	Thousand Kerner weight (g)	Biomass Yield
		N fertilizer			
150	73.54^{D}	7.15 ^{C}	6.66 ^{C}	35.50 ^{D}	9414.38 ^{D}
200	79.62^{C}	8.316 ^{B}	8.41 ^{B}	43.41 ^{C}	10329 ^{C}
250	92.17^{B}	9.19^{A}	10.066^{A}	45.66 ^{B}	11370 ^{B}
300	97.108^{A}	9.016^{A}	10.375^{A}	47.58 ^{A}	12425 ^{A}
DMRT	**	**	**	**	**
		Seed rate			
125	83.833 ^{B}	8.725 ^{A}	9.87 ^{A}	43.83 ^{A}	10602 ^{D}
150	85.025 ^{B}	8.50 ^{A}	9.108 ^{B}	43.41^{A}	10791 ^{C}
175	85.93^{BA}	8.60 ^{A}	8.58 ^{CB}	43.41^{A}	10980 ^{B}
200	87.66 ^{A}	7.858 ^{B}	7.9583 ^{C}	41.5 ^{B}	11167^{A}
DMRT	*	**	**	**	**
CV	3.24	5.88	8.88	2.75	11.8

*Means with the same letter (s) in the column are not significantly different at 5% level of significance; NS=non-significant; CV (%) = Coefficient of variation, DMRT= Duncan multiple range test at 5% level, *= significant at 5% level of significant, **= significant at 1% level of significant*

4.2.2. Number of productive tillers

The analysis of the variance shows that the main effect of N rate, seed rate and the interaction of the two factors had a highly significant ($p<0.01$) effect on the number of productive tillers per plant of bread wheat (Appendix table 4). The maximum number of productive tillers (9.5) had been recorded from a combination of 250 kg ha^{-1} N fertilizer with 175 kg ha^{-1} seed rate, followed by 300 kg ha^{-1} N fertilizer with 125 kg ha^{-1}seed rate. While the minimum productive tiller per plant (3.83) was recorded from a combination of 150 kg ha^{-1} N fertilizer with 200 kg ha^{-1} seed rate (Table 4. 3).

This may be due to the number of productive tillers per plant varies depending on nitrogen fertilizer and seed rates per hectare. Nutrient availability, seed rate, and optimal combination are key factors. Higher nitrogen fertilizer levels may support increased tillering, while higher seed rates may reduce tillering due to resource limitations. The optimal combination ensures adequate nutrients and spacing for vigorous growth and tillering. The combination of 250 kg ha^{-1} nitrogen fertilizer with a seed rate of 175 kg ha^{-1} resulted in the highest number of productive tillers per plant, (9.5 tillers). This suggests that this specific combination effectively promotes tiller development and ultimately contributes to higher grain yield potential. The significant number of tillers indicates robust plant growth and vigor, which are crucial for maximizing yield. The combination of 150 kg ha^{-1} nitrogen fertilizer with a seed rate of 200 kg ha^{-1} resulted in the lowest number of productive tillers per plant, with only 3.83 tillers. In this case the lower nitrogen input combined with a higher seed rate seemed to have limited tiller development, indicating suboptimal conditions for crop growth and potentially leading to reduced yield potential.

This result is in line with the finding of Rahel Tigabu and Fikadu Asfaw (2016), who reported that the productive tillers were higher at a lower at seed rate, when compared with higher nitrogen rates. Similarly, the finding of Zewdie and Hunegnaw 2020), showed that a higher seed rate produced many numbers of tillers, but it might not produce many numbers of effective tillers per unit area. Adugna Weysa (2017), reported that total and productive tiller numbers decreased as seeding rate increased indicating negative effect of increased seed rate on number of tillers.

The current finding has shown that the application of 175 kg of seed along with 250 kg of nitrogen (N) fertilizer can result in a higher productive tiller number. This means that when this specific combination of seed and nitrogen fertilizer is used, bread wheat crops tend to produce more tillers that contribute positively to grain yield. The relationship between seed and nitrogen fertilizer in promoting productive tiller numbers can be explained by their roles in stimulating plant growth and development. Adequate seeding rates ensure a sufficient plant population, while nitrogen fertilizer provides essential nutrients for vigorous plant growth and tiller development. In practical terms, ensuring the right balance of seed and nitrogen fertilizer application is vital for optimizing tiller production and ultimately enhancing grain yield in bread wheat cultivation.

Table.4. 3. Interaction effect of N fertilizers and seed rate on number of productive tillers of bread wheat in Menz Mama midir district, north Shewa zone, during of 2023main cropping season

N fertilizer rate (kg ha^{-1})	Seed rate (kg ha^{-1})			
	125	150	175	200
150	5.00^{FGH}	5.00^{FGH}	4.16^{GH}	3.833^{H}
200	$7.00B^{ECD}$	6.50^{FECD}	6.00^{FED}	5.50^{FEG}
250	7.83^{BC}	7.33^{BCD}	9.50^{A}	$7.00B^{ECD}$
300	8.16^{BA}	7.50^{BCD}	7.16^{BCD}	6.33^{FECD}
P value	<0.0053			
CV	9.34			

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance; CV = Coefficient of variation.

4.2.3. Number of kerner/grain per spike

The results of the analysis of variance indicated that the number of kernels per spike was significantly affected ($p<0.01$) by the main effects of nitrogen and seed rates as well as their interaction (Appendix Table 4). Plots sown at 250 kg N ha^{-1} with a seed rate of 175 kg ha^{-1} produced the highest number of kernels per spike (53.83), whereas plots sown at 150 kg N ha^{-1} with a seed rate of 125 kg ha^{-1} produced the lowest number of kernels per spike (38.0) (Table 4. 4).

This result may be due to that nitrogen availability is crucial for plant growth, especially in cereal crops like bread wheat. Higher availability leads to increased vegetative growth and biomass accumulation, supporting more spike development and kernel numbers per spike. Seed rate influences plant density and resource allocation, with optimum seed rates resulting in better resource utilization and higher kernel numbers per spike.

The optimal combination of nitrogen availability and seed rate in this result was 250 kg ha^{-1} N) and 175 kg ha $^{-1}$), resulting in optimal growth and development. From this result, we can conclude that by applying 250 kg ha^{-1} of N fertilizer, the bread wheat likely received an ample supply of nitrogen, which could have positively influenced their reproductive processes, including flowering, pollination, and grain filling. As a result, the number of kernels per spike increased, ultimately contributing to a higher grain yield. This finding underscores the importance of proper nutrient management, particularly nitrogen fertilization, in optimizing bread wheat production.

This result also agreed with that of Teketel Molla (2019), who showed that the main effects of N and seed rates as well as their interaction were highly significant ($p< 0.01$) on the number of kernels per spike. In contrast to this result, Khalil *et al*. (2011) showed that the interaction of nitrogen fertilizer and seed rate was non-significant on number of kerner per spike. The finding of Girma Dawit (2018) also show that when seed rate increase from 100 kg ha^{-1} to 150 kg ha^{-1} number of kernels per spike decrease from 56.85 to 51.96.

Table.4. 4 Interaction effect of N fertilizers and seed rate on number of Kerner per spike of bread Wheat in Menz Mama midir district, north Shewa zone, during of 2023main cropping season

N fertilizer rate (kg ha^{-1})	Seed rate (kg ha^{-1})			
	125	150	175	200
150	38.06^{G}	39.46^{G}	42.50^{F}	39.66^{G}
200	45.66^{ED}	46.66^{CD}	48.00^{CB}	44.33^{E}
250	48.00^{CB}	50.00^{B}	53.83^{A}	49.33^{B}
300	49.33^{B}	49.66^{B}	50.00^{B}	46.33^{CD}
P value	<0.0049			
CV	2.33			

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance; CV = Coefficient of variation

4.2.4. Thousand kernels weight (g)

The result of the analysis of the variance shows the weight of bread wheat in thousand kernels was significantly influenced ($P<0.01$) by the main effects of N and seed rate. However, the two-factor interaction had no significant effect on thousand kernel weight (Appendix table 4). The application of 300 kg N ha^{-1} produced the highest weight (47.58 g), which was followed by 250 kg N ha^{-1}, inversely the lowest weight (35.50 g) was noted at a nitrogen rate of 150 kg ha^{-1} (Table 4.2). This is due to high nitrogen levels promote vigorous growth, leading to larger plant sizes and higher grain yields. A high seed rate ensures dense populations, causing intense competition for resources. Moderate nitrogen levels support decent growth but may not maximize grain yields. Moderate seed rates may result in less competition but smaller kernel weights.

The finding of Bekalu Abebe and Mamo Manchore (2016), in line with the current result, reported that the rate of N fertilizer application had a significant ($p \leq 0.001$) effect on thousand seed weight when the N rate increased from 46 kg ha^{-1} to 92 kg ha^{-1} N thousand seed weight increase by 15.2%. Similarly, Gebrekidan (2016) reported that highest thousand kernels weight (59.99 g) at the highest N rate (92 kg ha^{-1}) for durum wheat. The result was also similar with Tufa (2021), who reported maximum thousand kernel weight recorded (49.93g) from plot treated with 92 kg ha^{-1} N while the minimum thousand kernel weight (45.17g) was recorded from plot treated with zero N kg ha. $^{-1}$

The main effect of seed rate had a highly significant ($P< 0.01$) effect on thousand kernels weight of bread wheat. The highest weight (43.83 g) was recorded at seed rate of 125 kg seed rate ha^{-1} followed by 150 kg and 175 kg ha^{-1} though no statistically difference between them. On the other hand, the minimum weight (41.5 g) was observed at seed rate of 200 kg (Table 4.2). This means that, on average, the bread wheat crop grown with 125 kg seed rate produced the heaviest grains. Interestingly, there was no statistically significant difference in grain weight between the seed rates of 150 kg ha^{-1} and 175 kg ha^{-1} per hectare. This suggests that increasing the seed rate beyond 175 kg ha^{-1} did lead to a significant reduction in grain weight.

This result also agreed with Alemayehu Biri *et al*. (2022), low seed rate (100 kg ha^{-1}) produced heavier grains (33.37 g), whereas a higher seed rate (150 kg ha^{-1}) produced lighter grains (31.06 g). Similarly, Taminaw, Zewdie and Hunegnaw (2020) reported that the maximum thousand seed weight (41.3 g) was reported at a seed rate of 100 kg ha^{-1}, while the minimum thousand seed weight was recorded from a seed rate of 150 kg ha^{-1} which is 39 g. In contrast, J. Iqbal *et al*. (2012) reported that the heaviest grains (47.28 g) and (47.17 g) were observed at a seeding rate of 150 kg ha^{-1} and 175 kg ha^{-1} respectively, while the lowest grains weight (44.39 g) was recorded at a seeding rate of 125 kg ha^{-1}.

4.2.5. Biomass yield (kg ha^{-1})

The analysis of variance showed that the main effects of N and seed rates were highly significant ($p< 0.01$) on above ground dry biomass yield, while their interaction of the two factors was non-significant (Appendix Table 4). The highest aboveground dry biomass (12,425.00 kg ha^{-1}) was recorded when 300 kg ha^{-1} N was used, while the lowest biomass (9,414.4 kg ha^{-1}) was recorded at a 150 kg ha^{-1} N rate (Table 4. 2). This is due to nitrogen is crucial for plant growth and biomass production. A high nitrogen application rate maximizes growth potential and biomass accumulation. Conversely, a low nitrogen application rate results in reduced growth and reduced biomass accumulation.

The current result was in line with the finding of Alemayehu Abdeta *et al*. (2022), who showed that the highest total aboveground dry biomass yield (10.73-tons ha^{-1}) was recorded for plants supplied with the highest application of N rate. Similarly, Hunduma & Buni (2017) , reported that biomass yield was linearly increasing with the increment of both seed rate and fertilizer rate, with the highest biomass yield of 7522.22 kg ha^{-1} was recorded by using 103.5kg ha^{-1} N. Adugna Weysa (2017), reported that the maximum above ground biomass in teff were recorded at the highest N rate, while the lowest above ground biomass were recorded at the lowest N rat. Similarly, Tolera Abera *et al*. (2020) reported that the highest aboveground dry biomass (11,772 kg ha^{-1}) was obtained at the application of the highest rate of 183 kg ha^{-1} NPSB.

The main effect of seed rates also has a highly significant ($p<0.01$) effect on above ground biomass. The highest above ground biomass (11,167 kg ha^{-1}) was recorded from the application of the highest seed rate 200 kg ha^{-1}, while the lowest biomass (10,602 kg ha^{-1}) was recorded from the application of the lowest seed rate of 125 kg ha^{-1}(Table 4.2). Higher seed rates increase competition for resources like water, nutrients, and sunlight, leading to vigorous growth and higher biomass production. The optimal plant density for a specific species may also be affected by seed rates. A threshold effect may occur where, under a certain seed rate, the plant population is too sparse to efficiently utilize resources, resulting in lower biomass production.

The findings of Teketel Molla (2019) were in line with the current result, who reported that the highest aboveground dry biomass yield (11,667 kg ha^{-1}) was recorded at a height seed rate of 175 kg ha^{-1}. The findings of Rahel Tigabu and Fikadu Asfaw (2016), showed that the maximum above ground dray biomass was recorded from the highest application of seed rate. Similarly, Girma Dawit (2018), reported that as the seeding rate increased from 100 kg ha^{-1} to 150 kg ha^{-1} the aboveground dry biomass yield increased. The finding of Khalil *et al*. (2011) indicate that a higher seed rate (150 kg ha^{-1}) produced the maximum biological yield (10421 kg ha^{-1}, while a lower seed rate (100 kg ha^{-1}) produced lower yield (9643 kg ha^{-1}).

4.2.6. Grain yield (kg ha^{-1})

The interaction between nitrogen application and seed rates significantly influenced grain yield in bread wheat. Proper management strategies that optimize nitrogen fertility and seeding density are essential for achieving high yields and sustainable wheat production. The main effects of N fertilizer and seed rate, as well as the interaction, effect had a highly significant ($p < 0.01$) effect on the grain yield of bread wheat. The highest grain yield (4943.4 kg ha^{-1}) was obtained at combined rates of 300 kg ha^{-1} N fertilizer with 175 kg ha^{-1} seed rate, followed by 250 kg ha^{-1} N fertilizer with 175 kg ha^{-1} seed rate with grain yield of (4905.67 kg ha^{-1}) with no statistically significant difference between them, whereas the lowest grain yield (3026.67 kg ha^{-1}) was recorded at 150 kg ha^{-1} N fertilizer with 125 kg ha^{-1} seed rate (Table 4. 5).

These results suggest that increasing the nitrogen fertilizer rate from 150 kg ha^{-1} to 300 kg ha^{-1} while keeping the seed rate constant at 175 kg ha^{-1} increased grain yield (Fig 4.3). Conversely, decreasing the nitrogen fertilizer rate to 150 kg ha^{-1} and using a lower seed rate of 125 kg ha^{-1} led to a substantially lower grain yield. It's also noteworthy that there might be an optimal balance between nitrogen fertilizer and seed rate that maximizes yield without wasting resources. According to Central statistical Agency data the national average productivity of bread wheat was 3.1-ton ha^{-1} in farm yield, however the current result shows 4.9 ton by applying optimum nitrogen rate and appropriate seed rate. It shows 1.8-ton increment.

The finding of J. Iqbal *et al*. (2012) indicates that maximum grain yield (4626 kg ha^{-1}) was observed when nitrogen fertilizer increased from 100 kg to 125 kg ha^{-1}, while the lowest grain yield (3193 kg ha^{-1}) was recorded at zero levels of nitrogen. Similar results were obtained by Teketel Molla (2019a), with the highest grain yield at the highest nitrogen fertilizer rate. Alemayehu Abdeta *et al*. (2022) reported that the highest grain yield (6.38-ton ha^{-1}) was recorded from the application of the highest N rate. Similarly, the findings of Hunduma and Buni (2017) showed that the interaction of the N rate and seed rate was significant in Tef. According to Hailu Feyisa *et al*. (2023), the maximum grain yield of bread wheat was attained from the use of maximum N levels. Similarly, Ali Shah *et al*. (2011b) indicated that the interaction between seed rate and nitrogen levels had significantly affected the grain yield of bread wheat.

In contrast, Ali *et al*. (2011b) reported that the highest value for grain yield (3.848 tons ha^{-1}) was obtained for N rate of 130 kg N ha^{-1}, while 180 kg N fertilizer produced the lowest grain yield (3.21-ton ha^{-1}). The findings of Iqbal *et al*. (2010) indicate that Seed rate of 150 kg produced significantly higher grain yield (4.120-ton ha^{-1}) followed by 175 and 200 seed rates (3.904 and 3.785-ton ha^{-1}).

Table.4. 5 Interaction effect of N fertilizers and seed rate on yield of bread wheat in Menz Mama midir district, north Shewa zone, during of 2023main cropping season

N fertilizer rate (kg ha^{-1})	Seed rate (kg ha^{-1})			
	125	150	175	200
150	3026.67^{H}	3184.00 ^{G}	3294.00 ^{G}	3170.10 ^{G}
200	3563.33 ^{F}	3670.60 ^{FE}	3736.23 ^{E}	3739.23 ^{E}
250	4311.83 ^{D}	4480.47 ^{C}	4905.67 ^{A}	4591.33 ^{C}
300	4755.47 ^{B}	4900.33 ^{BA}	4943.40^{A}	4823.77 ^{BA}
P value	<0.0017			
CV	9.5			

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance; CV = Coefficient of variation

4.2.7. Straw Yield (Kg Ha^{-1})

Bread wheat straw is a valuable forage resource for livestock, particularly as bedding material or supplemental feed. Utilizing bread wheat straw as feed can reduce the demand for other forage sources and provide additional income streams for farmers. The results of the analysis of variance indicated that the main effects of N fertilizer and seed rate, had a highly significant ($P < 0.01$,) and also the interaction effect of the two factors had significant ($P< 0.05$) effect on the straw yield of bread wheat (Appendix Table 5). The combination of the greatest rates (300 kg ha^{-1} N fertilizer with 200 kg ha^{-1}seed rate) produced the maximum straw yield (7879.2kg ha^{-1}), while the application of 150 kg ha^{-1} N fertilizer with 125 kg ha^{-1} seed rate produced the lowest straw yield 5991.5 kg ha^{-1} (Table 4. 6).

The reason for producing the highest straw yield is the application of the highest N fertilizer and seed rate, where nitrogen is crucial for plant growth and straw yield, and higher fertilizer rates promote growth. A higher seed rate increases competition for nutrients, water, and light, but can also lead to higher overall yields. A synergistic effect maximizes yield potential by optimizing nutrient uptake and plant growth.

The findings of Abiot Mekonnen (2017) indicate that the maximum straw yield was recorded in the plots where a seeding rate of 175 kg ha^{-1} was used. The finding of Teketel Molla (2019a) reported that the highest straw yield (7584 kg ha^{-1}) was obtained at the highest rate (69 kg ha^{-1} N), whereas the lowest straw yield (6154 kg ha^{-1}) was recorded in response to unfertilized treatments.

In contrast to this result, finding of Amare Assefa and Mulatu Kassaye (2017) indicates that the main effect of seed rate did not have significant effect on straw yield. Similarly, Teketel Molla (2019) reported that the main effect of seed rate and the interaction of two factors were not significant. The highest biological yield (9281 kg ha^{-1}) was calculated at a seeding rate of 150 kg ha^{-1}, while the lowest biological yield (8975 kg ha^{-1}) was recorded at a seeding rate of 125 kg ha^{-1} and was statistically lower than the seeding rate of 175 kg ha^{-1} (9178 kg ha^{-1}) (J. Iqbal *et al*., 2012).

Table.4. 6 *Interaction effect of N fertilizers and seed rate on straw yield of bread wheat in Menz Mama midir district, north Shewa zone, during of 2023main cropping season*

N fertilizer rate (kg ha^{-1})	Seed rate (kg ha^{-1})			
	125	150	175	200
150	5991.5^{E}	6114.7^{DE}	6253.9^{DE}	6622.7^{DEC}
200	6557.3^{DEC}	6569.0^{DEC}	6656.0^{BDEC}	6824.6^{BDEC}
250	6803.5^{BDEC}	6800.3^{BDEC}	6573.0^{DEC}	7015.7^{BDAC}
300	7398.5^{BAC}	7444.0^{BAC}	7556.6^{BA}	7879.2^{A}
P value	<0.043			
CV	18.7			

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance; CV = Coefficient of variation

4.2.8. Harvest Index (%)

The analysis of variance indicated the main effects of nitrogen and seed rates, as well as the interaction effects of the two factors highly significant ($P < 0.01$) effect on the harvest index (%) of bread wheat. The highest harvest index (42.79%) was recorded from the application of 250 kg ha^{-1} N fertilizer with a 175 kg ha^{-1} seed rate. However, the lowest harvest (33.58%) index was measured from the application of the lowest N fertilizer, 150 kg ha^{-1}, with the lowest seed rate 125 kg ha^{-1} (Table 4. 7).

From this analysis, it can be inferred that both nitrogen fertilizer application rate and seed rate have significant effect on the harvest index. The highest harvest index of 42.79% was recorded when 250 kg ha^{-1} of nitrogen fertilizer was applied in conjunction with a seed rate of 175 kg ha^{-1}. This indicates that this specific combination of nitrogen fertilizer and seed rate effectively optimized the allocation of assimilates towards grain production, resulting in a higher proportion of total biomass being converted into grain yield. Optimum rates of nitrogen fertilizer and seed generally result in a higher harvest index, indicating better resource use efficiency and higher grain yield relative to total biomass.

The finding of Aga Duressa and Geleta Ayana (2020) showed that the harvest index of wheat increases with an increase in fertilizer rate up to a certain level. The finding of Khyber *et al*. (2012), indicates that harvest index significantly increased with an increase in seeding rate up to the normal seeding rate (186 seed m^2), with no further increase above the normal seeding rate. Bekalu Abebe and Mamo Manchore (2016), in conformity with the current result, reported that the combined effect of nitrogen and seed rates significantly ($P < 0.05$) affected harvest index (%).

In contrast to the current result, the finding of Teketel Molla (2019) indicated that the main effect of seed rate and the interaction of two factors were not significant for harvest index. Similarly, the finding of Khyber *et al*. (2012) indicates that harvest index (%) was non-significantly affected by seed rates. According to the finding of J. Iqbal *et al*. (2012), the highest harvest index (45.48) was calculated at a seeding rate of 150 kg ha^{-1}, while the lowest harvest index (43.83) was recorded at a seeding rate of 125 kg ha^{-1} and was statistically lower than the seeding rate of 175 kg ha^{-1}.

Table.4. 7 Interaction effect of N fertilizers and seed rate on harvest index of bread wheat in Menz Mama midir district, north Shewa zone, during of 2023main cropping season

N fertilizer rate (kg ha^{-1})	Seed rate (kg ha^{-1})			
	125	150	175	200
150	33.58^{FE}	34.30^{FE}	34.607^{FE}	32.47^{F}
200	35.27^{FED}	35.89^{CED}	36.00^{CED}	35.43^{FED}
250	38.807^{CB}	39.74^{B}	42.79^{A}	39.590^{B}
300	39.15^{B}	39.74^{B}	39.60^{B}	37.997^{CBD}
P value	<0.0042			
CV	2			

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance; CV = Coefficient of variation.

4.3. **C**orrelation **A**nalysis on **Y**ield and **Y**ield **R**elated **P**arameters on **B**read **W**heat

As it is mentioned in (Table 4.8) the correlation study among bread wheat agronomic characteristics were measured and a high positive correlation was observed between the majority of bread wheat yield components. Bread wheat height has a positive and very highly correlation with biomass Yield (r = ***0.96), grain Yield (r = ***0.90) and Straw Yield (r = ***0.84). This is due to taller plants have greater access to sunlight, enhancing photosynthetic efficiency and assimilate production, leading to greater biomass accumulation and improved grain and straw production. Plant height also influences biomass allocation, with taller plants allocating more resources towards stem elongation and overall biomass production. Environmental conditions, such as nutrient availability, water availability, temperature, and photoperiod, can enhance the expression of positive correlations between plant height and biomass, grain, and straw yields. This suggests that as plant height increases, there is a considerable increase in biomass, grain, and straw production. This relationship underscores the importance of plant height as a reliable indicator or predictor of yield potential in this particular plant species.

Effective tiller numbers have positively and highly correlated with number of kerner r = 0.80), thousand seed weight (r = 0.83) and spike length (r = 0.82), while they are positively and least corelated with straw yield (Table 4. 10). This is due to efficient resource allocation, as well as the role of effective tillers as sinks for assimilates. However, the correlation between effective tiller numbers and straw yield is weaker, possibly due to factors like plant height, stem strength, and lodging resistance playing more significant roles. Additionally, resource allocation dynamics may prioritize grain production over straw biomass accumulation in certain genetic backgrounds or environmental conditions.

The relationship between biomass yield and thousand kerner weight (r = 0.82414) and straw yield (r = 0.90) is positive and highly significant. This is due to plants with higher biomass tend to produce larger and heavier seeds, indicating better resource utilization and grain production. Physiological processes, such as carbon assimilation and nutrient uptake, also contribute to biomass accumulation and distribution.

Grain yield in this study exhibited a positive and strong correlation with its constituents, including number of kerner (r = 0.85), thousand kerner weight (r=0.86) biomass yield (r = 0.91), and productive tiller numbers (r = 0.75). This indicates that grain yield is influenced by various factors, including resource allocation and utilization, sink strength, assimilate partitioning, genetic traits, physiological processes, and environmental influences. Plants with higher kernel numbers, larger kernel size, greater biomass production, and productive tillers are likely to achieve higher grain yields. Positive correlations between grain yield and its constituents may reflect coordinated developmental dynamics, including reproductive growth, grain filling, and resource allocation.

Aside from this, there was a positive but weak correlation (r = 0.14) between harvest index and straw yield. The harvest index is a measure of the proportion of biomass allocated to grain production, with higher indexes indicating better efficiency.

Table.4. 8 Correlation Analysis on Yield and Yield Related Parameters on Bread Wheat

Pearson Correlation Coefficients, N = 48

Prob > |r| under H0: Rho=0

	PH	NT	NPT	SL	NK	BY	GY	TSW	HI	SY
PH	1.00000	0.74183	0.72384	0.65628	0.73390	0.96429	0.90920	0.80358	0.58181	0.84610
		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
NT	0.74183	1.00000	0.78722	0.78279	0.72103	0.69536	0.76964	0.82136	0.66829	0.48741
	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0004
NPT	0.72384	0.78722	1.00000	0.82359	0.80037	0.68920	0.75625	0.83570	0.64384	0.49016
	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0004
SL	0.65628	0.78279	0.82359	1.00000	0.78732	0.62343	0.76956	0.81922	0.76151	0.35139
	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	0.0143
NK	0.73390	0.72103	0.80037	0.78732	1.00000	0.73838	0.85659	0.88243	0.79311	0.47523
	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	0.0006
BY	0.96429	0.69536	0.68920	0.62343	0.73838	1.00000	0.91795	0.82414	0.55257	0.90425
	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
GY	0.90920	0.76964	0.75625	0.76956	0.85659	0.91795	1.00000	0.86612	0.83697	0.66066

	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
TSW	0.80358	0.82136	0.83570	0.81922	0.88243	0.82414	0.86612	1.00000	0.69693	0.62726
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001
HI	0.58181	0.66829	0.64384	0.76151	0.79311	0.55257	0.83697	0.69693	1.00000	0.14474
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		0.3263
SY	0.84610	0.48741	0.49016	0.35139	0.47523	0.90425	0.66066	0.62726	0.14474	1.00000
	<.0001	0.0004	0.0004	0.0143	0.0006	<.0001	<.0001	<.0001	0.3263	

4.4. **R**egression **A**nalysis of **I**ndependent **V**ariable on **Y**ield of **B**read **W**heat

Table.4. 9 Summary Output of dependent Variable (Grain Yield) for variable of seed and N rate

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.966509099
R Square	0.934139837
Adjusted R Square	0.931212719
Standard Error	183.7381412
Observations	48

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	958.40	189.39	5.060	7.52E-06	576.95	1339.8	576.95	1339.86
N fertilizer kg ha^{-1}	11.91	0.47	25.10962	4.15E-28	10.95	12.86	10.95	12.86
Seed rate kg ha^{-1}	2.64	0.94	2.788	0.007	0.73	4.55	0.73	4.55

From this table, we can conclude that the regression model's Multiple R (Multiple Correlation Coefficient) indicates a strong positive linear relationship between the independent (seed and N rate) and dependent variables (grain yield). The R-squared (coefficient of determination) explains 93.4% of the variance in the dependent variable. The adjusted R-squared (modified R-squared) accounts for the number of predictors in the model, preventing overfitting. The standard error (average distance from the regression line) indicates the accuracy of the predictions, with a lower standard error indicating better predictive accuracy. The intercept is the estimated value of the dependent variable when all independent variables are zero. In this case, it's 958.41.

The equation derived from the given summary output is:

Y (grain yield) = 958.40+11.91×N fertilizer kg ha^{-1}+2.64×Seed rate kg ha^{-1}

This equation represents a regression model that predicts the dependent variable (crop yield) based on the levels of nitrogen fertilizer and seed rate applied per hectare. For each unit increase in nitrogen fertilizer, the dependent variable (grain yield) is estimated to increase by approximately 11.91 units. For each unit increase in seed rate, the dependent variable (grain yield) is estimated to increase by approximately 2.65 units. The high R square value suggests that the model explains a significant portion of the variability in the dependent variable.

Both nitrogen fertilizer and seed rate have a statistically significant influence on the dependent variable (grain yield), as indicated by their low p-values. Farmers or agricultural practitioners can use this information to optimize their fertilizer and seed rate practices to maximize yield or desired output. However, it's essential to consider other factors not included in the model that might influence the dependent variable, such as weather conditions, soil quality, pest infestation, etc. It is important to assess the practical significance of the coefficients, considering cost-benefit analysis for different levels of fertilizer and seed rates.

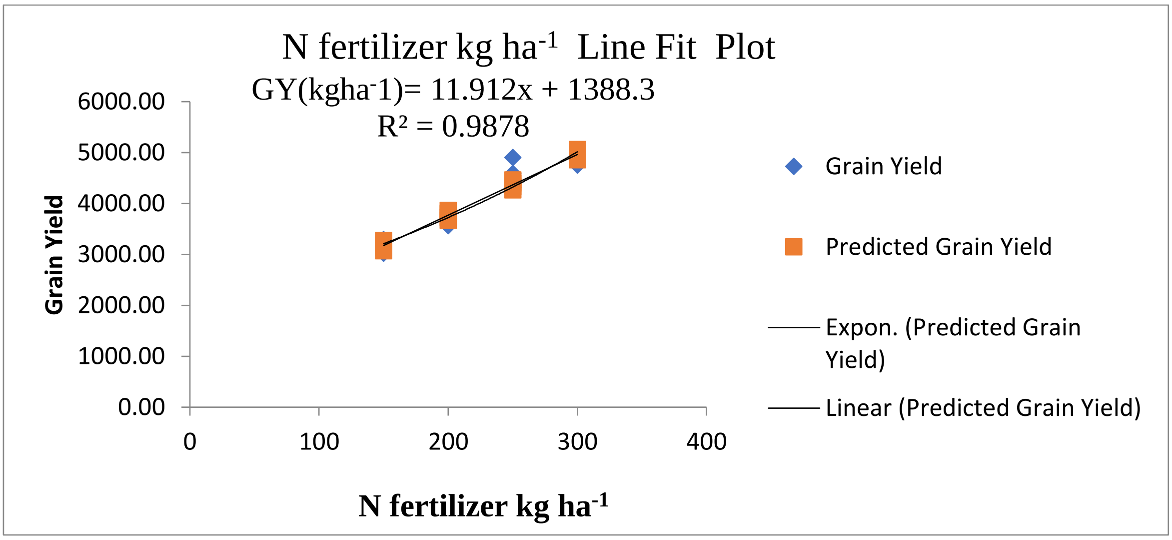

Figure 4. 3 Simple linear regression between N fertilizer rates and grain yield of bread wheat (GY)

4.5. **P**artial **B**udget **A**nalysis

The outcome of the partial budget analysis was indicated in (Table 4. 10). Based on the partial budget analysis, the largest net benefit (Birr 258145.6ha^{-1}) was observed when 300 kg ha^{-1} N was applied at a rate of 175 kg ha^{-1} seed rate. This was followed by 250 kg ha^{-1} N fertilizer and 175 kg ha^{-1} seed rate (Birr 256284.1 ha^{-1}). On the other hand, the lowest net benefit (Birr 159998.4 ha^{-1}) was observed when 150 kg ha^{-1} N fertilizer application was made at a rate of 125 kg ha^{-1}.

The lowest allowable marginal rate of return, as suggested by CIMMYT (1988), should be greater than 100%. Even though the study's greatest net benefit (Birr 258145.6 ha^{-1}) was achieved with a 300 kg N fertilizer with a 175 kg seed rate ha^{-1}. Consequently, the largest economic advantage (Birr 256284.1 ha^{-1}) offered with the highest marginal rate of return (22561.1%) was obtained by applying 250 kg ha^{-1} of N fertilizer in conjunction with a 175 kg ha^{-1} seed rate (Table 4.12). Thus, for the production of bread wheat in the research area and other places with comparable agro-ecological parameters, it would be most cost-effective to apply 250 kg ha^{-1} N fertilizer at a seed rate of 175 kg ha^{-1}.

Table.4. 10 Summary of partial budget and marginal rate of return analysis for response of bread wheat to N fertilizers and seed rate in Menz Mama District, North Shewa Ethiopia

Treatment		Wheat yield kg ha^{-1}			Income (ETB ha^{-1})					
N fertilizer kg ha^{-1}	Seed rate kg ha^{-1}	UGY	AGY	Straw	Grain	Straw	GBF ETB ha^{-1}	TVC (ETB ha^{-1})	NBT ETB ha^{-1}	MRR (%)
150	125	3026.67	2724	5991.5	163440.2	8987.3	172427.4	12429.0	159998.4	
150	150	3184.00	2866	6114.7	171936.0	9172.1	181108.1	13804.0	167304.1	531.3
200	125	3563.33	3207	6557.3	192419.8	9836.0	202255.8	14080.3	188175.4	7553.1
150	175	3294.00	2965	6253.9	177876.0	9380.9	187256.9	15179.0	172077.9	D
200	150	3670.60	3304	6569.0	198212.4	9853.5	208065.9	15455.3	192610.6	7430.5
250	125	4311.83	3881	6803.5	232838.8	10205.3	243044.1	15731.6	227312.5	12559.9
150	200	3170.10	2853	6622.7	171185.4	9934.1	181119.5	16554.0	164565.5	D
200	175	3736.23	3363	6656.0	201756.4	9984.0	211740.4	16830.3	194910.1	10981.3
250	150	4480.47	4032	6800.3	241945.4	10200.5	252145.8	17106.6	235039.2	14524.3
300	125	4755.47	4280	7398.5	256795.4	11097.8	267893.1	17382.9	250510.2	5599.2
200	200	3739.23	3365	6824.6	201918.4	10236.9	212155.3	18205.3	193950.0	D
250	175	4905.67	4415	6573.0	264906.2	9859.5	274765.7	18481.6	256284.1	22561.1
300	150	4800.33	4410	7444.0	264617.8	11166.0	275783.8	18757.9	251625.9	D
250	200	4591.33	4132	7015.7	247931.8	10523.6	258455.4	19856.6	238598.8	D
300	175	4943.40	4449	7556.6	266943.6	11334.9	278278.5	20132.9	258145.6	7074.4
300	200	4823.77	4341	7879.2	260483.6	11818.8	272302.4	21507.9	250794.5	D

Where, UGY = Unadjusted grain yield; AGY = adjusted grain yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D =dominated treatments.

5. CONCULUSION AND RECOMMENDATION

5.1. Conclusion

Bread wheat is a staple crop in the highlands of Ethiopia; however, the decline in soil fertility and inappropriate fertilizer application are among the key factors limiting wheat yields in the North Shewa region of Ethiopia.

Almost all Growth, yield and yield component parameters except DH and DPM were significantly influenced by the main effects of both factors, while DH and DPM were affected only by N fertilizer. Further, NPT, NK, GY, SY and HI were significantly affected by the Interaction effects of N and seed rate. The highest GY (4943.40 kg) and (4905.67 kg ha^{-1}) was recorded from the combination of 300 and 250 kg N ha^{-1} with 175 kg ha^{-1} seed rate respectively. The lowest GY (3026.67 kg) recorded from combination of 150 kg N fertilizer with 125 kg seed rate ha^{-1}. The highest net return (256284.1 ha^{-1} with MRR (22561.1%) was obtained by applying 250 kg ha^{-1} of N fertilizer with 175 kg ha^{-1} seed rate. The biological yield and GY increased significantly with the increase of nitrogen rates. The use of 175 kg ha^{-1} seed rates was effective as compared to lower seed rate 125 kg ha^{-1} for obtaining maximum yield. The study identifies the optimal combination of seed and nitrogen rates for maximizing wheat yield and its components. The combined use of seed rate of 175 kg ha^{-1} with Nitrogen rate of 250 kg ha^{-1}, gave the highest net returns and maximum yield. In conclusion, the study showed that optimizing seed rates and N fertilizer treatments can enhance bread wheat production and economic returns in the research area and similar agroecological regions.

5.2. Recommendation

From the result of present study that the application of the 250 kg N ha^{-1} in addition to with 175 kg ha^{-1} seed rate can be recommended for farmers for production of bread wheat in the study area and other areas with similar agro-ecological conditions. Further research has to be done at the study area, Since the experiment was conducted for one season and location, it should be repeated over seasons or multiple locations for best recommendation.

6. **REFRENCE**

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7. APPENDIX

Appendix Table 1. Mean monthly annual total rainfall and minimum and maximum temperatures of five years (2018-2022); and the experimental year of test crop (January 2023– November 2023).

	Last five-year Meteorological Data				2023Gc Meteorological Data			
Month	Total rainfall (mm)	Min. temp. (ºC)	Max temp. (ºC)	Average temp. (ºC	Total rainfall	Min. temp. (ºC)	Max temp. (ºC)	Average Temp (oC)
January	9.93	6.24	20.79	23.91	1.3	5.5	19.61	22.36
February	18.8	6.37	19.03	22.22	33.7	5.6	18.15	20.95
march	47.67	7.61	20.28	24.09	108.3	7.91	19.16	23.12
April	59.53	8.44	20.08	24.3	49.5	5.72	19	21.87
May	51.53	8.79	22.12	26.525	74.3	8.2	19.87	23.97
June	92.77	8.61	20.493	24.8	89.3	12.16	13.5	19.58
Juley	297.43	9.05	17.81	22.33	146.2	9.12	21.06	25.62
August	243.2	7.42	17.43	21.14	145.6	9.2	19.59	24.19
September	63.27	6.85	17.37	20.8	70.3	8.34	17.94	22.117
October	13.68	4.94	16.29	18.765	25.2	8.04	18.36	22.38
November	1.97	7.49	20.79	24.53	2.1	10.93	17.82	23.29
December	2.77	8.7	19	23.395	0	6.72	21.05	24.41
Total	902.55				745.8			
Average		7.54	19.29	23.069		8.12	18.76	22.82

Source: Ethiopian Meteorology Institute,

Appendix Table 2. Mean squares of ANOVA for days of heading (DH) and days to physiological maturity (DPM) of bread wheat as affected by N fertilizer and seed rates

Source of variation	Means D.F	DH	DPM	LP
Replication	2	0.25Ns	116.33**	2.52**
N fertilizer rate	3	59.03**	397.33**	15.46**
Seed rate	3	0.033*Ns*	0.05*Ns*	0.75**
N*seed rate (SR)	9	0.04*Ns*	0.043Ns	0.086*Ns*
Error	30	0.45	3.53	0.067
CV		1.10	1.54	8.5

*Where, D.F = degrees of freedom, ANOVA =Analysis of variance; CV = coefficient of variation, NS, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.*

Appendix Table 3. Mean squares of ANOVA for Plant height, spike length and Number of tillers of bread wheat as affected by N fertilizer and seed rates

Source of variation	Means D.F	Plant height	Spike length	Number of Tiller
Replication	2	356.40**	0.25Ns	0.98Ns
N fertilizer rate	3	1427.10**	10.21**	35.026**
Seed rate	3	31.31*	1.79**	7.92**
N*seed rate (SR)	9	0.86Ns	0.23Ns	0.14Ns
Error	30	7.70	0.25	0.62
CV		3.24	5.88	8.88

*Where, D.F = degrees of freedom, ANOVA =Analysis of variance; CV = coefficient of variation, NS, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.*

Appendix Table 4. Mean squares of ANOVA for Numbers of productive tillers, number of Kerner and Thousand Kerner weight of bread wheat as affected by N fertilizer and seed rates

Source of variation	Means D.F	Number of productive Tiller	Number of Kerner/spike	Thousand Kerner weight
Replication	2	5.06**	1.75Ns	6.52*
N fertilizer rate	3	26.78**	252.039**	338.14**
Seed rate	3	3.97**	32.87**	13.14**
N*seed rate (SR)	9	1.25**	4.02**	0.53Ns
Error	30	0.36	1.16	1.41
CV		9.34	2.33	2.76

*Where, D.F = degrees of freedom, ANOVA =Analysis of variance; CV = coefficient of variation, NS, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.*

Appendix Table 5. Mean squares of ANOVA for Biomass yield, Grain Yield, Straw Yield and Harvest Index of bread wheat as affected by N fertilizer and seed rates

		Means			
Source of variation	D.F	Biomass Yield	Grain Yield	Straw Yield	Harvest index
Replication	2	3800609.57**	24019.52*	3425094.95**	36.84**
N fertilizer rate	3	20320046.07**	7344969.71**	3681811.56**	109.01**
Seed rate	3	708953.49**	187685.10**	397332.69**	8.30**
N*seed rate (SR)	9	12221.79Ns	25762.79**	37153.99*	1.95**
Error	30	16515.26	6299.9	16270.54	0.55
CV		11.8	9.5	18.7	2

*Where, D.F = degrees of freedom, ANOVA =Analysis of variance; CV = coefficient of variation, NS, * and ** = non-significant and significant at 5% and 1% level of significance, respectively.*

Appendix Table. 6 Treatment Combination

No	N rate ha^{-1}	Seed rate kg ha^{-}1	Combination of treatment
1	150 kg N fertilizer/69 N	125	150 kg N, S125
2	150 kg N fertilizer /69 N	150	150 kg N, S150
3	150 kg N fertilizer /69 N	175	150 kg N, S175
4	150 kg N fertilizer /69 N	200	150 kg N, S200
5	200 kg N fertilizer /92 N	125	200 kg N, S125
6	200 kg N fertilizer /92 N	150	200 kg N, S150
7	200 kg N fertilizer /92 N	175	200 kg N, S175
8	200 kg N fertilizer /92 N	200	200 kg N, S200
9	250 kg N fertilizer /115 N	125	250 kg N, S125
10	250 kg N fertilizer /115 N	150	250 kg N, S150
11	250 kg N fertilizer /115 N	175	250 kg N, S175
12	250 kg N fertilizer /115 N	200	250 kg N, S200
13	300 kg N fertilizer /138 N	125	300 kg N, S125
14	300 kg N fertilizer /138 N	150	300 kg N, S150
15	300 kg N fertilizer /138 N	175	300 kg N, S175
16	300 kg N fertilizer /138 N	200	300 kg N, S200