EFFECTS OF SEEDING AND NPSB BLENDED FERTILIZER RATES ON YIELD AND YIELD COMPONENTS OF BREAD WHEAT (*Triticum aestivum* L.) IN ABAY CHOMEN DISTRICT, HORO GUDURU WOLLEGA ZONE, WESTERN ETHIOPIA

M.Sc. THESIS

BY

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Effects of Seeding and NPSB Blended Fertilizer Rates on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) in Abay Chomen District, Horo Guduru Wollega Zone, Western Ethiopia

By

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A Thesis Submitted to the Department of Horticulture and Plant science Jimma University College of Agriculture and Veterinary Medicine in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agronomy.

Major Advisor: Mohammed Worku (PhD)
Co-advisor: Jima Nego (M.Sc., Assistant Professor)

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Thesis Submission Request Form (F-08)

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I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisors. Hence, I hereby kindly request the Department to allow me to present the findings of my work and submit the thesis.

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DEDICATION

This thesis work is dedicated to my wife, Talile Gurmessa, and my mother, Sakatu Wirtu for their unreserved help and prays for my success throughout my educational career.

STATEMENT OF AUTHOR

I declare that this is my bona-fide work and all sources of materials used for this thesis work have been duly acknowledged. The thesis has been submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy at Jimma University and is reserved at the University Library to be made available to users. I solemnly declare that this thesis work is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. With accurate acknowledgment of the source, users are free to use this thesis without special permission. Permission for extended quotation or duplication of the manuscript in whole or in part may be granted by the Horticulture and Plant Science Department Head, or Dean of School of Graduate Studies of Jimma University. In all other instances, however, permission should be obtained from the author.

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BIOGRAPHICAL SKETCH

Hambissa Feyissa was born on December 13, 1989 at Abay Chomen District, Horro Guduru Wollega Zone of Oromia Region. He attended his elementary School at Shambu during 1998-2005, and Secondary School and Preparatory school at Fincha from 2006 - 2009. Following the completion of his preparatory education, he joined Jimma University College of Agriculture and Veterinary Medicine and graduated with B.Sc. Degree in Plant Science on June 28, 2012. He was employed by Sugar Corporation Omo Kuraz Sugar Development Project, and served as Sugar cane plantation Supervisor for five years. Then after, in 2018, he rejoined Jimma University College of Agriculture and Veterinary Medicine, to pursue his study leading to M.Sc. Degree in Agronomy and before accomplishing his study, he joined Oromia Agricultural Research Institute and now, he was employed by Haro Sabu Agricultural Research Center as Assistant II Researcher.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
BARC	Bako Agricultural Research Center
CEC	Cation exchange capacity
CIMMYT	International Centre for Wheat and Maize Improvement
CSA	Central Statistical Agency of Ethiopia
DAP	Di-Ammonium Phosphate
EthioSIS	Ethiopian Soil Information System
FAO	Food and Agricultural Organization of the United Nations
LSD	Least significance difference
masl	Meter above sea level
NPSB	Nitrogen, Phosphorus, Sulfur and Boron
RCBD	Randomized complete block design
USDA	United States Department of Agriculture
MC	Moisture content

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Effects of Seeding and NPSB Blended Fertilizer Rates on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) in Abay Chomen District, Horo Guduru Wollega Zone, Western Ethiopia

ABSTRACT

*Low soil fertility and poor crop management practices including use of inappropriate seeding rate are among the major constraints limiting the productivity of wheat in Ethiopia in general and in the study area in particular. Thus, the field experiment was conducted to enhance bread wheat productivity in the study area by determining the optimum seeding and NPSB blended fertilizer rates. Factorial combination of three levels of seeding rates (100, 125 and 150 kg ha^{-1}) with five levels of NPSB blended fertilizer rates (0, 50, 100, 150 and 200 kg ha^{-1}) were laid out in a Randomized Complete Block Design (RCBD) with four replications. Phenological, growth, yield and yield components data were collected. The results revealed that days to 90% physiological maturity, grain filling period, plant height, weed dry biomass, spike length, and harvest index were very highly significantly ($P < 0.001$) affected by the main effect of NPSB fertilizer rate. However, days to 50% heading was not significantly ($p > 0.05$) affected by the main effect of NPSB fertilizer rate. On the other hand, plant height, weed dry biomass and spike length were very highly significantly ($P < 0.001$) affected by the main effect of seeding rate. Phenological variables, number of spikelets spike^{-1} and harvest index were not significantly ($p > 0.05$) affected by the main effect of seeding rate. The interaction effect of seeding and NPSB fertilizer rates also very highly significantly ($P < 0.001$) affected number of total tillers m^{-2}, number of productive tillers m^{-2}, number of grains spike^{-1}, aboveground dry biomass ha^{-1}, thousand grain weight, grain yield and straw yield. The longest spikes (8.96 cm) and the maximum weed dry biomass (234.8 g) were recorded from the lowest seeding rate (100 kg ha^{-1}), whereas, the shortest spikes (8.19 cm) and minimum weed dry biomass (176.4 g) were obtained from 150 kg ha^{-1} of seeding rate. Moreover, the maximum plant height (79.3 cm) and weed dry biomass (240.67 g) were recorded from 200 kg ha^{-1} NPSB fertilizer rate, while the minimum plant height (65.2 cm) and weed dry biomass (168 g) were recorded from the control. The highest thousand grains weight (51.26 g) was recorded from the combination of 125 kg ha^{-1} seeding and 150 kg ha^{-1} NPSB fertilizer rates, while the lowest thousand grains weight (35.59 g) was recorded from 125 kg ha^{-1} seeding rate combined with 50 kg ha^{-1} of NPSB fertilizer rate. Moreover, the maximum aboveground dry biomass ha^{-1} (12888.8 kg ha^{-1}) was obtained from the combination of 150 kg ha^{-1} seeding and 200 kg ha^{-1} NPSB fertilizer rates. Grain yield (5800 kg ha^{-1}) was recorded from the combination of 150 kg ha^{-1} seeding and 150 kg ha^{-1}NPSB fertilizer rates. The correlation analysis showed that grain yield was strongly and positively correlated with plant height (r =0.73**), number of spikelet spike^{-1} (r = 0.73**), above ground dry biomass yield (r = 0.96**), straw yield (r = 0.87**) and harvest index (r =0.60**). The partial budget analysis revealed that the highest net benefit (42182 Birr ha^{-1}) with acceptable MRR (63976%) was obtained from a combined application of 150 kg ha^{-1} seeding and 150 kg ha^{-1} NPSB blended fertilizer rates. Therefore, 150 kg ha^{-1} NPSB fertilizer rate with 150 kg ha^{-1} seeding rate can be recommended for bread wheat production in the study area and areas with similar agro ecologies.*

Keywords: Blended fertilizer, Grain yield, Liben variety, Yield components.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to the grass family Poaceae and to the tribe Hordeae in which several-flowered spikelets are sessile and alternate opposite side of the rachis forming a true spike (Feldman and Sears, 1981). The crop is used as staple food for about one third of the worldwide population and provides around 20% of protein and calories consumed worldwide (Hussain *et al*., 2006). The crop is grown between 6-16 °N latitude and 35 - 42 °E longitude and can grow at an altitude ranging from 1500 to 3000 meters above sea level. The most suitable agro- ecological zones of the crop however, fall between 1900 and 2700 meters above sea level and the ideal daily temperature for different stages of wheat development varies from 20 to 25°C for germination, 16 to 20°C for good tillering, and 20 to 23°C for proper plant development (Hundie *et al*., 2000).

Wheat is one of the major cereal crop produced in Ethiopia. In Ethiopia, the production of bread wheat increased due to the introduction of modern bread wheat cultivars that have replaced the traditional durum wheat landraces and it covers about 65% of the total wheat area (Tidiane *et al*., 2019). According to central statistics authority (CSA, 2022) of Ethiopia, wheat ranked third in terms of area overage and second in terms of total production in 2021/2022 main cropping season. Wheat ranks third after tef and maize in area coverage and second in total production next to maize (CSA, 2022). Out of the total grain crop area in the country wheat covers 15.31% (1.87 million ha). Despite the large area under wheat, the national average productivity of wheat is about 3.11 t ha^{-1} (CSA, 2022). According to CSA (2022), the area covered and total production of wheat in the study Zone was about 0.02 million ha and 0.07 million tons respectively with 3.39 t ha^{-1} of yield. This shows that the crop is very important for the study area. Bread wheat in Ethiopia is used in different forms such as bread, porridge, soup and roasted grain. The straw is used for animal feed, thatching roofs and bed decking. In spite of its tremendous importance, wheat production in Ethiopia faced immense production constraints affecting both its yield potential and industrial quality (Aleminew *et al*., 2015).

However, the yield of this crop could be maximized to above 5 t ha^{-1} by using improved wheat varieties with improved agronomic management practices (MoA, 2012). The production of bread wheat in Ethiopia and in the study area is constrained by both biotic and abiotic factors such as diseases and pests, poor management practices, poor soil fertility, moisture stress, slow progress in developing wheat cultivars with durable resistance to diseases, inappropriate use of seeding rate and others. Low soil fertility and poor crop management practices including use of inappropriate seeding rate are among the major constraints limiting the productivity of wheat in Ethiopia in general and in the study area in particular. Application of inorganic fertilizers especially those containing N and P have long been practiced to improve soil fertility for enhanced wheat and other crop production (Tanner *et al*., 1993; ATA, 2014). Boke and Fekadu (2014) reported that Ethiopian soils lack most of the macro and micronutrients that are required to sustain optimal growth and development of crops.

For the last three decades, Ethiopian crop production has been dependent on imported fertilizer products; which holds only urea and di-ammonium phosphate (DAP), as a source of N and P (Ethio SIS, 2013). However, recently it is perceived that the production of high protein cereals like wheat and legumes can be limited by the deficiency of S and other nutrients. According to the soil fertility map made over 150 districts, most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) (Ethio SIS, 2013). Feyisa (2020); Jalata *et al*. (2022) and Sigaye *et al*. (2022) reported that the highest grain yield of bread wheat was recorded from 200 kg ha^{-1} NPSB blended fertilizer rate. However, Abera *et al.* (2021) reported that the highest grain yield was recorded from 250 kg ha^{-1} of NPSB blended fertilizer rate. Diriba *et al*. (2019) reported that the highest yield components and yield of Wane variety were recorded from 300 kg ha^{-1} of NPSB fertilizer rate while 200 kg ha^{-1} of NPSB fertilizer rate obtained the highest grain yield of Kingbird variety.

Seeding rate has also a significant influence on productivity of bread wheat (Nizamani *et al*., 2014). High seed rate increases the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield. If low seed rate is used yield will be less due to lesser number of plants per unit area (Hameed *et al*., 2002). Better growth, yield, nutrient uptake and minimum lodging were recorded from 125 kg ha^{-1} of seeding rate as compared with higher seeding rates of 175 - 200 kg ha^{-1} (Laghari *et al*., 2011). Similarly, bread wheat produced higher number of tillers, plant height, thousand grain weight and grain yield when 125 kg ha^{-1} seeding rate was used (Ayalew *et al*., 2017). On the other hand, more yield and economic profit was recorded from 120 kg ha^{-1} of seeding rate as compared with higher seeding rate (Shah *et al*., 2011). Iqtidar *et al*. (2010) reported that the highest grain yield was recorded from 200 kg ha^{-1} of seeding rate. In contrast from this result, Tigabu and Asfaw (2016) reported that the highest biological, straw and grain yield were recorded from 100 kg ha^{-1} of seeding rate.

The use of optimum seeding and fertilizer rates were significantly influences the yield and yield component variables of bread wheat. Hence, number of grains $spike^{-1}$, the spike length, number of grains $spike^{-1}$, thousand grains weight and grain yield were significantly affected by the combination of seeding and fertilizer rates (Iqbal, 2010). Yimenu and Bekele (2021) reported that the highest grain yield was produced from 175 kg ha^{-1} Seeding combined with 150 kg ha^{-1} NPSB fertilizer rates. Moreover, the highest grain yield (6250 kg ha^{-1}) was obtained at combined rates of 200 kg NPS ha^{-1} with 150 kg ha^{-1} of seeding rate (Dawit, 2018). In contrast from this, the highest grain yield was recorded from 150 kg ha^{-1} seeding with 150 kg ha^{-1} NPS blended fertilizer rates (Kedir, 2022). However, there is no location specific recommendation of the seeding rate, NPSB blended fertilizer rate and their interaction. Therefore, this study was undertaken to determining the optimum seeding and NPSB blended fertilizer rates in the study area.

1.1. Objective of the Study

1.1.1. General objective

To enhance bread wheat productivity in the study area by determining the optimum seeding and NPSB blended fertilizer rates

1.1.2. Specific objectives

To determine optimum and economically feasible seeding rate for bread wheat production in the study area

To determine optimum and economically feasible NPSB blended fertilizer rate for bread wheat production in the study area

2. LITERATURE REVIEW

2.1. Description of Wheat

Wheat evolved from wild grasses, probably somewhere in the Near East. The first cultivation of wheat occurred about 10,000 years ago, as part of the 'Neolithic Revolution', which saw a transition from hunting and gathering of food to settled agriculture. These earliest cultivated forms were einkorn and emmer wheat and their genetic relationships indicate that they originated from the south-eastern part of Turkey (Dubcovsky and Dvorak, 2007). For 8000 years it has been the basic staple food of the major civilizations of Europe, West Asia and North Africa (Curtis, 2000). Wheat is poorly adapted to warm or moist climates unless there is a comparatively cool dry season that favors plant growth and hinders parasitic diseases (Martin and Leonard, 1967). The major world wheat crop is grown in temperate regions where the annual rainfall averages between 254 to 1780 mm, with the exception of drier irrigated areas; and it is mostly grown in regions with annual precipitation of 380 to 1,140 mm (Martin and Leonard, 1967).

It is, a self-pollinating annual plant in the true grass family Poaceae, is extensively grown as staple food sources in the world. It is exclusively produced under rain fed conditions, *meher* and *belg* (long and short rainy seasons), respectively. The species of *Triticum* and their close relatives can be divided into diploid, tetraploid and hexaploid groups, with chromosome numbers of 2n = 14, 28 and 42, respectively, in which the basic chromosome number of wheat is x = 7 (Tefera, 2012).

In Ethiopia, the crop is grown at an altitude ranging from 1500 to 3000 meters above sea level (masl), between 6-16° N latitude and 35- 42° E longitude. The most suitable agro ecological zones, however, fall between 1900 and 2700 masl (Kotu *et al*., 2000). Wheat in Ethiopia is produced from 1600-3200 masl. However, wheat is best grown from 1800 - 2800 masl with average temperature of 15-25°C. On the average, rainfall of 400-1200 mm is required. The distribution of rainfall throughout the crop growth period is very important. Wheat can be produced on different soil types such as black clay soils, red and brown soils. Sandy soils and soils with problems of water logging are unsuitable for wheat production. Suitable soil pH for wheat ranges from 5.5-8.0 (MoA, 2012).

2.2. Factors Affecting Wheat Production

Despite the fact that wheat is among the cereal crops widely grown in Ethiopia, the yields have been consistently well below African and world average yields, indicating low productivity of the crop. Recent estimates showed that wheat farmers in Ethiopia produce on average 2.53 t ha^{-1}, which is far below the experimental yield of above 5.0 t ha^{-1} (MoA, 2012). The yield has consistently lagged behind Africa's and world average wheat yields. In 2012, for instance, Ethiopia's wheat yield was 29% below the Kenyan average, 13% below the African average, and 32% below the world average yield (FAO, 2014).

On average, about 20% of the global wheat production is lost due to diseases and pests every year. In 2012, these losses amounted to about 140 million tons, equivalent to about $35 billion (Anonymous, 2001). Fungal pathogens like rusts (*Puccinia ssp*.), Septoria leaf blotch (Septoria spp.), powdery mildew (Blumeria graminis) and Fusarium species are ranked among the top ten of the most important fungal pathogens (Dean *et al*., 2012). Historical and current sources report epidemics leading to sometimes devastating yield losses in wheat caused by these pathogens. In regions with low productivity where no seed dressing is conducted, smuts and bunts are also important pathogens (Oerke and Dehne, 2004). Furthermore, in specific wheat-growing areas, fungal pathogens such as Pyrenophora tritici-repentis causing tan spot, Oculimacula spp. causing eyespot of wheat or Cochliobolus sativus are of importance.

Several abiotic and biotic constraints such as poor agronomic practices, poor soil fertility, inappropriate seed rate, diseases and pest, lack of improved varieties, weed and low/erratic rainfall are the factors that contribute for these yield gaps. The use of modern production enhancing inputs like improved seeds and fertilizers among wheat farmers in Ethiopia is remarkably low. For instance, the 2012 national estimates on input use indicated that only 8.4% of wheat was planted with improved seed and 48% of wheat areas were fertilized. Fertilizer application rates on fertilized lands are estimated below the average recommended rates although blanket recommendation is common in farmers (MOA, 2012) only about 39.27% of the wheat area was cultivated using improved managements and packages (CSA, 2016).

The national soil inventory data also revealed that in addition to nitrogen and phosphorus, sulfur deficiencies are widespread in Ethiopian soils, while some soils are also deficient in potassium, copper, Boron, manganese and iron (EthioSIS, 2013), which all potentially hold back crop productivity despite continued use of N and P fertilizer as per the blanket recommendation. Thus, future gains in food grain production will be more difficult and expensive considering the increasing problem of multi nutrient deficiencies. Other constraints of medium importance include poor land preparation due to lack of oxen, weak oxen, dry season feed shortage, and poor performing plows; water logging problems on Vertisols which forces farmers to plant late, leach of nutrients and yield reduction.

Basically, low availability of N and P has been demonstrated to be a major constraint to wheat production in Ethiopia and this is largely because the cereal dominated mono-cropping system results in continuous nutrient mining through removal by plants with no consideration for replenishment through application of either mineral or organic fertilizer sources (Mamo *et al*., 1988).

2.3. Economic Importance of Wheat

Wheat is one of the important cereal crops in the world and it has the widest distribution among cereal crops. Substantial amount of wheat is produced in tropical and subtropical environments, although the crop is more produced cereal in the temperate regions. Wheat is the most important among all cereals used as a food grain in the world. It ranks first in the world cereal production and is a staple food of about one third of the world's population (Anonymous, 2001). Wheat has the largest proportion within cereals. Owing to its sowing area of 225 million hectares it occupies 15% of area being under crop production in the world and 32% of area being under cereals in the world (FAO, 2011).

Nutritionally, wheat provides an optimum amount of energy (339 kcal of energy), protein (10.3 g of protein), calcium (49 mg of calcium) and iron (1.5 mg of iron) per 100 g of whole grain. Wheat is the most widely grown crop in the world with its unique protein characteristics that serves as an important source of food and energy (Cooke and Law, 1998). Mature wheat grains contain 8 – 20% protein, which are divided into two major categories:

prolamins including gliadins and glutenins and non-prolamins consisting of water-soluble albumins and salt-soluble globulins (Singh and Skerritt, 2001).

Ethiopia is the second largest producer of wheat in sub-Saharan Africa following South Africa and about 1.69 million hectare of land is cultivated in 2016/2017 cropping season for both bread and durum wheat production (CSA, 2017). In area of production, wheat ranks 4th after tef, maize, and sorghum and 3rd in total grain production after maize and tef and 2nd in yield to maize. It is cultivated by 4.846 million farmers and accounts for more than 15.63% of the total cereal production and 4.54 million tons of wheat was produced on an area of 1.69 million ha in 2016/2017 cropping season (CSA, 2017).

Wheat produced in Ethiopia is used mainly for domestic food consumption, seed and industrial use. It accounts for about 10-15% of all the calories consumed in country (Berhane *et al*., 2011; FAO, 2014). Moreover, estimated total wheat consumption (for food, seed and industrial use) is rapidly increasing at the national level. Annual wheat consumption in Ethiopia reached 7.17 million metric tons in 2021/22 from (USDA, 2022). Wheat consumption growth is higher in urban areas due to higher population growth, changes in life style, and the rising prices for tef. In Ethiopia, bread wheat is used for different purpose. Its grain is used to prepare a variety of local food such as *Dabo, Dabokolo, Enjera, Kolo, Genfo, Nifro, Tela* etc. In addition to this the straw of wheat is used for animal feed and for thatching of house.

2.4. Seed Rate and Wheat Productivity

Seeding rate is one of the important production factors. Higher wheat grain yield with better quality requires appropriate seeding rate for different cultivars. Increase in seed rate above optimum level may only enhance production cost without any increase in grain yield (Sajjad *et al*., 2009). Optimum seed rate is one of the most important agronomic practices for maximum yield of crop.

Seleiman *et al*. (2010) reported that the translocation of photo-assimilate from the sources (leaves, sheath, culm and chaff) to the grain was higher at lower seeding rates (250 grains m^{-2}) than at higher seeding rate (400 grains m^{-2}). Many researchers reported that increasing seeding rates caused an increase in grain and straw yield ha^{-1} (Salem, 1993; El-Bana, 2000; Gooding *et al*., 2002; Gafaar, 2007). The highest biological yield was achieved by using 400 grains m^{-2}. In contrary, the lowest seeding rates produced the lowest biological yield. Similar results were obtained by Ali *et al*. (2004) who found that biological yield was increased by increasing seeding rate. Moreover, (Gafaar, 2007) reported that the highest value of biological yield was obtained by increasing seeding rate up to 400 grains m^{-2}. Seeding rates (350 and 400 grains m^{-2}) appeared to obtain higher values of harvest index as compared with low plant densities (250 and 300 grains m^{-2}). Wheat produced higher number of tillers, plant height, 1000-grain weight and grain yield when 125 kg ha^{-1} seed rate was used. The higher grain yield of 25.8 qt ha^{-1} was recorded when 125 kg ha^{-1} of seed rate used followed by 100 kg ha^{-1} seed rate which produced a grain yield of 1828 kg ha^{-1}. The lowest grain yield was obtained from 175 kg ha^{-1} seed rate followed by 150 kg ha^{-1} seed rate which produced 899 and 1470 kg ha^{-1} respectively. Further decrease in planting densities beyond 125 kg seed rate ha^{-1} resulted in slightly lower grain yield, whereas an increase in seed rate beyond 125 kg ha^{-1} resulted with statistically lower grain yield (Ayalew *et al*., 2017). Baloch *et al*. (2010), also reported a decline in yield of wheat with increasing seed rate, this might be explained that dense wheat population creates keen competitions between plants for production resources leading to a decreasing grain yield.

2.5. Fertilizer Rate and Wheat Productivity

Recent studies have indicated that elements like N, P, K, S and Zn levels as well as B and Cu are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country (ATA, 2013). Further studies showed that most Ethiopian soils are deficit in macronutrients (N, P, K and S) and micronutrients (Cu, B, and Zn) (EthioSIS, 2014). Macronutrients as well as micronutrients are of primary importance in our agriculture system but due to unawareness of the farmers about importance of applying micronutrients and unavailability, the soils are becoming deficient in micronutrients (Tahir *et al*., 2009). Micronutrients are essential for plant growth and play a vital role in increasing crop yields as they develop plant nutrition and increase soil efficiency (Rawashdeh and Sala, 2013). The increases in crop yields from application of B, Cu, Fe, Mn, Mo, and Zn occur in many parts of the world (Martens and Westermann, 1991).

The tallest plants height (105 cm) of bread wheat was observed when 150 kg ha^{-1} NPSB blended fertilizer rate was applied, which is statistically at par with 104.9 cm when 200 kg ha^{-1} NPSB fertilizer was applied. The shortest plant height (77.9 cm) was recorded from unfertilized plot. The result showed that plant height increased with an increase of blended fertilizer rate supplemented by nitrogen fertilizer (Urea). This might be due to a total increase of nitrogen nutrient fertilizer provided for plants with the increase rate of blended NPSB fertilizer and adequate supply of other nutrients for the growth and development of plants thereby resulting in increment of plant height (Feyisa *et al*., 2020). In agreement with this result, Diriba *et al*. (2019) reported highest plant height (95.5cm) for bread wheat was recorded at a maximum application of 300 kg ha^{-1} blended NPSB fertilizer along with 100 kg ha^{-1} of urea and the shortest plant height was obtained from the control plots. Debnath *et al*. (2014) also reported that plant height was increased by nitrogen fertilizer application up to 120 kg ha^{-1} and boron application up to 2 kg ha^{-1}. Likewise, Ali *et al*. (2013) also reported that the combined application of 2 kg ha^{-1} B and 5 kg ha^{-1} Zn enhanced the plant height by 30.6% over NPK.

The highest grain yield (4549 kg ha^{-1}) was obtained under application of 200 kg ha^{-1} NPSB blended fertilizer supplemented with nitrogen fertilizer whereas the lowest was under no fertilizer application. Grain yield was increased with the increment of blended NPSB fertilizer from 50 kg ha^{-1} to 200 kg ha^{-1}. Grain yield obtained at an application of 200 kg ha-1 NPSB blended fertilizer with supplementary nitrogen increased grain yield by 38.62% and 54.51% as compared to blanket recommendation (64/20 NP) and control respectively (Feyisa *et al*. 2020).

2.5.1. Effect of N fertilizer on yield and yield components of bread wheat

Abebe and Manchore (2016) reported that grain yield of wheat was highly influenced by the rate of N fertilizer. N applied with rate of 46 kg ha^{-1} had 36.1% more grain yield than control plot. The grain protein content is directly connected with the overall available nitrogen, both from mineral fertilizers and from mineralization processes in soil (Gaj *et al*., 2013). Nitrogen fertilization contributes significantly to protein content, especially when fertilizer rates satisfy the requirements of both yield and protein formation (Woyema *et al*., 2012). Its application is an important input for wheat production (Waraich *et al*., 2010). Nitrogen is the most important nutrient which affects the assimilate production and distribution and also affecting directly and indirectly the source-sink relation (Aynehband *et al*., 2010).

Nitrogen is an integral component of many essential plant compounds such as amino acids, which are the building blocks of all proteins including enzymes, nucleic acid and chlorophyll (Brady and Weil, 2008). Grains are the most active sink for carbon and N assimilates in cereal after flowering (Aynehband *et al*., 2010). Studies have shown that grain N in wheat mainly represents N accumulated in the vegetative parts until anthesis and translocated to kernel during the reproductive phase. This is mainly due to a reduction in available N when soil N mineralization is not enough to fulfill the crop demand (Salvagiotti *et al*., 2009). The number of spikes per unit area is set before stem elongation (Li *et al*., 2001). So N has a significant impact on tillering stage. Wheat is highly responsive to N fertilization, with significant amounts of supplemental N required to maximize grain yields (Tana *et al*., 2015). Application of N fertilizers has been the most direct and effective approach to increase wheat production. In Ethiopia, erratic seasonal rainfall, inadequate availability of other nutrients, nitrate leaching during the short but heavy rainy seasons, ammonia volatilization and continuous removal in the cereal mono cropping systems of the highlands may be the major factors that result in inefficient use of N fertilizer (Haile *et al*., 2012).

In Ethiopia, wheat is grown during the high rainfall season and losses of applied N through leaching may be decreased through proper rate and timing of N application (Haile *et al*., 2012). The bread-making quality of bread wheat was primarily dependent on mineral N fertilization; necessary values for bread wheat were predominantly obtained only when mineral N-fertilization rates of 110-160 kg ha^{-1} were applied (Erekul *et al*., 2005). Application of 105 kg N ha^{-1} gave the highest mean values of all yield and its components compared as control treatment such increments might be attributed to the favorable role of nitrogen in encouraging in catabolic processes in wheat plants (Gomaa *et al.*, 2015). Actually, fertilizer rate depends on variety, soil, environmental and associated management practices. Grain yield was affected by annual weather conditions in the first place, followed by mineral N fertilization and organic fertilization, respectively (Erekul *et al*., 2005). At higher N application rates, top-dressing of N fertilizer significantly increased grain yield, improved grain protein content, and grain N uptake. The increase in grain N uptake and protein content led to an improvement in wheat grain quality (Mohammed *et al*., 2013).

High nitrogen supply favours the conversion of carbohydrates into proteins, which in turn promotes the formation of protoplasm (Arnon, 1972). The increase in the level of applied N increased grain protein percentage. Protein value reached 11.29% (300 kg ha^{-1} N rate) and was higher than 10.32% (250 kg ha^{-1} N rate). Grain yield increased by 1.4 t ha^{-1} in response to N fertilizer applications up to 250 kg N ha^{-1} (De Ruiter and Martin, 2001). Nitrogen increased grain yield primarily by increasing the number of mature spikes (Campbell and Davidson, 1979). With the increasing amount of nitrogen fertilizer, the wheat quality gradually improved and the percentage of weight gain in grain filling stage in kernel increased and got higher kernel yield; the wheat with nitrogen fertilizer rate in 300 kg ha^{-1} gained the best quality and decreasing percentage of wheat gain in grain filling stage in kernel and lower yield (Dandan and Yan, 2013).

Highest values of plant height, effective tillers m^{-2}, spike length, seeds per spike and biomass yield were obtained from the maximum fertilizer (138/115 N/P_2O_5 $kgha^{-1}$) (Assefa *et al*., 2015). Waraich *et al*. (2010) reported that increasing levels of nitrogen fertilizer improved grain yield, which seems to be the result of enhanced tiller production and increased kernel number per spike. However, N rate beyond the optimum prolongs the vegetative stage and thereby reducing yield and quality. Nitrogen fertilizer applications that exceed crop N requirements lead to environmental pollution including nitrate N leaching and gaseous N emissions (Abedi *et al*., 2011).

Lakew (2019) reported that, time to heading of bread wheat was significantly affected by different rate of nitrogen fertilizers. Similarly, Solomon and Anjulo (2017) reported that, as the increments in yield of wheat with increasing N rates up to 46 kg ha^{-1} might be attributed to the effective role of N as an essential constituent of chlorophyll on dry matter accumulation and nitrogen applied at the rate of 46 kg ha^{-1} enhanced wheat productivity and produced the maximum grain yield per nitrogen unit increase and showed the greatest agronomic efficiency. Shahzad and Akmal (2017) found that days to anthesis was significantly affected by nitrogen application rate and time in which the maximum days to anthesis was recorded with the application of 160 kg ha^{-1} N indicating that increasing nitrogen application rate delayed the anthesis of wheat. Likewise, Harfe (2017) also reported similar result who found that flowering was significantly affected due to nitrogen rate which indicated that flowering of wheat crop was delayed as nitrogen level increased from 0 to 69 kg ha^{-1} due to greater vegetative development for longer period of time before reproductive phase begins.

2.5.2. Effect of P fertilizer application on yield and yield components of bread wheat

Phosphorus is an important nutrient element on crop production. An adequate quantity from available source of phosphorus is vital for the growth, reproduction, yield and quality of wheat (Alam and Jahan, 2013). It is critical in the metabolism of plants, playing a role in cellular energy transfer, respiration, and photosynthesis. It is also a structural component of the nucleic acids of genes and chromosomes and of many coenzymes, phosphor-proteins and phospholipids (Khan *et al*., 2010). Phosphorus is also essential for cellular respiration, metabolism of starch and fats which has been investigated by many researchers (Kaleem *et al*., 2009).

Application of adequate amount of phosphorus improves wheat grain yield (Alam and Jahan, 2013). Thus, there is a need to apply the adequate level of phosphorus for obtaining higher yield with good quality product of wheat. Wheat is very responsive to phosphorus fertilizer application on soils that do not provide adequate amounts of this essential nutrient (Maqbool *et al*., 2012). Phosphorus is the second to nitrogen as the nutrient that most commonly limits wheat growth and development. Maximum grain yield was obtained at 128 kg P ha^{-1} indicating importance of phosphorus at its highest dose in achieving maximum wheat productivity (Alam and Jahan, 2013). Maximum phosphorus dose contributed in achieving highest 1000 grain weight and finally resulted in significantly higher grain yield ha^{-1}. The phosphorus fertilizer use can help to reduce the adverse effect of drought under rain fed conditions (Khan *et al*., 2010).

Due to deficiency of phosphorus, growth of root and shoot is restricted, plants become thin and spindly, premature shedding of leaves and flowering occur, yields are consequently decreased (Alam and Jahan, 2013). An application of 60 kg P_2O_5 ha^{-1} to each crop would be desirable for cost effective, optimum production of the soybean-wheat system (Aulakh *et al*., 2003). Wheat has high phosphorus requirement, especially during the early growth stages, as phosphorus affects rooting and tillering (Rastija *et al*., 2010). Application of the highest dose of phosphorus contributed to maximum dry matter and physiological attributes towards the yield attributes in wheat and therefore, helped in achieving highest number of grains per spike, thousand grain weights and ultimately yield of wheat (Alam and Jahan, 2013). In many parts of Northwestern and Northern Ethiopia, applying P fertilizer at the highest rate has significantly enhanced yield and yield components of wheat, maize, barley and teff (Gebreslassie and Demoz, 2016). Application of phosphorus fertilizer increased yield component, grain and straw yield of bread wheat as compared to unfertilized plot and maximum grain and straw yield were recorded from treatment involving at 22 kg ha^{-1} phosphorus (Assefa *et al*., 2021).

2.5.3. Effect of S fertilizer application on yield and yield components of bread wheat

Sulfur is an essential plant nutrient in crop production required for protein and enzyme synthesis as well as it is a constituent of some of the amino acids (Scherer, 2001). Sulphur, an essential secondary plant nutrient, plays a vital role in biosynthesis of primary metabolities for improving yield and quality of oil seed crops and for accruing better yield under balanced fertilization (Anwar *et al.*, 2002). Oil concentration in seed increased with S fertilization (Malhi *et al*., 2007). So an insufficient S supply can affect both yield and quality of the crops (Inal *et al*., 2003). Plants can take up sulfur (S) from the soil as sulfate (SO_4^{-2}) ions and from the atmosphere in a gaseous form as SO_2 through the stomata in leaves (Inal *et al*., 2003). It is an essential constituent of amino acids like cysteine and methionine, several co-enzymes, thioredoxins, sulfolipids, and all proteins containing cysteine and methionine (Anwar *et al.*, 2002; Inal *et al*., 2003). Sulfur fertilization increased the amino acids content in the protein of wheat in field trials on average of cysteine by 24.5%, methionine by 35.3%, threonine by 14.4% and lysine by 7.7% (Järvan *et al*., 2008). Some of the most important functions of S include its role in specialized peptides, such as glutathione and thioredoxins, in redox reactions, and the role of disulfide bond (S-S) formation in the stabilization of protein structure (Inal *et al*., 2003).

Sulfur deficiency had a significant influence on the yield and yield components of wheat (Järvan *et al*., 2012). In addition to its effects on wheat yields, the S status of grain is an important parameter for the quality of wheat products (Hoel, 2011). Reproductive growth of wheat appears to be more sensitive to sulfur deficiency than vegetative growth, with decreased grain size under sulfur-limiting conditions (Järvan *et al*., 2008). The primary form of plant-available S is sulfate (SO_4^{-2}), which is very mobile and readily leached from the rooting zone, if not adsorbed by soil particles (Mascagni and Harrison, 2008). In S deficient environments, it is expected that a higher N uptake will enhance nutrient use efficiency when S is added (Mascagni and Harrison, 2008). The increase in grain yield in response to S addition was associated with a higher N uptake rate before anthesis confirming the positive interaction between both nutrients (Mascagni and Harrison, 2008).

Responses of the bread making quality of wheat to sulfur are more common than responses in terms of grain yield. Sulfur application did not affect grain protein concentration directly, but tended to increase gel protein weight in flour and the proportion of polymeric proteins. Dough extensibility was increased by sulfur and all major parameters of winter wheat's baking quality improved: stability and quality number of dough, loaf volume and specific volume and round loaf's height-to-diameter ratio (Järvan *et al*., 2008). Without adequate sulfur, crops cannot reach their full potential in terms of yield (Järvan *et al*., 2008); the most important role in such an increase of grain yield was performed by the number of grains per ear as one of the yield components. Addition of S to a calcareous soil may result in a decline in soil pH and consequently may increase availability of micronutrients like B (Nadian *et al*., 2010).

Total number of tillers and productive tillers were significantly influenced by sulphur fertilizer rates. The highest number of total tillers plant^{-1} (23.53) and productive tillers plant^{-1} (15) were recorded from 75 kg ha-1 sulphur fertilizer, while the lower number of total tillers plant^{-1} (12.70) and productive tillers plant^{-1} (8) were obtained from non sulphur fertilizer applied The grain yield of wheat was significantly affected by S rates and the highest grain yield (7.89 t ha^{-1}) was recorded from 45 kg ha^{-1} S followed by 60 kg ha^{-1}, whereas the lowest grain yield (6.69 t ha^{-1}) was obtained from the control plot. Highest grain yield produced at 45 kg ha^{-1} sulphur application was improved by 14% as compared to those produced on the control plot. (Alemu *et al*., 2023). Assefa *et al*. (2021) reported that the yield components of bread wheat like spike length; number of grains spike^{-1} and number of spikelets spike^{-1} were significantly affected by sulphur application. The highest spike length, maximum number of grains spike^{-1} and number of spikelets spike^{-1} of wheat were recorded from 30 kg ha^{-1} sulphur, however, significantly similar with 15 kg ha^{-1}. Higher thousand grain weight was recorded from 15 kg ha^{-1} than 30 kg ha^{-1} and control.

2.5.4. Effect of B Fertilizer Application on Yield and Yield Components of Bread Wheat

Boron is unique among the essential mineral micronutrients because it is the only element that is normally present in soil solution as non-ionized molecule over the pH range suitable for plant growth (Singh *et al.*, 2015). It is an essential micronutrient required for normal plant growth and development (Dursun *et al.*, 2010; Singh *et al.*, 2015). Boron is an essential element for better utilization of macro-nutrients by plants and thereby greater translocation of photo-assimilates from source to sink during growth period (Ali *et al.*, 2013). Boron plays a vital role in grain setting of wheat. The supply of Boron helps in grain filling and ultimately sterility is reduced and number of grains per spike increased (Tahir *et al.*, 2009). Boron is very much essential for flowering and grain formation in rice (Dash *et al.*, 2015). 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). It is common that B concentrations in soils vary widely in humid regions, in both calcareous soil and also Entisols (Dursun *et al.*, 2010).

Boron-deficiency symptoms first become evident on the younger leaves, which change color and become hardened, malformed, and necrotic (Dursun *et al.*, 2010). Deficiency of boron can also cause reduction in crop yield and inferior crop quality (Singh *et al.*, 2015). In the field trial, sexual reproduction is often more affected by low boron and significant grain yield reductions may occur without visual symptoms expressed during vegetative growth (Tahir *et al.*, 2009). Boron normally becomes less available to plants with increasing soil pH and yield and yield components of crops were affected positively and negatively by B, depending upon soil status, crop types and the doses used (Dursun *et al.*, 2010). Yield and the component in vegetative and reproductive stages of sunflower may both be affected positively and negatively by B depending upon the dose used as a fertilizer (Mekki, 2015). Boron deficiency impairs grain setting in wheat, resulting in increased number of open spikelets and decreased number of grains per spike (Tahir *et al*., 2009). Deficiency of boron causes inhibition of leaf expansion and reduction in photosynthesis, though exact role of boron in photosynthesis remain to be explored.

Boron is an essential nutrient for vascular plants, but high concentration is toxic and limits crop productivity (Ali *et al*., 2014). Tahir *et al.* (2009) reported that as the boron requirement of male reproductive organ, the anthers was also greater than carpel, since the boron requirement in the anthers for successful fertilization was met by application of boron at booting stage so the grain yield was higher than control. Debnath *et al.* (2014) observed that the interaction of N and B levels showed no significant effect on plant height. The highest plant height (85.60cm) was found when the crop was fertilized with 120 kg N + 2 kg B ha^{-1} and the lowest (74.53cm) was from control. Muhmood *et al.* 2014) reported that application of 2 kg B ha^{-1} along with recommended doses of chemical fertilizer gave 11% more grain yield than with the alone application of N, P and K fertilizers.

2.6. Blended Fertilizers and Wheat Productivity

The application of different blended fertilizers had significant influence on plant height, spike length, number of tillers m^{-2} and number of kernel spike^{-1} of barley. The maximum plant height (109.9 cm), spike length (7.1 cm), number of tillers m^{-2} (61.67) and number of kernel spike^{-1} (53) were obtained from application of 200 kg ha^{-1} NPSB blended fertilizer rate (Melkamu *et al*., 2019). Several authors, report that macro and micro nutrients (Nitrogen, Phosphorous, Sulphur and Boron) fertilizers application can increase plant height, spike length, number of tillers and number of kernel with increasing doses and combination (Dewal and Pareek, 2004; Muhammad *et al*., 2006; Gupta *et al*., 2004; Haileselassie *et al*., 2014).

The maximum aboveground biomass (12.63 t ha-1) was recorded from 200 kg ha-1 NPSB of blended fertilizer application, whereas, the lowest (4.29 t ha^{-1}) was recorded from unfertilized plot (Melkamu *et al*., 2019). Demissie *et al*. (2017) also reported that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased the biomass by 11.5 t ha^{-1}. This is due to sulphur enhanced the formation of chlorophyll and encouraged vegetative growth and boron helps in nitrogen absorption.

The maximum grain yield (4.91 t ha^{-1}) was obtained from 200 kg ha^{-1} NPSB of fertilizer application, conversely, the lowest grains yield (1.45 t ha^{-1}) was perceived in control plot. The grain yield was 70.4% and 22.4% from recommended NP fertilizer and control by application of 200 kg ha^{-1} NPSB fertilizer (Melkamu *et al*., 2019). Klikocka *et al*. (2016) also found that a positive reaction of N and S fertilization on grain yield, which was the highest grain yield (5.40 t ha^{-1}) was obtained due to application of 80 kg ha^{-1} N increasing by 1.30 t ha^{-1} (13.1%) with respect to the control and S fertilization increased grain yield by 3.58%. Besides, Khan *et al*. (2006) reported 43% raise in grain yield with the addition of 90 kg ha^{-1} P and 60 kg ha^{-1} S. Likewise, Malakouti (2000) reported that the grain yield increased due to application of boron was also witnessed by the combined application of boron with micro nutrients, with the benefits 4 to 11% wheat yield. Brzegen (2019) reported that plant height increases with increasing NPS fertilizer rate hence, NPS fertilizer has a great contribution to the vigorous vegetative growth and development.

As reported by Abera *et al*. (2020), the highest numbers of total tillers m^{-2} (301.7) and productive tillers m^{-2} (245.6) were recorded from 183 kg ha^{-1} of NPSB fertilizer rate while, the lowest total number of tillers m^{-2} (142.4) and productive number of tillers m^{-2} (102.4) were recorded from the control. The increase in the numbers of tillers in response to increasing rate of blended NPSB fertilizer indicated the importance of availability of balanced nutrients for better growth and development of wheat and the more availability of N at the highest rates of NPSB might have played a positive role in cytokinin synthesis and cell division and thereby accelerated the vegetative growth of plants (Abera *et al*., 2020). Increasing the rates of NPSB fertilizer increased the number of kernels per spike. The highest number of kernels per spike (42.7) was produced from the highest rate of NPSB fertilizers (183 kg ha^{-1}) whereas the minimum number of kernels per spike (30.3) was produced at nil NPSB rate (Abera *et al*., 2020). The increase in the number of kernels per spike with the increase in NPSB fertilizer rate might be due to the fact that P is essential nutrient in the development of grains. Moreover, boron plays a vital role in grain setting of wheat as the supply of boron containing fertilizer helps in grain filling and ultimately sterility is reduced and number of grains per spike is increased (Mengel and Kirkby, 2001).

Jalata *et al*. (2022) reported that bread wheat produced the largest and most significant spike length (7.63 cm), thousand kernel weight (44.96 g), above-ground biomass production (12481 $kg \cdot ha^{-1}$), straw yield (7298.4 $kg \cdot ha^{-1}$), and grain yield (5182.5 $kg \cdot ha^{-1}$) when 200 $kg \cdot ha^{-1}$ of NPSB fertilizer rate combined with 112.2 $kg \cdot ha^{-1}$ of N while, the smallest spike length (5.49 cm), thousand kernel weight (34.09 g), above-ground biomass (12481 $kg \cdot ha^{-1}$), straw yield (7298.40 $kg \cdot ha^{-1}$), and grain yield (5182.5 $kg \cdot ha^{-1}$) were recorded from the control. All yield components and yield of bead wheat were significantly affected by the rate of NPSB fertilizer application. Plant height was increased by increasing the rate of NPSB fertilizer from 150-250 $kg \cdot ha^{-1}$ of NPSB fertilizer rate. The longest plant height (94.3 cm), spike length (7.9 cm) and the maximum numbers of tillers m^{-2} (237) were obtained from the application of 200 $kg \cdot ha^{-1}$ of NPSB fertilizer rate when combined with 250 $kg \cdot ha^{-1}$ of Urea. The improvement in total number of tillers at highest rates of combined application of blended NPS-B and N might be attributed to the synergetic roles of the four nutrients played in enhancing growth and development of the crop. Also, Phosphorus found in NPSB responsible for improved root development at early growth stage and which in turn promotes N uptake and N assimilation by growth points triggering tillers which subsequently resulted to overall plant growth and increase in bread wheat (Sigaye *et al*., 2022).

As reported by Mamo *et al*. (2022), the phonological parameters of wheat were significantly affected by the application of NPSB fertilizer rate. Hence, delayed days to 50% heading (58.33 days) and days to 90% physiological maturity (73 days) period were observed from 125 kg ha^{-1} of NPSB fertilizer application. The maximum (44.91 g) thousand kernels weight was recorded from 200 kg ha^{-1} of NPSB fertilizer and the lowest (36.79 g) thousand kernel weight was obtained from control while, the highest grain yield (5800 kg ha^{-1}) was obtained by application of 150 kg ha^{-1} of NPSB fertilizer rate and the lowest grain yield (1598 kg ha^{-1}) was obtained from the control treatment (Iticha *et al*., 2022). Diriba (2019) reported that, the application of NPSB at the rate of 300 kg ha^{-1} and 200 kg ha^{-1} of NPSB fertilizer were recommended for the production of Wane and Kingbird varieties at Kulumsa area. An application of NPSB blended fertilizer significantly influences both the grain yield and quality like hectoliter weight. Hence, the highest Hectoliter Weight was obtained from the NPSB fertilizer rate of 100 kg ha^{-1} and 150 kg ha^{-1} which might be due to the role of balanced nutrients on quality of wheat such as flour yield (Usman *et al*., 2020).

Abera *et al*. (2020) reported that, as the rate of NPSB fertilizer increased, the thousand kernels weight was also increased. Hence, the maximum thousand kernels weight (44.8 g) was recorded from 183 kg ha^{-1} of NPSB fertilizer rate while, the lowest thousand kernels weight (37.2 g) was recorded from the control. The increase in thousand kernels weight with increased rates of NPSB might be due to the provision of adequate and balanced nutrients which enhanced accumulation of assimilate in the grains, resulting in good grain filling and development of bigger kernels. Likewise, highest grain yield of 3640 kg ha^{-1} was obtained from the application of 183 kg ha^{-1} NPSB blended fertilizer while the lowest grain yield of 1230.3 kg ha^{-1} was obtained from the control and the highest grain yield at the highest NPSB rate might have resulted from improved root growth and increased uptake of nutrients and better growth due to the synergistic effect of the four nutrients which enhanced yield components and yield.

2.7. Interaction Effect of Seeding and Fertilizer Rates on Wheat Productivity

Yimenu and Bekele (2021) reported that the highest number of grains $spike^{-1}$ (49.5) and thousand grain weight (40g) were recorded from 150 kg ha^{-1} NPSB fertilizer and 125 kg ha^{-1} seeding rates, whereas, the lowest number of grains $spike^{-1}$ (30.17) and thousand grains weight (34.67g) were recorded from non NPSB fertilizer application with 200 kg ha^{-1} seeding rate. The maximum grain yield (5.2 t ha^{-1}) was produced, by using the combination of 46 kg ha^{-1} N and 150-200 kg· ha^{-1} seeding rates of bread wheat (Feyisa *et al*., 2023).

Increasing seeding rates with optimum fertilizer application resulted in increased plant height and grain yield (Otteson *et al*., 2007). Khuong *et al*. (2008) indicated that higher net benefit and grain yield obtained at higher seeding and higher NPK rates. Dawit (2018) reported that the higher number of effective tillers (413.3) were obtained from combination of higher seeding rate (150 kg ha^{-1}) with higher NPS rate (200 kg ha^{-1}) while, lower number of effective tillers (110) were obtained from the combination of the lower seeding rate (100 kg ha^{-1}) and control NPS rate (0 kg ha^{-1}). The author also showed the higher grain yield (6250 kg ha^{-1}) was obtained from the combination of 150 kg ha^{-1} seeding with 200 kg ha^{-1} NPS fertilizer rates, respectively. Minimum grain yield (2014 kg ha^{-1}) was obtained from the combination of 100 kg ha^{-1} seeding rate with 0 kg ha^{-} NPS, respectively.

Grain yield increased with an increase in plant density and N application (Yang *et al*. 2019). Similarly, Assefa *et al*. (2015) reported that grain yield at the higher rate of nitrogen and phosphorus fertilization (138/115 kg ha^{-1} N/P_2O_5) with higher seed rate (177 kg ha^{-1}) provided maximum grain yield of 5210 kg ha^{-1} with comparing to the lowest grain yield of 3520 kg ha^{-1} at the lowest rate of nitrogen and phosphorus fertilization 46/46 kg ha^{-1} N/ P_2O_5 with lowest seed rate (66 kg ha^{-1}). This may probably be due to the highest efficiently utilizing of nitrogen and phosphorus fertilization at highest seed rate. similarly, Iqbal *et al*. (2012) also showed that, higher grain yield (4894 kg ha^{-1}) was found in the combination of 150 kg ha^{-1} seeding rate with 125 kg ha^{-1} nitrogen rate while, lower grain yield (3117 kg ha^{-1}) was observed from the combination of 125 kg ha^{-1} seeding rate with zero level of nitrogen fertilizer.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Homi kebele, in Abay Chomen district, Horo Guduru Wollega Zone during rainy season of 2019. Abay Chomen district is one of the districts of Oromia Regional State and located in the western Ethiopia. Geographically, It is located between 9°31'42" to 9°59'48" N latitude, and 37°10'03" to 37°28'44" E longitude and at an altitude ranging from 880 to 2,400 masl. Fincha is capital town of the district and it is located at 289 km in the west of Addis Ababa and 47 km away from Shambu, a capital town of Horo Guduru Wollega Zone. The mean annual temperature and rainfall of the area are 22 to 27°C and 510 to 1530 mm respectively with Weina Dega Agro-ecological Zone (Bellete, 2014). Smallholder farmers practice mixed farming systems that integrate both crops and livestock (animals used for traction, meat and milk). The area is commonly known by intensive cultivation of maize, teff, bread wheat, niger seed, barley, field pea and faba bean (CSA, 2022). The soil of the study area is characterized by pH of < 5.5 which is strongly acidic, available phosphorus ranged from 3.22 to 13.62 ppm and exchangeable acidity ranged from 0.12 to 0.27 cmol (+) kg^{-1} and sandy clay loam to clay loam soil textural class (Chimdessa *et al*., 2023; Feyisa *et al*., 2023).

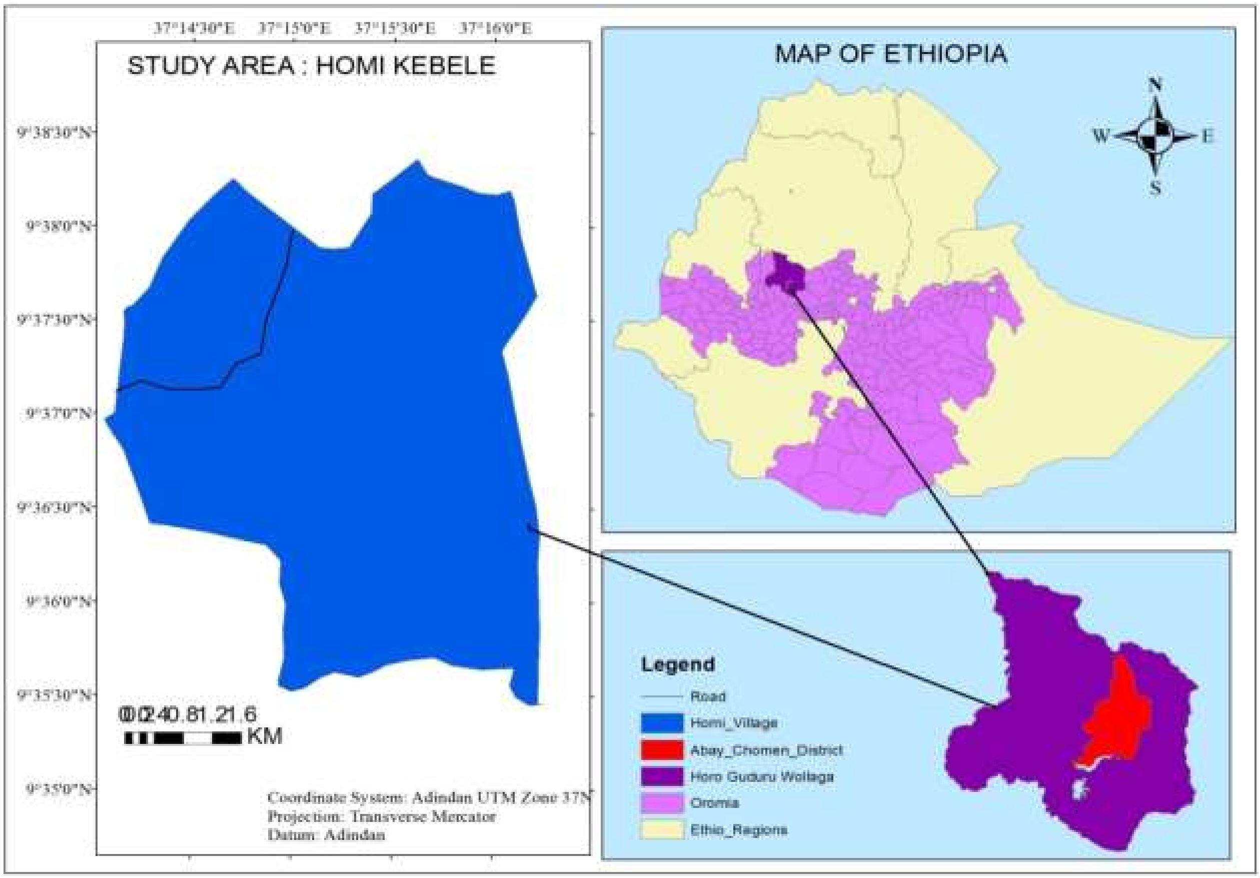

Figure 1. Map of the Study Area

3.2. Description of the Experimental Materials

Bread wheat variety, "Liben" (ETBW 5653), was used as an experimental material. The variety was released by Bako Agricultural Research Center (BARC) in 2015. The variety is characterized by high tillering, seeds/spike, tolerant to diseases like yellow rust and stem rust, early maturing, good crop stand, good yield, easy to thresh and small seed size compared with others like Danda'a and Bulluq varieties which indicate that the variety is preferred for the study area than the varieties mentioned above (Geneti *et al.* 2017). NPSB blended fertilizer (18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B was used as a source of fertilizer.

3.3. Treatments and Experimental Design

The treatments consisted of a factorial combination of three seeding rates: (100, 125 and 150 kg ha^{-1}) and five rates of NPSB blended fertilizer: (0, 50, 100, 150 and 200 kg ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with four replications in factorial arrangement of 3 x 5 = 15 treatment combinations (Table 1).

Table 1. Treatment combinations of Seeding and NPSB fertilizer rates with its compositions

No	Factors		Total nutrient composition (kg)				
	Seed rates ($kg\ ha^{-1}$)	NPSB rates ($kg\ ha^{-1}$)	N (from 100 $kg\ ha^{-1}$ urea)	N (from NPS)	P_2O_5	S	B
1		0	46	0	0	0	0
2		50	46	9.45	18.85	3.475	0.05
3	100	100	46	18.9	37.7	6.95	0.1
4		150	46	28.35	56.55	10.425	0.15
5		200	46	37.8	75.4	13.9	0.2
6		0	46	0	0	0	0
7		50	46	9.45	18.85	3.475	0.05
8	125	100	46	18.9	37.7	6.95	0.1
9		150	46	28.35	56.55	10.425	0.15
10		200	46	37.8	75.4	13.9	0.2
11		0	46	0	0	0	0
12		50	46	9.45	18.85	3.475	0.05
13	150	100	46	18.9	37.7	6.95	0.1
14		150	46	28.35	56.55	10.425	0.15
15		200	46	37.8	75.4	13.9	0.2

The gross size of each plot was 3 m × 2 m (6 m^2) consisting of ten rows and, which be arranged in 20 cm row spacing. The distance between plots and blocks was 1 m and 1.5 m, respectively. Phenological, yield and yield components data were collected accordingly from middle eight rows.

3.4. Experimental Procedures and Field Management

The experimental field was ploughed five times to a fine tilth by oxen and then after, the plots were manually leveled. The field layout was made and each treatment was assigned randomly to each plot within a block. Sowing was done by manual drilling method. The whole of NPSB blended fertilizer rates respective to the treatments were applied at the time of sowing. 100 kg ha^{-1} of UREA (46 kg of N) was applied for all treatments including control plots uniformly in split form; half at the time of sowing and the left half at mid-tillering stage as top dressing. All agronomic management practices such as weeding, harvesting and threshing were done for all plots uniformly as required.

3.5. Data Collection Procedures

3.5.1. Soil sampling and analysis

Initially, the soil samples were taken in zigzag pattern at a depth of 0 - 20 cm across the experimental field from 10 spots using auger. Then, the composite sample was air-dried under shade and well prepared for laboratory analysis. The soil sample was analyzed for selected physico-chemical properties like soil texture, soil pH, cation exchange capacity (CEC), organic carbon, organic matter, total nitrogen, available phosphorus, available sulphur and available boron at Jimma University College of Agriculture and Veterinary Medicine Soil Laboratory and Addis Ababa University Chemistry Laboratory following standard laboratory procedures.

The pH of the soil was determined at 1:2.5 soils to water dilution ratio using a glass electrode attached to 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) whereas available phosphorus was determined by extraction with 0.5 M $NaHCO_3$ according to the methods of Olsen *et al*. (1954). Soil organic carbon content was determined by the wet digestion method as described by Walkley and Black (1954). Total nitrogen was determined using Kjeldahl method as explained in (Sahelemedhin and Taye, 2000). Particle size distribution (soil texture) was done by hydrometer method (differential setting within a water column) according to FAO (2008) using particles less than 2 mm diameter. The procedure measures percentage of sand (0.05 - 2.0 mm), silt (0.002 - 0.05 mm) and clay (< 0.002 mm) fractions in soils. Available B and S were determined by using hot water extraction colorimetric method at Addis Ababa University Chemistry Laboratory.

3.5.2. Crop Phenology and Growth Parameters

Days to 50% heading: Days to spike heading was taken as the number of days taken from the date of emergence to the date of 50% heading of the crops from each plot by visual observation.

Days to 90% physiological maturity: Days to physiological maturity was taken as the number of days from the date of emergence to the date when 90% of the peduncle turned to yellow in straw color. It was recorded when no green color remained on glumes and peduncles of the tagged plants, i.e. when grains were difficult to break with thumb nail.

Grain filling period: It was determined the number of days from anthesis to physiological maturity, i.e. the number of days to maturity minus the number of days to heading.

Plant height (cm): Plant height was measured from the root collar to the tip of the spike (excluding awns) of 10 randomly tagged plants from the net plot area during physiological maturity.

Weed dry biomass (g plot^{-1}): Dry biomass of weeds from each net plot was taken during the three weeding times by using oven dry for 72 hours at 60^{o}C (Jhala *et al*., 2008).

3.5.3. Yield and yield components

Number of total tillers: Number of total tillers was determined from 1 m length of two rows from the net plot and converted to per meter square of net plot at physiological maturity by counting the number of tillers.

Number of productive tillers: Number of productive tillers was determined at maturity time by counting all grain bearing spikes from 1 m length of two rows from the net plot and converted to per meter square of net plot at physiological maturity.

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

Number of spikelets spike^{-1}: The number of spikelet in main tillers of each of the ten randomly selected plants from the net plot was taken.

Number of grains spike^{-1}: The mean number of grains per spike was computed as an average of 10 randomly taken spikes from the net plot area.

Above ground dry biomass plant^{-1} (g): The above ground dry biomass plant^{-1} was determined from 10 randomly selected and tagged plants from the net plot area at harvest.

Above ground dry biomass (kg ha^{-1}): The above ground dry biomass was determined from plants harvested from the net plot area after sun drying and converted to kg ha^{-1}.

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

$$\text{Adjusted thousand grain wheight} \quad = \frac{\text{Grain weight obtained (g)}*(100-\text{MC})}{(100-12.5)}$$

Grain yield plant^{-1} (g): Grain yield per plant was taken from 10 randomly selected and tagged plants from the net plot area at harvest.

Grain yield (kg ha^{-1}): Grain yield was taken by harvesting and threshing the seed yield from net plot area. The grain weight of each plot was recorded in kg and finally, yield plot^{-1} was converted to kg ha^{-1}. The yield was adjusted to 12.5% moisture content.

$$\text{Adjusted grain yield} = \frac{\text{Grain yield obtained }(\frac{\text{kg}}{\text{ha}}) * (100 - \text{MC})}{(100 - 12.5)}$$

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

Harvest index (%): Harvest index was calculated as the ratio of grain yield plot^{-1} to total aboveground dry biomass yield plot^{-1}.

3.6. Statistical Data Analysis

The collected data were subjected to analysis of variance (ANOVA) using the GLM procedure of SAS software. Significantly different treatment means were separated and compared using Least Significant Difference (LSD) test at 5 % significant level and $Y_{ijk} = \mu + B_i + SR_j + FR_k + SR*FR_{jk} + E_{ijk}$ where: μ= overall mean, B_i= block effect, SR_j= seed rates effect, FR_k= fertilizer rates effect, $SR*FR_{jk}$= interaction effect and E_{ijk}= random error effect model was used. Pearson correlation analysis was also performed to determine the association between yield and yield related variables.

3.7. Partial Budget Analysis

Partial budget analysis was performed to investigate the economic feasibility of the treatments. The analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting was used. All costs and benefits were calculated in hectare basis in birr. Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield that the farmers expected from the same treatment.

Gross field benefit (GFB) (ETB ha^{-1}) was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield as GFB = AGY × field/farm gate price for the crop. Total variable cost (TVC) (ETB ha^{-1}) was calculated by summing up the costs that vary, including the cost of NPSB, seed and the application costs of NPSB. The costs of other inputs and production practices such as labour cost for land preparation, planting, weeding, harvesting and threshing were considered as the same for all the treatments or plots. The net benefit (NB) was calculated as the difference between the gross field benefit and the total variable cost using the formula: NB (ETB ha^{-1}) = GFB (ETB ha^{-1}) – TCV (ETB ha^{-1}). Marginal Rate of Return (MRR %) was calculated by dividing the change in net benefit (ΔNB) by change in total variable cost (ΔTVC) then multiplied by 100.

$$\mathrm{MRR}\ (\%) = \frac{\Delta\mathrm{NB}\ (\mathrm{NBb} - \mathrm{NBa})}{\Delta\mathrm{TVC}\ (\mathrm{TVCb} - \mathrm{TVCa})} * 100$$

Where TVCa and TVCb are consecutive treatments, arranged in ascending order based on their TVC. The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and undominated treatments, respectively. Then the treatment with the highest net benefit and marginal rate of more than 100% was considered for the recommendation as described by CIMMYT (1988).

4. RESULTS AND DISCUSSION

4.1. Soil Physico-chemical Properties of the Experimental Site

The results of the physico-chemical properties of the soil were presented in Table 2. The result showed that the soil textural class was clay with a particle size distribution of 18.67% sand, 20.66% silt and 60.67% clay. According to Mariam (1991), soil types used for wheat production vary from well-drained fertile soils to water-logged heavy *Vertisols*. Thus, the soil of the experimental site is suitable for the production of wheat. The pH of the soil was 5.41, which is strongly acidic (Tadesse, 1991). FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range for productive soils for bread wheat.

The soil of the study site had 2.73% of organic carbon (OC) and 4.71% of organic matter (OM), which is medium for both parameters (Table 2). According to the rating of Tadesse (1991), who rated soils having OC value in the range of 0.5-1.5% as low, indicating low potential of the soil to supply nitrogen to plants through mineralization of organic carbon. The medium amount of soil organic carbon might be due to medium addition of crop residues as smallholder farmers use the crop residues for animal feed and wood in the study area. Tadesse (1991) has classified soil total N content of <0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and > 0.25% as high. According to this classification, the soil had moderate total N (0.23%).

The analysis revealed that the available P of the soil was 7.13 mg kg^{-1} (Table 2). Indicative ranges of available phosphorus have been established by Olsen *et al*. (1954), as <5 mg kg^{-1} (very low), 5-15 mg kg^{-1} (low), 15-25 mg kg^{-1} (medium), and >25 mg kg^{-1} of soil (high). Thus, the soil of the experimental site was considered as low in available P content. Thus, it is important to apply phosphorus fertilizer from external sources based on the recommended rate. The analysis for available sulphur also indicated that the experimental soil had values of 6.96 mg kg^{-1} which is very low according to Ethiosis (2014). Thus, indicating that the sulphur nutrient to be a limiting factor for wheat production in the study area. This might be mainly due to poor sulphur containing parent material of soil, land degradation, crop residue removal, crop uptake, and low soil organic matter, use of non-S containing fertilizers (only N and P).

The analysis for available boron also indicated that the experimental soil had value of 0.41 mg kg^{-1} which is rating as very low according to waldren (2004).

Table 2. Selected physico-chemical properties of the soil of the experimental site before sowing

Parameter	Values	Rating	References
Soil Texture			
Sand (%)	18.67		
Silt (%)	20.66		
Clay (%)	60.67		
Textural class		Clay	
pH (1 : 2.5 H_2O)	5.41	Strongly acid	Tadesse (1991)
Organic Carbon (%)	2.73	Medium	Tadesse (1991)
Organic Matter (%)	4.71	Medium	Tadesse (1991)
Total N (%)	0.23	Moderate	Tadesse (1991)
Available Phosphorus (mg kg^{-1})	7.13	Low	Olsen (1954)
Available Sulfur (mg kg^{-1})	6.96	Very low	Ethiosis (2014)
Available Boron (mg kg^{-1})	0.41	Very low	waldren (2004)
CEC [Cmol(+) kg^{-1} soil]	39.74	High	Landon (1991)

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), topsoil having CEC greater than 40 cmol (+) kg^{-1} are rated as very high and 25-40 cmol (+) kg^{-1} as high, and 15-25, 5-15 and < 5 cmol (+) kg^{-1} of soil are classified as medium, low and very low, respectively, in CEC. According to this classification, the soil of the experimental site had high CEC (39.74 cmol (+) kg^{-1} soil), indicating its high capacity to retain cations (Table 2).

4.2. Main Effects of NPSB Fertilizer and Seeding Rates on Phenological and Growth Variables

4.2.1. Days to 50% heading

The analysis of variance revealed that the main effects of NPSB blended fertilizer rate, seeding rate as well as the interaction of the two factors had no significant effect ($P > 0.05$) on days to 50% heading (Appendix Table 1).

4.2.2. Days to 90% physiological maturity

The analysis of variance showed that the main effect of NPSB fertilizer had significant ($P < 0.05$) effect on the days to 90% physiological maturity of bread wheat, while the main effects of seeding rate and interaction had no significant ($P > 0.05$) influence on this parameter (Appendix Table 1). The longest period to physiological maturity (107 days) was observed from the highest rate of NPSB (200 kg ha^{-1}) whereas, 97.83 days was observed from the control (Table 3). The longest period of physiological maturity might be due to adequate blended NPSB fertilizer has a great contribution to the vigorous vegetative growth and development. Nitrogen is involved in all major processes of plant development and yield formation. Besides, a good supply of nitrogen to the plant stimulates root growth and development as well as uptake of other nutrients (FAO, 2000; Brady and Weil, 2002). An adequate supply of N is associated with high photosynthetic activity and vigorous vegetative growth as a result it delayed the crop maturity.

The current result is in agreement with the result of Diriba *et al.* (2019) who reported that the longest days to physiological maturity (113 days) of bread wheat was observed from 300 kg ha^{-1} NPSB application with supplementary urea while, the shortest days to physiological maturity was observed from the control. This result is also in agreement with the finding of Brzegen (2019) who stated that increasing days to 90% physiological maturity with increasing NPS rates and the longer days to 90% physiological maturity was recorded from 210 kg ha^{-1} NPS and the shorter days to 90% physiological maturity was recorded from 120 kg ha^{-1} of NPS.

Similarly, the result of Harfe (2017) showed that increasing the N/P_2O_5 fertilizer from zero level to 69/30 kg ha^{-1} for wheat, prolonged the physiological maturity from 124.87 to 127 days. Tigre *et al*. (2014) also reported that, days to maturity in barley was delayed by the effect of Nitrogen and phosphorous fertilizers in combination with the other important nutrients and delay in maturity time was greater at higher fertilizer combinations. On the other hand, the current result is in contrast with that of Kedir (2023) who reported that the longest and shortest days to physiological maturity were recorded from the application of the 0 kg ha^{-1} and 150 kg ha^{-1} of NPS fertilizer rates, respectively.

4.2.3. Grain filling period

The analysis of variance indicated that the main effect of NPSB fertilizer had significant ($P < 0.05$) effect on the grain filling period of bread wheat, while the main effects of seeding rate and interaction had no significant ($P > 0.05$) effect on this parameter (Appendix Table 1). The result indicated that, grain filling period was increased with increasing the rate of NPSB fertilizer. Thus, increasing NPSB fertilizer rate from 100 to 200 kg ha^{-1} increased days to grain filling period from 36.83 to 46.33 days. However, statistically, there was no a significant difference between control and the treated treatments of 50, 100 and 150 kg ha^{-1} (Table 3). Increased grain filling period as the NPSB fertilizer rate increased might be due to sufficient nitrogen application that makes plants to take up nitrogen from the time the roots begin to function until all uptakes of nutrients ceases with maturity which could have extended green canopy duration by delaying whole plant senescence and extend the grain filling period. This result is in line with Ishete and Tana (2019) who reported that grain filling period was increased with increasing rate of supplemented nitrogen and increasing the rates of nitrogen supplemented from nil to the highest 92 kg ha^{-1} N increased days to grain filling period by about 7.76%.

4.2.4. Plant height

The analysis of variance revealed that the main effects of NPSB fertilizer and seeding rates had significant ($P < 0.05$) effect on plant height, while the interaction effect had no significant ($P > 0.05$) effect on this parameter (Appendix Table 1). The maximum application of NPSB fertilizer rate (200 kg ha^{-1}) resulted in the highest plant height (79.28 cm), while the shortest plant height (65.19 cm) was recorded from the rate of 0 kg ha^{-1} NPSB (Table 3). Generally, plant height increases with increasing NPSB rate could be due to NPSB fertilizer has a great contribution to the vigorous vegetative growth and development of the crop. The current result is in line with the finding of Abera *et al*. (2020) who reported that increasing the rate of NPSB fertilizer significantly increased plant height and the maximum application of NPSB blended fertilizer rate (183 kg ha^{-1}) resulted in the highest plant height (78.5 cm). This result is also in agreement with the finding of Brzegen (2019) who showed that the highest plant height (91.22 cm) was recorded from the highest NPS fertilizer rate (210 kg ha^{-1}). Similar finding was reported by Tesfahun (2018) who indicated that increase in plant height with increasing NPS fertilizer could be attributed due to sufficient supply of nutrient which in turn facilitates plants growth since nitrogen plays a crucial role in the structure of chlorophyll and P_2O_5 involved in the energy transfer for cellular metabolism. Similarly, Geneti *et al.* (2017) reported the highest plant height (65.5 cm) was recorded from durum wheat when maximum rate (92 kg ha^{-1}) of nitrogen was applied.

With respect to seeding rate, plant height was increased as seeding rate increased (Table 3). The highest plant height (77 cm) was recorded from 150 kg ha^{-1} seeding rate while, the shortest plant height (68.37 cm) was obtained from 100 kg ha^{-1} of seeding rate. Higher plant height was resulted at higher seeding rate due to high competition for light among wheat plants as a result plants prefer to grow up ward rather than expand horizontally. At higher seeding rate, lower light penetration results in increasing inter node length, reducing stem thickness and increasing plant height (Otteson *et al*., 2007).

The current result is in line with the result of Ali *et al*. (2004) who reported that increasing plant density from 300 to 400 or 500 grains m^{-2} significantly increased plant height (103.8 cm). Similarly, Kilic and Gursoy (2010) reported that the highest plant height was recorded from 550 seeds m^{-2} while the shortest plant height (96.7 cm) was recorded from 50 seeds m^{-2}. Likewise, Soomro *et al*. (2009) showed that wheat sowing at higher seeding rate produced highest plant height (101.25 cm). This result is also in line with the result of Brzegen (2019) who showed that the highest plant height (91.93cm) was recorded from the higher seeding rate of 175 kg ha^{-1}, while the shortest plant heights of 86.01cm and 86.04 cm were recorded from 125 and 100 kg ha^{-1} seeding rates, respectively.

The current result is in conformity with the result of Mekonnen (2017) who obtained that as seeding rate increased from 100 kg ha^{-1} to 175 kg ha^{-1}, the height of the plant correspondingly increased from 76.86 to 81.76 cm. Naseri *et al*. (2012) also reported that the highest plant densities (450 m^{-2}) and the lowest plant densities (300 m^{-2}) results in highest and shortest plant height, respectively. In addition, other authors reported that plant height of wheat grown at the lowest seeding rate was significantly lower than the height of plants grown at higher seeding rates (Laghari *et al*. 2011; Haile *et al*. 2013; Ayalew *et al*. 2017). However, the current result is in contrast with that of (Laghari *et al.* 2011; Tigabu and Asfaw 2016) who reported that when the seeding rate for wheat increased from 100 kg ha^{-1} to 150 kg ha^{-1}, the plant height was decreased which might be due to the fact that increasing of seeding rate without consideration of resources like water, nutrient, light and other management factor in an area of production could result in maximum competition for resource and the plant become stunted.

Table 3. Main effects of NPSB fertilizer and seeding rates on phenological, growth and yield components of bread wheat

Seeding rate (kg ha^{-1})	DH (days)	DM (days)	GFP (days)	PH (cm)	SL (cm)	NSPS	GYPP (g)	HI (%)	WDB (g)
100	60.8	99.7	38.9	68.37^{c}	8.96^{a}	18.76	1.78^{a}	44.34	234.80^{a}
125	61	100.25	39.25	71.95^{b}	8.56^{b}	18.45	1.85^{a}	46.01	202.00^{b}
150	60.7	99.95	39.25	77.00^{a}	8.20^{c}	18.85	1.73^{b}	44.89	176.40^{c}
LSD	1.07	1.36	1.63	1.68	0.3	0.41	0.09	1.96	9.13
P value	0.8487	0.718	0.8827	<.0001	<.0001	0.1292	0.04	0.23	<.0001
NPSB rate (kg ha^{-1})									
0	60.75	97.83^{b}	37.08^{b}	65.19^{e}	7.10^{c}	13.93^{d}	1.62^{b}	39.18^{d}	168.00^{d}
50	60.5	98.67^{b}	38.17^{b}	69.49^{d}	8.67^{b}	18.78^{c}	1.79^{a}	43.82^{c}	191.67^{c}
100	61.08	97.92^{b}	36.83^{b}	72.87^{c}	9.00^{ab}	19.89^{b}	1.84^{a}	47.62^{ab}	200.67^{c}
150	61.17	98.42^{b}	37.25^{b}	75.37^{b}	9.01^{ab}	20.19^{ab}	1.88^{a}	48.87^{a}	221.00^{b}
200	60.67	107.00^{a}	46.33^{a}	79.28^{a}	9.08^{a}	20.64^{a}	1.80^{a}	45.90^{bc}	240.67^{a}
LSD (0.05)	1.39	1.75	2.1	2.17	0.39	0.53	0.12	2.54	11.78
P value	0.85	<.0001	<.0001	<.0001	<.0001	<.0001	0.0009	<.0001	<.0001
CV (%)	2.77	2.13	6.53	3.63	5.56	3.44	8.18	6.9	7

Means followed with the same letter (s) in the column of each factor is not significantly different at 5% level; CV (%) = Coefficient of variation; LSD (0.05) = Least Significant Difference at 5% level; SE = Standard Error; DH= Days to heading; DM= Days to physiological maturity; GFP= Grain filling period; PH= Plant height; SL= Spike length; NSPS= Number of spikelet per spike; GYPP= Grain yield per plant; HI= Harvest index; WDB= Weed dry biomass.

4.2.5. Spike length

The analysis of variance revealed that the main effects of NPSB fertilizer and seeding rates had significant ($P < 0.05$) effect on spike length, while the interaction effect had no significant ($P > 0.05$) effect on this parameter (Appendix Table 1). The result showed that increasing the rate of NPSB fertilizer increased the spike length. Thus, the longest spike (9.08 cm) was obtained from 200 kg ha^{-1} NPSB fertilizer rate, but statistically similar with 100 and 150 kg ha^{-1} of NPSB fertilizer rates, while the shortest spike length (7.1 cm) was recorded from control (Table 3). The increase in spike length at the highest NPSB fertilizer rate might have resulted from improved root growth and increased uptake of nutrients, better growth and activate cell division favored due to the synergetic effect of the four nutrients and availability of adequate crop nutrients at the highest rate.

This result is in line with the result of Dawit (2018) who reported that increasing the rate of NPS fertilizer increased spike length and the longest spike (7.77 cm) was obtained from 200 kg ha^{-1} NPS fertilizer rate, while the shortest spike (6.7 cm) was recorded from control. This result also in agreement with the findings of Getachew and Dechassa (2014) who reported that the maximum spike length (8.29 cm) was recorded from a combined application of 64 kg ha^{-1} P_2O_5 + 46 kg ha^{-1} N. Similarly, Masebo (2016) also reported that the highest spike length (7.7 cm) was recorded from 50/150 N/P_2O_5 kg ha^{-1}. In contrast with this result, Khan *et al.* (2000) reported that spike length is a genetic character of a variety, which is less influenced by agronomic practices like fertilizer application.

The longest spike (8.96 cm) was recorded from the lowest seeding rate (100 kg ha^{-1}) whereas, the shortest spike length (8.20 cm) was obtained from the highest seeding rate (150 kg ha^{-1}) (Table 3). Higher spike length at lower seeding rate might be due to presence of more free space between plants might help to avoid competition between plants in the lower seeding rates. In harmony with the present findings, Assefa *et al.* (2015) reported that the highest spike length (7.65 cm) was measured from the lowest planting density (150 m^{-2}) and the lowest spike length (7.25 cm) was measured from the highest planting density (500 m^{-2}). Similarly, Seleiman *et al.* (2010) reported that higher seeding rate reflects lower rate of photosynthesis and growth of wheat plants, which was expressed in noticeable decrease in spike length.

Furthermore, Jemal *et al*. (2015) reported that with increasing seeding rate from 125 kg ha^{-1} to 200 kg ha^{-1}, the spike length was declined by 8.57%. Additionally, Adinew (2015) reported that increasing seeding rate from 100 kg ha^{-1} to 150 kg ha^{-1} decrease the spike length. Similarly, Tigabu and Asfaw (2016) reported that increasing seeding rate from 75 to 150 kg ha^{-1}, the spike length was decreased from 6.80 cm to 6.33 cm. The present result is also similar with the result of Brzegen (2019) who reported that the highest (8.50 cm) and the lowest (7.81 cm) spike length were recorded from the lowest seeding rate (100 kg ha^{-1}) and the highest seeding rate (150 kg ha^{-1}) respectively. In contrast with current result, Iqbal *et al.* (2012) reported that maximum spike length (12.81 cm) was recorded from seeding rate of 150 kg ha^{-1} and it was statistically at par with 175 kg ha^{-1} (12.60 cm), while the minimum spike length (12.08 cm) was recorded from 125 kg ha^{-1} seeding rate. The current result is also in contrast with the result of Baloch *et al.* (2010) who reported that different seeding rates had no significant effect on spike length which might be a condition when there is an ample resource, which indicates no more competition.

4.2.6. Weed dry biomass

The analysis of variance revealed that the main effects of NPSB fertilizer and seeding rates had significant ($P < 0.05$) effect on weed dry biomass, while the interaction effect had no significant ($P > 0.05$) effect on this parameter (Appendix Table 1). The highest weed dry biomass (240.67 g) was recorded from 200 kg ha^{-1} NPSB fertilizer rate followed by 150 kg ha^{-1} NPSB fertilizer rate (221 gm) whereas, the lowest weed dry biomass (168 g) was recorded from control (Table 4). Weed dry biomass increased significantly by 25.56% when the NPSB fertilizer rate was increased from 50 to 200 kg ha^{-1} (Table 3).

The result also showed that increasing the seeding rate from 100 kg ha^{-1} to 150 kg ha^{-1} decreased the weed dry biomass. Thus, the highest weed dry biomass (234.8 g) was recorded from 100 kg ha^{-1} seeding rate followed by 125 kg ha^{-1} (202 g) whereas; the lowest weed dry biomass (176.4 g) was recorded from 150 kg ha^{-1} seeding rate (Table 3). Weed dry biomass was decreased significantly by 33.12% when seeding rate increased from 100 to 150 kg ha^{-1}.

At low seeding rate, weeds might have a favorable environment that provided them an opportunity for easier germinate and faster growth and development. But at high seeding rates, the crop had a competitive advantage over weeds and closed canopy earlier, thus, reducing weed growth (Phuong *et al*. 2005; Lemerle *et al*. 2004; Anwar *et al*. 2011). This finding was in conformity with the results of Ahmed *et al*. (2014) who reported that weed dry biomass was decreased when seeding rate increased.

4.3. Main Effects of NPSB Fertilizer and Seeding Rates on Yield Components and Yield

4.3.1. Numbers of spikelets spike^{-1}

The analysis of variance showed that the main effect of NPSB fertilizer had significant ($P < 0.05$) effect on numbers of spikelets spike^{-1}, while the main effects of seeding rate and interaction had no significant ($P > 0.05$) effect on this parameter (Appendix Table 2). As shown in Table 3, the maximum numbers of spikelets spike^{-1} (20.64**)** were counted from 200 kg ha^{-1} NPSB fertilizer rate but, it was statistically similar with 150 kg ha^{-1} of NPSB fertilizer rate, while the minimum numbers of spikelets spike^{-1} (13.93) were counted from the control (Table 3). Nitrogen fertilizer has significant effects on the numbers of spikelets spike^{-1} as reported by (Khan *et al.* 2001; Naeem 2001; Khan *et al.* 2002).

4.3.2. Grain yield plant^{-1}

The analysis of variance revealed that the main effect of NPSB fertilizer rate had significant ($P < 0.05$) effect on grain yield plant^{-1}. The main effect of seeding rate had significant ($P < 0.05$) effect on grain yield plant^{-1} while, the interaction effect had no significant ($P > 0.05$) effect on this parameter (Appendix Table 2).The highest grain yield plant^{-1} (1.88 g) was obtained from 150 kg ha^{-1} NPSB fertilizer rate but, it was statistically at par with 50, 100, and 200 kg ha^{-1} NPSB fertilizer rates whereas, the lowest grain yield plant^{-1} (1.62 g) was recorded from the control (Table 3).

The current result also showed that increasing of seeding rate from 125 kg ha^{-1} to 150 kg ha^{-1} decreased the grain yield plant^{-1}. Thus, the highest grain yield plant^{-1} (1.85 g) was recorded from 125 kg ha^{-1} seeding rate but, it was statistically similar with 100 kg ha^{-1} seeding rate

(1.785 gm) whereas, the lowest grain yield plant^{-1} (1.73 g) was recorded from 150 kg ha^{-1} of seeding rate (Table 3).

4.3.3. Harvest index

The analysis of variance indicated that the main effect of NPSB fertilizer had significant ($P < 0.05$) effect on the harvest index, while the main effects of seeding rate and interaction had no significant ($P > 0.05$) effect on this parameter (Appendix Table 2). Hence, the highest harvest index (48.87%) was calculated from 150 kg ha^{-1} NPSB fertilizer rate but, it was statistically at par with 100 kg ha^{-1} of NPSB fertilizer rate (47.62%) whereas, the lowest harvest index (39.18%) was calculated from the control (Table 3). Harvest index tended to increase with increased application of NPSB fertilizer until 150 kg ha^{-1} might be attributed to greater photo assimilate production and its ultimate partitioning into grains as compared with biomass yield.

This finding was in conformity with the results of (Dawit 2018; Amare 2018) who reported that the highest harvest index (42% and 46.2%) were obtained from 150 kg ha^{-1} NPS fertilizer rate, whereas the lowest harvest index (32% and 33%) were recorded from the control. The current result is also in agreement with the result of Brzegen (2019) who reported that the highest harvest index (39.54 %) was recorded from 210 kg ha^{-1} NPS fertilizer rate, while the lowest harvest index (35.47 %) was recorded from 120 kg ha^{-1} of NPS fertilizer rate. In contrary to this result, Habte *et al*. (2015) reported that harvest index was not significantly affected by N and P fertilizer rates. The current result is also in contrast with the result of Diriba *et al*., (2019) who reported that the highest and lowest harvest index (40.1 % and 30.4%) were recorded from control and 300 kg ha^{-1} NPSB fertilizer rates respectively.

4.4. Interaction Effect on Yield Components and Yield

4.4.1. Numbers of total tillers m^{-2}

The analysis of variance indicated that the main effects of NPSB fertilizer rate, seeding rate and their interaction highly significant ($P < 0.05$) effect on numbers of total tillers m^{-2} (Appendix Table 1). Hence, The maximum numbers of total tillers m^{-2} (431.87) were counted from 150 kg ha^{-1} NPSB fertilizer rate with 150 kg ha^{-1} of seeding rate but, statistically there was no significant difference with 100 kg ha^{-1} NPSB fertilizer rate combined with 100 and

125 kg ha^{-1} of seeding rates, whereas the minimum numbers of total tillers m^{-2} (196.25) were counted from 100 kg ha^{-1} seeding rate with the control (Table 4). This might be due to the rapid conversion of synthesized carbohydrates into protein and consequently the increase in number and size of growing cells, which enhances increased number of tillers. Root proliferation might be increased in high phosphorus region to enhance phosphorus uptake, especially during early growth stage (Cook and Veseth, 1991).

In conformity with this result, Dawit (2018) reported that the total numbers of tillers were increased significantly across the increased NPS fertilizer combined with seeding rates and the maximum numbers of total tillers m^{-2} (466.7) were recorded from 200 kg ha^{-1} NPS fertilizer with 150 kg ha^{-1} seeding rates followed by 150 kg ha^{-1} NPS fertilizer with 150 kg ha^{-1} seeding rates. However, the minimum numbers of total tillers m^{-2} (160) were recorded from 100 kg ha^{-1} of seeding rate with the control. In contrast with this result, Kedir (2023) reported that the interaction effect of NPS fertilizer and seeding rates was non-significant effect on numbers of total tillers.

4.4.2. Numbers of productive tillers m^{-2}

The analysis of variance indicated that the main effects of NPSB fertilizer rate, seeding rate and their interaction had significant ($P < 0.05$) effect on numbers of productive tillers m^{-2} (Appendix Table 1). The maximum numbers of productive tillers m^{-2} (318.12) were recorded from 100 kg ha^{-1} NPSB fertilizer combined with 125 kg ha^{-1} of seeding rate but, statistically there was no significant difference with 150 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} of seeding rate, whereas the minimum numbers of productive tillers m^{-2} (161.87) were recorded from 100 kg ha^{-1} of seeding rate combined with the control (Table 5). This might be due to the increasing seed rate increased plants emerged in an area and NPSB fertilizer favored tillering as a result the more number of fertile tillers were obtained. The current result is in line with the result of Kedir (2023) who reported that the more numbers of productive tillers m^{-2} (631.7) were recorded from 150 kg ha^{-1} NPS fertilizer rate combined with 150 kg ha^{-1} of seeding rate, while less numbers of productive tillers m^{-2} (485) were recorded from 100 kg ha^{-1} seeding rate combined with the control.

The current result is in agreement with the result of Dawit (2018) who reported that the maximum numbers of productive tillers m^{-2} (413.3) were recorded from 200 kg ha^{-1} NPS fertilizer rate combined with 150 kg ha^{-1} seeding rate followed by 150 kg ha^{-1} NPS fertilizer rate combined with 150 kg ha^{-1} of seeding rate, whereas the minimum numbers of productive tillers m^{-2} (110) were recorded from 100 kg ha^{-1} of seeding rate combined with the control. Likewise, Assefa *et al*. (2015) reported that the highest numbers of effective tillers m^{-2} (357.3) were recorded from the combination of 92/69 N/P_2O_5 kg ha^{-1} fertilizer rates with 177 kg ha^{-1} seeding rate.

4.4.3. Numbers of grains spike^{-1}

The analysis of variance indicated that the main effects of NPSB fertilizer rate, seeding rate and their interaction had significant ($P < 0.05$) effect on numbers of grains spike^{-1} (Appendix Table 2). The highest numbers of grains spike^{-1} (55.27) were obtained from 150 kg ha^{-1} NPSB fertilizer rate combined with 125 kg ha^{-1} of seeding rate but, it was statistically at par with 150 kg ha^{-1} NPSB fertilizer rate combined with 100 kg ha^{-1} seeding rate, 100 kg ha^{-1} NPSB fertilizer rate combined with 100 and 125 kg ha^{-1} seeding rates and 50 kg ha^{-1} NPSB fertilizer rate combined with 125 kg ha^{-1} of seeding rate. However, the lowest numbers of grains spike^{-1} (38.22) were recorded from 100 kg ha^{-1} seeding rate combined with the control (Table 4). Increased numbers of grains spike^{-1} might be due to optimum crop stand with better nutrition of NPSB fertilizer. Better nutrition enhanced the source capacity to better fill of the sink. Nitrogen is the most important nutrient which affects the assimilate production and distribution and also affecting directly and indirectly the source-sink relation (Aynehband *et al*., 2010).

This indicated that the number of grains per spike was more enhanced by NPSB, which might be P is essential in development of grains. This might be also due to the reason that Boron plays a vital role in grain setting of wheat. Therefore, the supply of boron contains fertilizer helps in grain filling and ultimately sterility is reduced and number of grains per spike increased. At higher seeding rate most grains would fade at early stage because of competition between growing grains to absorb preserved matters and as the result low grains per spike would be produced (Naseri *et al*., 2012). This result is in agreement with the result of Yimenu and Bekele (2021) who reported that the highest and lowest numbers of grains spike^{-1} (49.5) and (30.17) were recorded from 125 kg ha^{-1} of seeding rate combined with 150 kg ha^{-1} NPSB fertilizer rate and 200 kg ha^{-1} seeding rate combined with the control respectively.

The current finding was also in conformity with the results of Kedir (2023) who reported that the maximum numbers of grains spike^{-1} (40.67) were recorded from 250 kg ha^{-1} NPS fertilizer rate combined with 100 kg ha^{-1} seeding rate; 200 kg ha^{-1} NPS fertilizer rate combined with 150 kg ha^{-1} seeding rate and the minimum numbers of grains spike^{-1} (25) were recorded from 150 kg ha^{-1} of seeding rate combined with the control. This finding was also in conformity with the results of Shah *et al*. (2011) who reported that the maximum (68.25) numbers of grains spike^{-1} were recorded from 120 kg ha^{-1} seeding rate combined with 120 kg ha^{-1} N, while less (44.75) numbers of grains spike^{-1} were recorded from 60 kg ha^{-1} seeding rate combined with the control. However, the present finding is in contrast with the finding of Dawit (2018) who reported that the interaction effect of NPS fertilizer rate and seed rate was not significantly affected the number of grains spike^{-1} of bread wheat.

4.4.4. Thousand grains weight

Thousand grains weight is an important yield determining component of the crop. The analysis of variance showed that the main effects of NPSB fertilizer rate, seeding rate and their interaction had significant ($P < 0.05$) effect on thousand grains weight (Appendix Table 2). It is evident from the data that the maximum thousand grains weight (51.26 g) was obtained from 150 kg ha^{-1} NPSB fertilizer rate combined with 125 kg ha^{-1} of seeding rate, while the minimum thousand grains weight (35.59 g) was recorded from 50 kg ha^{-1} NPSB fertilizer rate combined with 125 kg ha^{-1} of seeding rate but, it was statistically at par with 50 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} seeding rate, 100 kg ha^{-1} NPSB fertilizer rate combined with 100 and 125 kg ha^{-1} seeding rate, 150 kg ha^{-1} NPSB fertilizer rate combined with 100 kg ha^{-1} seeding rate and 200 kg ha^{-1} NPSB fertilizer rate combined with 125 and 150 kg ha^{-1} of seeding rate (Table 4). The reduced grains weight with higher seeding rate might be due to greater competition among plants in plots seeded at the highest rate as compared to plants in plots where less seeding rate was used. Higher NPSB fertilizer rate leads to higher vegetative growth but decreases the grain weight. This result is in agreement with the result of Yimenu and Bekele (2021) who found that the highest thousand grains weight (40 g) was recorded, from 125 kg ha^{-1} seeding rate combined with 150 kg ha^{-1} of NPSB fertilizer rate, while the lowest thousand grains weight (34.67 g) was recorded from 200 kg ha^{-1} of seeding rate combined with the control.

Brzegen (2019) also reported that, the maximum thousand grains weight (64.08 g) was recorded from 100 kg ha^{-1} seeding rate combined with 150 kg ha^{-1} of NPS fertilizer rate but, it was statistically similar with 125 kg ha^{-1} seeding rate combined with 150 kg ha^{-1} of NPS fertilizer rate. Yang *et al*. (2019) also showed that, the increment of thousand grains weight from the maximum N fertilizer rate combined with the minimum seeding rate. The current result is in contrast with the result of shah *et al*., (2011) who reported that, the maximum thousand grains weight (44.2 g) was obtained from 120 kg ha^{-1} seeding rate combined with 120 kg ha^{-1} N fertilizer rate while, the minimum thousand grains weight (35.35 g) was obtained from 60 kg ha^{-1} of seeding rate combined with the control. The current result is also in contrast with the result of Dawit (2018) who reported that thousand grains weight was not significantly affected by main effect of NPS fertilizer rate, seeding rate, and their interaction effect, in which it is a genetic characteristic of a plant and therefore, less affected by environmental factors.

Table 4. Interaction effects of NPSB fertilizer and seeding rates on yield and yield components of bread wheat

NPSB rate (kg ha^{-1})	Seed rate (kg ha^{-1})	NTT m^{-2}	NPT m^{-2}	NGPS	TGW (g)	ADBPP (g)	ADB (kg ha^{-1})	GY (kg ha^{-1})	SY (kg ha^{-1})
	100	196.25^{h}	161.87^{g}	38.22^{g}	38.89^{bcde}	2.57^{e}	5247.60^{h}	2007^{i}	3240.6^{f}
0	125	270.62^{f}	193.12^{f}	45.87^{ef}	41.22^{bc}	2.57^{e}	5714.60^{h}	2200^{i}	3514.6^{ef}
	150	340.00^{d}	245.00^{e}	44.15^{f}	38.96^{bcde}	2.95^{d}	5338.90^{h}	2100^{i}	3238.9^{f}
	100	251.25^{g}	191.25^{f}	50.55^{bcd}	39.65^{bcd}	3.57^{a}	5800.30^{h}	2475^{h}	3325.3^{f}
50	125	302.50^{e}	241.87^{e}	51.45^{abc}	35.59^{f}	3.10^{bcd}	6941.50^{g}	3100^{g}	3841.5^{def}
	150	336.87^{d}	271.25^{d}	46.67^{def}	37.04^{def}	3.32^{abc}	10197.30^{d}	4330^{c}	5867.3^{b}
	100	313.12^{e}	248.75^{e}	52.02^{abc}	38.07^{cdef}	3.45^{a}	7099.30^{fg}	3300^{fg}	3799.3^{def}
100	125	423.75^{a}	318.12^{a}	53.75^{ab}	36.32^{ef}	3.05^{cd}	7241.50^{fg}	3480^{ef}	3761.5^{def}
	150	345.62^{d}	271.87^{d}	50.75^{bcd}	40.99^{bc}	3.40^{ab}	10950.30^{c}	5100^{b}	5850.3^{b}
	100	261.87^{fg}	183.75^{f}	54.30^{ab}	38.02^{cdef}	3.05^{cd}	7612.00^{f}	3568de	4044.0^{e}
150	125	391.87^{b}	282.50^{cd}	55.27^{a}	51.26^{a}	3.32^{abc}	8517.60^{e}	4200^{c}	4317.6^{cd}
	150	431.87^{a}	304.37^{ab}	49.35^{cde}	41.94^{b}	3.42^{a}	11941.60^{b}	5800^{a}	6141.6^{b}
	100	395.62^{b}	278.12^{d}	50.22^{bcd}	38.99^{bcde}	3.40^{ab}	8527.40^{e}	3790^{d}	4737.4^{c}
200	125	375.00^{c}	296.87^{bc}	50.22^{bcd}	37.23^{def}	3.37^{ab}	10528.00^{cd}	4900^{b}	5628.0^{b}
	150	338.75^{d}	272.50^{d}	50.32^{bcd}	37.55^{def}	3.05^{cd}	12888.80^{a}	5750^{a}	7138.8^{a}
LSD (0.05)		13.04	15.9	4.3	3.21	0.3	588.85	256.22	651.54
P value		<.0001	<.0001	0.0278	<.0001	0.0007	<.0001	<.0001	<.0001
CV (%)		2.75	4.44	6.08	5.37	6.69	4.97	4.8	10

Means followed with the same letter (s) in the column are not significantly different at 5% level; CV (%) = Coefficient of variation; LSD (0.05) = Least Significant Difference at 5% level; SE = Standard Error; NTT= Number of total tillers; NPT= Number of productive tillers; NGPS= Number of grains spike^{-1}; TGW= Thousand grain weight; ADBPP= Above ground dry biomass plant^{-1}; ADB= Above ground dry biomass ha^{-1}; GY= Grain yield; SY= Straw yield.

4.4.5. Above ground dry biomass plant^{-1}

Biological yield represent the overall growth performance of the plant and is considered to be the essential yield parameter to get useful information about overall growth of the crop. The analysis of variance revealed that the main effects of NPSB fertilizer rate and interaction had significant ($P < 0.05$) effect on above ground dry biomass plant^{-1} while, the main effect of seeding rate had no significant ($P > 0.05$) effect on this parameter (Appendix Table 2). The highest aboveground dry biomass plant^{-1} (3.57 g) was recorded from 50 kg ha^{-1} NPSB fertilizer rate combined with 100 kg ha^{-1} seeding rate but, it was statistically similar with 50 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} seeding rate, 100 kg ha^{-1} NPSB fertilizer rate combined with 100 and 150 kg ha^{-1} seeding rate, 150 kg ha^{-1} NPSB fertilizer rate combined with 125 and 150 kg ha^{-1} seeding rate and 200 kg ha^{-1} NPSB fertilizer rate combined with 100 and 125 kg ha^{-1} seeding rate. Whereas, the lowest aboveground dry biomass plant^{-1} (2.57 g) was recorded from 100 kg ha^{-1} seeding rate combined with the control but, it was statistically similar with 125 kg ha^{-1} of seed rate combined with the control (Table 4).

4.4.6. Above ground dry biomass ha^{-1}

The analysis of variance showed that the main effects of NPSB fertilizer rate, seeding rate and their interaction had significant ($P < 0.05$) effect on the above ground dry biomass ha^{-1} (Appendix Table 2). The highest aboveground dry biomass yield (12888.8 kg ha^{-1}) was recorded from 200 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} of seeding rate, whereas the lowest aboveground dry biomass yield (5247.6 kg ha^{-1}) was recorded from 100 kg ha^{-1} of seeding rate combined with the control but, it was statistically at par with 125 kg ha^{-1} seeding rate combined with the control, 150 kg ha^{-1} seeding rate combined with the control and 100 kg ha^{-1} seeding rate combined with 50 kg ha^{-1} of NPSB fertilizer rate (Table 4). This might be due to the increased plant population from the highest seeding rate with the highest NPSB fertilizer rate improved root growth and increased uptake of nutrients favoring better growth due to synergetic effect of the four nutrients.

This result is similar with the findings of Brzegen, (2019) who reported that the highest total biomass yield (12.46 t ha^{-1}) was recorded from 175 kg ha^{-1} seeding rate combined with 210 kg ha^{-1} of NPS fertilizer rate and it was statistically similar with 125 kg ha^{-1} seeding rate combined with 150 kg ha^{-1} NPS fertilizer rate and 150 kg ha^{-1} seeding rate combined with 210 kg ha^{-1} of NPS fertilizer rate. On the other hand, the lowest total biomass yield (9.86 t ha^{-1}) was obtained from the lowest seeding rate (100 kg ha^{-1}) combined with the lowest NPS fertilizer rate (120 kg ha^{-1}). The current result is also in agreement with the results of Feyisa *et al*. (2023) who reported that the dry biomass yield of wheat was significantly affected by N fertilizer rate combined with seeding rate and the highest dry biomass yield (10.7 t ha^{-1}) was obtained from 92 kg ha^{-1} N combined with 175 kg ha^{-1} of seeding rate. In line with the current finding, Shah *et al*., (2011) reported that the maximum biological yield (11270 kg ha^{-1}) was resulted from 120 kg ha^{-1} seeding rate combined with 120 kg ha^{-1} N fertilizer rate, while the minimum biological yield (6741.25 kg ha^{-1}) was resulted from 60 kg ha^{-1} seeding rate combined with the control.

Similarly, Iqbal *et al*., (2012) also reported that, the higher biological yield (9906 kg ha^{-1}) was found from 150 kg ha^{-1} seeding rate combined with 125 kg ha^{-1} N fertilizer rate while, the lower biological yield (8141 kg ha^{-1}) was obtained from 125 kg ha^{-1} seeding rate combined with the control. However, in contrast to the present result, Dawit (2018) reported that interaction between seeding rate and NPS fertilizer rate had no significant effect on biomass yield of bread wheat.

4.4.7. Grain yield ha^{-1}

The analysis of variance revealed that the main effects of NPSB fertilizer rate, seeding rate and their interaction had significant ($P < 0.05$) effect on the grain yield ha^{-1} (Appendix Table 2). The highest grain yield (5800 kg ha^{-1}) was obtained from 150 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} of seeding rate but, it was statistically similar with 200 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} of seeding rate with grain yield of 5750 kg ha^{-1}, whereas the lowest grain yield (2007 kg ha^{-1}) was recorded from 100 kg ha^{-1} seeding rate combined with the control but, it was statistically at par with 125 and 150 kg ha^{-1} seeding rate combined with the control (Table 4). This might be due to the increment of plant population which increase the number of productive tillers and finally increase grain yield. Additionally, this might have resulted from improved root growth, increased uptake of nutrients and better growth favored due to synergetic effect of the four nutrients and the highest seeding rate produced greater plant population which enhanced yield and yield related traits. The grain yield (5800 kg ha^{-1}) recorded from 150 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} seeding rate was 86.43% and 71.09% higher than the national average yield (3111 kg ha^{-1}) and the study Zone average yield (3393 kg ha^{-1}) of bread wheat respectively. On the other hand, an application of 150 kg ha^{-1} of NPSB fertilizer rate has 176.2% yield advantage over the control. The current result agrees with the finding of Dawit (2018) who reported that the highest grain yield (6250 kg ha^{-1}) was obtained from 200 kg ha^{-1} NPS fertilizer rate combined with 150 kg ha^{-1} seeding rate and the lowest grain yield (2014 kg ha^{-1}) was recorded from 100 kg ha^{-1} seeding rate combined with the control.

Similar with the present result, Brzegen (2019) reported that the maximum grain yield (4.97 t ha^{-1}) was recorded from the highest seeding rate (175 kg ha^{-1}) combined with 210 kg ha^{-1} of NPS fertilizer rate but, it was statically at par with grain yield obtained from 125 kg ha^{-1} seeding rate combined with 150 kg ha^{-1} of NPS fertilizer rate (4.94 t ha^{-1}). While, the minimum grain yield (3.4 t ha^{-1}) was recorded from the lower seeding rate (100 kg ha^{-1}) combined with the lower NPS fertilizer rate (120 kg ha^{-1}). Similarly, Iqbal *et al*. (2012) also showed that, higher grain yield (4894 kg ha^{-1}) was recorded from 150 kg ha^{-1} seeding rate combined with 125 kg ha^{-1} N fertilizer rate while, the lower grain yield (3117 kg ha^{-1}) was recorded from 125 kg ha^{-1} seeding rate with the control. The current result is also in conformity with the result of Feyisa *et al*. (2023) who reported that the highest grain yield (8.9 t ha^{-1}) of bread wheat was obtained from 23 kg ha^{-1} of N fertilizer rate combined with 150 kg ha^{-1} of seeding rate.

4.4.8. Straw yield

Straw yield is an important component because farmers are also interested in straw for animal feed and as income source. The analysis of variance revealed that the main effects of NPSB fertilizer rate, seeding rate and their interaction had significant ($P < 0.05$) effect on the straw yield (Appendix Table 2). The highest straw yield (7138.8 kg ha^{-1}) was obtained from 200 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} seeding rate, whereas the lowest straw yield (3238.9 kg ha^{-1}) was recorded from 150 kg ha^{-1} of seeding rate combined with the control but, it was statistically similar with 100 and 125 kg ha^{-1} of seeding rates combined with the control, 100 and 125 kg ha^{-1} seeding rates combined with 50 kg ha^{-1} NPSB fertilizer rate and 100 and 125 kg ha^{-1} seeding rates combined with 100 kg ha^{-1} of NPSB fertilizer rate (Table 4). This might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to synergetic effect of the four nutrients and the highest seed rate produced higher plant population which enhanced growth and yield components thereby resulting in the highest straw yield.

This result is similar with the result of Brzegen (2019) who reported that the maximum straw yield (7.49 t ha^{-1}) was recorded from the higher seeding rate (175 kg ha^{-1}) combined with the higher NPS fertilizer rate (210 kg ha^{-1}) whereas, the minimum straw yield (6.46 t ha^{-1}) was recorded from 100 kg ha^{-1} seeding rate combined with 120 kg ha^{-1} of NPS fertilizer rate In line with the present result, (Rajesh Kumar *et al*., 2006; Otteson *et al*., 2007) reported that increasing seeding rate up to 150 kg ha^{-1} with optimum fertilizer application resulted in increased straw yield of wheat.

The current result is also in conformity with the result of Dawit (2018) who reported that maximum straw yield (8646 kg ha^{-1}) was obtained from the higher seeding rate (150 kg ha^{-1}) combined with higher NPS fertilizer rate (200 kg ha^{-1}) while, the minimum straw yield (4375 kg ha^{-1}) was obtained from the lower seeding rate (125 kg ha^{-1}) combined with the control.

4.5. Correlation between Grain Yield and Growth and Yield Component Variables

The correlation analysis showed that grain yield was strongly and positively correlated with plant height (r =0.73**), number of total tillers m^{-2} (r = 0.62**), number of productive tillers m^{-2} (r = 0.67**), number of spikelet spike^{-1} (r = 0.73**), above ground dry biomass yield (r = 0.96**), straw yield (r = 0.87**) and harvest index (r =0.60**) (Table 5). This result indicates that, the grain yield could be increased by targeting management options that could increase those parameters. However, grain yield had a non-significant negative correlation with days to heading (r = -0.01ns) and a non-significant positive correlation with weed dry biomass (r = 0.17ns) and grain yield plant^{-1} (r = 0.16ns). Abebe and Manchore (2016) reported that grain yield was strongly and positively correlated with plant height, total biomass yield, straw yield and harvest index. Number of grains spike^{-1} was strongly and positively correlated with spike length and number of spikelet spike^{-1}, whereas above ground dry biomass was strongly and positively correlated with number of total tillers m^{-2} and number of productive tillers m^{-2}. In contrary, spike length was negatively correlated with weed dry biomass (Table 5).

Table 5. Correlation among phenological, growth, yield and yield components of bread wheat

	DH	DM	GFP	PH	WDB	NTT	NPT	SL	NSPS	NGPS	ADBPP	ADB	TGW	GYPP	GY	SY	HI
DH	1																
DM	-0.01ns	1															
GFP	-0.36*	0.93**	1														
PH	0.05ns	0.47**	0.42**	1													
WDB	-0.01ns	0.39**	0.37**	0.08ns	1												
NTT	0.09ns	0.23ns	0.18ns	0.50**	0.05ns	1											
NPT	0.03ns	0.26*	0.23ns	0.51**	0.02ns	0.95**	1										
SL	0.06ns	0.24ns	0.21ns	0.21ns	-0.50**	0.23ns	0.25*	1									
NSPS	0.07ns	0.38*	0.33*	0.53**	0.49**	0.55**	0.58**	0.81**	1								
NGPS	0.02ns	0.19ns	0.17ns	0.23ns	0.35*	0.41**	0.39**	0.64**	0.67**	1							
ADBPP	0.12ns	0.11ns	0.06ns	0.14ns	0.21ns	0.39**	0.41**	0.58**	0.66**	0.46**	1						
ADB	-0.05ns	0.44**	0.43**	0.72**	0.11ns	0.56**	0.62**	0.32*	0.65**	0.24ns	0.34**	1					
TGW	0.16ns	-0.03ns	-0.08ns	0.29*	0.28*	0.45**	0.38**	0.53**	0.58**	0.58**	0.36**	0.27*	1				
GYPP	0.05ns	0.11ns	0.08ns	0.10ns	0.28*	0.24ns	0.21ns	0.55**	0.49**	0.83**	0.29*	0.08ns	0.46**	1			
GY	-0.01ns	0.41**	0.38**	0.73**	0.17ns	0.62**	0.67**	0.39**	0.73**	0.34**	0.42**	0.97**	0.389**	0.16ns	1		
SY	-0.08ns	0.45**	0.44**	0.66**	0.04ns	0.45**	0.53**	0.24ns	0.53**	0.12ns	0.24ns	0.97**	0.14ns	-0.003ns	0.87**	1	
HI	0.08ns	0.09ns	0.06ns	0.41**	0.35**	0.53**	0.52**	0.47**	0.68**	0.57**	0.48**	0.38**	0.58**	0.39**	0.60**	0.15ns	1

Level of significance: ** = p<0.01; * = p<0.05; ns = non significance difference; DH = days to 50% heading; DM= days to 90% physiological maturity; GFP = grain filling period; PH = plant height; WDB = weed dry biomass; NTT = number of total tillers m^{-2}, NPT = number of productive tillers m^{-2}; SL = spike length; NSPS = number of spikelet $spike^{-1}$; NGPS = number of grains $spike^{-1}$; ADBPP = above ground dry biomass $plant^{-1}$; ADB = above ground dry biomass ha^{-1}; TGW = thousand grain weight; GYPP = grain yield $plant^{-1}$; GY = grain yield ha^{-1}; SY = straw yield; HI = harvest index

4.6. Partial Budget Analysis

The result of this study indicated that the application of NPSB blended fertilizer and seeding rates resulted in higher net benefits than the unfertilized/control treatments (Table 6). As indicated in Table 6, the partial budget analysis showed that the highest net benefit (42182 ETB ha^{-1}) was recorded from 150 kg ha^{-1} of seeding rate combined with 150 kg ha^{-1} of NPSB blended fertilizer rate with acceptable marginal rate of return (63976%) followed by (41343 ETB ha^{-1}) from 150 kg ha^{-1} of seeding rate combined with 200 kg ha^{-1} NPSB fertilizer rate, whereas the lowest net benefit (14961 ETB ha^{-1}) was recorded from 150 kg ha^{-1} of seed rate combined with the control.

Table 6. Summary of partial budget analysis for effects of seeding and NPSB blended fertilizer rates on yield and yield components of bread wheat in Abay Chomen district

Factors		Yield (kg ha^{-1})			Income (ETB ha^{-1})		GFB (ETB ha^{-1})	TVC (ETBha^{-1})	NB (ETBha^{-1})	MRR (%)
Seed rate (kg ha^{-1})	NPSB rate (kg ha^{-1})	UGY	AGY	SY	Grain	Straw				
100	0	2007	1806.3	3240.64	15353.55	1296.26	16649.81	1600	15050	-
125	0	2200	1980	3514.57	16830	1405.83	18235.83	2000	16236	296.5
100	50	2475	2227.5	3325.31	18933.75	1330.12	20263.87	2375	17889	440.8
150	0	2100	1890	3238.9	16065	1295.56	17360.56	2400	14961	D
125	50	3100	2790	3841.49	23715	1536.60	25251.60	2775	22477	2004.27
100	100	3300	2970	3799.27	25245	1519.71	26764.71	3150	23615	303.47
150	50	4330	3897	5867.34	33124.5	2346.94	35471.44	3175	32296	34724
125	100	3480	3132	3761.51	26622	1504.60	28126.60	3550	24577	D
100	150	3568	3211.2	4043.98	27295.2	1617.59	28912.79	3925	24988	109.6
150	100	5100	4590	5850.3	39015	2340.12	41355.12	3950	37405	49668
125	150	4200	3780	4317.64	32130	1727.06	33857.06	4325	29532	D
100	200	3790	3411	4737.38	28993.5	1894.95	30888.45	4700	26188	D
150	150	5800	5220	6341.56	44370	2536.62	46906.62	4725	42182	63976
125	200	4900	4410	5627.96	37485	2251.18	39736.18	5100	34636	D
150	200	5750	5175	7138.79	43987.5	2855.52	46843.02	5500	41343	1676.75

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. Cost of bread wheat seed= 16ETB kg^{-1}, cost of NPSB fertilizer = 15.50 ETB kg^{-1}. The labor cost for application of NPSB (8 persons ha^{-1} , each 60 ETB day^{-1}), Market price of bread wheat seed = 8.5 ETB kg^{-1} and market price of straw yield = 0.4 ETB kg^{-1} in Homi Kebele at harvesting time in December 2019.

This result was in agreement with the result of Kedir (2022) who reported that the highest net benefits of (67533.2, 51336.4 and 37531.6) ETB ha^{-1} with marginal rate of return (1048.1, 378 and 679 %) were obtained from 150 kg ha^{-1} seeding rate combined with 150 kg ha^{-1} of NPS fertilizer rate at Adami Tulu, Dugda and Lume area respectively. From the current result, the use of 150 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} of seeding rate provided 180.3% and 181.9% net benefits over the use of 100 and 150 kg ha^{-1} of seeding rate combined with the control respectively. Therefore, 150 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} of seeding rate were economical and recommended for the production of bread wheat in the study area and other areas with similar agro ecological conditions.

5. SUMMARY AND CONCLUSIONS

Bread wheat is one of the major staple and strategic food security crops in Ethiopia. Low soil fertility and poor crop management practices including use of inappropriate seeding rate are among the major constraints limiting the productivity of wheat in Ethiopia and in the study area. Thus, addition of nutrients such N, P, S and B and use of proper seed rate are important management practices to increase the productivity of wheat, Therefore, the present study was conducted to assess the effects of seeding and NPSB fertilizer rates on yield and yield components of bread wheat and to enhance wheat productivity in the study area by determining the optimum seeding and NPSB blended fertilizer rates.

The initial soil analysis results of the physico-chemical properties showed that the soil textural class was clay with a particle size distribution of 18.67% sand, 20.66% silt and 60.67% clay. The pH of the soil was 5.41, which is strongly acidic, which was within the range for productive soils for wheat. The analysis of variance (ANOVA) revealed that days to 90% physiological maturity, grain filling period, plant height, weed dry biomass, spike length, number of spikelet spike^{-1}, grain yield plant^{-1} and harvest index were significantly ($P < 0.05$) affected by the main effect of NPSB fertilizer rate. The maximum days to physiological maturity (107 days), grain filling period (46.33 days), plant height (79.28 cm), weed dry biomass (240.67 g), spike length (9.07 cm) and number of spikelet spike^{-1} (20.64) were recorded from 200 kg ha^{-1} NPSB blended fertilizer rate, while the highest grain yield plant^{-1} (1.85 g) and harvest index (48.87%) were recorded from 150 kg ha^{-1} NPSB fertilizer rate.

The main effect of seeding rate also significantly ($P < 0.05$) affected plant height, weed dry biomass, spike length and grain yield plant^{-1}. The maximum plant height (77.003 cm) was obtained from 150 kg ha^{-1} of seeding rate; the maximum weed dry biomass (234.8 g) and spike length (8.96 cm) were recorded from 100 kg ha^{-1} seeding rate, while the highest grain yield plant^{-1} (1.83 g) was recorded from 125 kg ha^{-1} of seeding rate.

The interaction effect of NPSB blended fertilizer and seeding rates also had significant ($P < 0.05$) effect on number of total tillers m^{-2}, number of productive tillers m^{-2}, number of grains spike^{-1}, aboveground dry biomass plant^{-1}, aboveground dry biomass ha^{-1}, thousand grain weight, grain yield ha^{-1} and straw yield. The maximum number of total tillers m^{-2} (431.87) and grain yield (5800 kg ha^{-1}) were recorded from 150 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} seeding rate; the maximum number of productive tillers m^{-2} (318.12) was obtained from 100 kg ha^{-1} NPSB fertilizer rate combined with 125 kg ha^{-1} seeding rates. Moreover, the maximum number of grains $spike^{-1}$ (55.27) and thousand grains weight (55.56 g) were recorded from 150 kg ha^{-1} NPSB fertilizer rate combined with 125 kg ha^{-1} of seeding rate. The maximum aboveground dry biomass (12888.8 kg ha^{-1}) and straw yield (7138.8 kg ha^{-1}) were obtained from 200 kg ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} seeding rate. The maximum aboveground dry biomass $plant^{-1}$ was obtained from 50 kg ha^{-1} NPSB blended fertilizer rate combined with 100 kg ha^{-1} of seeding rate. On the other hand, the lowest number of total tillers m^{-2} (196.25), number of productive tillers m^{-2} (161.87), number of grains $spike^{-1}$ (38.23), aboveground dry biomass $plant^{-1}$ (2.57 g), aboveground dry biomass ha^{-1} (5247.60 kg) and grain yield (2007 kg ha^{-1}) were recorded from 100 kg ha^{-1} seeding rate combined with the control whereas, the lowest thousand grain weight (33.57 g) and straw yield (3238.9 kg ha^{-1}) were obtained from 150 kg ha^{-1} seeding rate combined with the control.

The correlation analysis showed that grain yield was strongly and positively correlated with plant height (r =0.73**), number of total tillers m^{-2} (r = 0.62**), number of productive tillers m^{-2} (r = 0.67**), number of spikelet $spike^{-1}$ (r = 0.73**), above ground dry biomass yield (r = 0.96**), straw yield (r = 0.87**) and harvest index (r =0.60**). The partial budget analysis revealed that combined applications of 150 kg ha^{-1} NPSB fertilizer with 150 kg ha^{-1} seeding rate gave the higher net benefit of 42182 ETB ha^{-1} with MRR of 63976% which is above the acceptable minimum range (MRR > 100%), while the lowest net benefit (14961 ETB ha^{-1}) was recorded from 150 kg ha^{-1} seeding rate combined with the control. The use of 150 kg·ha^{-1} NPSB fertilizer rate combined with 150 kg ha^{-1} seeding rate provided 180.3% and 181.9% net benefits over the use of 100 and 150 kg ha^{-1} seeding rate combined with the control respectively. Therefore, 150 kg ha^{-1} NPSB blended fertilizer rate combined with 150 kg ha^{-1} seeding rate were economical and recommended for production of bread wheat in the study area and other areas with similar agro ecological conditions. However, to make reliable and acceptable recommendation, this study should be repeated across locations and over seasons.

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7. APPENDICES

Appendix Table 1. Mean squares of ANOVA for growth, yield and yield components of bread wheat as influenced by NPSB fertilizer rate, seeding rate and their interaction

Source of variation	DF	DH	DM	GFP	PH	WDB	NTT	NPT	SL
Seed rate	2	0.467^{ns}	1.517^{ns}	0.817^{ns}	376.321**	17139.2**	34792.6**	21871.25**	2.944**
NPSB	4	0.958^{ns}	186.942**	197.442**	350.874**	9275.6**	25078.6**	14121.51**	8.444**
Replication	3	7	3.756	15.956	61.554	5151.644	152.5	304.028	2.58
Seed x NPSB	8	0.696^{ns}	6.142^{ns}	5.442^{ns}	10.981^{ns}	194.2^{ns}	10288.568**	3473.464**	0.077^{ns}
Error	42	2.833	4.541	6.527	6.921	204.597	83.452	124.117	0.227
CV (%)		2.767	2.132	6.528	3.632	6.998	2.754	4.443	5.558

ns: Non- significant, *: Significant at 0.05, **: Highly significant at 0.01, DF: Degree of freedom, DH: Days to heading, DM: Days to maturity, GFP: Grain filling period, PH: Plant height, WDB: Weed dry biomass, NTT: Number of total tillers, NPT: Number of productive tillers, SL: Spike length.

Appendix Table 2. Mean squares of ANOVA for yield and yield components of bread wheat as influenced by NPSB fertilizer rate, seeding rate and their interaction.

Source of variation	DF	NSPS	NGPS	ADBPP	ADB	TGW	GYPP	GY	SY	HI
Seed rate	2	0.89^{ns}	50.40**	0.124ns	61976555.5**	77.076**	0.073*	13012160**	18369162.09**	14.24^{ns}
NPSB	4	90.43**	196.09**	0.854**	45871544**	283.216**	0.12**	14061299.33**	9792140.95**	169.34**
Replication	3	1.276	34.513	0.076	189956.4	3.423	0.056	34069.44	161568.3	7.44
Seed x NPSB	8	0.69^{ns}	22.30*	0.196**	4521951.8**	35.747**	0.037^{ns}	919409.33**	1440792.92**	1.75^{ns}
Error	42	0.413	9.068	0.045	170277.4	4.942	0.021	32239.09	208466.65	9.47
CV (%)		3.44	6.078	6.688	4.970	5.370	8.181	4.801	10.006	6.905

ns: Non- significant, *: Significant at 0.05, **: Highly significant at 0.01, DF: Degree of freedom, NSPS: Number of spikelet per spike, NGPS: Number of grains per spike, ADBPP: Above ground dry biomass per plant, ADB: Above ground dry biomass, TGW: Thousand grain weight, GYPP: Grain yield per plant, GY: Grain yield, SY: Straw yield, HI: Harvest index

Appendix Figure 1. Field layout of the experimental area and sowing time

Appendix Figure 2. Germination time

Appendix Figure 3. Early growth stage

Appendix Figure 4. Peak maturity time

Appendix Figure 5. Spike length measurement

Appendix Figure 6. Harvesting time