EFFECT OF BLENDED NPSB FERTILIZER RATES ON YIELD AND YIE LD COMPONENTS OF FOOD BARLEY (*Hordeum vulgare* L.) VARIETIES IN DEBICHA DISTRICT OF SIDAMA REGION, ETHIOPIA

MSc THESIS

BY

ALEMAYEHU FARA BOE

HAWASSA UNIVERSITY COLLEGE OF AGRICULTURE

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EFFECTS OF BLENDED NPSB FERTILIZER RATES ON YIELD AND YIELD COMPONENTS OF FOOD BARLEY *(Hordeum Vulgare* L.*)* VARIETIES

IN DEBICHA DISTRICT OF SIDAMA REGION, ETHIOPIA

ALEMAYEHU FARA BOE

MAJOR ADVISOR: ANDARGACHEW GEDEBO (PhD)

A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL SCIENCES

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APPROVAL SHEET-I

This is to certify that the thesis entitled as "Effect of Blended NPSB Fertilizer Rates on Yield and Yield Components of Food Barley (*Hordeum vulgare* L.*)* Varieties In Debicha District of Sidama Region, Ethiopia" submitted in partial fulfillment of the requirements for the degree of Master of Science in Plant Sciences with specialization in Agronomy of the Graduate Program of the School of Plant and Horticultural Sciences, Collage of Agriculture, and has been carried out by Alemayehu Fara Boe, under my/our supervision. Therefore I/we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

ANDARGACHEW GEDEBO (PhD)

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Name of Major Advisor Signature Date

APPROVAL SHEET- II

We, the undersigned, members of the Board of Examiners of the final open defense by Alemayehu Fara Boe, have read and evaluated his thesis entitled as ‘‘Effect Of Blended NPSB Fertilizer Rates On Yield And Yield Components Of Food Barley (*Hordeum Vulgare L.)* Varieties at Dabicha, Sidama Region, Ethiopia, and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Plant Sciences with Specialization in Agronomy.

______________________	____________________	_______________
Name of the Chairperson	Signature	Date
ANDARGACHEW GEDEBO	____________________	__________________
Name of Major Advisor	Signature	Date
______________________	____________________	____________________
Name of Internal Examiner	Signature	Date
______________________	____________________	____________________
Name of External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the Department of Graduate Council (DGC) of the candidate's major department.

DEDICATION

This thesis is dedicated to my wife Kefelech Sarmisa, and all my beloved family for their encouragement, support and love for their whole hearted partnership in the success of my life.

STATEMENT OF THE AUTHOR

I declare that this thesis is my work and all sources of materials used for this thesis have been duly acknowledged. I declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Name: ALEMAYEHU FARA Signature: ______________________

Place: College of Agriculture, Hawassa University, Hawassa, Ethiopia

Date of submission____________________

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LISTS OF ACCRONYMS

ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CEC	Cation Exchange Capacity
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
DAP	Di ammonium Phosphate
ETB	Ethiopian Birr
EIAR	Ethiopian Institute of Agricultural Research
Ethio SIS	Ethiopian Soil Information System
FAO	Food and Agriculture Organization of the United Nation
FTC	Farmer Training Center
ICARDA	International Center for Agricultural Research in the Dry Areas
HARC	Holeta Agricultural Research Centre
LSD	List Significant Difference
NPSB	Nitrogen, Phosphorous, Sulfur, and Boron Blended.
RCBD	Randomized Complete Block Design
USDA	United States Department of Agriculture

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ALEMAYEHU FAR (BSc, MSc candidate)

ANDARGACHEW GEDEBO (PhD, Major advisor)

ABSTRACT

Barley is an important cereal crop in the highlands of Ethiopia, but its productivity is low due to a lack of improved varieties and a decline in soil fertility. A field experiment was conducted to determine the effects of different NPSB fertilizer rates on the yield and yield components of food barley varieties at Debicha in the Teticha District of Sidama Region, Ethiopia.The comprised of 15 treatment combinations, five fertilizer rates(control,50,100,1507& 200 kg NPSB with three food barley varieties (HB1966, EH1493, and HB-1307).days to heading, days to physiological maturity, Plant height, number of total tillers and effective tillers, thousand grain weight, number of kernels per spike, above-ground biomass, straw yield, and harvest index all phenology, growth and yield components was collected, As the soil analysis of the study area revealed the soil texture was clay loam, moderately acidic (pH 5.6), low in organic carbon (2.38%), low in total nitrogen (0.14), very low in available P (4.21 mg kg^{-1}), low in B (0.47 mg kg^{-1}), and medium in CEC (19.78cmol kg^{-1}). The analysis of variance showed that days to heading, and days to physiological maturity decreased with the increasing rate of NPSB fertilizer. Plant height, number of total tillers and productive tillers, thousand grain weight, number of kernels per spike, above-ground biomass, straw yield, and harvest index increased with the increasing rates of NPSB fertilizer. The interaction effects of NPSB fertilizer levels and variety were significant on grain yield. The variety EH1493 produced the highest mean grain yield (4.3 t ha $^{-1}$) at 150 kg NPSB ha^{-1}. Economic analysis revealed that the highest net benefit (71697.5 Et birr ha^{-1}) with a marginal rate of return of 79.2 was achieved from the application of 150 kg NPSB ha^{-1} with the EH1493 variety. Therefore, it is recommended that farmers in the Teticha district and similar agro-ecologies use 150 kg NPSB ha^{-1} with the EH1493 variety. However, further experiments should be conducted across multiple locations and seasons, incorporating more blended fertilizer rates and varieties, to provide more conclusive recommendations.

***Keywords**: Blended, food barley, NPSB fertilizer and variety*

1. INTRODUCTION

1.1 Background and Justification

Barley (*Hordeum vulgare L.*) is a significant cereal crop globally, ranking fourth in production area after wheat, maize, and rice (USDA, 2017). In Ethiopia, barley ranks fifth in area coverage and bulk grain yield production, covering 7.39% of the land allocated for grain crops (CSA, 2020). It is an important grain crop in the highland areas of Ethiopia, growing in diverse ecologies from 1800 to 3400 meters above sea level under various production systems (Muluken, 2013).

Ethiopia is the second-largest barley producer in Africa, accounting for about 26 percent of the total barley production on the continent (FAO, 2014).

In Ethiopia, barley is one of the most important staple cereal crops, alongside teff, maize, sorghum, and wheat (CSA, 2014). However, its productivity has been below the expected yield due to various abiotic and biotic factors.

Barley is mainly produced for human consumption and is a crucial staple food crop (Grando and Macpherson, 2005). The grain is used in the form of bread, injera, kolo, porridge, soup, and for malting purposes. Among local beverages, Tella and Borde are well-known and best made from barley grain (Grando, 2005). According to Grando and Macpherson (2005), barley straw is a good source of animal feed, especially during the dry season. In Ethiopia, barley productivity was 2.17 tons per hectare in the main season in the year 2019 (CSA, 2019).

At Sidama Regional State level, an area covered by barley in 2018/19 was 43,862 ha and the production is estimated to be about 991, 28.1.2 ton with mean yield of 2.2 ton ha-1 in main cropping season (CSA, 2019).

In 2018/19 cropping season the area coverage of barley in Teticha district was 3,500 ha and its production was 80,500 ton with average productivity of 2.33ton ha-1 (CSA, 2019).

According to Bayeh and Stefania (2011), in Ethiopia, efforts have been made to generate improved production technologies; however, the productivity of barley in production fields has remained very low, at 1.6 tons per hectare compared with the world average of 2.95 tons per hectare (CSA, 2016 and USDA, 2017). The major production limiting concerns are poor soil fertility the national average (2.17 tons per hectare) is relatively lower than the world average (2.99 tons per hectare) (USDA, 2018)., waterlogging, and insect pests like aphids and barley fly, as well as leaf diseases like scald, blotch, smuts, and leaf rust, moisture stress, low-yielding varieties, and inadequate agronomic practices (Bekele *et al*., 2005). As a result, assuming the genetic potential of the crop,

The low-yielding ability of farmers' cultivars, the influence of several biotic and abiotic stresses, and the minimal promotion of improved barley production technologies in the district have contributed to the low productivity in Ethiopia. Several biotic and abiotic factors such as poor crop management practices, low-yielding cultivars, the limited availability of the released improved cultivars, weeds, insects, and diseases (Bayeh and Stefania, 2011) constrain barley productivity. Additionally, barley productivity is constrained by poor soil fertility, waterlogging, drought, soil acidity, soil erosion, continuous cultivation of the same land, inadequate applications of organic and inorganic fertilizers, and weeds (ICARDA, 2012).

Poor soil fertility and low pH are among the most important constraints that threaten barley production in Ethiopia. The major barley-producing areas of the country, mainly located in the highlands, have suffered severe soil erosion and lack appropriate soil conservation practices, resulting in soils with low fertility and pH (Grando and Macpherson, 2005). The various factors contributing to poor soil fertility include topography, soil erosion, deforestation, and continuous cultivation without soil fertility maintenance (Chilot *et al*., 2002). Even though several types of research have been conducted in highland areas of Ethiopia, such as Bale, Arsi, Gojam, and the central part of the country, many barley-producing highland areas lack new technology, including improved varieties and appropriate rates of fertilizer (Wakene *et al*., 2014). Moreover, recently acquired soil inventory data revealed widespread deficiencies of most nutrients such as nitrogen (86%), phosphorus (99%), sulfur (92%), boron (65%), and zinc (53%) in Ethiopian soils and similarly in the study area (Ethio-SIS, 2016). Although micronutrient concentrations increase with decreasing soil pH, studies have found that boron deficiency is particularly widespread in acidic soils of the southern highlands, limiting cereal yields (Elias, 2019; Haque, Lupwayi, and Tadesse, 2000). Recently, the Ministry of Agriculture (MoA) introduced a new brand of NPSB fertilizer with proportions of 18.9% N, 37.7% P2O5, 6.95% S, and 0.1% B as the main source of phosphorus, substituting DAP for adoption by farmers, which is useful in improving the efficiency of fertilizer recovery, resulting in higher crop yield and quality to overcome the problem (MoANR, 2013). Therefore, balanced fertilizer is the key to sustainable barley crop production and maintenance of soil health, with economic and environmental considerations (Abiye *et al.,* 2004).

1.2. Statement of the Problem

One of the major issues affecting food production in Africa, including Ethiopia, is the rapid depletion of nutrients in smallholder farms' fields (Achieng *et al.*, 2010). The low availability of nitrogen and phosphorus has been shown to be a major constraint to cereal production (Tekalign *et al.*, 2001). Nitrogen is deficient in almost all soils, and phosphorus is deficient in about 70% of the soils in Ethiopia due to erosion and the absence of nutrient recycling.

Most areas used for grain production, particularly barley, teff, and wheat, have low-fertility soils. Soils in the highlands of Ethiopia generally have low levels of essential plant nutrients and organic matter content (Zohary and Hopf, 1993). Smallholder farmers in Ethiopia typically apply low amounts of mineral fertilizers to crops (Morris *et al.*, 2007). DAP (di-ammonium phosphate) and urea have been the only chemical fertilizers used for crop production, with the initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils (Bekabil and Hassan, 2006).

The application of only fertilizers, such as nitrogen (N) and phosphorus (P), without due consideration of other nutrients, has led to the depletion of other important nutrient elements such as potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), boron (B), and micronutrients in soils (Abiye *et al.,* 2004). Low fertilizer use efficiency, resulting from using improper fertilizers, has led to less economic returns and poses a higher threat to the environment.

Plant growth and crop production require an adequate and balanced supply of nutrients. Most research has focused on the NP requirements of crops, with limited information available on various sources of nutrients like sulfur (S), zinc (Zn), boron (B), and other micronutrients. Recent soil inventory data (Ethio-SIS, 2016) has indicated deficiencies of sulfur, boron, and zinc nutrients, along with nitrogen and phosphorus in Ethiopian soils. Therefore, the application of other sources of nutrients beyond urea and DAP, especially those containing S, Zn, B, and other micronutrients, could increase crop productivity (Ethio SIS, 2014).

However, there is currently little information on the site-specific recommendation of blended (NPSB) fertilizer rates for food barley production in the study area. Information on the application of blended fertilizer (NPSB) rates, especially for recently released food barley varieties, has not been determined for the study area. Therefore, to improve food barley productivity and grain quality, it is essential to determine the optimal blended NPSB fertilizer rate for the study area. The current study was conducted with the following objectives:

1.3 Objectives of the study

1.3.1. General Objective

- To determine the effects of blended NPSB fertilizer rates on yield and yield components of food barley (*Hordeum vulgare* L.) varieties at Debicha in Teticha district of Sidama region, Ethiopia

1.3.2. Specific Objectives

- To identify the effects of blended NPSB fertilizer rates on the growth and yield of food barley varieties.
- To determine the optimal blended NPSB fertilizer rate for maximum food barley yield in the study area.
- To determine the economically feasible combination of variety and the blended NPSB fertilizer rate.

2. LITRATURE REVIEW

2.1. Origin and Distribution

Barley, (*Hordeum vulgare L.*) is one of the founder crops of Old World agriculture. Archaeological remains of barley grains found at various sites in the Fertile Crescent (Zohary and Hopf 1993; Diamond 1998) indicate that the crop was domesticated about 8000B.C

During the sixth and fifth millennium BC, barley spread from its center of diversity in the Near- and Middle-East to eastern parts of the Mediterranean basin, highlands of Ethiopia and the Indian subcontinent, and the Caucasus and Trans-Caucasus regions. Barley reached China during the second half of the second millennium BC from where it spread further to the Korean peninsula and Japan. Barley remained the main cereal food crop of northern Europe until the 16th century when it was gradually supplanted, mainly due to culinary preference for wheat which showed a better processing ability into numerous types of food products. Barley was first introduced into North America probably by Columbus in 1492 and later by immigrants and settlers from Europe.

Barley can be cultivated at altitudes between 1500 up to 3500 m, but is predominantly grown between altitudes of 2000 up to 3000 m. Research on barley improvement was started in 1955 at the Debre Zeit Agricultural Research Center. Since 1967 the Institute of Agricultural Research (IAR) took the responsibility of coordinating the crop improvement work on food and malting barley.

2.2 Food Barley Production in Ethiopia

Ethiopia is a center of origin and diversity for many cultivated crops and their wild relatives. The altitudinal variation, temperature and rainfall differences coupled with edaphic factors create a wide range of ecological conditions in the country (Mulatu and Grando, 2011). Since a wide range of agro-climatic conditions characterizes Ethiopia, barley is one of the major cereals grown in wide agro-ecology of the country with its economic and social importance. The useful characteristics of Ethiopian barley include high tillering capacity and tolerance to marginal soil conditions, barley shoot fly, aphids, frost, vigorous seedling establishment and quick grain filling period (Hailu and Alemayehu, 1991).

Barley is one of the oldest cultivated crops and has been grown in the highland parts of Ethiopia and various sources agree that it has been in cultivation for at least the past 5000 years and it is cultivated in all regions of the country (Kemelew and Alemayehu, 2011; Girma, 2014). The first Ethiopians to have ever cultivated barley are believed to be the Agew people, in about 3000 BC (reviewed by Zemede, 1996). The area coverage for barley production in Ethiopia over the past 25 years has fluctuated. It was around 0.8 million hectares in the late 1970s, and rose to more than 1 million hectare in the late 1980s. It then declined and remained between 0.8 and 0.9 million hectare until the beginning of the third millennium. The production of barley usually has been below 1767518 hectares per year (CSA, 2018/19). Barley is a major staple food crop in the 8highlands of northern Ethiopia. The crop is used for preparing various types of traditional food and beverage consumption such as Kita, Kolo, Beso, Enjera, Giat, Tihlo and many others (Araya, 2011). Concerning drinks the study showed that as many as 6 alcoholic and non-alcoholic local beverages are brewed in the household from barley grains for daily consumption or for holidays and celebrations. The barley straw is used in the construction of traditional huts and grain stores either as thatching or as a mud plaster (Zemede, 2000).

2.3 Importance of Food Barley

Barley (*Hordeumvulgare L*.) is one of the most important cereal crops in the world next to maize, wheat, rice among ten top world plants and one of the main cereal crops produced in the Ethiopia. It is an important food crop in the high land parts of Ethiopia and an important cereal crop grown by subsistence farmers on small-scale farms (Ejigu, 2012).

According to Abraha *et al*., (2013) barley is used for making local recipes, bread, porridge, soup, and roasted grain and for preparing alcoholic and non-alcoholic beverages in 20 different ways. Its straw is a good source of animal feed. It is also used for thatching of roofs and bedding (Bekele *et al*., 2005).

2.4 Major Barley Producing areas in Ethiopia

Barley produced in all regions of Ethiopia, but the major producers are Shewa, Gojam, Arsi, Gonder, Wollo and Bale, from where more than 85% of the total production comes (Adugna A, 2008). In some parts of Ethiopia, barley is produced twice annually (bimodal rainfall), i.e. during the main rainy season, Meher (from June to September), and the short rainy season, Belg (from February to April). Belg barley is important in Wollo, Bale and Shewa. Barley has a number of attributes that makes it desirable among farming communities in the country because it is a source of food and suitable for the Belg season; it performs well in marginal areas; provides an earlier harvest than some other cereals; and requires low investment.

2.5 Food Barley Production Constraints

The most Constraints factors that reduce yield of barley in Ethiopia are poor soil fertility, soil acidity, diseases, insects, and weed competition (ICARDA, 2008).lack of soil fertility and low pH are among the highest constraints that threaten barley production in Ethiopia. Since the major barley producing of the country are mainly(ICARDA ,2008).located in the highlands, severe soil erosion and lack of appropriate soil conservation practices in the past have resulted in soils with low fertility and pH (Grando and McPherson,2005).

Some of the constraints are poor crop management practices, new introduced barley varieties are susceptible to mildew, barley yellow dwarf virus, net blotch and scald diseases and the limited availability of the very few improved cultivars released, weeds, insects and the inherently low yield potential of the prevalent local varieties (Bayehe and Stefania, 2011).

2.6 General Concepts of Soil Fertility

Soil fertility refers to the ability of the soil to supply the nutrients needed by the plants. According to Kirkham, (2005) the study of soil fertility involves examining the forms in which plant nutrients occur in the soil, how these become available to the plant, and factors that influence their uptake. This, in turn leads to a study of the measures that can be taken to improve soil fertility and crop yields by supplying nutrients to the soil-plant system. This is usually done by adding fertilizers, manures and amendments to the soil but sometimes by supplying nutrients directly to the plant parts by means of sprays. A mineral element is considered essential to plant growth and development if the element is involved in plant metabolic functions and the plant cannot complete its life cycle without the element; if usually the plant exhibits a visual symptom indicating a deficiency in specific nutrient, it can be corrected or prevented by supplying that nutrient (Patricia and Lisette Van, 2008).

Fertilizer usage plays a major role in the universal need to increase food production to meet the demands of the growing world population. Fertilizer application results in marked crop yield increases, which for most crops can be more than 100%. The extent to which fertilizers are used still differs considerably between various regions of the world (Brhan, 2012). The quantity of fertilizer nutrients required for optimum crop production depends on the inherent capacity of the soil to supply adequate levels of nutrients to growing plants, the yield potential of the crop variety grown, the availability and cost of fertilizers, and the climatic conditions prevailing during the crop growing season (Ghulam *et al.*,2010; Refissa, 2012).

2.7 The Need for Blended Fertilizer

Blending fertilizer is defined as the mechanical mixing of two or more granular fertilizer materials to produce mixtures containing nitrogen (N), phosphorus (P), sulfur (S) and other essential plant nutrients (Beaton D, 1997). It allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner toward contributing additional profit for farmers and improving the environment because it provides balanced fertilization (James, 1997). Since fertilizers were introduced to Ethiopia in 1960s through programs such as the Freedom from Hunger Campaign, virtually all fertilizers used in Ethiopia are limited to DAP and urea. However, recent completed research and soil tests through the Ethiopian Soil Information System Project revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and Urea (ATA, 2013).

2.8 Roles of Blended NPSB Fertilizer on yield and yield components of Food Barley

Macronutrient includes nitrogen (N), phosphorus (P), potassium (K), sulfur (S), magnesium(Mg) and calcium (Ca), which are needed in large amounts, and large quantities have to be applied if the 10 soil is deficient in one or more of them (FAO, 2000). The micronutrients or trace elements are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B) (FAO, 2000). They are part and parcel of the key substances in plant growth and are comparable with the vitamins in human nutrition. Being taken up in minute amounts, their range of optimal supply is very small (FAO, 2000).

Applying multi nutrient blended fertilizers are acknowledged not only for enhancing productivity but also nutrient use efficiency of crops (Redai, Tesfay, and Yemane 2018). Besides yield advantage, balanced fertilization has substantial role for sustainable crop production and soil fertility maintenance (Abiye *et al.* 2004).

In spite of these general reports which narrate the beneficial effects of blend fertilizers over straight fertilizers, there are no sufficient information on the agronomic ally optimum and economically feasible rates of blend fertilizer on food barley.

The extension system recommends 100 kg NPSB blend for all crops and soil types as a blanket rate in spite of wide differences in soil and crop types. Moreover, there is no enough information's on the impact of different types of fertilizers containing macro and micronutrients especially boron as it is reported to be the most limiting micronutrient in the southern highlands (Elias 2019; Ethio-SIS. 2016).

An increasing the application of blended NPSB fertilizers, highest yield and yield components of food barley like plant height, spike length, number of tillers per square meter and number of kernel per spike (Bereket *et al*., (2014).Several authors, Dewal and Pareek (2004) and Gupta *et al*., (2004) report that macro and micro nutrients (Nitrogen, Phosphorous with Sulfur and Boron) fertilizers application can increase plant height, spike length, number of tillers and number of kernel with increasing doses and combination.

Blended fertilizer supply had a marked effect on the aboveground biomass, grain yield, and straw yield. It enhances sustainable production and provides nutrient needs to crops according to their physiological requirements and expected yields (Ryan, 2008).

Previous fertilizer research work in Ethiopia has been focused on nitrogen (N) and phosphorous (P) fertilizer sources under different soil types and various climatic conditions, while very limited work has been reported with other essential macro- and micro-nutrients (K, S, Fe, Zn, B, etc.) Understanding plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Nevertheless, increasing crop yields through the application of N and P alone can deplete other nutrients (FAO, 2000). Fertilizers are efficient exogenous source of plant nutrients (Akram *et al*., 2007), since plant growth and crop production require adequate and balanced supply of nutrients in order to maximize productivity by optimizing the plant nutrient uptake (Mengel and Kirkby, 2001). Several studies reported that chemical fertilizers are the major nutrient sources to improve crop productivity (Tamene *et al*., 2017). For instance, application of N, P, S and B fertilizers improved dry marketable fruit yield and yield contributors through better nutrient uptake, growth and development (Obidiebube *et al*., 2012).

Application of different types of blended fertilizers significantly influences apparent nutrient recovery and agronomic nutrient use efficiency on barley. Both apparent nutrient recovery and agronomic nutrient use efficiency consistently decreased with increasing blended fertilizers rates. According to Jones *et al*., (2011) matching appropriate essential macro and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield.

2.8.1. Role of Nitrogen in Barley Production

Nitrogen is the key nutrient input for achieving higher yield of barley. Barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization (Alam *et al.*, 2007). Similarly, Sinebo *et al*. (2003) also reported that about 65% of grain yield variability in barley was attributed to nitrogen stress. The most important role of nitrogen in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances from which the living material or protoplasm of every cell is made. Nitrogen increased leaf area, tiller formation, leaf area index and leaf area duration and this increasing is led to much greater production of dry matter and grain yield (Franklin *et al.,* 2017).Among the plant nutrients, nitrogen plays a very important role in crop productivity (Oikeh *et al.,* 2007; Worku *et al.,* 2007). Although judicious dose of nitrogen elevates the yield and quality of seed but excessive dose causes the economic loss as well as reduced yield and quality of barley seeds. Barley farmers in Ethiopia have not fully adopted modern inputs like fertilizer and modern seeds that help boost production (CSA, 2014).

The yield attributes and quality of food barley seed is therefore, dependent on appropriate dose of nitrogen. Sustaining soil and soil fertility in intensive cropping systems for higher yields and better quality can be achieved through optimum levels of fertilizer application. Thus, information on fertility status of soils and crop response to different soil fertility management is very crucial to come up with profitable and sustainable crop production. Besides to this, optimum dose of nitrogen depends on the climate and soil of the location as well as variety used (Shahnaj *et al.*, 2014).

2.8.2. Role of Phosphorus in Barley Nutrition

Phosphorus has great importance in plant nutrition. It involves in the processes of energy transformations, genetic inheritance, protein synthesis and cell division. Moreover phosphorus enhances root development and strengthening of straw, affects flowering, fruiting, seed formation and crop maturation. Inline to this availability of phosphorus in soil, it is affected by different factors like soil reaction and climate. In Ethiopia Phosphorus application as fertilizer is important in increasing crop production of barley. Based on the various findings of P fertilization results the yield and yield components of barley and were increasing with increasing P fertilizer application rates. The critical level (optimum level) of P fertilizer rate after which crop response declines or not significant in economic point of view is different for variety type, soil type and agro ecology. Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth particularly development of lateral roots and fibrous rootlets (Brady and Weil, 2002).

Oxisols high in iron oxides and aluminum oxides, and many sandy soils low in humus content, for instance, have low available phosphorous (Miller and Danahaue, 1995). Addition of organic matter indirectly reduces phosphorous adsorption by inhibiting aluminum oxide and to certain extent Fe-oxide crystallization, while addition of manure and fertilizer phosphorous reduces phosphorous fixation by increasing saturation of adsorption sites. According to Boeggaad *et al*., (1990) in acid soils with high Al and Fe contents, phosphoric acid and soluble phosphorous fertilizer transformed into insoluble forms of phosphorous so quickly that plants can derive very little from phosphorous fertilized treatments (Sinha,1999). Brady and Weil, (2002) indicated that at pH lower than 5.5, the retention results largely from the reactions with Fe, Al and their hydrous oxides resulting into low forms of available phosphorous. At pH higher than 7.0, high concentration of Ca, Mg and their carbonates cause precipitation of the added phosphorus and reduce the availability of phosphorous (Mengel and Kirkby, 1996).

Large addition of phosphorous is required to reach a given level of solution phosphorous in fine textured compared to coarse textured soils. Consequently, high clay calcareous soils will often require more fertilizer phosphorous to optimize yields compared to loam soils. Soils containing large quantities of clay will fix more phosphorous than soils with low clay content. In other words, the more surface area exposed with a given type of clay, the greater is the tendency to absorb P (Tisdale *et al*., 2002).

2.8.3. Role of Sulfur in Barley Growth and Development

Sulfur is essential for the growth and development of all crops, without exception. Sulfur is a constituent of three S-containing amino acids (cysteine, cysteine and methionine), which are the building blocks of protein. Sulfur is also a key ingredient in the formation of chlorophyll and about 90% of plant sulfur is present in these amino acids (Klikocka *et al*., 2016).

Sulfur is a macronutrient required for proper growth and development of plants. It is increasingly being recognized as the fourth major plant nutrient after N, P and potassium (K) in crop production Sulfur is reported to be a macro-nutrient that is taken-up by grain crops in amounts similar to and sometimes beyond those of P, 10-30 kgha^{-1}(Jamal *et al*., 2012), and is considered to be one of the most limiting nutrient element for crop production. It is usually present in relatively small amounts in soils in the available forms (Brady and Weil, 2008) and also reported that at lowest Sulfur rate, N uptake was 42%, but increased to 70% as S fertilizer was increased. It enhances other nutrients use efficiency and ranks second only to N in importance for optimum crop yield and quality (Zorb *et al*., 2013), also stated that Sulfur application from the leaf had a minimum effect on the grain yield of barley. Sulfur based fertilizers decrease the pH of soil and increases the uptake of other plant nutrients, therefore, the yield increases.

2.8.4. Role of Boron in Barley Production

Boron (B) is an essential nutrient for normal growth of higher plants and its availability in soil and irrigation water is an important determinant of agricultural production (Saleem *et al.*, 2011). Boron deficiency causes different effects on very diverse processes in vascular plants such as root elongation, indoleacetic acid oxidase activity, sugar translocation, carbohydrate metabolism, nucleic acid synthesis, and pollen tube growth (Blevins and Lukaszewski, 1998; Goldbach and Wimmer, 2007; Saleem *et al.*, 2011).It is the only non-metal among the micronutrients and also the only micronutrient present over a wide pH range as a neutral molecule rather than an ion (Epstein and Bloom, 2005). Boron is an essential element for better utilization of macro-nutrients by plants and there by greater translocation of photo assimilates from source to sink during growth period (Ali *et al*., 2013). Boron is also involved in the transport of sugars across cell membranes and in synthesis of cell wall material. It influences transportation through the control of sugar and starch formation (Singh *et al*., 2015)**.**

2.8.5 Effect of Nitrogen on Phenology, growth, Yield and Yield Components of food barely

Nitrogen is a key nutrient input for achieving higher yield of food barley. Food barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization (Alam *et al.*, 2007). Similarly, Sinebo *et al.*, (2003) also reported that about 65% of grain yield variability in food barley was attributed to nitrogen stress. The most important role of nitrogen in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances from which the living material or protoplasm of every cell is made. Nitrogen increased leaf area, tiller formation, leaf area index and leaf area duration and this increasing is led to much greater production of dry matter and grain yield (Franklin et al., 2017).

The atmosphere is made up of 79% N by volume as inert N2 gas that resists reacting with other elements to create a form of N most plants can use. However, the amount of this element in available forms in the soil is small, while the quantity withdrawn annually by crops is comparatively large (Brady and Weil, 2002).

According to Moselhy and Zahran (2002) barley was provocatively increased with increasing N fertilization.They further revealed application of nitrogen fertilizer significantly increased spike length, number of grains spike1,1000grain weight, grain yield and N uptake by the crop (Wakene *et al.,* 2014).On the other hand indicated that plant height was linearly increased with increasing levels of N fertilization (Rashid *et al.,* 2007).

2.8.6 Effects of phosphorus on Phenology, growth, Yield and Yield Components of food barely

Phosphorus (P) is classified as the second most important element for crop production. It is known to be involved in many physiological and biological processes of plants (Tisdale *et al.,*2002).Phosphorus is an essential nutrient required by the plant for normal growth in the semiarid region of the Kurdistan Region of Iraq, because most of the agricultural soils in Kurdistan region suffer from severe P deficiency.

More than 80% of added P to such soil will be fixed, and only a part of it get dissolved in the soil solution which may be either taken up by plants or precipitates (Leytem and Mikkelsen, 2005). They found that the chlorophyll contents were increased in fertilized soil by the different levels of phosphorus fertilizer application to the soil. Similar results were obtained by Noori *et al.* (2014) and by Wakene *et al.* (2014) obtained the highest total biomass at the highest P level, used and the lowest biological yield in the controls.

2.8.7. Effect of Sulfur Fertilizer on Phenology, growth, Yield and Yield Components of food barely

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of Phosphorus (Ali *et al.*, 2002).

Sulfur deficient plants have also less resistance under stress conditions (Doberman and Fairhurst, 2000).Its fertilization helps enhancing the uptake of NPK and Zn in the plant. Due to its synergistic effect, the efficiency of these elements is enhanced which results in increased crop productivity. Similarly its deficiency results in stunted growth, reduced plant height, tillers, spikelet's and delayed maturity .Eriksen *et al.(*2001) provide a useful explanation of S mobility in barley and how S mobility interacts with N nutrition.

In terms of disease control foliar application of S increased the effectiveness of fungicide (Zahid and Leitch, 2005).Sulfur deficiency decreases grain size and baking quality because of formation of disulfide bonds formed from the sulfhydryl groups of cysteine. This affects the viscoelasticity of dough (Gyori, 2005).

2.8.8. Effect of Boron Fertilizer on Phenology, growth, Yield and Yield Components of food barely

Boron (B) is an essential micronutrient for plants, and plant requirements for this nutrient are lower than the requirements for all other nutrients except molybdenum and copper. It is the only non-metal among the micronutrients and also the only micronutrient present over a wide pH range as a neutral molecule rather than an ion (Epstein and Bloom, 2005).

Boron deficiency affects vegetative and reproductive stages of plant growth. In the vegetative stage, B deficiency leads to the inhibition of growth, the death of growing meristems and the inhibition of the development of vascular bundles (Godfray *et al.,* 2010). Cereal crops are relatively tolerant to B deficiency during vegetative growth phase. Nonetheless, during reproductive phase, B deficiency may cause severe yield losses through sterility (Uraguchi and Fujiwara, 2011).Considering the range between deficiency and toxicity of B is quite narrow, application of B can be extremely toxic to plant at concentrations only slightly above the optimum rate (Gupta, 2002). Several earlier investigations revealed that application of boron significantly enhanced the growth, yield and quality of various food barley crops (Kabir *et al.*, 2013.Therefore, an adequate supply of B is necessary to achieve better nutrient balances and more biomass production.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment took place at the Debicha Farmers Training Center (FTC) in the Teticha district of the Sidama region in Ethiopia (Fig. 1). It was conducted during the 2023/24 cropping season under rain-fed conditions. The site is situated at 6° 33' 13" and 38° 32' 38" East longitude, with an altitude of 2695.8 meters above sea level. The soil at the site is clay loam, with a pH of 5.6 and high-water holding capacity. The average annual rainfall in the area ranges from 1100 to 1800 mm, with maximum and minimum temperatures of 24°C and 12°C, respectively. (SARC, 2022)

Teticha is one of the 36 districts in the Sidama national region, located in southern Ethiopia. It shares boundaries with the districts of Bona zuria to the east, Hula to the south, Bursa to the west, and Aleta Wondo to the north. The district is characterized by its highlands and bimodal rainfall patterns, known as ‘Maher’ (June-September) and Belg (March-May), making it highly suitable for crop production. During the ‘Belg’ season, approximately 1050 hectares of land in the district are cultivated with annual crops such as maize, potato, and bean, while 4009.25 hectares are cultivated during the ‘Meher’ season with wheat, barley, tef, faba beans, field peas, and vegetable crops.

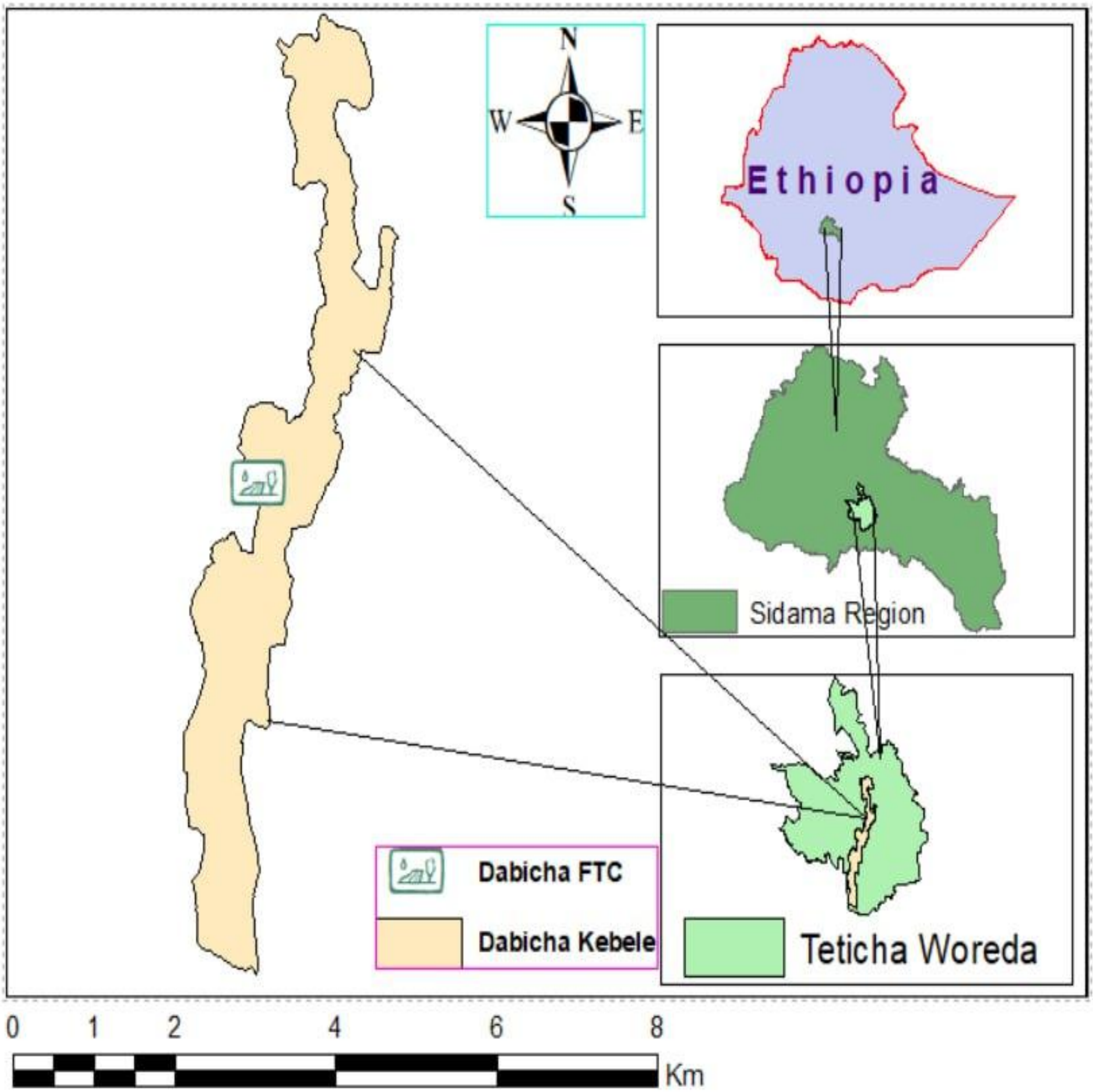


Figure 1. Location map of Dabicha FTC Teticha District, Sidama Region, South Ethiopia

3.2. Description of Experimental Materials

3.2.1. Plant materials

Seeds of three food barley varieties namely HB 1307, EH 1493 and HB1966 which are adapted to the agro-ecology of the area, were used for the study. The seeds of these varieties were generously provided by Kulumsa Agricultural Research Center (KARC). The description of varieties is given in Tab1e 1.

Table 1. Food barley varieties studied

No	Varieties	Year of release	Center of release	Maturity days	Area of adaptation		On-station productivity ton/ha
					Altitude(m)	Rainfall(mm)	
1	HB1307	2006	Holeta	137	2000-3000	700-1000	48
2	HB 1966	2017	Holeta	137	2000-4000	500-700	35-54
3	EH 1493	2012	Holeta	139	2300-2800	700-1000	25-61

Source: HARC (2019)

3.2.2 Fertilizer

The experiment involved applying Fertilizer NPSB, which contains 18.9% nitrogen, 37.7% P_2O_5, 6.95% sulfur, and 0.1% boron, at the planting time. In the Teticha district, the recommended application rate of NPSB was 100 kg/ha (ATA, 2013). Additionally, Urea (46% N) was uniformly applied to all the plots at a rate of 100 kg/ha in two split doses. Half, 50 kg/ha, was applied at planting date and the other half at the tillering stage of food barley, ensuring the presence of soil moisture to prevent potential nitrogen loss into the atmosphere.

Table 2. Fertilizer treatment rates that were used for the experiment

Fertilizer rates Kg/ha	N(kgha^{-1})	P2O5(kgha^{-1})	S(kgha^{-1})	B(kgha^{-1})
Control	0	0	0	0
50NPSB	9.45	18.85	3.475	0.05
100NPSB	18.9	37.7	6.95	0.1
150NPSB	28.35	56.55	10.425	0.15
200NPSB	37.8	75.4	13.9	0.2

Table 3 Combinations of the treatments under the study

Barely varieties	Rates of NPSB kg/ha	Combination kg/ha	Treatments
HB 1966	0	HB 1966 0	T1
	50	HB 1966 50	T2
	100	HB 1966 100	T3
	150	HB 1966 150	T4
	200	HB 1966 200	T5
HB 1307	0	HB 1307 0	T6
	50	HB 1307 50	T7
	100	HB 1307 100	T8
	150	HB 1307 150	T9
	200	HB 1307 200	T10
EH 1493	0	EH 1493 0	T11
	50	EH 1493 50	T12
	100	EH 1493 100	T13
	150	EH 1493 150	T14
	200	EH 1493 200	T15

3.2.3 Treatments and experimental design

The experiment involved three varieties of food barley and five different rates of blended NPSB fertilizer containing four nutrients (N, P, S, and B). It was set up in a Randomized Complete Block Design with three replications. The NPSB fertilizer rates used were 0, 50, 100, 150, and 200 kg/ha, and the three food barley varieties are labeled as HB1307, EH1493, and HB1966. There are a total of 15 treatment combinations (5 x 3). Each plot measures 2 m x 1.8 m ($3.6m^2$), with a path of 0.5 m between plots and 1 m between blocks. To avoid border effects, a 10 cm space was left on both sides of the plots. Seeding was done by hand drilling in rows of 20 cm apart, with each plot consisting of 9 rows. The two outermost rows on both sides of each plot are considered border plants and were not included in data collection. The net plot area used for data collection comprises 7 rows (2.8m).

3.3. Experimental Procedures and Field Management

The experimental land was prepared by ploughing with a local plough (Maresha) following conventional farming practices. Fine seedbeds were manually prepared and leveled, with a row made across each plot. Each treatment was then randomly assigned to the experimental plots within a block. The rate of each NPSB was applied for all treatments according to the randomizations. Nitrogen fertilizer from urea, at a rate of 100 kg N ha^{-1}, was applied 45 days after planting .Agronomic management of the experiment included weeding, cultivation, and pest control. Weeds were removed by hand as needed, and any late-emerging grasses and off-type plants were rouged out to prevent interference with the barley cultivars. Seeds of three food barley varieties, namely HB 1307, EH 1493, and HB 1966, were sown in rows 20 Cm apart, with a seed rate of 135kg/ha.

3.4. Agronomic Data Collected

3.4.1. Phonological and growth parameters

Days to heading: was determined as the number of days from sowing to the date when 50% of plants reached heading based on visual observation.

Days to Maturity: was determined as the number of days from sowing to the date when 90% of the plants reached maturity based on visual observation. It was indicated by senescence of the leaves as well as threshing of grain from the glumes when pressed between the forefinger and thumb.

Plant Height (cm): The plant height was measured at physiological maturity from the soil surface to the top of the spike excluding awns from ten randomly selected plants from the net plot area. The total measured plant height was summed together and divided by the numbers of plant to get height per plant.

3.5. Yield and Yield Related Characters

Kernels per spike (number spike^{-1}): The mean number of kernels per spike was determined from10 randomly selected spikes from the net plot area.

Total number of tillers per m^2: The number of seedlings in each plot was determined by counting the seedlings in a marked area of 0.5 Cm x 0.4 Cm after all the seedlings had emerged. Then, at flowerings, all the plants in the marked area of each plot were counted. The difference between the second and first count gives the total number of tillers counted in that particular area (0.5 Cm x 0.4 Cm), which is then converted to the total number of tillers per square meter.

Number of effective tillers per m^2: It was determined by counting effective tillers from (0.5 Cmx0.4 Cm) 0.2 Cm^2 areas of each plot which was used for determining total number of tillers per m^2. Then the difference between the counts after flowering of the first count is the number of effective tillers per 0.2 Cm^2. This should be counted to effective number of tillers per m$^{2.}$ For agronomy purpose tillers per m^2 is more appropriate than tillers per plant which is important for plant breeders in selecting high yielding varieties.

Thousand kernels weight (g): It was determined based on the weight of 1000 seeds sampled from the bulk grain yield of each treatment by counting on an electronic seed counter and their weight taken with an electronic balance and the measured moisture content areas adjusted at 12% grain moisture content.

Grain yield (tonha^{-1}): Grain yield was measured from the harvested central unit areas of 1.2 Cm from net plot are. Grains was cleaned following harvesting and threshing, weighted using electronic balance, and adjusted to 12.5% moisture content using the following formula (Biru.1979). Grain yield (t/ha) =yield obtained (t/ha) x$\frac{(100-\%\ Actual\ moistuer\ content)}{100-12.5}$

Straw yield (t/ha): straw yield was calculated as the difference between above-ground biomass and grain yield.

Above ground biomass (t/ha): At maturity, the whole plant parts, including leaves and stems, and seeds from the net plot area in each plot was harvested and sun dried (for a week) until a constant weight, then the aboveground biomass was weighed and then expressed in kg $ha^{-}1$.

Harvest index: Harvest index was calculated as the ratio of grain yield to total above ground biomass yield.

Harvest index (%) = $\boldsymbol{\frac{Grain\ yield\ per\ plot}{Aboveground\ dry\ biomass\ per\ plot} x100}$

Harvest Index=Grain yield/total above ground biomass x100%

3.6. Soil Sampling and Analysis

Initial representative composite surface soil samples was collected from 0-20 cm depth from experimental field using Auger sampler by using W-shaped pattern from the whole experimental plots and composited into one sample before sowing the crop and bulked. The sample was air dried, ground using a pestle and mortar and allowed to pass through a 2 Cm sieve. Analyzed for selected Physic-chemical properties mainly texture (Particle size), soil pH, Cation exchangeable capacity (CEC), organic carbon, total N, available P, S and B. The laboratory analysis was done at Hawassa University Agriculture College soil laboratory based on the standard procedure of soil analysis methodology, .Available soil phosphorous was determined according to the methods of (Olsen and Dean 1965). The soil pH was determined in 1:2.5 soils: water dilution ratio using a glass electrode attached to a digital pH meter**.**

3.7 Data Analysis

The collected data were subjected to the analysis of variance (ANOVA) using the SAS computer package version 9.0 (SAS Institute, 2002). Mean separation was carried out using least significance difference (LSD) test at 5% or 1% probability level depend on ANOVA result as described in Gomez and Gomez (1984).

3.8. Economic Analyses of Treatment Effects

Economic analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The net benefit was calculated as the difference between the gross field benefit (ETB ha^{-1}) and the total costs (ETB ha^{-1}). The average price of both inorganic fertilizers and the price of certified seed varieties was determined Birr per kg. Labor cost for fertilizer and seed sowing estimated as days required to sown. Each person-day labor cost was determined in ETB birr. Following the CIMMYT partial budget analysis method, total variable costs (TVC), gross benefits (GB) and net benefits (NB) was calculated. Then treatments were arranged in an increasing TVC order and dominance analysis was performed to exclude dominated treatments from the marginal rate of return (MRR) analysis.

Analysis of marginal rate of return (MRR %) was carried out for non-dominated treatments, and the MRRs was compared to a minimum acceptable rate of return (MARR) of 100% in order to select the optimum treatment (CIMMYT, 1988).

A treatment is said dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower net benefit. A treatment which is non-dominated and having a MRR of greater or equal to 100% and the highest net benefit is said to be economically profitable (CIMMYT, 1988). The net benefit per hectare for each treatment is the difference between the gross benefit and the total variable costs. The average yield was adjusted downward by 10% to reflect the difference between the experimental field and the expected yield at farmers' fields and with farmer's practices from the same treatments (CIMMYT, 1988). This is done with the assumption of variation in crop management; postharvest loss in farmer managed experiments was compared to experiments managed by researchers. The income from grain and straw was calculated by multiplying the total yield per ha with the farm gate price.

Net Benefit (NB) = Gross Benefit (GB) – Total variable cost (TVC)

Income from grain and straw =Total yield/ha X Farm gate price

MMR (%) = $\frac{NBT2-NBT1}{TVCT2-TVCT1}$X100

Where MMR= Marginal rate of return, NB=Net benefit, TVC=Total variable cost

T1&T2 where are consecutive treatments (T) arranged in ascending order based on their TVC after excluding treatments with low NBC& high Total variable cost. A treatment which is non-dominated C& having the highest net benefit is said to be economical profitable (CIMMYT, 1988).

Different costs in this study were as follows: NPSB cost= 42 Birr kg-1, Urea cost= 38 Birr kg-1, Seed cost=EH1493, HB1966 and HB 1307 are 42, 40, 40 Birr kg-1, respectively. Labor cost=120 Birr 2manday's^{-1} , sales of price of food barley grain=27Birr kg-1 , Straw sales price=1birr kg-1, TVC, GB and NB were expressed as the following consideration: The prices of the inputs that were prevailing at the time of its use were considered for working out the cost of cultivation i.e. Sale Price of food barley grain = Birr 32 and 27 kg-1 for all, straw sale price = Birr 1.00 kg-1 for all, Seed cost of food barley = Birr 42,40 and 40 kg-1 for EH 1493, HB 1307 and HB 1966 respectively, fertilizer costs were expressed as; birr = 42.00 for NPS and 38.00 for Urea kg-1 and power needed for sowing of food barley = number of labors in person (60,70, 80 and 90,100 man days ha-1), for 0,50, 100, 150 and 200 kg ha-1 NPSB rates, respectively and labor cost man 6 day-1 = Birr 200 were used as constant for all treatments for land preparation, sowing, weeding and pest management, urea application, harvesting, threshing and winnowing, packing, material and transportation cost = birr 300 costs per 100 kg for each treatments during 2023 rain fed field experiments were conducted areas of cropping year.

4. RESULTS AND DISCUSSION

4.1. Physico-Chemical Properties of the Soil of the of Study Area

The physical and chemical properties of the soil of the study area were analyzed at Hawassa University College of agriculture soil science laboratory. The soil texture (proportion of sand, silt and clay in the soil) of experimental site was 42% sand, 20% silt and 38 % clay. Thus, the texture of the soil was clay loam (Table 3). The textural properties of the soil influence water holding capacity, plant water, aeration, root penetration and soil fertility.

The pH of the experimental site soil is 5.6. Thus, the pH of the experimental site is categorized under moderately acidic soil classification (Tekalign, 1991. This might be due to removal of crop residual which results in low organic matter. The OC concentration of the study site was 2.38% (Table3).Thus, the OC content of the soil is rated as low. This could be due to intensive agricultural activities that led to depletion of soil organic matter content. In addition, removal of crop residues for livestock feed and constriction of house aggravated depletion of SOC. Total nitrogen value of the experimental soil was (0.14).The result indicated N is a limiting factor for crop growth. The optimum N level needed for crop production under most soils of Ethiopia is reported to be$< 0.2\%$ according to EthioSIS (2013). Due to this nitrogen amendment is important at study area. Available P content of the experimental site was 4.21 mg kg^{-1} (Table 3). EthioSIS (2014) suggest optimum P content for most Ethiopian soil as 15 mg kg^{-1}. Based on this, the available phosphorous of the study area is very low and needs phosphorous fertilizer. This low phosphorous content is due to intensive mining of the farm fields and fixation by heavy metals (Al, Fe and Mn). Masresha (2014) also reported low amount of P content on soils which are cultivated repeatedly due to P fixation and P mining. Similarly, Habtamu, *et al.* (2015) reported that under acidic soil low content of P was due to fixation problem. The CEC of the site was 19.78cmol kg^{-1} (Table 3). According to the result obtained from soil laboratory, the value of CEC was in medium range. Available boron in the study area was 0.47 mg kg^{-1} (Table 3). According to Ethio SIS (2014) critical B value for most Ethiopian soils is 0.8 mg kg^{-1}. This shows that soils of the study area are deficit in B suggesting application for fertilizer which contains B. Intensive cultivation and crop residual removal in the area might be responsible for low B content of the soil.

Table 4: Physic- chemical characteristics of the Experimental soil before sowing at Debicha during 2023 main cropping season

Parameters	Value	Rating	Reference
Soil Ph	5.6	Moderately acidic	Tekalign (1991)
OC	0.2	Low	Tekalign (1991)
TN (%)	0.08	Low	Tekalign (1991)
Available P(mg kg-1)	8	Very low	Olsen et al (1954)
Available S(mg kg-1)	0.018	Low	Turib(EthioSIS,2014)
Available B(mg kg-1)	0.47	Low	Havlin et al,(1999)
CEC(Cmol/kg-1)	12.5	Medium	Kookers(1991)
Sand (%)	42	-----	---
Silt (%)	20	-----	--
Clay (%)	38	-----	---
Textural class	------	Clay loam	----

4.2. Phenologicals and Growth Parameters

4.2.1. Days to heading

The NPSB fertilizer rate and varietal difference showed significant effects on days to heading. But their interaction was not significant (Table 4, Appendix Table 1). The mean number of days required for spike heading ranged from 92.35 to 101. Among the varieties, HB1966 variety took the shortest time to head (92.35 days), while EH1493 variety took the longest (101 days). The number of days to heading showed an increasing trend with decreasing blended NPSB fertilizer rates (Table, 4). Overall, decreasing the NPSB fertilizer application rate significantly prolonged the number of days to heading for the barley plants across all application rates.

The maximum number of days to heading (98.44 days) was observed at the rate of 0 kg NPSB ha^{-}1 (control), while the minimum number of days to heading (94.135 days) was observed at 200 kg NPSB ha^{-}1, although the difference was not significant compared to that of 200 and 150 kg ha^{-}1. The earlier heading of food barley with increased blended fertilizer rate might be attributed to the role of phosphorus and the synergistic effects of blended NPSB fertilizers in plants, which is involved in dry matter distribution that facilitates plant development. Additionally, phosphorus is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, and nutrient movement within the plant. It is a key constituent of nucleic acids, phospholipids, and ATP, and plays a role in a range of plant cellular processes such as cell division, energy storage and transfer, respiration, photosynthesis, and enzymatic regulation (Lambers and Plaxton, 2015). Phosphorus is also involved in seedling development, early root growth, early heading formation, and accelerates the maturity of crops (Alinajoati *et al.*, 2011). Similar results were reported by Ottman (2009), who found that an increase in phosphorus rate decreased the time to heading, anthesis, and maturity.

Table 5: Effect of blended NPSB fertilizer rates and varieties on phenological parameters of food barley**,** at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

Treatments NPSB (kg ha^{-1})	Days to heading	Days to physiological maturity
0	98.44^{a}	122.56^{a}
50	97.78^{a}	121.67^{b}
100	95.56^{b}	120.56^{c}
150	94.33^{c}	119.67^{d}
200	94.14^{c}	118.89^{d}
Mean	96.05	120.66
LSD $_{(0.05)}$	0.8034	0.812
Varieties		
EH 1493	101a	131.8a
HB1307	94.8b	116.33b
HB1966	92.35c	113.86c
Mean	96.05	120.66
LSD $_{(0.05)}$	0.62	0.623
CV%	1.02	0.88

Key CV (%) = coefficient of variation in percent   LSD= Least significant difference

Means followed by the same letters are not significantly different at (P>0.05)

4.2.2 Days to physiological maturity

The use of blended NPSB fertilizer rates different varieties significantly affected the number of days to reach physiological maturity(Appendix Table 1) $p< 0.01$) .The varieties showed a range of 113.86 to 131.8 days to reach 90% physiological maturity, with EH1493 varieties taking the longest and HB 1307 and HB 1966 taking the shortest time to mature(Table 4). The differences in maturity among the varieties may be due to genetic variations, leading to different responses to environmental conditions. Similarly, the application of different blended NPSB fertilizer rates also affected the number of days to physiological maturity, with 200 kg NPSB treatment resulting in the shortest time and 0 kg NPSB treatment resulting in the longest time. This variation could be attributed to the role of phosphorus in accelerating maturity and the combined effects of blended NPSB fertilizers on plant development. These findings are consistent with previous research showing that increased levels of NPSB fertilizers can decrease the time to heading, anthesis, and maturity (Ottman, 2009). Additionally, the application of blended fertilizer (100NPSBZn +29N) was found to hasten days to flowering compared to NP fertilizers and unfertilized plots, suggesting that boron plays a crucial role in flowering and fruit formation in crops.

4.3. Growth Parameter of Food Barley

4.3.1. Plant height

The analysis of variance revealed that plant height was significantly ($p< 0.001$) affected by the main effects of barley varietal and difference fertilizer rates, as well as their interaction (Figure 2 Appendix Table 1). The height of all barley varieties increased significantly with the respective levels of blended NPSB fertilizer. The highest mean plant height value (87.28Cm) was observed with the HB 1307 variety at a fertilizer rate of 200Kg NPSB ha^{-1}, while the lowest plant height (61 cm) was recorded with the combination of 0Kg NPSB ha^{-1} and HB-1966 variety. This variation in plant height could be attributed to genetic differences among the varieties in response to the applied blended fertilizer. These results align with previous findings by Dewal and Pareek (2004), Gupta *et al.* (2004), Arif *et al.* (2006), Bereket *et al.* (2014) and Melkamu *et al.* (2019), and who reported that the application of macro and micronutrient (nitrogen, phosphorous with sulfur and boron) fertilizers can increase HB1307, plant height with increasing doses and combinations.

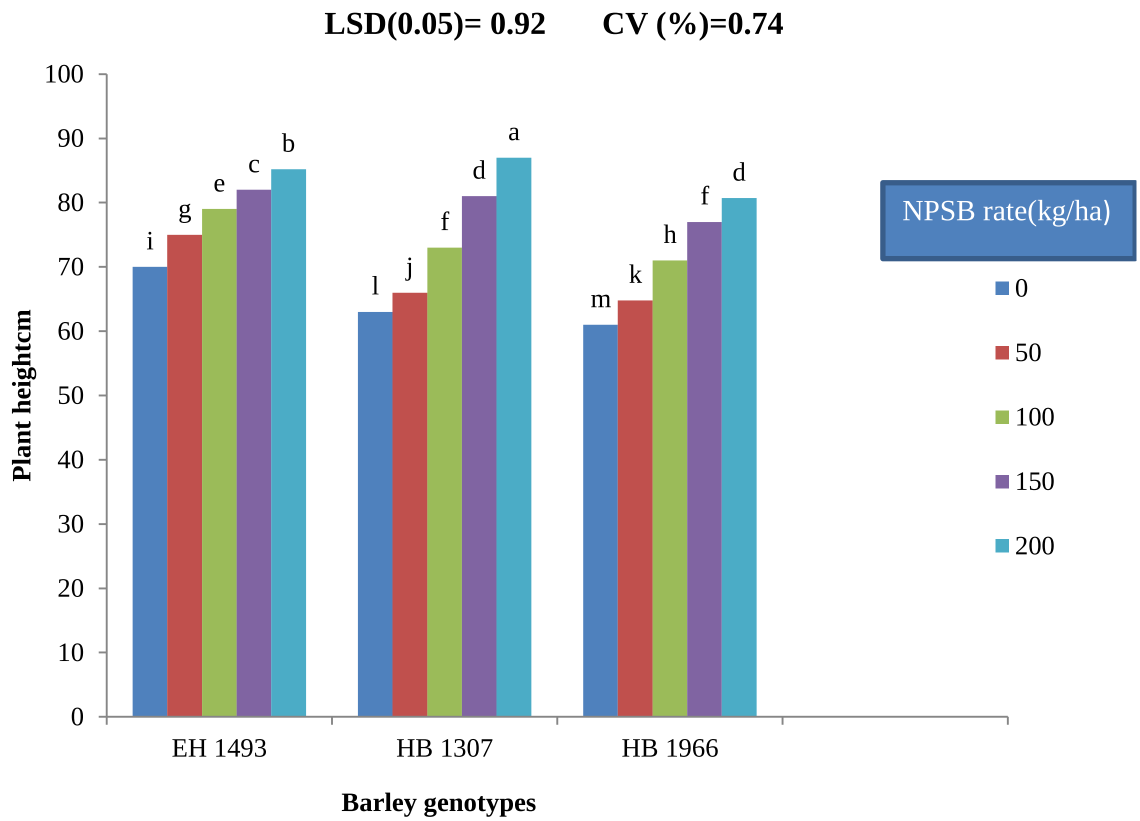


Figure 2. Interaction effect of blended NPSB fertilizer level and varieties on plant height (cm) of food barley at Debicha in Teticha district, Sidama Region, South Ethiopia

Where; LSD= Least significant difference at 5%, CV (%) Coefficient of variation in percent,

4.4. Yield and Yield Components

4.4.1 Number of kernels per spikes

The number of kernels per spike was significantly affected by the main effects of food barley varieties and blended NPSB fertilizer (Appendix Table 3). The highest number of kernels (42.6) was recorded from 200kg NPSB ha^{-1}, while the minimum number of kernels per spike (36) was produced from the control NPSB rate (Table5). This suggests that the number of kernels per spike was enhanced by NPSB, likely due to the increase in phosphorous levels, which is essential for grain development, and the vital role of boron in grain setting. Supplying boron-containing fertilizer helps in grain filling, reduces sterility, and increases the number of grains per spike. This demonstrates the synergistic effect of the fertilizers resulting in increased kernel number per spike and grain production. Furthermore, readily available phosphorous from phosphorous application contributes to young plants absorbing more phosphorus, freeing plants from early stresses, and resulting in enhanced grain formation and development. NPSB fertilizer treatments also resulted in a significant improvement in the number of kernels per spike. Similarly, increasing the rates of both NPS and N increased the number of kernels produced per spike, with the maximum number of kernels produced at the combination of the highest rate of NPS fertilizers (200 kg ha^{-1} NPS) and urea rates of 100 kg ha^{-1}.

Variation was observed among varieties in the number of kernels per spike, with variety EH1493 producing the maximum number of kernels per spike (41.867) and variety HB-1966 producing the minimum number (37.16) (Table 5). This variation is due to genotypic differences in food barley, which in turn result in higher numbers of grains per spike. These components are directly related to productivity in barley and can be modified under different environmental factors, including genetic factors.

4.4.2. Number of Productive Tillers

The analysis of variance revealed that only the main effects of varietal differences and blended fertilizers had a significant influence ($P<0.001$) on the number of effective tillers (Appendix Table 2). The highest mean number of effective tillers (7.4) was observed with the application of 150 kg NPSB ha^{-1} of blended fertilizer (Table 5). In contrast, the lowest mean number of effective tillers (3.11) was recorded from the unfertilized control plot, which was significantly different from the other rates (Table 5).

Furthermore, the application of 150 kg NPSB ha^{-1} blended fertilizer enhanced the productive tillers of food barley. However, an increase in the supply of blended fertilizer beyond this amount tended to decrease the number of productive tillers. This decrease might be due to the high number of total tillers produced at the highest rate (200 kg NPSB ha^{-1}), which initially resulted in severe competition among the tillers, leading to a decrease in the survival percentage of productive tillers. According to Wakene et al. (2014), the number of productive tillers per plant was significantly affected by phosphorus fertilizer application. Similarly, Berhan (2012) reported that the application of blended fertilizer made a significant difference in this parameter. These findings are consistent with those of Prystupa et al. (2004) in their research on food barley.

Variety also played a significant role, with the highest mean number of effective tillers (6) recorded for EH1493 variety and the lowest mean number of effective tillers (4.93) recorded for HB-1966 variety (Table 5). This difference in productive tiller capacity among varieties aligns with the findings of Suleiman et al. (2014), who reported significant differences among varieties for productive tillering.

Table 6: Effect of blended NPSB fertilizer rates and varieties on productive tillers per plant and kernels per spike of food barley,at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

Treatments	Productive tillers $plant^{-1}$	Kernels per spike
NPSB (kg ha^{-1})		
0	3.11^{e}	36^{e}
50	4^{d}	37.9^{d}
100	6.4^{c}	39.4^{c}
150	7.4^{b}	41.3^{b}
200	6.8^{a}	42.6^{a}
Mean	5.5	39.49
$LSD_{(0.05)}$	0.46	0.79
Varieties		
EH1493	6^{b}	41.87^{a}
HB1307	5.57^{a}	39.3^{b}
HB1966	4.39^{c}	37.2^{c}
Mean	5.5	39.49
$LSD_{(0.05)}$	0.59	0.61
CV%	11.04	2.08

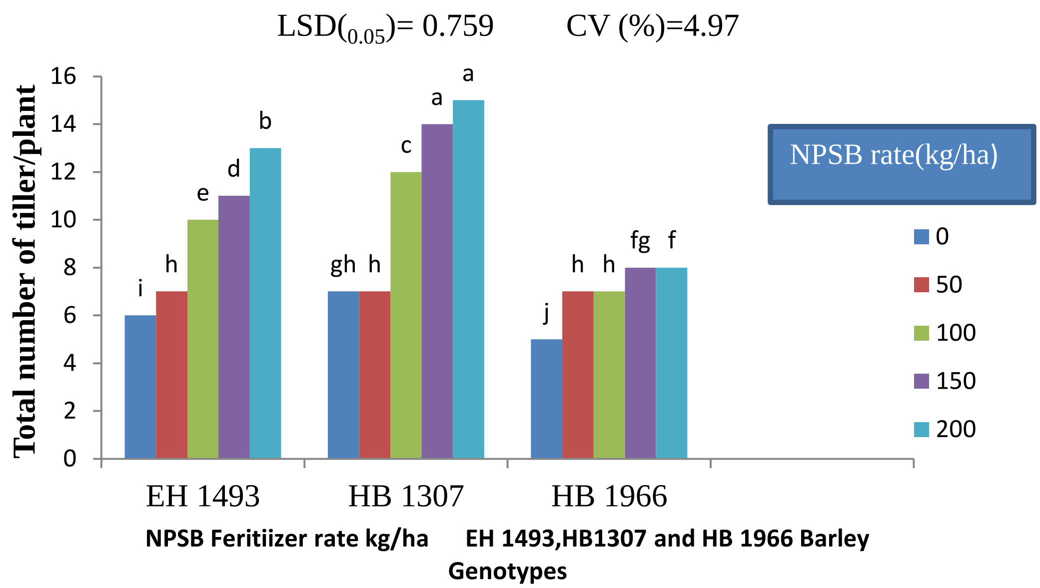
Where, CV (%) coefficient of variation in percent, LSD= Least significant difference at 5%

Means followed by the same letters are not significantly different at (P> 0.05)

4.4.3. Number of total tillers

The analysis of variance indicated that the application rate and of NPSB blended fertilizer and varietal difference, as well as their interaction, significantly ($P < 0.01$) affected the total number of tillers per plant (Appendix Table 2). The highest number of total tillers (15.1 per plant) was observed from variety HB1307 at an application rate of 200 kg NPSB ha$^{-1,}$ followed by variety EH1493 (13.2 per plant) with the same application rate(Figure,2) . Conversely, the lowest total number of tillers (5.33 per plant) was recorded from the HB-1966 variety without NPSB application. The total number of tillers per plant showed variable responses to blended NPSB and variety. The increase in the number of tillers in response to increasing the rate of NPSB blended fertilizer may indicate the importance of balanced nutrient availability for improved growth and development_of the plant. This is supported by previous studies such as Berhan (2012) who reported a significant increase in total tillers of barley with the application of blended fertilizer, and Bizuwork (2018) who observed the highest number of total tillers in plants treated with the highest NPSB rate.

Overall, the combination of blended NPSB fertilizer at a rate of 200 kg ha^{-1} with HB1307 variety resulted in more than a two-fold increase in total tillers compared to the combination of control plot (0 kg NPSB ha$^{-1)}$ with HB-1966 variety. The improvement in the total number of tillers at the 200 kg ha^{-1} application of blended NPSB might be attributed to the synergistic roles of the nutrients in enhancing crop growth and development, particularly phosphorus, which promotes root development and subsequent tiller formation, leading to overall plant growth.



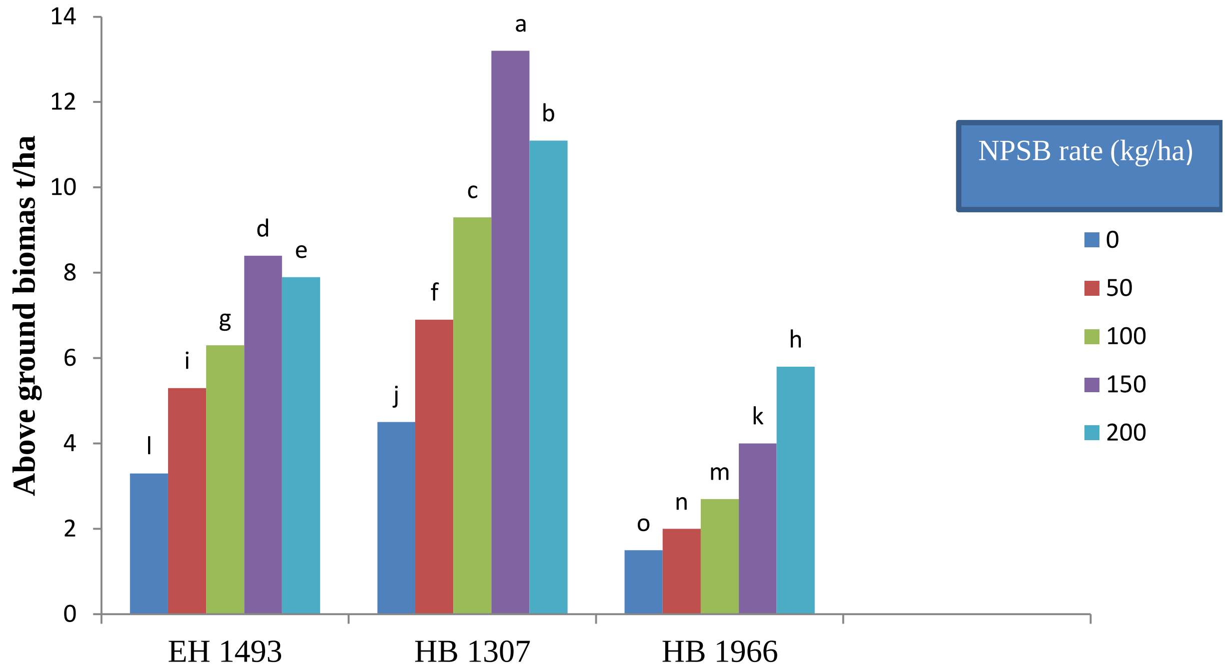
Where, 0, 50,100,150 and 200 are N PSB fertilizer rate per hectare, CV (%) coefficient of variation in percent, LSD= Least significant difference

Figure 3 Interaction effects of blended NPSB fertilizer levels and varieties on total number of tillers per plant, at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

4.4.4. Above Ground biomass Yield

The analysis of variance revealed that the above ground biomass yield was significantly affected by the main effects of blended fertilizers rates ($p < 0.001$), varieties ($p < 0.05$), and their interaction ($p < 0.001$) (Appendix Table 2). The highest difference biomass yield (13.2 t ha$^{-1)}$ was achieved with variety HB1307 and the application of 150 kg NPSB ha^{-1}, while the lowest biomass yield (1.5 t ha^{-1}) was observed with variety HB1966 and 0 kg NPSB ha^{-1} (Figure 3) Additionally, research by Wakene et al. (2014) indicated that supplying P_2O_5 at a rate of 69 kg ha^{-1} in wheat was sufficient to produce maximum aboveground dry biomass. This finding aligns with the results of Woubshet et al. (2017), who demonstrated that the application of 150 kg NPSB ha^{-1} blended fertilizer increased biomass by11.5 t/ha^{-1}. This outcome could be attributed to the sulfur content, which enhances chlorophyll formation and promotes vegetative growth, as well as the presence of boron, which aids in nitrogen absorption. Furthermore, the significant increase in spike length, number of seeds per spike, number of fertile tillers, and grain yield due to the use of blended fertilizer contributed to the overall increase in total biomass.

LSD($_{0.05}$)= 0.416 CV=4.04



Where, 0, 50,100,150 and 200 are NPSB Fertilizers per hectare, CV (%) coefficient of variation in percent, LSD= Least significant difference

Figure 4 Interaction effects of blended NPSB fertilizer levels and varieties on above ground dry biomass (t ha^{-1}) of food barley, at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

4.4.5. Grain Yield

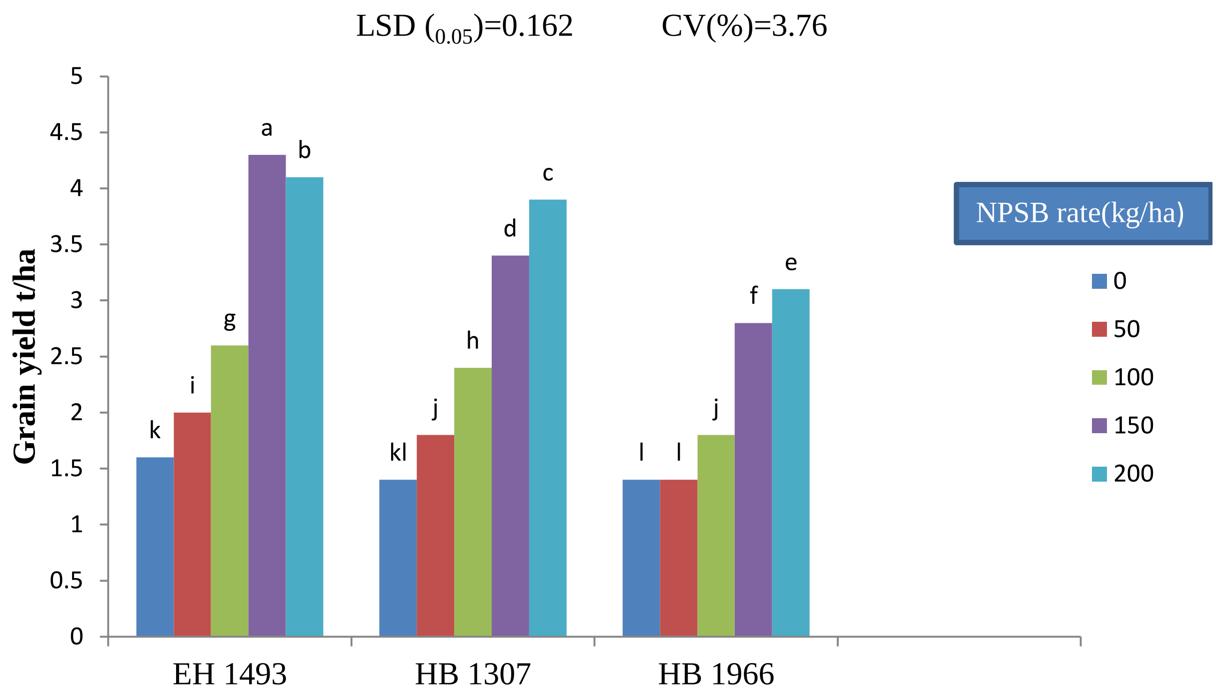
The main objective in crop production is to achieve the highest economic yield, which depends on various factors such as the genetic potential of the cultivars and inputs used. In the case of cereals, growth and development are directly linked to grain yield. Grain yield is determined by the number of grains per unit area and the weight of individual grains (Peltonen et al., 2007). According to the current analysis of variance, both fertilizer rate and variety had a highly

Significant effect ($P<0.001$) on grain yield per hectare, and their interaction effect was also significant ($p<0.05$) (figure 4). The grain yield of the tested varieties ranged from 1.4 t/ha for variety BH1966 at a fertilizer rate of 0 kg/ha to 4.3 t/ha for variety EH1493 at a fertilizer rate of 150 kg/ha (Figure, 4).

The differences in grain yield among barley varieties may be attributed to variations in yield components such as the number of effective and total tillers per m^2, spike length, kernels per spike, and thousand kernel weights, some of which were examined in this study and Showed significant effects.

The highest grain yield (4.3 t/ha) was recorded for variety EH1493 with a fertilizer rate of 150 kg/ha, which is 50% higher than the national average rain fed barley productivity of 2.17 t/ha (CSA, 2020). The high grain yield obtained from EH 1493 varieties could be due to the varietal response to NPSB blended fertilizer and its high fertilizer use efficiency. Additionally, the synergistic effect of the four nutrients might have contributed to improved root growth, increased nutrient use efficiency, and enhanced yield components, resulting in higher overall yield.

This result is consistent with previous findings by Woubshet et al. (2017), who reported that the application of NPSB blended fertilizer increased grain yield. Similarly, Khan et al. (2006) reported a 43% rise in grain yield with the addition of 90 kg P and 60 kg/ha Sulfur. Likewise, Malakouti (2000) reported that grain yield increased due to the application of boron with micronutrients, providing a yield benefit of 4 to 11%.

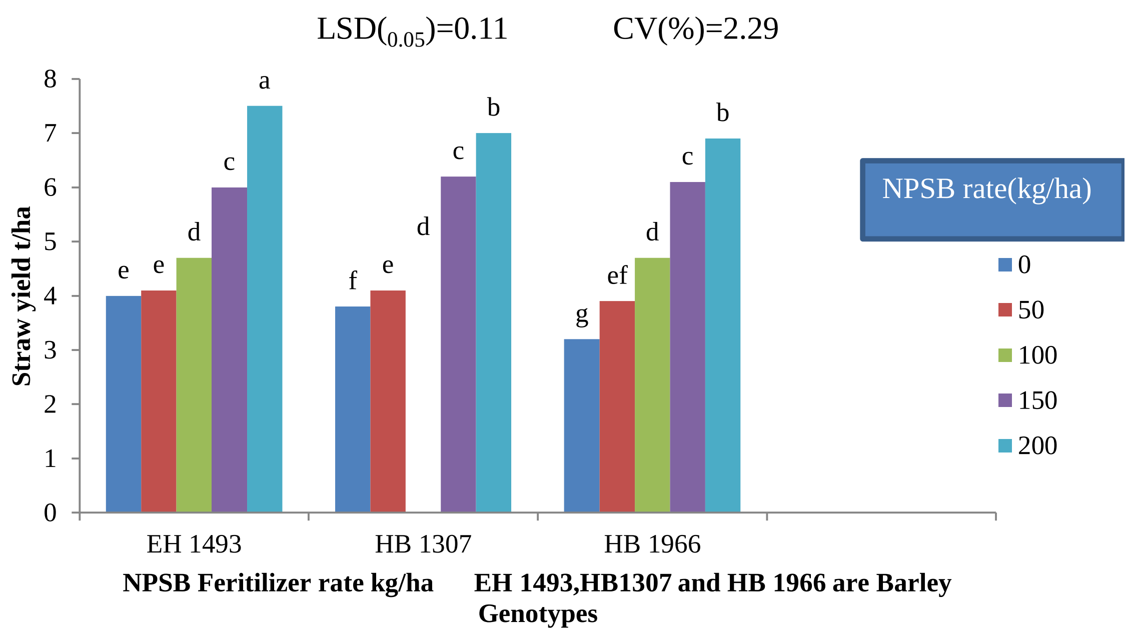


Where, 0, 50,100,150 and 200 are NPSB Fertilizers per hectare, CV (%) coefficient of variation in percent, LSD= Least significant difference

Figure 5: Interaction effects of blended NPSB fertilizer levels and varieties on grain yield (t ha^{-1}) of food barley,at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

4.4.6. Straw Yield

The straw yield ranged from 3.2 to 7.5 tons per hectare as the NPSB fertilizer application increased from zero to 200 kg per hectare (Appendix Table 3). The highest straw yield of 7.5 tons per hectare was observed with the application of 200 kg NPSB per hectare, while the lowest yield of 3.2 tons per hectare was noted in the unfertilized plot (Figure 5).Analysis of variance indicated that the straw yield was significantly affected by the barley varieties, blended fertilizer and their interaction, significantly ($P < 0.01$) This could be attributed to the higher fertilizer rate resulting in increased plant population and taller plant height, leading to a higher straw yield. This finding is consistent with the study by Woubshet et al. (2017), which reported a 5.9 t/ha increase in straw yield with the application of 150 kg/ha NPSB blended fertilizer. The combined application of a high rate of NPSB blended fertilizer with the EH 1493 variety significantly increased straw yield, possibly due to the synergistic roles of the nutrients in promoting the growth and development of the barley crop. Sulfur fertilizers were found to be the most effective in terms of straw yield, similar to their impact on grain yield. EH 1493 variety recorded the highest mean straw yield of 7.5 t/ha, whiles the lowest mean straw yield of 3.2 t/ha was obtained from HB1966. The EH 1493 variety produced more straw yield compared to HB1307 and HB 1966 varieties, demonstrating its higher biomass yield production.



Where, 0, 50,100,150 and 200 are NPSB Fertilizers per hectare, CV (%) coefficient of variation in percent, LSD= Least significant difference

Figure 6: Interaction effects of blended NPSB fertilizer levels and varieties on Straw Yield (t ha^{-1}) of food barley.at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

4.4.7. Harvest Index

The harvest index (HI) represents the ratio of grain to the total biological yield and is used to measure how efficiently a crop allocates photosynthetic products to grains (Fageria, 2009). The analysis of variance revealed that the harvest index was significantly affected by both the main effects of blended fertilizer rates and varieties ($p<0.001$) (Appendix Table 3). However, the interaction effect of blended NPSB fertilizer was not significant ($p>0.05$) for the harvest index (Appendix Table 3). The maximum harvest index (40.298%) was observed from the application of 200kg NPSB ha-1, while the lowest (35.711%) was obtained from the control or unfertilized plot. Tahir et al. (2009) suggested that a higher transfer of assimilates to the grain would maximize the harvest index and reduce the proportion of dry matter produced.

The higher barley harvest index with increased fertilizer rate might be due to a higher grain yield per plant at higher fertilizer rates. Similarly, Solomon et al. (2003) reported a significant and positive relationship between harvest index and grain yield in barley. Harvest index is considered to be a quantitative trait and an indicator of a plant's efficiency in distributing dry matter to grain (Shahryari and Mollasadeghi, 2011). Variety HB1966 had the lowest statistically recorded harvest index. The highest harvest index (46.773%) was observed for variety EH1493. The variation in the harvest index of various food barley varieties is due to their genetic variability.

Table7: Main effects of blended NPSB fertilizer levels and varieties on harvest index of food barley, at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

NPSB (kg ha^{-1})	Harvest index(%)
0	35.71^{b}
50	37.92^{b}
100	38.94^{b}
150	44.1^{a}
200	47.83^{a}
Mean	40.9
LSD(0.05)	3.1
Varieties	
EH 1493	46.77^{a}
HB1307	40.87^{b}
HB1966	35^{c}
Mean	40.9
LSD(0.05)	4.04
CV%	10.23

Where, CV (%) coefficient of variation in percent, LSD= Least significant difference

Means followed by the same letters in the column are not significantly different at ($P> 0.05$)

4.4.8 Thousand Kernel Weight

The analysis of variance revealed that the thousand kernel weight (TKW) was significantly ($P<0.01$) affected by the main effect of NPSB rate, but not influenced by the tested varieties and their interaction effect (Appendix Table 2). In this study, the thousand kernel weight obtained from the 150 kg/ha and 200 kg/ha was significantly higher than the unfertilized, although the difference between 200 kg/ha and 150 kg/ha NPSB was not significant (Table 6). This difference might be due to the improvement of seed quality and size resulting from balanced nutrient application. The highest mean thousand kernel weight (41.411 g) was obtained from the 150 kg NPSB/ha, followed by 41.322 g from 200 kg NPSB/ha, and the lowest (40.067 g) was obtained from the control treatment. The higher grain weight for blended fertilizer might be attributed to the positive interaction of nutrients in the blended fertilizers. These results are consistent with Asghari et al. (2006), who reported that an increase in fertilization rate increased thousand kernel weights. Similarly, Rashid (2010) reported that the 1000 kernel weight of barley significantly increased with all specify them levels of fertilizers compared to the control. This may be due to the genetic variation of EH1493 variety with internal physiological factors, which may lead to an increase in the photosynthesis process and accumulation of carbohydrates in kernels, resulting in heavier kernels and consequently increased kernel weight per spike. Reports have shown the variation of thousand kernel weight as a function of barley genotype (Alam *et al.*, 2007).

Table 8. Effect of blended NPSB fertilizer rates and varieties on thousand kernels weight of food barley, at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

NPSB (kg ha^{-1})	Thousand kernels weight (g)
0	40.067^{c}
50	40.378^{ab}
100	40.878^{ab}
150	41.41^{a}
200	41.32^{a}
Mean	40.84
LSD (0.05)	0.42
Varieties	
EH 1493	$40.\ 9^{a}$
HB1307	40.9^{a}
HB 1966	40.6^{a}
Mean	40.84
LSD ($_{0.05}$)	0.548 NS
CV%	1.39

Where, CV (%) coefficient of variation in percent, LSD= Least significant difference

Means followed by the same letters in the column are not significantly different at (P< 0.05)

4.5 Partial Budget Analysis:

The partial budget analysis was used to estimate the gross benefit, total variable costs, net benefit, and marginal rate of return that could be obtained from different alternative treatments. This analysis helps to determine the level of profitability and decide whether to adopt a new technology. The interest of producers in using NPSB fertilizer rates and food barley varieties is not only to increase yield, but also to make a profit. Factors such as different barley varieties, NPSB fertilizer rates, and cost of seed, fertilizers, and the price of yields play a role in maximizing profit.

To identify treatments with the best return on the farmer's investment, marginal analysis was performed on non-dominated treatments. Treatments with a marginal rate of return (MRR) between 50% and 100% were considered worthwhile to farmers. The partial budget analysis showed that the maximum net benefit of 71697.5 ETB-Birr was obtained from a plot treated with 150 kg NPSB ha-1 and EH1493 variety with a marginal rate of return of 79.2%. The lowest net benefit of 8,775 Birr ha^{-1} was obtained from 0 kg NPSB ha^{-1} application and HB1966 variety (Table 8).

The economic analysis of the treatments using a partial budget method indicated that net benefit income was higher in the NPSB fertilizer rates and EH1493 variety than in the other treatments. The net benefits had increased in most cases, except for treatments with 0 kg NPSB ha^{-1}.

Table 9. Partial budgets analysis of food barley varieties yield as influenced by blended fertilizer rates application, at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

Var	**NPSB**	**AGY**	**ASY**	**TGB**	**TVC**	**NB**	**MRR**	**Dom**
HB1966	0	1284.3	890.64	35675	5400	**8775**	-	
HB1307	0	1328.4	2636.4	36900	5400	10000	-	
EH1493	0	1461.3	1706.2	43839.9	5670	16669.9	2470.3	
HB1966	50	1310.04	1322.9	36391.6	10500	4391.6	-	D
HB1307	50	1686.7	3829.9	45850	10500	13850	-	
EH1493	50	1881.9	3065.9	52275	10770	20005	2279.6	
HB1966	100	1624.14	1914.93	45116.6	12600	11016.6	-	D
HB1307	100	2205	6082.6	61250	12600	27150	-	
EH1493	100	2284.8	4248.72	65957.5	12870	31587.5	1643.5	Un-D
HB1966	150	2522.4	2880.8	70065.5	14700	33865.5	843.7	Un-D
EHB1307	150	3115.5	7507.8	86542.5	14700	50342.5	-	
EH1493	150	3894	5489.6	108167.5	14970	**71697.5**	7909.2	Un-D
HB1966	200	2818	3541.8	78250	16800	40050	-	D
HB1307	200	3586.5	6347.8	99625	16800	61325	-	-
EH1493	200	3742.5	4619.4	103957.5	17070	65387.5	1504.6	Un-D

Where, AGY10%= Adjusted grain yield, ASY10%=Adjusted straw yield, TGB=Total gross benefit, TVC=Total variable cost, NB=Net benefit, MRR (%) =Marginal Rate of Return, D= Dominated treatment, Control= Unfertilized treatment.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

Based on the result of the study, the following conclusions are drawn: - Depletion of soil fertility, inadequate of improved varieties and poor agronomic practices are among the major challenges responsible for the low productivity of food barley in the study area. Based on the soil physico-chemical analysis, the soil in the study area is clay in texture and strongly acidic, with low levels of organic matter, organic carbon, available phosphorus, available sulfur, and total nitrogen. However, the cation exchange capacity and available boron are at medium levels. These issues make the soil unsuitable for crop production.

The application of NPSB fertilizer enhanced soil productivity and grain yield of food barley in the study area.

The days to heading and maturity decreased as the NPSB fertilizer application increased. Moreover, the kernel per spike, number of total and productive tillers, grain yield, and thousand kernel weights increased with NPSB fertilizer levels up to 150 kg/ha. However, when NPSB fertilizer levels exceeded 150 kg/ha, these parameters decreased.

Among the tested food barley varieties, the EH1493 variety exhibited higher yield performance than others. Furthermore, when paired with 150 kg/ha NPSB fertilizer, the EH1493 variety yielded the highest grain yield of 4.3 t/ha and provided a net benefit of ETB 71697.5, with a marginal rate of return of 79.2%.

5.2. RECOMMENDATIONS

Based on the findings of this research, the following recommendations are suggested to enhance the production and productivity of food barley in the study area:

- Since the highest grain yield (4.3 t/ha-1) and the highest net benefit (71697.5 ETB) with a marginal rate of return of 79.09% were obtained from the EH1493 variety with 150 kg/ha of NPSB fertilizer, it is recommended that farmers in the study area, as well as in areas with similar agro-ecology and soil type, consider growing the EH1493 variety with 150 kg/ha of NPSB fertilizer to improve the production and productivity of food barley.
- It's important to note that the conclusions drawn from this research are limited, as the results are based on a single season. Therefore, it is advisable to conduct further research across different soil types, seasons, and locations to develop comprehensive recommendations.

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7. APPENDEX

Appendex Table 1:Mean Square of phoenological parameters and plant height at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season

Source of variation	DF	Date to heading	Date to physiological maturity	Plant height(cm)
Replication	2	4.641	0.09	0.384
Variety	2	297.332**	1414.81**	199.904**
Fertilizer	4	34.920**	19.66***	566.173**
Fertilizer× Varite	8	0.503ns	1.33ns	14.567***
Error	28	0.692	0.71	0.303

*DE = degree of freedom, *** = significance level at 0.001, ** = significance level at 0.01, * = significance level at 0.05 & ns = not significant at 0.05 level of probability.*

Appendix Table 2. Mean Square of yield and yield related parameters at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season.

Source of variation	DF	TNT	NPT	TKW
Replication	2	0.3324	0.0223	0.25757
Variety	2	60.14**	5.0581**	0.3814ns
Fertilizer	4	55.8**	32.6316**	3.06876**
Fertilizer ×Varite	8	6.2***	0.4210ns	0.2216ns
Error	28	0.2208	0.3794	0.32208

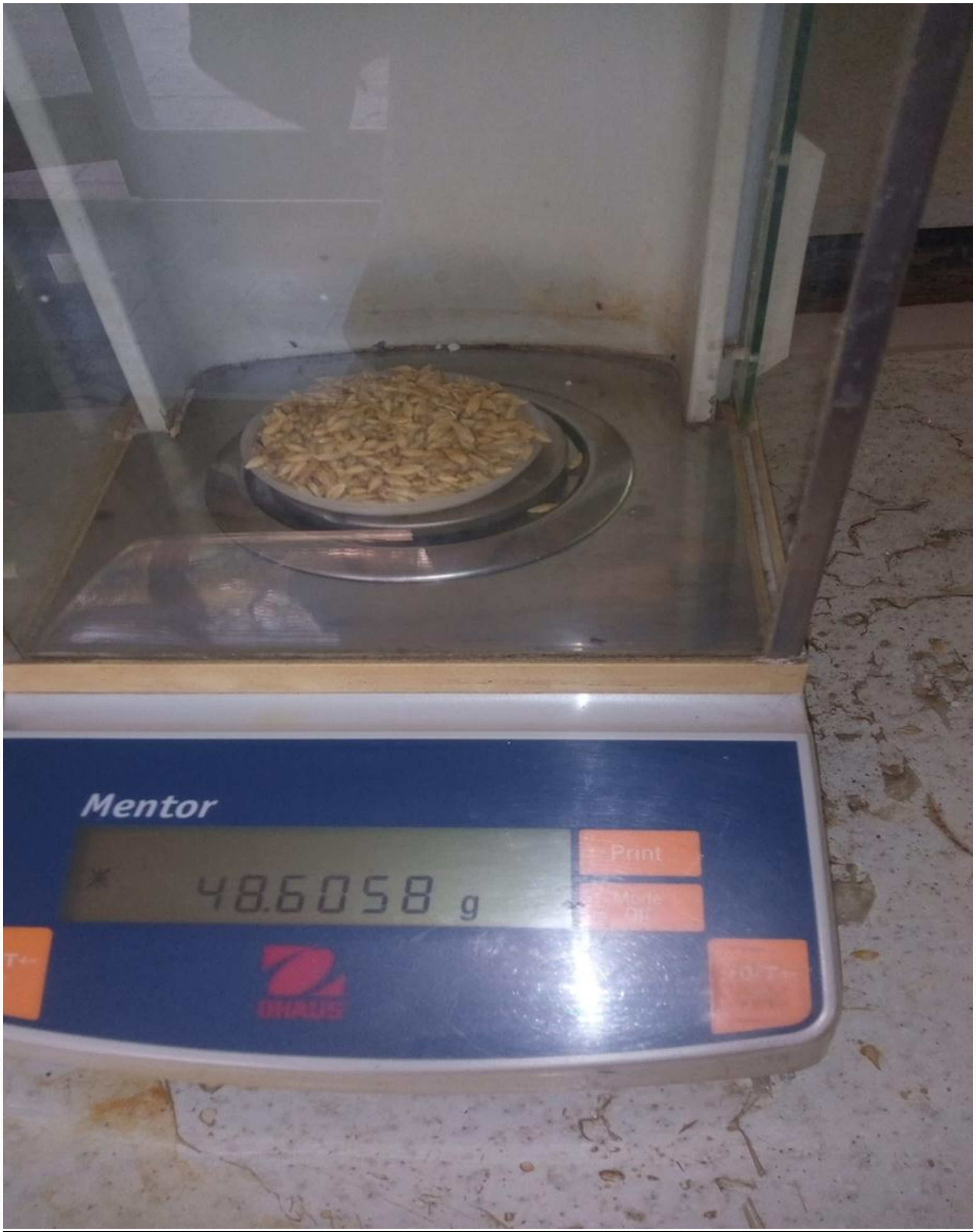
TNT = total number of tiller, NPT = number of productive tiller, TKW = thousand kernel weight, DF = degree of freedom, *** = significance level at 0.001, ** = significance level at 0.01, * Significance level at 0.05 & ns = not significant at 0.05 level of probability.

Appendix Table 3: Mean Square of yield and yield related parameters at Debicha in Teticha district, Sidama Region, South Ethiopia during 2023/24 main cropping season.

Source of variation	DF	KPS(N)	SY(t/ha	GY(t/ha	AGBM(t/ha	HI%
Replication	2	9.6056	9835.99	49730	68308.6	34.993
Variety	2	82.7973***	35618**	27192**	1.26 **	512.1**
Fertilizer	4	62.2778***	1.865**	91962 **	4.79 **	219**
Fertilizer ×Varite	8	1.2320ns	11830***	21488***	425255 ***	37.5 ns
Error	28	0.6710	14049. 9	9407	62100.5	17.516

KPS = kernel per spike, GY= grain yield, AGBM= above ground biomass SY = straw yield, HI = harvest index, DF = degree of freedom, *** = significance level at 0.001, ** = significance level at 0.01, * = Significance level at 0.05 & ns = not significant at 0.05 level of probability. Pictures at different growth stages of food barley from the experimental field in district

Appendix picture 1 physiological maturity



Appendix picture 2 Data collection

BIOGRAPHICAL SKETCH

The author, Alemayehu Fara Boe, was born in Hula Woreda, South Sidama Zone, Sidama, Ethiopia, on February 24, 1988 GC, to his parents Mr. Fara Boe, and Mrs.Almaz Kama. He attended Hula Woreda Balcha Elementary School from 1997 to 2005 GC, and then he went to Aleta Wondo Woreda Secondary School from 2006 to 2010 GC. After completing secondary school, he pursued a Bachelor's Degree in Plant Sciences at Ambo University from 2011 to 2013 GC. Following his graduation, he worked as a crop production and development expert at the Wondo Genet Woreda Agricultural Office for three years, and then for two years at CSA for the fourth round of population and house censuses cartographer. He also worked for one year at a different NGO as a data collector, and for one year at Teticha Woreda Agricultural Office as a crop production and development expert. Later, he joined Hawassa University College of Agriculture in August 2021 GC to pursue a Master of Sciences in Agronomy.