EFFECTS OF SEED AND BLENDED FERTILIZER RATES ON YIELD AND YIELD COMPONENTS OF BREAD WHEAT (*Triticum aestivum* L.) AT DUNA DISTRICT, HADIYA ZONE, SOUTHERN ETHIOPIA

MSc THESIS

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HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

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ADVISORS APPROVAL SHEET

(Submission sheet-1)

This is to certify that the thesis entitled˝ **Effects of Seed and Blended Fertilizer Rates on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) at Duna District, Hadiya Zone, Southern Ethiopia ”** submitted in partial fulfillment of the requirements for the degree of **masters** with specialization in **Agronomy**, the Graduate Program of the **School of Plant and Horticultural Sciences** and has been carried out by **Birhanu Araso Latebo** under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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EXAMINERS APPROVAL SHEET-1

(Submission sheet-2)

We, the undersigned member of the Board of Examiners of the MSc Thesis Open defense by **Birhanu Araso Latebo** have read and evaluated his thesis entitled ˝ **Effects of Seed and Blended Fertilizer Rates on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) at Duna District, Hadiya Zone, Southern Ethiopia ”,** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillments of the requirements for the Degree of Master of Science in Agriculture with specialization in **Agronomy**.

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Name of major advisor	Signature	Date
Name of internal examiner	Signature	Date
Name of external examiner	Signature	Date
SGS	Signature	Date

Final approval and acceptance of the Thesis is contingent upon the submission of its final copy of the thesis to the school of Graduate Studies (SGS) through the department or school graduate committee (DGC or SGC) of the candidate’s department.

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DEDICATION

I dedicate this thesis to all my family members for nursing me with affection and love and friends for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOUR

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

Birhanu Araso Latebo		
Name of student	Signature	Date

Place Hawassa University, Hawassa

Date of submission………………………

LIST OF ACRONYMS AND ABBREVIATION

AARC	Areka Agricultural Research Center
ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CEC	Cation Exchange Capacity
CSA	Central Statistical Agency
DAP	Di Ammonium Phosphate
DWAO	Duna Woreda Agricultural Office
EthioSIS	Ethiopian Soil Information System
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FTC	Farmers Training Center
GLM	General Linear Model
LSD	Least Significant Difference
MoA	Ministry of Agriculture
MRR	Marginal Rate of Return
NPSB	Nitrogen, Phosphorus, Sulfur, Boron
RCBD	Randomized Complete Block Design
SARC	Sinana Agricultural Research Center
SAS	System Analysis Software
SNNPR	South Nations Nationalities and People Region
SSA	Sub-Sahara Africa

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Effects of Seed and Blended Fertilizer rates on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) at Duna District, Hadiya Zone, Southern Ethiopia

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ABSTRACT

Bread wheat is one of the major staple and strategic food security crops in Ethiopia. However, the production and productivity of the crop are far below the global average. This is partly due to the low soil fertility and poor crop management practices including the use of sub-optimal seed and fertilizers rates. Hence, this experiment was conducted to assess the effect of seed and blended fertilizer (NPSB) rates on the growth and yield of bread wheat; and determine the economically feasible seed and NPSB fertilizers rates for wheat production in the study area. Treatments consisting of four levels of seed rates (80, 100, 120, and 140 kg ha^{-1}) and four levels of blended NPSB fertilizers (0, 50, 100, and 150 kg ha^{-1}), was laid out in a Randomized Complete Block design in factorial combinations with four replications. Data were collected on phenology, growth, and yield parameters and subjected to ANOVA using SAS software version 9.0. Results revealed that the days to heading, days to physiological maturity, plant height, spike length, thousand kernels weight, straw yield, and above-ground dry biomass were significantly ($p<0.01$) affected by the main effect of seed and NPSB fertilizer rates. The longest days to heading, days to physiological maturity, and spike length were recorded at 80 kg ha^{-1} seed rate. The maximum thousand kernels weight was obtained from the 120 kg ha^{-1} seed rate. However, the tallest plant height, straw yield, and above-ground dry biomass were recorded at 140 kg ha^{-1} seed rate. The tallest plant height, spike length, number of kernels spike^{-1}, thousand kernels weight, straw yield, and above-ground dry biomass were obtained from 150 kg ha^{-1} NPSB rate. However, the longest days to heading and days to physiological maturity were recorded from the control. The treatment interactions significantly ($p<0.05$) affected the number of total tillers, number of productive tillers, grain yield, and harvest index. The highest number of total and productive tillers were recorded at the combination of 140 kg ha^{-1} seed rate with 150 kg ha^{-1} NPSB fertilizer rate. However, the highest grain yield and harvest index were recorded from the combination of 120 kg ha^{-1} seed and 150 kg ha^{-1} NPSB fertilizer rates. Grain yield was strongly and positively correlated with plant height, number of total tillers, number of productive tillers, number of kernel spike^{-1}and above-ground dry biomass. As per the partial budget analysis the highest net benefit of 81,914 ETB ha^{-1} was obtained from the combined application of 120 kg ha^{-1} seed rate with 150 kg ha^{-1} NPSB fertilizer with a MRR of 988.2%. Hence, the combination of 120 kg ha^{-1}seed and 150 kg ha^{-1} NPSB fertilizer rates are profitable than other combinations, therefore this combination can be recommended for wheat production in the Duna District and areas sharing similar agro-ecology.

Keywords: Bread wheat, Blended fertilizer, Grain yield, Sanate variety, Seed rate

1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important crop plants in the world. It grows under a broad range of latitudes and altitudes (Mehraban, 2013). It belongs to the grass family *Poaceae* in which several-flowered spikelets and alternate opposite sides of the rachis forming a true spike (Mollasadeghi and Shahryari, 2011). Wheat is the most important staple food crop for more than one-third of the world population and contributes more calories and proteins than any other cereal crop (Shewry, 2009).

Among the cereals, wheat is the first most important cereal crop globally and cultivated on an area of 216.14 million hectares with production and productivity of 763.56 million metric tons and 3.53 tons ha^{-1}, respectively (USDA, 2020). The crop utilizes about 32% of the land area under cereal cultivation and accounts for about 27% of the world cereal production (USDA, 2020).

Sub-Sahara Africa (SSA) produces a total of 7.5 million tons on a total area of 2.9 million hectares (FAO, 2017). In the region, Ethiopia, South Africa, Kenya, Tanzania, Nigeria, Zimbabwe, and Zambia are the most important wheat-producing countries. According to FAOSTAT (2017), SSA accounts for 30% of Africa’s total area and production of wheat. Although many African countries producing wheat for consumption and sale, the levels vary from country to country. Among the African countries, Egypt and South Africa productivity 6.7, and 3.5 t ha^{-1}, respectively. However, its average yield in Ethiopia is lower than these African countries (FAOSTAT, 2017). Regarding total yield, since small-scale farmer's dominance relied on rainfed agriculture, and due to their traditional production system, Ethiopian wheat ranks 31st worldwide even below other sub-Saharan countries (Goshu *et al*., 2019)

In Ethiopia, wheat ranks fourth after teff (*Eragrostis teff*), maize (*Zea mays*), and sorghum (*Sorghum bicolor*) in area coverage, while third in total production after maize, and teff, and second in yield next to maize (CSA, 2020). Out of the total grain crop area in the country, the wheat crop covers 13.91% (1,789,372.23 hectares). Despite the large area under wheat, the national average productivity of wheat in Ethiopia is about 2.97 t ha^{-1} (CSA, 2020). This is far below the world's average of 3.53 t ha^{-1} (USDA, 2020).

The study area (Duna district) is found in Hadiya Zone. It is one of the wheat-producing Zones in southern Ethiopia, which covers an area of 34,363.77 hectares with a production of 95,670.09 tons and a yield of 2.784 t ha^{-1} in 2019/20 cropping season (CSA, 2020). However, its yield in Ethiopia in general and the study zone, in particular, are low as compared to the attainable yield of 5 t ha^{-1} (MoA, 2012). Such low yield of the crop is attributed due to biotic and abiotic factors such as diseases, insect pests, weed, sowing time, climatic condition, low soil fertility, poor agronomic practices such as the use of sub-optimal seed and fertilizer rates (Anderson and Schneider, 2010).

Fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen (N) and phosphorous (P) fertilizers in the form of Urea and Di Ammonium Phosphate (DAP) for almost all crops and soil types for the last three decades (EthioSIS, 2013). The farmers in the study area have limited information on the impact of different fertilizer rates and types except blanket recommendation (100 kg Urea and 100 kg DAP ha^{-1}). However, 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) (EthioSIS, 2013). In line with this, the recent studies showed that the production of cereals like wheat can be limited by the deficiency of sulfur (S), and other nutrients (Hailu *et al.,* 2015; Menna *et al.,* 2015). Thus, the addition of nutrients such as N, P, S, and B and the use of proper seed rate are important to increase yield and yield components of wheat whether it is for industrial purposes or consumption.

Optimal seeding rates are important in the establishment of a uniform stand with an optimal plant population. Stand densities above the optimum may increase disease, plant height, and lodging. Moreover, high seeding rates increases the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield (Jemal *et al.,* 2015). On the other hand, the use of low seed rate will reduce yields due to less number of plants per unit area (Hameed *et al.,* 2002). Thus, identifying the optimal seed rate allows for reduced risk from overpopulation while minimizing the risk of insufficient stand density. Optimum seed rate and suitable cultivars play an important role in achieving its potential yield (Sikander *et al.*, 2009).

Several studies by different authors have shown that the existence of differences on yield and yield components due to seed rate. For instance, Amare and Mulatu (2017) reported that the higher number of kernels spike^{-1} and grain yield from a seed rate of 100 kg ha^{-1} and the minimum number of kernels spike^{-1} and grain yield from 150 kg ha^{-1}. Similarly, Rahel and Fekadu (2016) reported that the maximum grain yield of 2.78 t ha^{-1} from a seed rate of 100 kg seed ha^{-1} rather than a seed rate of 150 kg ha^{-1}. The low grain yield due to higher plant density might be explained that the grains would fade at an early stage due to the competition between growing grains to absorb preserved dry matters and as the result, low grains spike^{-1} would be produced (Naseri *et al.,* 2012).

Several bread wheat varieties differing in height, maturity, and tillering capacity have been developed in Ethiopia (Jemal *et al.,* 2015). The recommended seed rate for all the varieties being used across the country is 100 kg ha^{-1}. However, the seed and fertilizer rate at one site may not be applied at other locations because of variation in weather, soil type, soil moisture, and varieties, that further trials are needed at each site to validate general recommendations (Azam-Ali and Squire, 2002). Similarly, farmers in the study area use variable seed rates. Moreover, there is no location-specific recommendation on seed and fertilizer rates, and their combined effects on the overall agronomic performance of wheat have not been well studied.

The objective of the study

- To assess the effect of seed and blended fertilizer (NPSB) rates on the growth performance and yield of bread wheat.
- To examine the interaction effect of the variable seed and blended fertilizer (NPSB) rates on bread wheat productivity.
- To determine the economically feasible seed and blended (NPSB) fertilizer rates for wheat production in the study area.

2. LITERATURE REVIEW

2.1. Description of Bread Wheat

Bread wheat (*Triticum aestivum* L.) is one of the most important crop plants in the world. Its cultivation spread to the Near East about 9000 years ago when bread wheat made its first appearance (Feldman, 2001). The main route into Europe was via Anatolia to Greece (8000 B.C) and then both northwards through the Balkans to the Danube (7000 B.C) and across to Italy, France, and Spain (7000 B.C), finally reaching the UK and Scandinavia by about 5000 BC. Similarly, wheat spread via Iran into central Asia reaching China by about 3000 B.C and to Africa via Egypt. It is, a self-pollinating annual plant in the true grass family *Gramineae* or *Poaceae*, which is extensively grown as a staple food source in the world (Mollasadeghi and Shahryari, 2011). It is exclusively produced under rain-fed conditions, *meher* and *belg* (long and short rainy seasons), respectively.

2.2. Ecological Requirements of Bread Wheat

In Ethiopia, the crop is grown in the highlands at altitudes ranging from 1500 – 3000 meters above sea level (masl) between 6 – 16°N latitude and 35 – 42°E longitude. However, wheat is best grown from 1500 – 2800 masl with average temperature of 12 – 25°C (MoA, 2016). On 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).

2.3. Importance of Bread Wheat

Wheat is the first important and strategic cereal crop for the majority of the world's population. It’s one of the most important industrial and food grains which ranks first in the world and is traded internationally (USDA, 2020). Nutritionally it contains 78.1% carbohydrate, 14.7% protein, 2.1% fat, 2.1% minerals, and considerable proportions of vitamins (thiamine and vitamin-B) and minerals (zinc, iron) (Kumar *et al.*, 2011). In Ethiopia, bread wheat is used for a different purpose. For instance, it is used mainly as a source of food, seed, and raw material for industry. It accounts for about 14% of all the calories consumed, and its consumption growth is higher in urban areas due to higher population growth and lifestyle changes (FAO, 2014).

2.4. Production Status of Wheat in Ethiopia

Ethiopia is the second-largest wheat producer in sub-Saharan Africa next to South Africa and covering about 1,786,372.23 hectares and contributing about 5,315,270.328 tons of grain yields, and 4,879,932 wheat-producing farmers in Ethiopia (CSA, 2020). In the country wheat accounts for 13.91% of the total area coved by grain crops (CSA, 2020).

Wheat is grown primarily in the highlands of Ethiopia, and the three main wheat-producing regions Oromia (54.2%), Amhara (32.3%), and SNNPR (7.5%) account for approximately 94% of national wheat (CSA, 2020). According to CSA (2019, 2020) report indicates that the production of wheat was 4.84 million tons and 5.31 million tons in 2018/2019 and 2019/2020 production seasons, respectively. Based on the report, there is an 8.9% change in production between the two production seasons due to both area expansion and yield improvements

(CSA, 2020). According to Gebreselassie *et al.* (2017), the main reason for this significant annual variation is primarily due to variation in rainfall which means that if the rainfall is good, the production is also good, whereas if the rainfall is not sufficient, the status of the production is also insufficient. The yield has increased from 2.53 tons in 2015/2016 to 2.97 tons in the 2019/2020 cropping season with a 14.6% yield increased (CSA, 2020).

2.5. Utilization of Bread Wheat in Ethiopia

Wheat produced in Ethiopia is used mainly for domestic food consumption, seed and industrial use (FAO, 2016). Both production and cultivated area has increased, contributing to increased yields over the past five years (CSA, 2020). This growth is attributed to investment in extension programs and an increased supply of inputs. Along with production increase in recent years, consumption of wheat and wheat products has also expanded significantly. The internal demand for wheat products is growing as a consequence of the changing lifestyle and population growth in Ethiopia. In Ethiopia, wheat is used for a different purpose. Its grain is used to prepare a variety of food such as bread, biscuit, burger, cookies, pancake, porridge, pizza, etc. Local alcoholic drinks, called *tella* and *katikalla*, are also made of wheat (Brasesco *et al.,* 2019). In addition to this, the straw of wheat is used for animal feed and roof thatching material of houses (CSA, 2018).

2.6. Socio-Economic Importance of Wheat in Ethiopia

Wheat is an important cereal crop that makes a significant contribution to the development of the agricultural sector and the farm household food security status in particular (Negassa *et al.*, 2013; Minot *et al.*, 2015; Amentae *et al.*, 2017). It is cultivated by smallholder farmers under rain-fed conditions (Demeke and Marcantonio, 2013). In Ethiopia about 84.4% of the farmers used seed from the informal seed sector, and 15.5% of the farmers used seed from the formal seed sector (Hei *et al*., 2017).

Wheat in Ethiopia is an important stable and cash crop in increasing income of the people, food security, employment, and national GDP increment. In Ethiopia, 4.879 million farmers are engaged in wheat production, namely about 27% of total farmers engaged in grain production (CSA, 2020). In addition, the wheat sub-sector creates many job opportunities along the value chain. A country's domestic production was 4.64 million tons, of which 59% was for household consumption, 18% was for seed requirement, 19% was sold for the domestic market, and the remainder is used for animal feeds, and other uses (CSA, 2018).

Wheat marketing refers to the process by which wheat moves from farmers to consumers. Wheat is significant ameliorations for farmers, food producers, and the food industry, these improvements of the production chains (i.e., wheat cultivation, wheat milling, and manufacturing of pasta, bread, and bakery products) (De Boni *et al.,* 2019).

2.7. Effect of Nitrogen on Bread Wheat Performance

Nitrogen (N) is one of the essential macro-elements needed by plants and has a greater limiting effect on plant productivity than any other element (Crawford and Glass, 1998). It is considered the motor of plant growth. It makes up 1 – 4% of the dry matter of the plant. Since N is present in so many essential compounds, the growth and development of crops without the application of N is slow (Brady and Weil, 2002).However, the amount of this element in available forms in the soil is small, while the quantity withdrawn annually by crops is comparatively large (Brady and Weil, 2002). A good supply of N for the plant is important also for the uptake of the other nutrients (FAO, 2000). Plants absorb N in their cationic form (NH_4^+) or anionic form (NO_3^-).

Nitrogen is the first limiting macro-element on many farms where bread wheat has been grown continuously for more than a decade (Kutman *et al.,* 2011; Ooro *et al.,* 2011). A significant increase in grain and straw yields are also attained through the application of N fertilizers (Akhter *et al.,* 2016). It also promotes activities essential for carbohydrate utilization and its most important function in plants is the promotion of rapid growth through increasing height, tiller number, size of leaves, and length of roots (Singh *et al.,* 2016). The right application of N increase crop yield and it requires a spilt application to use properly (Makowska *et al*., 2008).

The deficiency of N is one of the major constraints limiting wheat production in Ethiopia especially, in low soil fertility areas (Fassil and Charles, 2009). It causes stunted plant growth, development, low protein, and chlorosis as deficiency symptoms on older leaves, which could progress to necrosis under severe conditions. Its deficiency in cereals results in poor tillering and the number of kernels spike^{-1} is reduced (Mengel and Kirkby, 1996). Plants deficient in N respond quickly to its application if applied promptly and properly. On the other hand, excessive N supply causes higher photosynthetic activity, vigorous growth, weak stem resulting in crop lodging, dark green color, reduced product quality, delayed in maturity (Singh *et al*., 2016).

In generally, the number of total tillers, the number of effective tillers, plant height, spike length, above-ground biomass, straw yield, and grain yield were increased as N application increased (Bereket *et al*., 2014; Birru Tilahun *et al*., 2017). The plant height was significantly affected by N rates. Plant height increased with increasing rates of N (Gebreslasie *et al.*, 2020). The longest plant was recorded from plots that received 138 kg N ha^{-1} and the shortest plant was recorded from plots that didn't receive N fertilizer.

Higher tillers and more spikes were produced from N fertilized plants than the control. Similarly, the grain yield is closely related to the number of spikes per unit area (Geleto *et al*., 2006). Asif *et al*. (2009) also reported the longer spike length from 130 kg N ha^{-1}. However, the shortest spike length was recorded from the control. Generally, the number of heads per unit area is highly dependent on the use of a higher N rate to promote the initiation, survival, and development of secondary tillers (Power, 2004).

Gebreslasie *et al.* (2020) reported that the highest numbers of tillers were recorded for plots treated at 115 kg N ha^{-1} and 138 kg N ha^{-1}. However, the lowest numbers of tillers were recorded for plots that received zero N. This might be due to the role of N in accelerating the vegetative growth of plants. Similarly, Ali *et al*. (2011) reported that all the N treatments significantly increased the number of tillers m^{-2} than control. Likewise, Malghani *et al*. (2010) reported that increasing in the number of tillers with N fertilizer.

Gebreslasie *et al. (*2020) reported that the higher number of biomass, kernels spike^{-1}, thousand grain weight, and grain yield from N rate 138 kg N ha^{-1} and the minimum number of biomass kernels spike^{-1}, thousand grain weight, and grain yield from control. Similarly, Bekalu and Mamo (2016) also reported that an increasing rate of N fertilizer increased the straw and grain yield of bread wheat. The overall effect of N application is to increase the resource capture of the plant as well as to increase the sink capacity, which is determined by the number and size of grain and their rates of growth. These results are quite in line with (Iqbal *et al.*, 2010).

2.8. Effect of Phosphorus on Bread Wheat Performance

Phosphorus (P) is an essential macro-element necessary for the growth and development of plants. It makes up 0.1 – 0.4% of the dry matter of the plant and is classified as the second most important element for crop production (FAO, 2000; Tisdale *et al*., 2002). Balanced application of P enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth particularly the development of lateral roots and fibrous rootlets (Brady and Weil, 2002). The optimum amount of P application at an early stage enhanced early growth and development (Tisdale *et al*., 2002). Most of the P present in soils is in unavailable forms and added soluble forms of P are quickly fixed by many soils (Menezes *et al*., 2018). Most of the time plants absorb P as the primary orthophosphate ion (HPO_4^{2-} and $H_2PO_4^-$) (Gupta, 2011). As to which of the two anions plants take up depends primarily on the soil pH. In high pH soils, it is taken up mainly as $HPO_4{}^{-2}$ while in low pH soils it is taken up mainly as $H_2PO_4{}^{-}$ (Archer, 1998).

Deficiency of P in wheat caused reduced tillering, reduced leaf area, and increased susceptibility to several diseases. Besides, maturity is often delayed in P deficient plants as compared to plants containing abundant phosphate (Marschner, 1995). The reported readily availability of P during the early season saved the plants from early stresses and its higher uptake at higher levels resulted in an enhanced number of grains spike^{-1} and thousand grain weight due to its involvement in grain formation and development (Malhi *et al*., 2002). Tekalign and Haque, (1991) reported that most of the highland soils of Ethiopia are P deficient and it is one of the limiting elements in crop production. The total P content of the soils in

Ethiopia is in the range of 0.02 – 0.08% with an average value of 0.05% which shows low P content of the soil.

Islam *et al*. (2017) reported that the plant height of the wheat crop is affected by different levels of P. The highest plant height was recorded from the plots that were applied with 90 kg P_2O_5 ha^{-1}. The lowest plant height was observed in the control plots. Alam *et al*. (2003) reported that the plant height, spike length, number of productive tillers, straw and grain yield as well as P-uptake in grain significantly increased with increasing of application rates of phosphorus fertilizer to the soil.

The higher P application at a rate of 90 kg P_2O_5 ha^{-1} resulted in a higher grain yield 3.99 t ha^{-1} While, minimum grain yield (3.22 t ha^{-1}) was recorded from control plots (Islam *et al*., 2017). In another study, Bereket *et al*. (2014), indicated P application at a rate of 46 kg P_2O_5 ha^{-1} increased significantly grain and straw yields by 38% than unfertilized plot.

2.9. Effects of Sulfur on Bread Wheat Performance

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 – 0.5% in plant tissue on a dry matter basis (Ali and Khattak, 2008). It is a building block of protein and a key ingredient in the formation of chlorophyll (Duke and Reisenaue, 1986). The form of S in the soil is primarily as $SO4^{-2}$ (FAO, 2000). In soils, S presents in inorganic and organic forms and is cycled between these forms via mobilization, mineralization, and immobilization, oxidation, and reduction processes. Organic S compounds are largely immobile while, inorganic one is more mobile, and sulfate ($SO4^{-2}$) is the most mobile (Scherer, 2001).

Sulfur deficiency may delay maturity in grain crops and interveinal chlorosis may occur. Its deficiency symptoms are similar to those of N. However, N deficiency symptoms first appear in the older leaves; while, S deficiency symptoms first appear in the younger leaves because S is not easily translocated in the plant. Its deficiency can be corrected easily by the application of chemical fertilizers containing S (Clark, 1990). Crops cannot reach their full potential in terms of yield or protein content with S deficiency (Zhao *et al*. 1999). It is required for the synthesis of S containing amino acids such as cystine, cysteine, and methionine. Their deficiency results in stunted growth, reduced plant height, tillers, spikelets, and delayed maturity. The S deficient plants have also less resistance under stress conditions (Doberman and Fairhurst, 2000).

Sulfur fertilizer enhancing the uptake of N, P, K, and Zn in the plant. Due to its synergistic effect, the efficiency of these elements is enhanced which results in increased crop productivity. Application of S fertilizer is a feasible technique to suppress the uptake of undesired toxic elements sodium (Na) and chlorine (Cl) because of the antagonistic relationship, thus its application is useful not only for increasing crop production and quality of the product but also improves soil conditions for healthy crop growth (Zhang *et al*., 1999).

The grain yield and straw yield of wheat was significantly affected by S application. Increase in S rate up to 30 kg ha^{-1} had a positive effect on grain and straw yield of bread wheat while above this rate yield showed a decreasing trend (Assefa *et al.*, 2020). Application of 20 and 30 kg ha^{-1} S in Cambisols, have significantly increased grain yield by 9.0 and 10.1% over the control, respectively and straw yield by 10.4 and 10.5% over control, respectively. On Vertisols, 30 and 40 rates have significantly increased grain yield by 8.0 and 10.0% over control, respectively and the same treatments increased straw yield by 10.6 and 9.0% over control respectively (Assefa *et al.,* 2020).

In generally, the application of 20 kg ha^{-1} S at stem elongation stage significantly increased the yield of wheat by 28.5% over the control plot (Khan *et al*., 2015). Currently, in most countries, S has been identified as a limiting factor for crop quality, although wheat has a relatively low S requirement (Zhao *et al*., 1999)

2.10. Effects of Boron on Bread Wheat Performance

Boron (B) is an essential nutrient for better utilization of micro-nutrients by plants and thereby greater translocation of photo-assimilates from source to sink during growth and development period (Ali *et al.*, 2013). It is required for the normal development of reproductive tissues, and its deficiency results in a low grain set and poor seed quality. Crops like wheat and rice can suffer from impaired seed set due to B shortage at a critical growth stage (Shorrocks, 2005). Its deficiency symptoms first become evident on the younger leaves, which change color and become hardened, malformed, and necrotic (Dursun *et al.,* 2010). Plants absorb B in the form of H_3BO_3, and it moves to plant roots mainly by mass flow and diffusion. The uptake of B in crop plants is mainly determined by yield level (Fageria, 2009). In wheat its deficiency causes grain sterility (Rerkasem *et al.,* 1997). The reproductive stage, especially flowering, fruit, and seed setting are more sensitive to B-deficiency than a vegetative stage. The sterility problem in wheat as a consequence of B deficiency has been reported in different parts of the world (Rerkasem *et al.,* 1997).

Boron is an essential element for plants, but the high concentration is toxic and limits crop productivity (Fayaz *et al*., 2014). When plants are exposed to B toxicity, it will cause reduction of leaf area, formation of chlorotic and necrotic patches in older leaves, delay of development, and plant growth. Khan *et al.* (2016) reported that the application B resulted in maximum plant height (99.7cm) while the control plots produced minimum plant height (93.3cm) of wheat. An increase in plant height might be the involvement of micro-nutrients in different physiological processes like enzyme activation, chlorophyll formation, stomatal regulation, etc. Debnath *et al.* (2014) observed that the highest plant height was recorded with 120 kg N + 2 kg B ha^{-1} and the lowest was from the control plot of wheat.

Debnath *et al*. (2011) reported that the highest spike length was recorded in 2.25 kg B ha^{-1} and the lowest spike length was recorded 3 kg B ha^{-1}. Tahir *et al.* (2009) reported that maximum kernel spike^{-1} (54.8) were recorded when B applied at higher rate. Similarly, Mitra and Jana (1991) reported that B application significantly increased the number of kernel spike^{-1}.

Muhmood *et al.* (2014) reported that the application of 2 kg B ha^{-1} fertilizer gave 11% more grain yield. Boron plays a vital role in increasing the grain yield of wheat. The deficiency of boron can also cause a reduction in crop yield and crop quality. Singh *et al*. (2015); and Tahir *et al.* (2009) reported that maximum grain yield was observed in treatment where B application. Minimum grain yield was observed in control i.e. without B application.

2.11. Effects of Seed Rate on Wheat Yield

Seed is the most important agricultural input, and it is the basic unit for distribution and maintenance of plant population and it carries the genetic potential of the crop (welu, 2015). Although; high-quality seed, suitable cultivars and their optimum seeding rate, including crop management practices play an important role in achieving a potential yield of bread wheat (Nizamani *et al.,* 2014). A high seed rate increases the competition among crops for common resources particularly water, space, nutrients, and sunlight which results in low quality and low yield. If a low seed rate is used yield will be less due to the lesser number of plants per unit area (Hameed *et al.*, 2002). An increase of spike per unit of area and reduction of the number of seeds spike^{-1} due to increasing sowing density was also reported (Sharma, 1987).

Tewodros *et al.* (2017) reported that the maximum productive tillers were recorded from seed rate of 125 kg ha^{-1} while minimum productive tillers were recorded from a seed rate of 175 kg ha^{-1}. The highest number of productive tillers at the optimum seed rates might be increased number of fertile tillers. Amare and Mulatu (2017) reported that seed rate was increased from 100 kg ha^{-1} to 150 kg ha^{-1}, the number of kernels spike^{-1} decreased by 10.42%. Similarly, Jemal *et al*. (2015) reported that seed rates up to 150 kg ha$^{–1}$ gave the higher number of kernels spike^{-1} across varieties while seed rates of 175 and 200 kg ha$^{–1}$ gave fewer kernels spike^{-1}. Tewodros *et al.* (2017); and Awoke *et al. (*2017) reported that the highest grain yield of was obtained in response to the application of 125 kg ha^{-1} seed rate of bread wheat. This is because in the higher seed rate there is a presence of competition between plants for a common resource like moisture, nutrients, and light.

Several bread wheat varieties differing in height, maturity, and tillering capacity have been developed in Ethiopia (Jemal *et al.*, 2015). The recommended seed rate for all the varieties being used across the country is 100 kg ha^{-1}. However, the seed rate at one region may not be applied at other region due to the difference of climatic factors, type of soil, sowing date, and varieties that further trials are needed at each region to validate general recommendations (Lloveras, 2004).Thus, it is essential to determine the optimum seeding rates for newly developed bread wheat varieties for the maximum yield.

2.12. Combined Effect of Seed and NPSB Rates on Wheat Productivity

Applied NPSB fertilizer and seed rate affected both the phenological traits and yielding potential of the food barley (Habtamu *et al*., 2021). Increasing seeding and NPSB fertilizer rates application resulted in increased kernels spike^{-1}, thousand kernel weight, grain yield, and harvest index in bread wheat (Temesgen and Bewket, 2021). Combined effects NPSB and seed rates 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 greater plant population which enhanced yield. The plant height, number of effective tillers, thousand kernels weight, grain yield, above-ground biomass, and harvest index were significantly affected by bread wheat seed rate, NPS, and their interaction (Brzegen *et al.,* 2019). Increased effective tillers m^{-2} with increasing seed and NPS rates in bread wheat (Girma *et al*., 2018).

The higher grain yield was obtained from the combination of 150 with 200 kg ha $^{-1}$ of seed and NPS rates while minimum grain yield was obtained from the combination of 100 with 0 kg ha^{-1} of seed and NPS rates respectively (Girma *et al*., 2018). Similarly, Brzegen *et al.* (2019) reported that interaction effects, maximum grain yield was recorded from the combination of 175 kg ha^{-1} seeding rate with 210 kg ha^{-1} NPS rate. Grain yield, aboveground dry biomass, harvest index, and numbers of productive tillers were significantly affected by the effect of blended fertilizer rates (Woldetsadik *et al.*, 2018).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Halatebo Farmers 'Training Centre (FTC) in Duna District, Hadiya Zone during *meher* (main rainy seasons) of 2020. Duna District is located in the Southern, Nations, Nationalities, and Peoples' Region (SNNPR). It is located at 7° 20' 00"N latitude and 37° 39' 40"E longitude (Figure 1). This District is bordered by the Hadiya Zone of Soro Woreda to the North and west by Kambata Tambaro zone to the South and East. Duna districts' capital town Ansho is located at 275 km in the south of Addis Ababa, the capital of Ethiopia and, 211km north-west of Hawassa the capital city of SNNP and Sidama Regional States, and situated at 42 km to the south of the Zonal capital town of Hosanna.

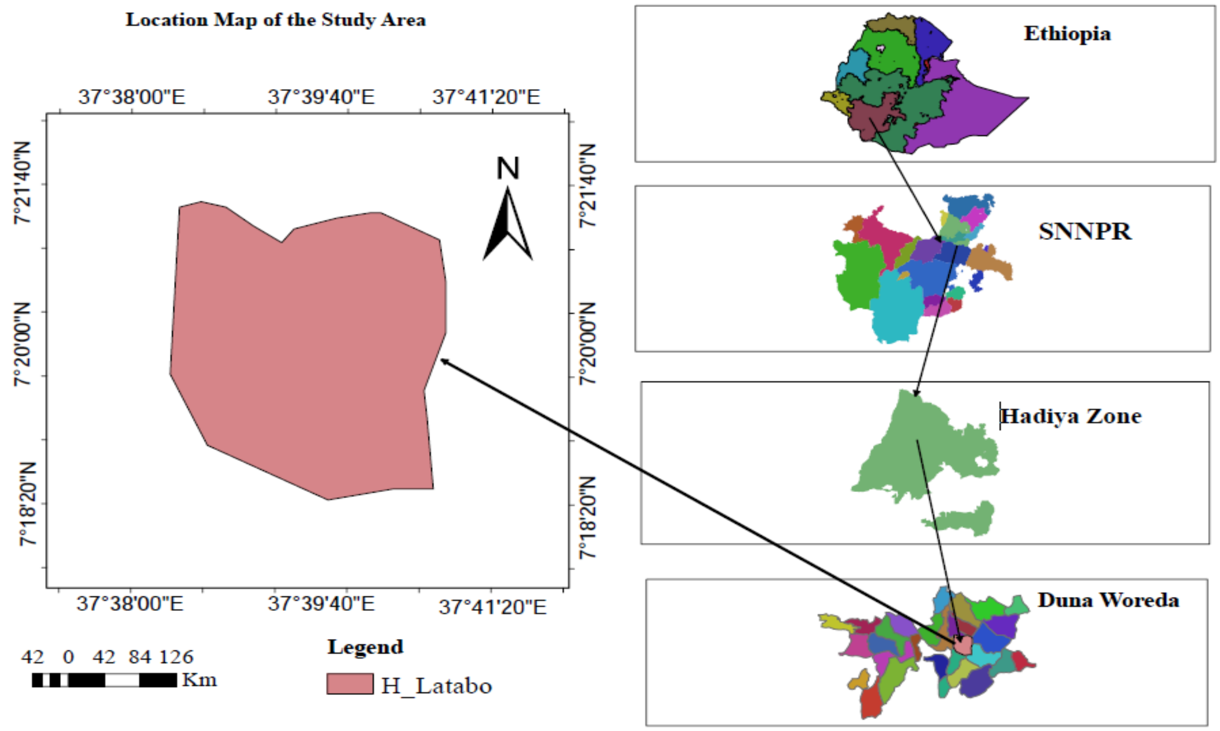
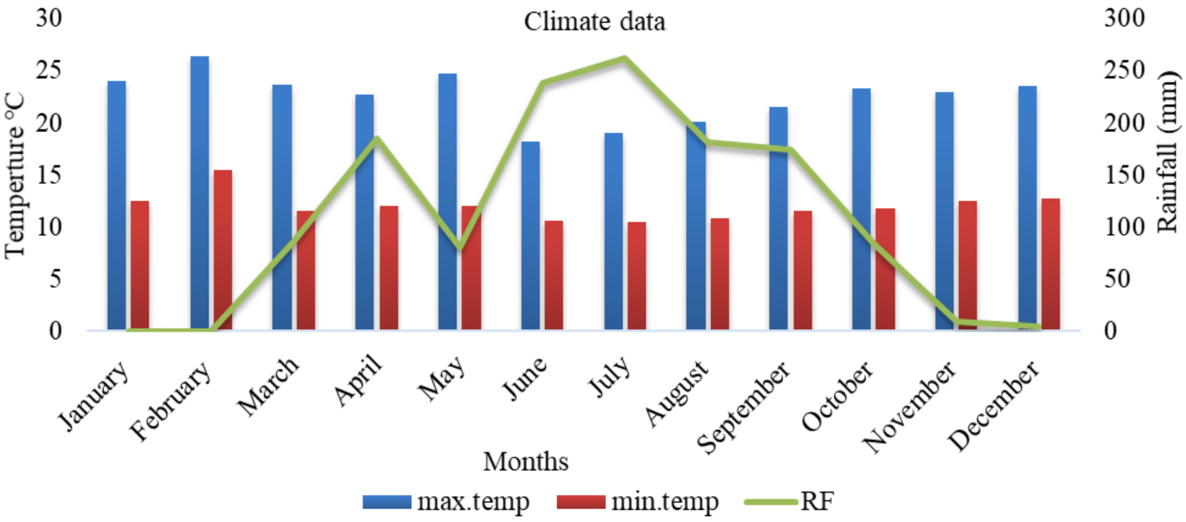


Figure 1. Description of the Study Area



Source: National Meteorological Agency, Hawassa Branch (2020)

Figure 2. Mean monthly rainfall and maximum and minimum temperatures recorded at Duna district during 2020 cropping season.

The long term annual rainfall ranges between 900-1390 mm with bimodal rainfall pattern with the main wet season (*meher*) extending from mid-June to September, and the small wet season (*belg*) extending from March to May and the annual average minimum and maximum air temperatures are 12 and 22.5°C, respectively figure 2. The District has three Agro-ecological Zones, 78% Dega, 15% Weina Dega, and 7% Moist Kolla climatic type. The elevation at FTC is 2320 masl. The soil of the experimental site is classified as clay loam in texture with a pH value of 5.9. (DWAO, 2020).

3.2. Experimental Materials

Sanate bread wheat variety was used as experimental material. The variety was released by Sinana Agricultural Research Center (SARC) in 2014 and is currently under production. The variety has a maturity period of 141 days with a yielding potential of 3.4 – 6.7 t ha^{-1} (MoA, 2017). The variety senate was selected based on its adaptation, yield, and disease resistance.

Blended NPSB fertilizer with (18.1% N, 36.1% P_2O_5, 6.75% S, and 0.71% B), and Urea (46% N) nutrient composition was used as the sources of fertilizers (ATA, 2016).

Table 1. N, P_2O_5, S and B contents of blended fertilizer

Fertilizer treatments (NPSB rates kg ha^{-1})	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	S(kg ha^{-1})	B(kg ha^{-1})
0	-	-	-	-
50	55.05	18.05	3.375	0.355
100	64 .10	36.10	6.750	0.710
150	73.15	54.15	10.125	1.065

3.3. Treatments Arrangement and Design

The experimental treatments consists of four NPSB-levels (0, 50, 100, and 150 kg ha^{-1}) and four seed rates (80, 100, 120, and 140 kg ha^{-1}) with a total of 16 treatments combinations were laid out using Randomized Complete Block Design with four replicates and factorial arrangement. The recommended rate of 100 kg NPSB ha^{-1} was used as a basis for setting the other treatments.

The total area of each plot was 1.8 m × 2.6 m (4.68 m^2) consisting of nine rows per plot. A distance between adjacent plots and blocks was 0.5 m and 1m, respectively. The net plot size (harvestable area) 1.4 m × 2.4 m (3.36 m^2) consisted of seven rows of 2.4 m in length. The outer most one row on both sides of each plot and 10 cm of the two ends was considered as border plants and was not considered for data collection to avoid border effects.

Table 2. Treatments combinations

Trt. No	Treatments	Trt. No	Treatments
1	0 kg NPSB ha^{-1} + 80 kg ha^{-1} wheat	9	0 kg NPSB ha^{-1} + 120 kg ha^{-1} wheat
2	50 kg NPSB ha^{-1} + 80 kg ha^{-1} wheat	10	50 kg NPSB ha^{-1} + 120 kg ha^{-1} wheat
3	100 kg NPSB ha^{-1} + 80 kg ha^{-1} wheat	11	100 kg NPSB ha^{-1} + 120 kg ha^{-1} wheat
4	150 kg NPSB ha^{-1} + 80 kg ha^{-1} wheat	12	150 kg NPSB ha^{-1} + 120 kg ha^{-1} wheat
5	0 kg NPSB ha^{-1} + 100 kg ha^{-1} wheat	13	0 kg NPSB ha^{-1} + 140 kg ha^{-1} wheat
6	50 kg NPSB ha^{-1} + 100 kg ha^{-1} wheat	14	50 kg NPSB ha^{-1} + 140 kg ha^{-1} wheat
7	100 kg NPSB ha^{-1} + 100 kg ha^{-1} wheat	15	100 kg NPSB ha^{-1} + 140 kg ha^{-1} wheat
8	150 kg NPSB ha^{-1} + 100 kg ha^{-1} wheat	16	150 kg NPSB ha^{-1} + 140 kg ha^{-1} wheat

3.4. Experimental Procedures and Field Management

The experimental field was plowed with oxen to a fine tilth four times and the plots were leveled manually. According to the design, the field layout was made and each treatment was assigned randomly to the experimental units within a block. Bread wheat seeds were sown as rows of 20 cm spacing manually by drilling on 24 July 2020. Urea and NPSB were used as a source of fertilizer and 100 kg ha^{-1} Urea was used for all treatments equally. The total quantity of NPSB fertilizer was applied at the time of planting. 1/3 of the urea fertilizers were applied at sowing while the remaining 2/3 of urea was applied at the mid-tillering stage as a top dressing (34 days after sowing). Weeding was done three times and harvesting and threshing were done manually.

3.5. Soil Sampling and Analysis

Soil samples were taken in the zigzag pattern before planting randomly from the experimental site at a depth of 0 – 30 cm across the experimental field from 10 spots using auger before planting and were composited to one. Then, the collected samples were air-dried at room temperature under shade and ground to pass through a 2 mm sieve and were submitted to Areka Agricultural Research Center (AARC) soil testing laboratory for analysis. For organic carbon (OC) and total N determination, the soil was ground to pass through a 0.2 mm sieve. Working sample of 1 kg was obtained from the prepared composite sample and was analyzed for selected physico-chemical properties mainly for soil texture, soil pH, cation exchangeable capacity (CEC), total N, available P, available S, and available B following standard laboratory procedures.

Soil texture was determined by Bouyoucos hydrometer method (Bouyoucos, 1962). Soil OC was determined by wet digestion method (Walkley and Black, 1934). Total N was determined by Kjeldhal method (Dewis and Freitas, 1970). The pH of the soil was determined at 1:2.5 soil to water dilution ratio using a glass electrode attached to digital pH meter (Page, 1982). The CEC was measured after saturating the soil with 1N ammonium acetate (NH_4OAC) and displacing it with 1N NaOAC (Chapman, 1965). Available P was determined using the Bray method (Olsen *et al.*, 1954) and available S was determined using turbid metric method (Chesnin and Yien, 1951) and available B was determined using hot water method (Berger and Truog, 1939).

3.6. Crop Data collected

3.6.1. Phenological parameters

Days to heading: days to spike heading were determined as the number of days taken from the date of sowing to the date of heading of plants from each net plot by visual observation.

Days to physiological maturity: days to physiological maturity were determined as the number of days from sowing 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 are hard to break with a thumbnail.

3.6.2. Growth parameters

Plant height (cm): plant height was measured from the soil surface to the tip of the spike (awns excluded) of 10 randomly tagged plants from the net plot area 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 area.

3.6.3. Yield and yield components

Number of total tillers: number of total tillers was counted per meter squares from net plot area of each plot at heading stage.

Number of productive tillers: number of productive tillers was recorded by counting all spikes bearing kernels from net plot area per meter squares of each plot at physiological maturity.

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

Thousand kernels weight (g): thousand kernels weight was determined based on the weight of 1000 kernels sampled randomly taken from the grain yield of each net plot counting by hand and weighed with sensitive balance, in three replicate.

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

Grain yield (t ha^{-1}): grain yield at harvest maturity, whole plants from the central 7 rows of net plot area were harvested and threshed manually. The grain yield was adjusted to 12.5% moisture content. Finally, yield per plot was converted to per hectare basis and the average yield was reported in t ha^{-1}.

Aboveground dry biomass (t ha^{-1}): the aboveground dry biomass was determined at maturity, whole plants harvested from each net plot area after sun drying to a constant weight and converted to t ha^{-1}.

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

3.7. Data Analysis

All the collected data were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedure with in SAS version 9.0 (SAS, 2004). Treatments mean separation were done using least significant difference (LSD) test at 5% level of significance and correlation analysis were carried out to identify relationship between yield and yield components.

3.8. Partial Budget Analysis

Economic analysis was performed following the CIMMYT partial budget analysis methodology (CIMMYT, 1988) to identify the economically profitable seed rates with NPSB rates for the experiments tested. All costs and benefits were calculated on hectare basis in Birr.

The mean grain and straw yield data was adjusted down by 10% and subjected to partial budget analysis. Gross field benefit (GFB) (ETB ha^{-1}) was computed by multiplying field/ farm gate price that farmers receive for the crop they sell as adjusted yield as GFB= AGY* field/ farm gate price for the crop. Total variable cost (TVC) (ETB ha^{-1}) was calculated by the sum of the costs that vary such as the cost of seed, NPSB, and the application costs. Cost of each variable; seed (24.5 birrs 1kg^{-1}), NPSB (16 birrs kg^{-1}), and transportation cost (seed 100 birr 100 kg^{-1}, and NPSB 40 birr 100 kg^{-1}) during sowing time (July 24, 2020). The labor cost for application of NPSB (8 person ha^{-1}, each 60 ETB day^{-1}) and seed (8 person's ha^{-1}, each 60 ETB day^{-1}), wheat harvesting, thrashing and winnowing cost (50 birrs 100 kg^{-1}), packing and material (20 birrs 100 kg^{-1}) were considered and other input costs used as constant for all treatments. The selling price of bread wheat grain at Ansho market was Birr 16.5 kg^{-1} and straw yield was Birr 0.3 kg^{-1} at harvesting time in December 2020.

The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that vary (TCV) using the formula NB= GFB – TCV. Where: - GFB = GY x P

GFB = Gross Field Benefit, GY = Adjusted Grain yield per hectare and, P = Field price per unit of the crop.

For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula MRR (%) = $\frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TCVb}-\text{TCVa)}} \times 100$ Where: - NBa = the immediate lower NB, NBb = the next higher NB, TCVa = the immediate lower TCV, and TCVb = the next highest TCV.

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 the technique were referred to as dominated and non-dominated treatments, respectively. Identification of a candidate recommendation was non-dominated treatments. Than the treatment which gives the highest net benefit and a marginal rate of return greater than the minimum acceptable to farmers (100%), was considered for recommendation as described by CIMMYT (1988).

4. RESULTS AND DISCUSSION

4.1. Soil Physico-Chemical Properties of the Experimental Site

The analysis of the experimental soil indicated that the soil was clay loam in textural class with a particle size distribution of 40% sandy, 29% silt, and 31% clay (Table 3). Hence, the soil of experimental site had good water holding and nutrient retention capacity. According to Hailu (1991), soil types used for wheat production vary from well-drained fertile soils to waterlogged heavy *Vertisols*. Thus, the soil of the experimental site is suitable for the production of wheat. The pH of the soil was 5.9, which is moderately acidic. According to the ratings of soil pH by Tekalign (1991), soils with pH < 5.2 are strongly acidic, 5.3 – 5.9 moderately acidic, 6.0 – 6.6 slightly acidic, 6.7 – 7.3 as neutral, 7.4 – 8.0 as moderately alkaline, > 8.0 are characterized as strongly alkaline. FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 5.5 to 8. Mengel and Kirkby (1996), reported an optimum pH ranges of 4.1 to 7.4 for wheat production. Thus, the pH of the experimental soil was suitable for wheat production.

The soil of the study site had 2.81% of OC content (Table 3), which is moderate according to the rating by Tekalign (1991), who rated soils having OC value in the range of < 0.5% as very low, 0.5 – 1.5% as low, 1.5 – 3.0% as moderate, > 3.0% as high indicating the medium potential of the soil to supply N to plants through mineralization of OC. The medium amount of soil OC might be due to less availability of crop residues as smallholder farmers use the biomass of wheat for animal feed in the study area. Cation exchange capacity (CEC) is an important parameter of soil because it indicates 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} was rated as very high and 25 – 40 cmol (+) kg^{-1} as high, 15 – 25 cmol (+) kg^{-1} as a medium, 5 – 15 cmol (+) kg^{-1} as low, and < 5 Cmol (+) kg^{-1} of soil as very low in CEC. In general, soils having high CEC contents are considered agriculturally fertile. According to this classification, the soils of the site had a medium CEC of 24.78 cmol (+) kg^{-1}, indicating its medium capacity to retain cations.

The soil of the study site had 0.24% of soil total N content (Table 3), which is moderate according to the rating of Tekalign (1991), who rated soils having a total N value in the range of <0.05% as very low, 0.05-0.12% as low, 0.12-0.25% as moderate, >0.25% as high, indicating that the nutrient to be a limiting factor for wheat production in the study area. The analysis revealed that the available P of the soil was 17.43 mg kg^{-1} (Table 3). Indicative ranges of available P have been established by Olsen *et al*. (1954), as < 5 mg kg^{-1} as very low, 5 – 9 mg kg^{-1} as low, 10 – 17 mg kg^{-1} as a medium, 18 – 25 mg kg^{-1} as high, and > 25 mg kg^{-1} as very high. Thus, the soil of the experimental site was considered as medium in available P, and it was a limiting factor for crop growth.

The soil available sulfur (S) analysis showed a value of 18.95 mg kg^{-1} (Table 3). According to EthioSIS (2013), soil available S rating which are < 10 mg kg^{-1} (very low), 10 – 20 mg kg^{-1} (low), 20 – 80 mg kg^{-1} (medium), 80 – 100 mg kg^{-1} of soil high, and >100 mg kg^{-1} very high. Thus, the soil of the experimental site was considered as low in available S content, which is not satisfactory to get potential yield from the crop. Thus, it is important to apply S-sourced fertilizer for good crop growth and yield. The available boron (B) of the soil was low at 0.79 mg kg^{-1} (Table 3). According to EthioSIS (2014) soil rating which are < 0.5 mg kg^{-1} (very low), 0.5 – 0.8 mg kg^{-1} (low), 0.8 – 2.0 mg kg^{-1} (medium), 2.0 – 4.0 mg kg^{-1} of soil high, and

>4.0 mg kg^{-1} very high. Thus, the soil of the experimental site was considered as low in available B content.

Table 3. Soil physico-chemical properties of the experimental site during 2020 cropping season

Parameters	Amount	Rating	References
Sand (%)	40		
Silt (%)	29		
Clay (%)	31		
Textural class	Clay loam		
pH (1:2.5 H_2O)	5.9	moderately acidic	Tekalign (1991)
OC (%)	2.81	moderate	Tekalign (1991)
Total N (%)	0.24	moderate	Tekalign (1991)
CEC[(cmol(+) kg^{-1}) soil]	24.78	moderate	Landon (1991)
Available (mg kg^{-1})			
Phosphorus	17.43	moderate	Olsen *et al*. (1954)
Sulfur	18.95	low	EthioSIS (2013)
Boron	0.79	low	EthioSIS (2014)

Where: - pH = Hydrogen power, OC = Organic carbon, Total N = Total nitrogen, CEC = Cation exchange capacity.

4.2. Phenological Parameters

4.2.1. Days to heading

The main effect of seed and NPSB fertilizer rates had highly significant ($P < 0.01$) effects on days to heading. However, the treatment interaction did not significantly affected days to heading (Appendix Table 2). The longest days to heading (72 days) were recorded from 80 kg ha^{-1} seed rate, while the shortest days to heading (70 days) was recorded from 140 kg ha^{-1} seed rate (Table 4). Days to heading decreased with increasing seeding rate from 80 - 140 kg ha$^{-1.}$ The earlier heading at the higher seed rate might be attributed to the higher competition for resources. As a result, plants no longer stay in the vegetative stage. In agreement with this result, Amare and Mulatu (2017) reported that increasing seed rate from 100 – 150 kg ha^{-1} decreased days to heading of bread wheat. Similarly, Brzegen *et al.* (2019) reported that the longest days to heading were recorded at the seeding rate of 100 kg ha^{-1}. Furthermore, Abiot (2017) reported that increasing seed rate decreased days to heading. In contrast, Jemal *et al*. (2015) reported that increasing seeding rates from 100 – 200 kg ha^{-1} increase the number of days from sowing to heading in wheat.

With the increasing rates of NPSB fertilizer, the days to heading decreased. The longer days to heading (74 days) were recorded from the control, while the shortest days to heading (68 days) were recorded from 150 kg NPSB ha^{-1} (Table 4). Application of NPSB fertilizer improves growth and development, and the early heading of wheat. In agreement with this result, Woldetsadik *et al.* (2018) reported that increasing NPSBZN rate significantly reduced days to heading in wheat. Similarly, Teklu *et al*. (2019) reported that increasing NPSB rate decreased days to heading in bread wheat. Moreover, Zemichael and Kiros (2019) reported increased fertilizer rate hastened heading in barley.

Table 4. Effect of seed and NPSB fertilizers rates on phenology of bread wheat at Duna district during 2020 cropping season

Treatments	Days to heading	Days to physiological maturity
Seed rate (kg ha^{-1})		
80	72^{a}	152^{a}
100	71^{b}	151^{ab}
120	71^{b}	150^{b}
140	70^{c}	149^{b}
LSD (0.05)	0.8	1.5
NPSB rate (kg ha^{-1})		
0	74^{a}	154^{a}
50	72^{b}	151^{b}
100	70^{c}	149^{c}
150	68^{d}	148^{c}
LSD (0.05)	0.8	1.5
CV (%)	1.7	1.4

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

4.2.2. Days to physiological maturity

The main effect of seed and NPSB fertilizer rates had a highly significant ($P < 0.01$) effect on days to physiological maturity of bread wheat. However, the treatment interaction did not significantly affected days to physiological maturity (Appendix Table 2). The longest days (152 days) to physiological maturity were recorded from 80 kg ha^{-1} seed rate followed by 100 kg ha^{-1}. However, the shortest days (149 days) were obtained from 140 kg ha^{-1} seed rate, and it was statistically similar with 120 kg ha^{-1} (Table 4). Increased seeding rate from 80-140 kg ha^{-1} decreased days to physiological maturity. The earlier maturity observed with the high seed rate might be due to the increased plant population that increased intra-plant competition for nutrients and light. As a result plants stay no longer in development stage. This may have also contributed to the reduction in grain filling period, because at higher seed rate maturity hastened as compared to lower seed rate. In agreement with this result, Brzegen *et al.* (2019) reported that the longest days to physiological maturity were recorded at the seed rate of 100 kg ha^{-1}, while the shortest was recorded at 175 kg ha^{-1} seed rate. Similarly, increasing seed rate from 100 – 150 kg ha^{-1} decreased days to physiological maturity (Amare and Mulatu, 2017; Abiot, 2017). In contrast, Jemal *et al*. (2015) reported that application of highest seeding rates significantly increased days to physiological maturity of wheat.

Increasing NPSB rates from 0 – 150 kg ha^{-1} showed decreasing tends for days to physiological maturity. The longer days to physiological maturity (154 days) were recorded from the control. However, the shorter days to physiological maturity (148 days) were recorded from 150 kg ha^{-1} NPSB rate, and it was statistically similar with 100 kg ha^{-1} (Table 4). The presence of balanced fertilizer due to increased fertilizer rates resulted in hastened physical maturity of wheat. In line with this result, Woldetsadik *et al.* (2018) reported that increasing NPSBZN rate decreased days to physiological maturity in bread wheat. Similarly, Teklu *et al*. (2019) reported that increasing NPSB rate from 0 – 300 kg ha^{-1} for bread wheat, decreased days to physiological maturity. Furthermore, Zemichael and Kiros (2019) reported increased fertilizer rate hastened days to physiological maturity in barley.

4.3. Growth Parameters

4.3.1. Plant height

The main effect of seed and NPSB fertilizer rates had a highly significant ($P < 0.01$) influence on plant height. However, their interaction did not show a significant influence on this parameter (Appendix Table 2). The tallest plants (95.1 cm) were recorded from a seed rate of 140 kg ha^{-1} followed by 120 kg ha^{-1}. However, the shortest plant (93.1 cm) were recorded at the seed rate of 80 kg ha^{-1}, and it was statistically similar with 100 kg ha^{-1} (Table 5). The tallest plant at the highest seed rate may be due to greater intraspecific competition between plants for light and space, which may encourage elongation of the stem. In agreement with this result, Girma *et al.* (2018) obtained that as the seed rate increased from 100 – 150 kg ha^{-1}, the height of the plant correspondingly increased. Similarly, Brzegen *et al.* (2019); and Bezabih (2020) reported a significant differences in plant height with variable seed rates. Additionally, Tewodros *et al.* (2017) reported an increase in plant height when a seed rate increased from 100 – 175 kg ha^{-1}. However, in contrast to this result, Jemal *et al*. (2015) reported that with increasing seed rate the plant height was declined. Similarly, Rahel and Fekadu (2016) reported a decreasing plant height of wheat when the seeding rate increased from 75 – 150 kg ha^{-1}.

Regarding the main effect of NPSB fertilizer rates, the tallest plant height (95.7 cm) was recorded from 150 kg ha^{-1} followed by 100 kg ha^{-1} NPSB fertilizer rates. However, the shortest plant (91.6 cm) was obtained from the control (Table 5). In general, the increasing plant height with higher NPSB fertilizer rates could be attributed to its greater contribution to wheat vegetative growth and development. This result is consistent with the finding of Gizachew *et al.* (2019), who reported that increased plant height due to increasing NPSB fertilizer from 0 – 200 kg ha^{-1}. Similarly, Amsale *et al.* (2019) reported an increase in plant height with increasing NPS fertilizer rate. Furthermore, Brzegen *et al.* (2019) reported longer plant height in response to increased application of blended fertilizer.

Table 5. Main effect of seed and NPSB fertilizers rates on plant height and spike length of bread wheat at Duna district during 2020 cropping season

Treatments	Plant height (cm)	Spike length (cm)
Seed rate (kg ha^{-1})		
80	93.1^{c}	7.6^{a}
100	93.7^{bc}	7.5^{ab}
120	94.4^{ab}	7.3^{bc}
140	95.1^{a}	7.1^{c}
LSD (0.05)	0.9	0.3
NPSB rate (kg ha^{-1})		
0	91.6^{c}	6.9^{c}
50	94.1^{b}	7.3^{b}
100	94.9^{ab}	7.5^{b}
150	95.7^{a}	7.8^{a}
LSD (0.05)	0.9	0.3
CV (%)	1.3	5.1

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.

4.3.2. Spike length

Seed and NPSB fertilizer rates had a highly significant ($P < 0.01$) effect on the spike length of bread wheat. However, their interaction did not show a significant effect on the spike length (Appendix Table 3). The result revealed that the increasing seed rates resulted in a decreased spike length. The longest spikes (7.6 cm) were produced at a seed rate of 80 kg ha^{-1} followed by 100 kg ha^{-1}, whereas the shortest spikes (7.1 cm) were obtained at the seed rates of 140 kg ha^{-1}, and it was statistically at par with 120 kg ha^{-1} (Table 5). Such an increase in the spike length with a lower seeding rate might be due to the availability of resources with less competition for growth and development. The present result is in line with the finding of Rahel and Fekadu (2016), who reported a shorter spike length in wheat as the seed rate increases from 75 – 150 kg ha^{-1}. A similar inverse relationship of spike length with the increasing or decreasing seeding rates has also been reported elsewhere (Amare and Mulatu, 2017; Brzegen *et al.*, 2019; Girma *et al.* 2018; Jemal *et al.*, 2015).

Regarding the effects of NPSB fertilizer rates, the longest spikes (7.8 cm) were recorded at the rate of 150 kg NPSB ha^{-1}, whereas the shortest spikes (6.9 cm) were recorded from the control (Table 5). The increase in spike length with NPSB fertilizer rate might have resulted from improved root growth and increased uptake of nutrients, better growth 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 finding of Firehiwot (2014), who reported that the maximum spike length from the combined application of N and P fertilizers sources. Similarly, Gizachew *et al.* (2019) reported that increased spike length with increased NPSB ha^{-1} rates. In addition, Amsale *et al.* (2019); and Girma *et al.* (2018) reported that the longest spike was obtained at the highest NPS ha^{-1} rates.

4.4. Yield and Yield Components

4.4.1. Number of total tillers

The number of total tillers m^{-2} was highly significantly ($P < 0.01$) affected by the main effects of seed and NPSB fertilizer rates, as well as by their interaction ($P < 0.05$) (Appendix Table 3). The maximum number of total tillers (539 m^{-2}) were produced from the combined use of 140 kg seed ha^{-1} + 150 kg NPSB ha^{-1} rates, followed by 120 kg seed ha^{-1} + 150 kg NPSB ha^{-1} combination. However, the minimum number of tillers (223 m^{-2}) were recorded from the combination of 80 kg seed + 0 kg NPSB ha^{-1} rates, and it was statistically similar with zero level of NPSB and 100, 120, and 140 kg ha^{-1} seed rates (Figure 3).

The highest number of tillers at the highest NPSB fertilizer rate might be due to the rapid conversion of synthesized carbohydrates into protein and consequently the increase in number and size of growing cells, ultimately resulting in an increased number of tillers plant^{-1} with optimal nutrient availability. The improvement in the total number of tillers with NPSB fertilizer application might be due to the enhancing role of P in emerging radical and seminal roots during seedling establishment in wheat. The highest number of total tillers at highest seed rates could be due to the highest number of plant per unit area. In agreement with this result, Girma *et al.* (2019) reported highest numbers of total tillers with the application of the highest rates of seed and NPS, while the lowest number of total tillers with the application of the lowest seed rate and unfertilized plots.

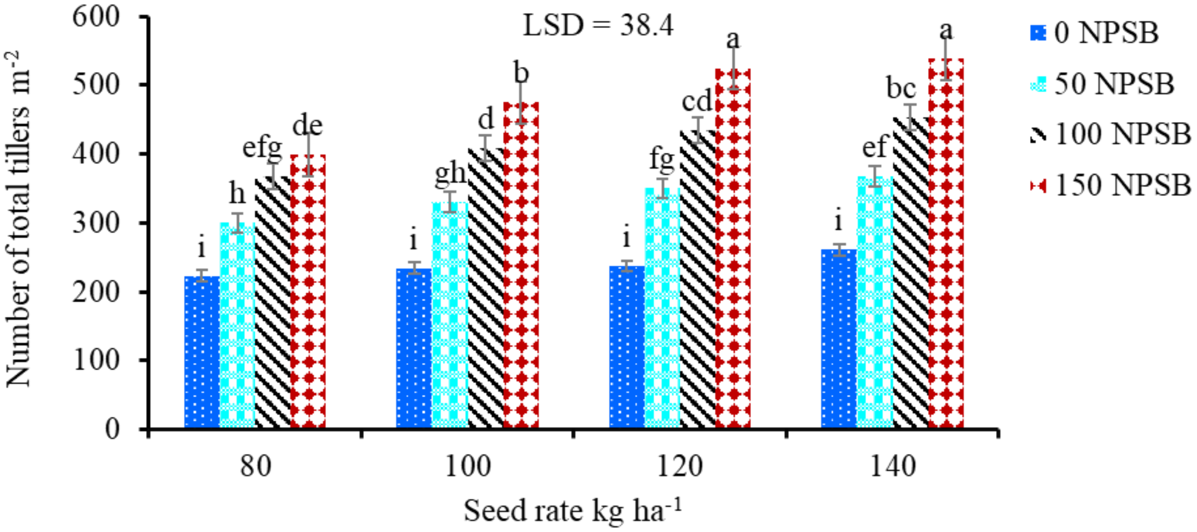


Figure 3. Interaction effect of seed and NPSB fertilizer rates on number of total tillers m^{-2} of bread wheat at Duna district during 2020 cropping season.

4.4.2. Number of productive tillers

The number of productive tillers produced m^{-2} were highly significantly ($P < 0.01$) affected by the main effects of seed and NPSB fertilizer rates, and by their interactions ($P < 0.05$)

(Appendix Table 3). The productive tillers showed an increasing trend with the increasing rates of both factors (Figure 4). The maximum number of productive tillers (518 m^{-2}) were produced with the application of the highest rates of seed and NPSB fertilizer (140 kg seed ha^{-1} + 150 kg NPSB ha^{-1}) rates followed by 120 kg seed ha^{-1} + 150 kg NPSB ha^{-1}, whereas the minimum number of productive tillers (217 m^{-2}) were recorded from the combination of 80 kg seed + 0 kg NPSB rates ha^{-1}, and it was statistically similar with zero level of NPSB and 100, and 120 kg ha^{-1} seed rate. The highest number of productive tillers at the highest seed and NPSB fertilizer rates could be due to their favorable effect on increasing the total tillers and tiller maintenance during crop growth and development. In line with this result, Brzegen *et al.* (2019) showed that increased seed and NPS rates resulted in an increased number of productive tillers m^{-2}. Similarly, Girma *et al.* (2018) reported highest numbers of productive tillers with the application of the highest number of seeding and NPS rates.

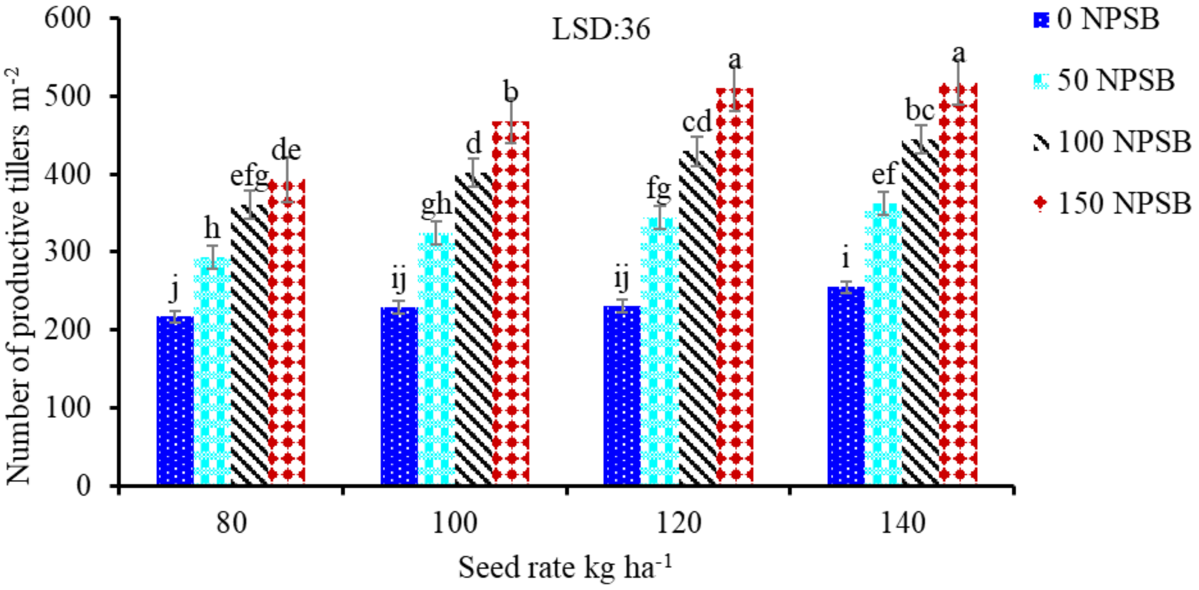


Figure 4. Interaction effect of seed and NPSB fertilizer rates on number of productive tillers m^{-2} of bread wheat at Duna district during 2020 cropping season

4.4.3. Number of kernels spike^{-1}

The main effect of the NPSB fertilizer rate had highly significant ($P < 0.01$) effect on the number of kernels spike^{-1}. However, the main effect of seed rate and their interaction had no significant effects on the number of kernels spike^{-1} (Appendix Table 6). The highest number of kernels spike^{-1} (73.5) was counted from the application of 150 kg ha^{-1} NPSB fertilizer followed by 100 kg ha^{-1}, while the lowest number of kernels spike^{-1} (55.2) was recorded from the control (Table 6). The highest number of kernels spike^{-1} from NPSB fertilizer application may be due to the role of each essential nutrient found in applied fertilizer. For instance, P plays many physiological processes that occur within developing kernels and are involved in enzymatic reactions in the plant and the development of grains. Similarly, B plays a vital role in the grain setting of wheat. So, the supply of B containing fertilizer helps in grain filling, and ultimately sterility is reduced and the number of grains spike^{-1} increased. In general, the synergistic effect of these elements plays a pivotal role in increasing kernels spike^{-1}, which increases the final grain yield in wheat. Consistent with these results, many authors reported that kernel numbers spike^{-1} had increased due to the application of optimum fertilizer in cereals (Amsale *et al.,* 2019; Desta and Yibekal, 2020; Dinkinesh *et al.,* 2020). Similarly, Gizachew *et al.* (2019) reported that the NPSB treatment resulted in a significant improvement in the number of kernels spike^{-1}.

Table 6. Main effect of seed and NPSB fertilizers rates on number of kernels spike^{-1} and thousand kernel weight of bread wheat at Duna district during 2020 cropping season

Treatments	Number of kernels spike^{-1}	Thousand kernel weight (g)
Seed rate (kg ha^{-1})		
80	67.4	41.7^{ab}
100	65.9	42.2^{a}
120	65.0	42.6^{a}
140	62.9	40.8^{b}
LSD (0.05)	NS	0.98
NPSB rate (kg ha^{-1})		
0	55.2^{c}	40.1^{c}
50	61.9^{b}	41.4^{b}
100	70.7^{a}	42.5^{a}
150	73.5^{a}	43.3^{a}
LSD (0.05)	3.3	0.98
CV (%)	7.1	3.3

Means followed with the same letter/s in the column are not significantly different at 5% level, CV (%) = Coefficient of variation, ns = not significant difference, LSD $_{(0.05)}$ = Least Significant Difference at 5% level.

4.4.4. Thousand Kernel weight

The analysis of variance revealed that the main effects of seed and NPSB fertilizer rates had a highly significant ($P < 0.01$) effect on thousand kernel weight. However, their interaction did not significantly affected thousand kernel weight (Appendix Table 4). The maximum thousand kernel weight (42.6g) was recorded at the seed rate of 120 kg ha^{-1}, and it was statistically at par with 100 and 80 kg ha^{-1} seed rates. However, a minimum thousand kernel weight (40.8g) was recorded at the seed rate of 140 kg ha^{-1} (Table 6). The thousand kernel weight increased with increasing seed rate up to 120 kg ha^{-1} and then showed a decreasing trend beyond this seed rate. High seed rates caused to increasing total number of tillers and as a result competition increase and little photosynthesis would be available to grain filling and finally thousand kernels weight reduced. In agreement with this result, Rahel and Fekadu (2016); and

Tewodros *et al.* (2017) reported a maximum thousand kernel weight from a seed rate of 125 kg ha^{-1}.

Regarding the main effect of NPSB fertilizer rates, the maximum thousand kernel weight (43.3 g) was recorded from the 150 kg ha^{-1} NPSB fertilizer rate and it was statistically similar with 100 kg ha^{-1}, while a minimum thousand kernels weight of (40.1g) was recorded from the control (Table 6). Thousand kernel weight obtained from fertilized plots was significantly higher than unfertilized plots. This might be the balanced application of nutrients has enhanced the accumulation of assimilating in the grains, and thus resulting in heavier grains of wheat. Moreover, adequate and better amount nutrients of the plants resulted in good grain filling and development of better seed size. In line with this result, Usman *et al.* (2018) reported that the highest thousand kernel weight from NPSB fertilizer rate of 150 kg ha^{-1}. Similarly, Amsale *et al.* (2019) showed a significant effect of NPS application on thousand seed weight on wheat. Consistent with these results, several authors reported an increase in thousand kernel weight due to the application of NPSB fertilizer in wheat (Gizachew *et al.*, 2019; Dinkinesh *et al*., 2020).

4.4.5. Straw yield

Straw yield is an important component because farmers are also used straw for animal feed and income sources in addition to grain. The main effects of seed and NPSB rates had a highly significant ($P < 0.01$) effect on straw yield of bread wheat, but the interaction effect was not significant (Appendix Table 4). The maximum straw yield of 7.7 t ha^{-1} was recorded from the 140 kg ha^{-1} seed rate while the minimum straw yield of 6.9 t ha^{-1} was recorded from the lower seed rate of 80 kg ha^{-1}, and it was statistically similar with 100, and 120 kg ha^{-1} (Table 7). In generally, the increase in straw yield with higher seed rates resulted in more plant population per unit area. In confirming this result, Brzegen *et al.* (2019) reported that maximum straw yield was recorded from the higher seed rate whereas the minimum straw yield was recorded from the lower seed rate. Similarly, Wahid and Al-Hilfy (2017) reported that the highest straw yield was produced from plants sown at the seed rate of 140 kg ha^{-1}.

With regards to the main effect of NPSB fertilizer rates, the maximum straw yield (8.2 t ha^{-1}) was recorded from 150 kg ha^{-1} NPSB fertilizer rate followed by 100 kg ha^{-1} NPSB fertilizer rate. However, the minimum straw yield (5.8 t ha^{-1}) was recorded from the control (Table 7). The significant increase in straw yield in response to the highest rate of application of NPSB might be attributed to the synergistic roles of the four nutrients played in enhancing the growth and development of the vegetative part of the crop. In confirming this result, Abebaw and Hirpa (2018) reported that the higher straw yield by the application of 150 kg ha^{-1} NPSB fertilizer rate in bread wheat. Similarly, many other researchers have reported an increase in straw yield production with application essential plant nutrients (Amsale *et al.,* 2019; Brzegen *et al.,* 2019; Gizachew *et al,* 2019; Haji *et al.,* 2020).

Table 7. Main effect of seed and NPSB fertilizers rates on straw yield and above-ground dry biomass of bread wheat at Duna district, during 2020 cropping season.

Treatments	Straw yield (t ha^{-1})	Aboveground dry biomass (t ha^{-1})
Seed rate (kg ha^{-1})		
80	6.9^b	10.9^c
100	7.1^b	11.5^b
120	7.1^b	11.8^b
140	7.7^a	12.4^a
LSD (0.05)	0.4	0.5
NPSB rate (kg ha^{-1})		
0	5.8^c	8.5^d
50	7.0^b	11.3^c
100	7.9^a	13.1^b
150	8.2^a	13.7^a
LSD (0.05)	0.4	0.5
CV (%)	8.2	6.2

Means followed with the same letter/s in the columns are not significantly different at 5% level, CV (%) = Coefficient of variation, LSD $_{(0.05)}$ = Least significant difference at 5% level.

4.4.6. Grain yield

The analysis of variance showed that the main effects of seed and NPSB fertilizer rates and their interaction had highly significant ($P < 0.01$) and significant ($P < 0.05$) effect on grain yield, respectively (Appendix Table 5). The highest grain yield (6.1 t ha^{-1}) was obtained at the combination of 120 kg seed with 150 kg NPSB rates ha^{-1}, followed by 140 kg seed ha^{-1} with 150 kg NPSB ha^{-1} with a grain yield of 5.7 t ha^{-1}. However, the lowest grain yield (2.6 t ha^{-1}) was recorded from the combination of 80 kg seed ha^{-1} + 0 kg NPSB ha^{-1}, and it was statistically at par with zero level of NPSB fertilizer with 100, 140, and 120 kg seed rate ha^{-1} (Figure 5).

The grain yield increased with increasing seed rate up to 120 kg ha^{-1} and then showed a decreasing trend beyond this seed rate (Figure 4). Such an increase in grain yield is associated with the improved yield components, such as the number of effective tillers and thousand kernel weight due to the seed rate increment up to the optimal (Figure 5). The highest grain yield at the highest NPSB rates might have resulted from improved root growth, nutrient availability and increased uptake of nutrients due to the synergistic effect of the four essential nutrients thereby leading to enhanced yield components and yield. In line with this result, Habtamu *et al*. (2021) showed that the highest grain yield was obtained at the combination of optimum amount of seed rate with NPSB rates in food barley. Similarly, Shah *et al.* (2011) reported maximum grain yield from the combination of 120 kg seed with 120 kg N ha^{-1} rates in wheat. Debnath *et al.* (2014) also reported highest grain yield due to optimal seed and blended fertilizer combinations in wheat. However, in contrast to this result, Girma *et al.* (2018); and Brzegen *et al.* (2019), reported the highest number of grain yield from the combination of highest seed and NPS rates in wheat.

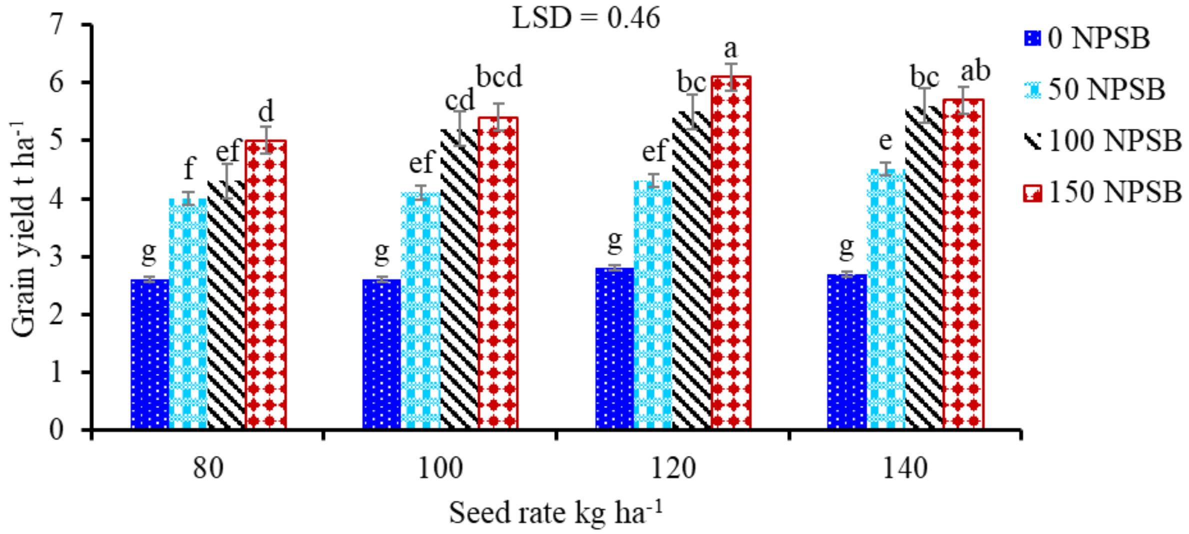


Figure 5. Interaction effect of seed and NPSB fertilizer rates on grain yield of bread wheat at Duna district during 2020 cropping season

4.4.7. Above-ground dry biomass

From a farmer's point of view, biological yield is also an important parameter since they use it as a source of feed for animals. The analysis of variance showed that the main effect of seed and NPSB fertilizer rates had a highly significant ($P < 0.01$) effect on the above-ground dry biomass of bread wheat, but the interaction effect was not significant (Appendix Table 5). The highest above-ground dry biomass (12.4 t ha^{-1}) was obtained from the seed rate of 140 kg ha^{-1}, while the lowest above-ground dry biomass (10.9 t ha^{-1}) was produced by 80 kg ha^{-1} seed rate (Table 7). In general, the increasing seed rates from 80 – 140 kg ha^{-1} resulted in an increased above-ground dry biomass mainly due to higher plant populations per unit area. In confirming with this result, Wahid and Al-Hilfy (2017) reported that the highest above-ground dry biomass was produced from wheat plants sown at the seed rate of 140 kg ha^{-1}, while the lowest above-ground dry biomass was obtained from 80 kg ha^{-1} seed rate. Similarly, Girma *et al.* (2018) reported that the highest above-ground dry biomass from 150 kg ha^{-1} seed rate in wheat. Furthermore, Brzegen *et al.* (2019) reported that above ground dry biomass was significantly affected by variable seed rates in wheat. In contrast, there are reports which indicate an increasing above-ground dry biomass as seed rates decreases (Rahel and Fekadu, 2016; Amare and Mulatu, 2017).

Regarding the main effect of NPSB fertilizer rates, the highest above-ground dry biomass (13.7 t ha^{-1}) was recorded from 150 kg ha^{-1} NPSB fertilizer application. However, the lowest above-ground dry biomass (8.5 t ha^{-1}) was recorded from the control (Table 7). In general, the increase in NPSB fertilizer rates has led to an improvement in above-ground dry biomass, which may be due to improved root growth and crop nutrient uptake. The result is in line with the finding of Abebaw and Hirpa (2018), who reported higher above-ground dry biomass due to higher NPSB fertilizer rate in bread wheat. Similarly, many other researchers have reported an increase in above-ground biomass production with application of essential plant nutrients (Brzegen *et al.,* 2019; Gizachew *et al.,* 2019; Zemichael and Kiros. 2019; Dinkinesh *et al.*, 2020; Haji *et al.*, 2020).

4.4.8. Harvest index

The analysis of variance showed that the main effects of seed rate and interaction of the factors significantly ($P < 0.05$) affected the harvest index, and blended NPSB fertilizer rate had a highly significant ($P < 0.01$) effect on the harvest index (Appendix Table 5). The highest harvest index (44.3%) was obtained at the combination of 120 kg seed with 150 kg NPSB ha^{-1}, followed by 120 kg seed rate with 100 kg NPSB ha^{-1} with a harvest index of (42%). However, the lowest harvest index (31.4%) was recorded from the combination of 80 kg seed + 0kg NPSB ha^{-1}, and it was statistically similar with zero level of NPSB and 140, 120 and 100 kg ha^{-1} seed rate (Figure 6).

The increment in harvest index with NPSB fertilizer application might be due to greater photo-assimilates production and it’s more partitioning to the grains compared to the straw. This result is in line with Debnath *et al.* (2014) who recorded highest harvest index from the combination of optimal seed and blended fertilizer rates wheat. In contrast to this result, Brzegen *et al.* (2019) revealed the maximum harvest index from the combination of highest seeding and NPS fertilizer rates in bread wheat.

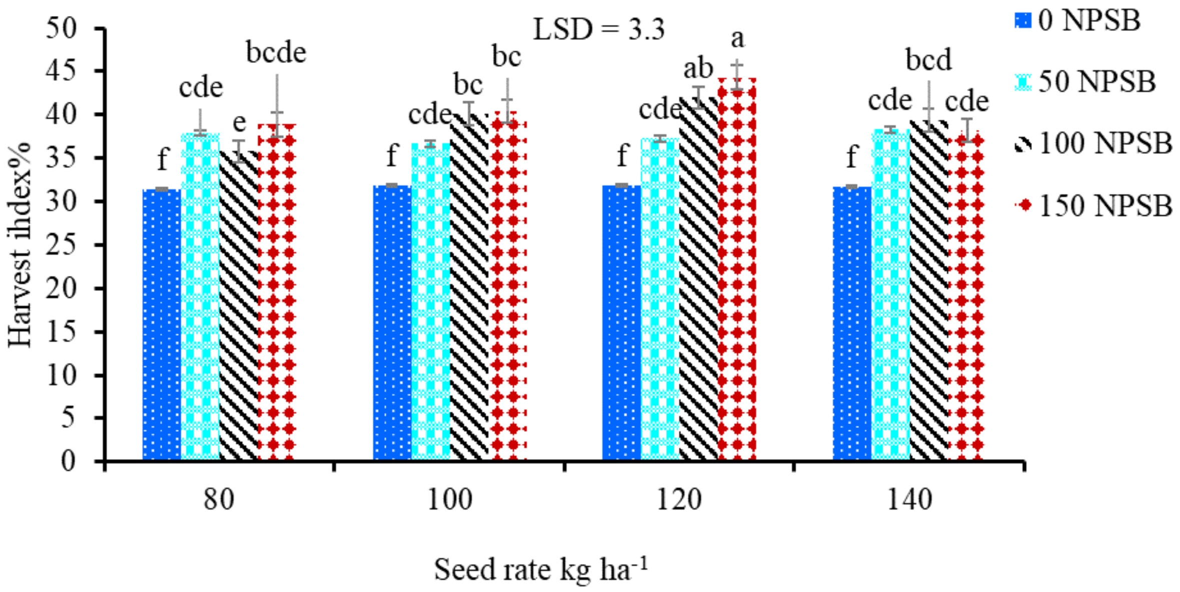


Figure 6. Interaction effect of seed and NPSB fertilizer rates on harvest index of bread wheat at Duna district during 2020 cropping season.

4.5. Correlation Analysis

Correlation analysis among yield and yield parameters revealed a positive and significant relationship for most of the parameters measured (Table 8). The result revealed that the grain yield had highly significant (*P<0.001*) and positive correlations with plant height (r = 0.78), number of total tillers (r = 0.93), number of productive tillers (r = 0.94), above-ground biomass (r = 0.95) and number of kernel per spike^{-1} (r = 0.74) (Table 8).

Above-ground biomass was highly significant (*P<0.001*) and positively correlated with plant height (r = 0.79), number of total tillers (r = 0.92), number of productive tillers (r = 0.92), number of kernel per spike^{-1} (r = 0.74), grain yield (r = 0.95) and straw yield (r = 95). Straw yield had highly significant (*P<0.001*) and positive correlations with plant height (r = 0.73), number of total tillers (r = 0.82), number of productive tillers (r = 0.82), and above-ground biomass (r = 0.95) (Table 8). Similar to this experiment, Haji *et al.* (2020) reported that grain yield was significantly and positively correlated with plant height, above-ground biomass, number of kernel per spike^{-1} and thousand kernels weight of wheat.

Table 8. Correlation among yield and yield components of bread wheat at Duna district during 2020 cropping season

	PH	NTT	NPT	SL	NPKS	TKS	AGBM	GY	SY
PH	1	0.79***	0.80***	0.43**	0.54***	0.46**	0.79***	0.78***	0.73***
NTT		1	0.99***	0.43**	0.70***	0.54***	0.92***	0.93***	0.82***
NPT			1	0.44**	0.70***	0.55***	0.92***	0.94***	0.82***
SL				1	0.59***	0.46**	0.45**	0.49***	0.37**
NPKS					1	0.55***	0.74***	0.74***	0.66***
TKS						1	0.54***	0.57***	0.45**
AGBM							1	0.95***	0.95***
GY								1	0.81***
SY									1

Where: - Level of significance: *** = *P<0.001*; ** = *P< 0.01*; * = *P< 0.05*; ns = non significance difference PH = plant height, NTT = number of total tillers, NPT = number of productive tillers, SL = spike length, NKPS = number of kernel spike^{-1}, TKW = thousand kernel weight, AGBM = above-ground dry biomass, GY = grain yield, and SY = straw yield.

4.6. Partial Budget Analysis

Partial budget analysis of the net benefits, total costs that vary, and marginal rate of returns are presented in Table 9. Information on the costs and benefits of treatments is a prerequisite for the adoption of technical innovation for farmers. Then the recommended level of 10% was adjusted to obtain net yield. The net yield was multiplied by the market price to obtain gross field benefit. Costs and benefits were calculated for each treatment. All variable costs were calculated based on the current market price especially for fertilizers and bread wheat seed. Variable costs were summed up and subtracted from gross benefits.

The results in this study indicated that the application of seed and blended NPSB fertilizer rate resulted in higher net benefits than the unfertilized treatments (Table 9). As indicated in Table

9, the partial budget analysis showed that the highest net benefit (81,914 ETB ha^{-1}) were obtained at the rate of application of 120 kg seed ha^{-1} with 150 kg blended NPSB ha^{-1} rates followed by 140 kg seed ha^{-1} with 100 kg blended NPSB ha^{-1} rates (75,392 ETB ha^{-1}), while the lowest net benefit (35,809 ETB ha^{-1}) were obtained from seed rate of 80 kg ha^{-1} and zero fertilizer application.

According to CIMMYT (1988) suggestion, the minimum acceptable marginal rate of return should be more than 100%. In this study, the application of 120 kg seed with 150 kg NPSB ha^{-1} rates gave the maximum economic benefit (81,914 ETB ha^{-1}) with a marginal rate of return (988.2%) (Table 9). Hence, the combination of 120 kg ha^{-1}seed and 150 kg ha^{-1} NPSB rates is profitable than other combinations, therefore this combination can be recommended for wheat production in the Duna District and areas sharing similar agro-ecology.

Table 9. Summary of partial budget and marginal rate of return analysis for response of bread wheat to seed and blended NPSB fertilizer rates at Duna District, Southern Ethiopia.

Treatments		Wheat yield (kg ha^{-1})			Income (ETB ha^{-1})		GFB(ETB ha^{-1})	TVC(ETB ha^{-1})	NB(ETB ha^{-1})	MRR %
Seed rate (kg ha^{-1})	NPSB rate (kg ha^{-1})	UGY	AGY	ASY	Grain	Straw				
80	0	2600	2340	5130	38610	1539	40149	4340	35809	0.0
100	0	2640	2376	5040	39204	1512	40716	4850	35866	11.2
120	0	2800	2520	5310	41580	1593	43173	5500	37673	278
140	0	2700	2430	5319	40155	1596	41751	5940	35811	D
80	50	4000	3600	5850	59400	1755	61155	6620	54535	2753
100	50	4100	3690	6390	60885	1917	62802	7200	55602	183.9
80	100	4300	3870	6930	63855	2079	65934	7650	58284	596
120	50	4300	3870	6570	63855	1971	65826	7850	57976	D
140	50	4500	4050	6480	66825	1944	68769	8500	60269	352.7
100	100	5200	4680	7020	77220	2106	79326	8790	70536	3540
80	150	5000	4500	7020	74250	2106	76356	8960	67396	D
120	100	5500	4950	6930	81675	2079	83754	9510	74244	1245
100	150	5400	4860	7200	80190	2160	82350	9750	72600	D
140	100	5600	5040	7740	83160	2322	85482	10090	75392	821.2
120	150	6100	5490	6930	90585	2079	92664	10750	81914	988.2
140	150	5700	5130	8280	84645	2484	87129	10980	76149	D

Where, UGY = Unadjusted grain yield, AGY = adjusted grain yield downwards by 10%, ASY = adjusted straw yield downwards by 10%, GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr ha^{-1}; D = dominated treatments. Cost of bread wheat seed= Birr 24.5 kg^{-1}, NPSB cost = 16 Birr kg^{-1}. The labour cost for application of NPSB (8 persons ha^{-1}, each 60 ETB day^{-1}) and seed(8 person's ha^{-1}, each 60 ETB day^{-1}), Market price of bread wheat grain = 16.5 Birr kg^{-1} and straw= 0.3 Birr kg^{-1} in Ansho market at harvesting time in December 2020.

5. SUMMARY AND CONCLUSION

Wheat is one of the most important cereal crops globally and is a staple food for about one-third of the world population. It has been selected as one of the targets and strategic food security crops in Ethiopia. In the study area, it is produced by smallholder farmers both for home consumption and market. However, wheat yield in Ethiopia and in the study district is low compared to the world average and attainable yield due to both abiotic and biotic constraints such as poor soil fertility, disease, insect pests, poor crop management practices including; the use of sub-optimal seed and fertilizer rates, and climatic factors among the others. Therefore, the current study was conducted to assess the effect of seed and NPSB fertilizer rates on growth performance and yield of bread wheat, and to determine the economic feasibility of these treatments for wheat production in the study area.

Bread wheat variety "Sanate" which was released by Sinana agricultural research center (SARC) in 2014 cropping season was used as experimental material. The experiment was laid out in a Randomized Complete Block design in factorial combinations with four replications. The treatment consists of the combinations of four levels of seed rates (80, 100, 120, and 140 kg ha^{-1}) and four levels of NPSB fertilizer rates (0, 50, 100, and 150 kg ha^{-1}). The experiment was conducted at Halatebo kebele farmers training center in Duna district, Hadiya zone, southern Ethiopia, during 2020 cropping season.

All data collected on phenological, growth, and yield and yield component parameters were analyzed using SAS software version 9.0. Results revealed that days to heading, days to physiological maturity, plant height, spike length, thousand kernel weight, straw yield and above-ground dry biomass were significantly ($P < 0.01$) affected by the main effect of seed and NPSB fertilizer rates. However, number of kernel spike^{-1} was only affected by NPSB fertilizer rate.

The longest days to heading, days to physiological maturity and spike length were obtained at the seed rate of 80 kg ha^{-1}. However, the heaver thousand kernel weight was recorded from the seed rate of 120 kg ha^{-1}. On the other hand, plant height, straw yield and above-ground dry biomass were higher at a seed rate of 140 kg ha^{-1}. The shortest days to heading, days to physiological maturity, spike length, lowest thousand kernel weight were obtained at the seed rate of 140 kg ha^{-1}, while the shortest plant height, lowest straw yield and above-ground dry biomass were recorded at a seed rate of 80 kg ha^{-1}.

Regarding the main effects of NPSB fertilizer rate, the longest days to heading and days to physiological maturity were obtained from the control. However, the longest plant height, spike length, number of kernel spike^{-1}, thousand kernel weight, above-ground dry biomass, and straw yield were recorded from 150 kg ha^{-1} NPSB fertilizer rate. On the other hand, the shortest plant height, spike length, number of kernels spike^{-1}, thousand kernel weight, above-ground dry biomass, and straw yield were recorded from the control.

Analysis of the results revealed that the number of total tillers, number of productive tillers, grain yield, and harvest index were significantly ($P < 0.05$) affected by the interaction of the seed and NPSB fertilizer rates. The highest number of total tillers and the number of productive tillers were recorded at the combination of 140 kg ha^{-1} seed + 150 kg ha^{-1} NPSB fertilizer rates, while the highest grain yield and harvest index were recorded at the combination of 120 kg ha^{-1} seed + 150 kg ha^{-1} NPSB fertilizer rate. The lowest number of total tillers, number of productive tillers, grain yield, and harvest index were recorded at the combination of the lowest rates of 80 kg ha^{-1} seed + 0 kg ha^{-1} NPSB fertilizer rate. In the correlation analysis, all parameters were positively correlated to grain yield. Grain yield had highly significant (*P<0.001*) and positive correlations with plant height (r = 0.78), number of total tillers (r = 0.93), number of productive tillers (r = 0.94), above-ground biomass (r = 0.95) and number of kernel per spike^{-1} (r = 0.74).

The partial budget analysis showed that the highest net benefit of 81,914 ETB ha^{-1} was obtained from 120 kg ha^{-1} seed + 150 kg ha^{-1} NPSB fertilizer rates with marginal rate of return of 988.2%, which is above the minimum acceptable marginal rate of return should be more than 100%, while the lowest net benefit of 35,809 ETB ha^{-1} was obtained from seed rate of 80 kg ha^{-1} and zero fertilizer application. In general, this study provided evidence that yield and economic returns of bread wheat can be improved by the combined use of optimum seed and blended NPSB fertilizer rates.

The results showed that using 120 kg ha^{-1} seed with 150 kg ha^{-1} NPSB rates gave better economic benefit, and therefore, this combination can be recommended for bread wheat production in the study area and other areas with similar agro-ecological condition. However, as the experiment was conducted for a single season at a location, the experiment has to be repeated over seasons and locations to put the recommendation in a firm ground.

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7. APPENDICES

Appendix Table 1. Mean monthly annual total rainfall and minimum and maximum temperatures of ten years (2011-2020) duna district 2020 cropping season

2011-2019 Meteorological data				2020 Meteorological data			
Months	Total rainfall (mm)	Min. temp ℃	Max. temp ℃	Total rainfall (mm)	Min. temp ℃	Max. temp ℃	Average temp℃
January	12.3	12.0	24.8	0.0	12.5	24.0	18.25
February	21.4	14.2	25.3	0.0	15.5	26.4	20.95
March	81.1	12.9	25.9	86.4	11.5	23.6	17.55
April	136.2	10.1	24.5	185.1	12.0	22.7	17.35
May	121.6	11.7	23.7	80.5	12.0	24.7	18.35
June	186.5	10.0	19.5	238.1	10.6	18.2	14.4
July	244.9	9.9	16.7	262.5	10.5	19.0	14.75
August	205.8	11.3	19.7	181.9	10.9	20.1	15.5
September	176.1	11.1	21.4	174.8	11.5	21.5	16.5
October	67.3	10.8	23.3	84.2	11.8	23.3	17.55
November	18.4	10.5	23.9	9.0	12.5	23.0	17.75
December	5.0	12.9	24.2	5.0	12.7	23.5	18.1
Total	1276.6	-	-	1307.5	-	-	-
Average	106.4	11.5	22.7	108.9	12	22.5	17.25

Source: National Meteorological Agency, Hawassa Branch (2020)

Appendix Table 2. Mean squares of ANOVA for day to heading, physiological maturity and plant height of bread wheat as affected by seed and NPSB rates

		Mean squares		
Source of variation	DF	Day to heading	Physiological maturity	Plant height
Replication	3	3.2	10.4	0.8
Seed rate (SR)	3	10.9**	19.9**	12.7**
Blended NPSB	3	82.9**	96.2**	50.7**
SR*NPSB	9	1.5^{NS}	4.1^{NS}	0.3^{NS}
Error	45	1.4	4.2	1.6
CV (%)		1.7	1.4	1.3

Where, DF= degree of freedom, CV = coefficient of variation, ANOVA=analysis of variance, NS=non-significant difference, * and ** significant at 5% and 1% level significant, respectively.

Appendix Table 3. Mean squares of ANOVA for number of total tillers, number of productive tillers, and spike length of bread wheat as affected by seed and NPSB rates.

		Mean squares		
Source of variation	DF	Number of total tillers	Number of productive tillers	Spike length
Replication	3	335.7	270.3	0.01
Seed rate (SR)	3	20295.2**	18770.7**	0.84**
Blended NPSB	3	179345.6**	170621.9**	2.43**
SR*NPSB	9	1759.7*	1408.5*	0.10^{NS}
Error	45	755.5	666.6	0.14
CV (%)		7.5	7.2	5.2

Where, DF= degree of freedom, CV = coefficient of variation, ANOVA=analysis of variance, NS=non-significant difference, * and ** significant at 5% and 1% level significant, respectively.

Appendix Table 4. Mean squares of ANOVA for number of kernels spike-1, thousand kernels weight, and straw yield of bread wheat as affected by seed and NPSB rates.

		Mean squares		
Source of variation	DF	Number of kernels spike^{-1}	Thousand kernels weight	Straw yield
Replication	3	2.7	1.9	0.02
Seed rate (SR)	3	57.3^{NS}	10.1**	2.01**
Blended NPSB	3	1117.8**	31.2**	18.87**
SR*NPSB	9	29.6^{NS}	0.8^{NS}	0.52^{NS}
Error	45	21.2	1.9	0.35
CV (%)		7.1	3.3	8.2

Where, DF= degree of freedom, CV = coefficient of variation, ANOVA=analysis of variance, NS=non-significant difference, * and ** significant at 5% and 1% level significant, respectively.

Appendix Table 5. Mean squares of ANOVA for grain yield, above ground dry biomass, and harvest index of bread wheat as affected by seed and NPSB rates.

		Mean squares		
Source of variation	DF	Grain yield	Above ground dry biomass	Harvest index
Replication	3	0.132	0.09	0.0003
Seed rate (SR)	3	1.81**	6.4**	0.0024*
Blended NPSB	3	25.84**	88.8**	0.0239**
SR*NPSB	9	0.28*	0.7^{NS}	0.0012*
Error	45	0.11	0.51	0.0006
CV (%)		7.4	6.2	6.3

Where, DF= degree of freedom, CV = coefficient of variation, ANOVA=analysis of variance, NS=non-significant difference, * and ** significant at 5% and 1% level significant, respectively.

Appendix figure 1. Experiment establishment stage

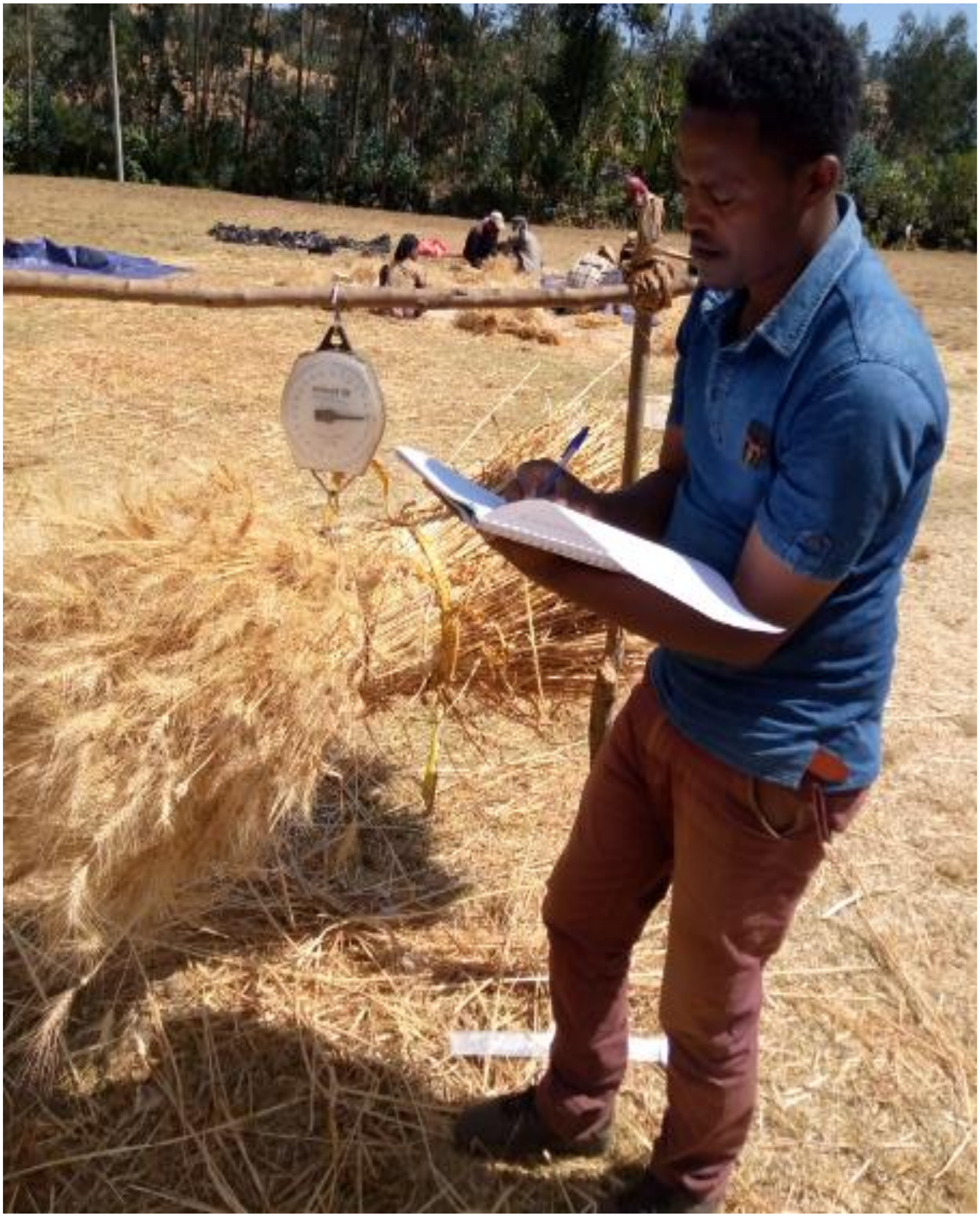
Appendix figure 2. Early performance of bread wheat, immediate after hand weeding.

Appendix figure 3. Full heading stage

Appendix figure 4. Kernel development stage

Appendix figure 5. During plant height measurement at physiological maturity

Appendix figure 6. Harvesting process



Appendix figure 7. Biomass measurement

Appendix figure 8. During thousand grain weight determination using a sensitive balance

8. BIOGRAPHICAL SKETCH

The author Birhanu Araso Latebo was born in June 1985 in Duna District, Hadiya Zone of Southern Ethiopia. He attended his junior elementary School at Bure-bulshana from 1992 to 1999 and his secondary school at Gimbichu from 2000 to 2003. After completion of his high school, he joined Alage ATVTE College for his diploma program and graduated in Plant Science in July 2006. After completion of his diploma, he also served in the Duna district Agriculture office, which is found in Hadiya Zone SNNPRS as a Plant Science professional. Then he joined Wolita Sodo University for the undergraduate program from 2010 – 2014 for a degree program. After completion of his study, he worked as an agronomist in the Duna district. Then after five years of service at Duna district Agricultural office, he joined the School of Graduate Studies of Hawassa University in 2019 to pursue his MSc Study in Agronomy.