



**EFFECTS OF BLENDED NPS FERTILIZER RATES ON GROWTH,
YIELD AND YIELD COMPONENTS OF BREAD WHEAT (*Triticum
aestivum* L.) VARIETIES IN GORCHE DISTRICT, SOUTHERN
ETHIOPIA**

MSc. THESIS

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HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

HAWASSA, ETHIOPIA

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ETHIOPIA**

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**A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND
HORTICULTURAL SCIENCES, COLLEGE OF AGRICULTURE,
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FEBRUARY, 2023

COLLEGE OF AGRICULTURE
SCHOOL OF PLANT AND HORTICULTURAL SCIENCES
ADVISORS APPROVAL SHEET – I

This is to certify that the thesis entitled “**Effect of NPS fertilizer rates on growth, yield and yield components of bread wheat (*Triticum aestivum* L.) varieties in Gorche district, southern Ethiopia**” submitted in partial fulfillment of the requirements for the degree of Master of Science with specialization in **Agronomy**, to graduate program of the School of Plant and Horticultural Sciences, College of Agriculture, and is a record of original research carried out by **Tamiru Elias**, ID. No. **GpAgroR/0011/11** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the Final MSc Open Defance by **Tamiru Elias**, have read and evaluated his thesis entitled “**Effect of NPS fertilizer rates on growth, yield and yield components of bread wheat (*Triticum aestivum* L.) varieties in Gorche district, southern Ethiopia**” and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Masters of Science in plant sciences with specialization in **Agronomy**.

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DEDICATION

This thesis is dedicated to my beloved, whole family for their contribution, encouragement, prayers and wholehearted partnership for my success in life.

STATEMENT OF THE AUTHER

By my signature below, I declare and affirm that this thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that included in the Thesis has been given recognition through citation.

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LIST OF ABBREVIATIONS

ATA	Agricultural Transformation Agency
CEC	Cation Exchange Capacity
CIMMYT	International Maize and wheat Improvement Center
CSA	Central statistical agency
ETB	Ethiopian Birr
EIAR	Ethiopian Institute of Agricultural Research
EthioSIS	Ethiopian Soil Information System
FAO	Food and Agricultural Organization
ICARDA	International Center for Agricultural Research in the Dry Areas
HARC	Holeta Agricultural Research Center
LSD	List Significant Difference
NPS	Nitrogen, Phosphorous, and Sulfur
RCBD	Randomized Complete Block Disgnine
SAS	Statistical Analysis Software
USDA	United States Department of Agriculture

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Effect of blended NPS fertilizer rates on growth, yield and yield components of Bread Wheat (*Triticum aestivum* L.) in Gorche district, Southern Ethiopia.

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ABSTRACT

*Bread wheat (*Triticum aestivum* L.) is an important cereal crop in the southern highland of Ethiopia; however, its yield is low due to low productivity of farmers cultivar in use and a decline in soil fertility due to nutrient depletion. A field experiment was conducted to evaluate the effect of blended NPS fertilizer rates on the growth, yield, and yield components of bread wheat varieties and their economic viability in the Gorche district of the Sidama region of southern Ethiopia, during the main cropping season of 2021. The factors studied consist of four fertilizer rates (0, 50, 100, and 150 kg NPS ha⁻¹), and three bread wheat varieties (Wane, Kingbird, and Hidase). The experiment was laid out in a Randomized Complete Block Design with a factorial arrangement with three replications. Days to heading, days to maturity, plant height, number of tillers, spike length, straw yield, number of kernels per spike, grain yield, and 1000 seed weight were significantly affected by both fertilizer rate and varieties, but their interactions were not significant. From the results of this study, a higher grain yield of 2884.4 kg ha⁻¹ was obtained from the Hidase variety. Likewise, a higher grain yield (3363.0 kg ha⁻¹) was obtained from 150 kg NPS ha⁻¹. However, the bread wheat yield obtained at NPS rates 100 and 150 kg ha⁻¹ did not show statistically significant differences with each other. Moreover, the Hidase variety at 100 kg ha⁻¹ NPS rate was found to be superior in terms of economic viability. Therefore, the Hidase variety and application of 100 kg NPS ha⁻¹ were recommended for the study area. However, as the experiment was conducted only for a single season, the repeat of the study is suggested for more seasons around the Gorche area and similar agroecology.*

Key words: Blended fertilizer, Bread wheat, Economic return, Growth, Phenology, Yield.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and is a common component of the diet for more than one-third of the world's population (Mathpal et al., 2015; Desta et al., 2017). Due to income growth and rapid urbanization, it is becoming a key staple crop in Africa and sub-Saharan countries. However, these countries generally produce only 30% to 40% of their domestic needs and are highly dependent on imports, making the region highly vulnerable to international markets and supply risks (Negassa et al., 2013).

In Ethiopia, wheat is an important staple food crop, and since 2005 the country has been the largest producer in sub-Saharan Africa (FAOSTAT, 2018). Ethiopia is one of the largest wheat producers in the Sub-Saharan Africa, with yearly estimated production of 4.5 million tons on 1.69 million hectares of land in 2018/19 (CSA, 2019) with 2.66 ton yield per hectares (CSA, 2019). Wheat ranks fourth in area coverage and third in total production after tef (*Eragrostis tef*), maize (*Zea mays*), and sorghum (*Sorghum bicolor*) (CSA, 2019). The major wheat-producing regions of the country are Oromia, Amhara, Tigray, and Southern Nation Nationalities People Region (SNNPR) which share more than 83% of wheat production (CSA, 2017).

Bread wheat and durum wheat are two types of wheat produced in Ethiopia with an annual average of 60% and 40% production respectively (CSA, 2015). Bread wheat is the most important of these two types and covers more than 90% of the total wheat production area in Ethiopia (Hadison et al., 2020). The crop mainly grows in the midland and highlands of Ethiopia (Solomon et al., 2018). In general, the average National(2.66 t ha⁻¹),Regional(sidama)

(2.3 t ha⁻¹) and Disrict/Gorche (2.4 t ha⁻¹) productivity of the crop is below national average 2.66t ha⁻¹ and the crops potential 7 t ha⁻¹ on experimental plot(CSA,2020).

It is cultivated in a wide range of soil conditions, although it prefers fertile, dry silt and clay soils (Zenebu et al., 2018).

Wheat is a major staple crop and is consumed heavily in different forms (Brasesco et al., 2019). It has several food uses which can be prepared with a modern or culturally processed technique. Injera is one of the traditional food for Ethiopia that can be prepared by using wheat. Besides, pasta and macaroni can also be prepared in an industrial processed way (Nigusie et al., 2014). Nutritionally, it contributes significantly to the caloric and protein intake and ranks second next to maize (Li et al., 2011; FAO, 2014). Moreover, its straw is commonly used as a roof-tacking material and as feed for animals. It also serves as an important source of income for Ethiopian small-holders. It is an important cash crop in increasing the income of the people, food security, employment and Ethiopian GDP increment.

Although the crop has all these benefits, its productivity at the national level is low (CSA, 2019). Such low productivity of the crop is mainly attributed to the low level of adoption of improved varieties and improved agronomic practices (Jeyabalasingh and Bayissa, 2019; Teklay and Girmay, 2016) and low soil fertility (Birhanu et al., 2016). In addition, continuous cropping and inadequate replacement of nutrients, removed in crop harvest or loss through erosion and leaching are the major causes of soil fertility decline in Ethiopia (Hillette et al., 2015). Moreover, lack of soil fertility databases as well as site and crop-specific fertilizer

recommendations have been identified as key barriers to realizing crop potential (IFDC, 2018).

To tackle this problem, the Ministry of Agriculture conducted a soil and plant nutrient survey to determine the key soil nutrient limitations along with the importation of different blended fertilizers and micronutrients from abroad and test these against Urea (100 kg ha^{-1}) and diammonium phosphate (DAP, 100 kg ha^{-1}) for their impact on crop yield in different areas and crops (EhioSIS, 2014). The Soil Fertility Map prepared by the Agricultural Transformation Agency (ATA) in 2016 indicated the deficiency of soil nutrients in the Southern Nations and People's Region State. Accordingly, Asefa et al. (2015) showed improvement in wheat yield and yield components by 100, 72.3, and 78% due to application of N, S and P containing fertilizers, respectively. Hence, balanced fertilizers containing a combination of these nutrients are recommended to address site-specific nutrient deficiencies and also increase crop yield and productivity (ATA, 2016).

Currently, at the national level there is a move towards diversification and away from DAP and Urea, which have long been the only type of fertilizer imported for grain crops. However, there is no recommended rate for these blended fertilizers in the study area for bread wheat production except for the blanket application of 100 kg ha^{-1} of NPS. Moreover, there is no adequate information on the response of bread wheat varieties to these blended fertilizers and optimum rate of application in the study area. Therefore, the present study aims to evaluate the growth and yield response of bread wheat varieties to different rates of blended NPS fertilizer in Gorche District, Southern Ethiopia.

The specific objectives of this study were:-

- To Determine the effects of NPS fertilizer rates on yield and yield components of bread wheat varieties.
- To identify high-yielding bread wheat varieties and determine the optimum rate of blended fertilizer.
- To determine high yielding bread wheat varieties under different rates of blended NPS fertilizer.
- To determine economic feasibility rates of NPS fertilizer rates and varieties of bread wheat for the study area.

2. LITERATURE REVIEW

2.1. Wheat: Origin, Distribution and Production

Bread wheat (*Triticum aestivum* L.) is a hexaploid species with ($2n=6x=42$) having AABBDD belonging to the family Poaceae (Yadawad et al., 2015). Archeological evidence suggests that the domestication of wheat took place over a very long period, stretching from 12 000 BC to 6 500 BC. Wheat cultivation is reported about 6 000 years ago in the Mesopotamian Fertile Crescent, and from there it apparently spread to the Middle East, North Africa, Asia, and ultimately Europe (Harlan, 1981). Currently, it is the most widely and diversely grown food crop in the world.

Globally, China, India, and Russia are the largest wheat producers, while South Africa and Ethiopia are the largest wheat producers in sub-Saharan Africa (SSA) (Nigusa et al., 2022). It grows in Ethiopia at altitudes ranging from 1500 to 3000 m.a.s.l., and it is produced exclusively under rain-fed conditions (Hailu et al., 2023). However, the most suitable areas fall between 1900 and 2700 m.a.s.l.; and currently, production under irrigation in lowland plains is under trial. It grows on a variety of soil types, ranging from well-drained fertile soils to heavy, waterlogged vertisols (Anbessie, 2020). The major wheat-producing areas in Ethiopia are located in Arsi, Bale, Shewa, Ilubabor, Western Hareghe, Sidamo, Tigray, Northern Gonder, and Gojam zones (Shiferaw et al., 2014; Anbessie, 2020).

2.2. Bread Wheat Production in Ethiopia

In Ethiopia, agriculture accounts for about 42% of the gross domestic product (GDP), 85% of employment opportunity, and contributes around 90% of the total export earnings of the country (CSA, 2017). Crops are the major agricultural commodities on which Ethiopians largely depend for their daily food. Among the crops, wheat is an important staple food crop in Ethiopia providing about 15% of the caloric intake for the country's over 90 million population, placing it second after maize and slightly ahead of teff, and sorghum (FAO, 2015; Minot et al., 2015). Ethiopia ranks 31st in the world with 4.2 million quintals produced on 1.7 million hectares of land and is one of the largest sub-Saharan African wheat producers and ranks second to South Africa in terms of its total area coverage and the amount produced (Degye et al., 2019; Hei et al., 2017).

However, its production and productivity are affected by complex and interactive effects of biotic and abiotic factors and socio-economic challenges, notably in the smallholder farming systems. Moreover, difficulties such as the lack of agricultural inputs, infrastructures, institutional services, storage materials, low product quality due to disease and pests like high incidence of yellow or stripped stem rust, low selling price, and price deception make its production and marketing difficult (Semahegn, 2021; Hei et al., 2017). As a result, the country ranks 67th globally by wheat productivity even below other sub-Saharan countries mainly due to the dominance of small-scale farmers who rely on rain-fed agriculture, and due to their traditional production system (Degye et al., 2019). For instance, the empirical studies on the assessment of wheat yield indicate that other African countries such as Egypt, South Africa, and Kenya had 67, 35, and 30 quintals per hectare, respectively (Minot et al. 2015). Whereas in Ethiopia annual production is about 5.8 million tons with mean productivity of 3 t

ha⁻¹ (CSA 2021), which is relatively lower than the attainable yield of the crop, reaching up to 5 t ha⁻¹ (Zegeye et al. 2020). The main reason for the low productivity of wheat among smallholder farmers was mainly the variability of rainfall, which means that if the rainfall is good, the production is good, and vice versa (Gebreselassie et al., 2017).

In contrast to these obstacles, accessible opportunities such as government policy, market expansion, rising wheat demand, and the potential for wheat production in the area encourage wheat producers and dealers to engage in wheat production (Adugnaw and Dagninet, 2020). Thus, its production and productivity have been increasing at an increasing rate for the last few years which is due to the implementation of several government programs and initiatives that promote agricultural growth and food security in the country (Gebreselassie et al., 2017).

Despite good production and productivity trends, Ethiopia has faced a growing supply deficit (Bergh et al., 2012). Even if it shows an increasing trend domestically, still Ethiopian wheat production is relatively small by global standards (Hei et al., 2017). As a result, wheat production in the country is insufficient to meet domestic demand, leading the country to import 30 to 50% of its wheat in recent decades to make up the difference (Abdulkadir et al., 2017). As a result, the country's wheat production is not enough to meet domestic demand, which has led the country to import 30 to 50% of its wheat from abroad in recent decades (Abdulqadir et al., 2017).

2.3. Importance of Bread Wheat in Ethiopia

In Ethiopia, wheat is one of the most important cereals cultivated. Thus, the country is the largest producer of wheat in SSA, with over 1.8 million hectares annually (Abeyo et al., 2012). Wheat is widely used throughout the country to meet the need for bread and other

consumables (Adugnaw and Dagninet, 2020). It is the dominant crop being used for human food and livestock feed. Its success depends partly on its adaptability and high yield potential but also on the gluten protein fraction which confers the visco elastic properties that allow the dough to be processed into bread, pasta, noodles, and other food products (Shewry, 2009). It also contributes essential amino acids, minerals, vitamins, beneficial phytochemicals, and dietary fiber components to the human diet, and these are particularly enriched in whole-grain products (Shewry, 2009). Likewise, it is consumed in a variety of products in Ethiopia, including bread, porridge (genfo), roasted grain (kolo) boiled grain (nifro), pasta, local beer (tela), and different confectionary products (Minot et al., 2015). Apart from using its grain for food, wheat residue, and other by-products are often used to alleviate the country's animal feed deficit, which is the sector's major limitation (Adugnaw and Dagninet, 2020). Despite the importance of bread wheat and the growing demand for it in Ethiopia, production and productivity remain extremely low, and several factors might be explained as a possible cause for its low productivity.

2.4. Constraints of Bread Wheat Production in Ethiopia

In Ethiopia, wheat production in 2018 was estimated at 4238836 tons from a 1748972-ha area harvested with an average yield of 2.5 t ha⁻¹ (FAOSTAT, 2018). Its production is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zones, and water-logging in the vertisol areas (Samuel et al., 2022). Inappropriate cropping systems, mono-cropping, nutrient mining, unbalanced nutrient application, removal of crop residues from the fields, and inadequate resupplies of nutrients have also contributed to declines in crop yields (Abebe et al., 2022). Low soil fertility due to monoculture cereal production systems is recognized as one of the

major causes of declining per capita food production. Declining soil fertility is also an important bottleneck for smallholder cereal growers in the central western parts of Ethiopia (Erkossa et al., 2022). Moreover, continuous monocultures of cereals result in a reduction of yields and soil nutrients. Declining yield and soil fertility as a result of continuous monocropping have also been reported for other cereal crops. Currently, such soil degradation and nutrient depletion trends have gradually increased in area and magnitude and have become serious threats to agricultural productivity (Gedamu, 2020).

Low soil fertility is exacerbated by soil fertility depletion through nutrient removal with harvest, tillage, weeding, and losses in runoff and soil erosion (Tilahun, 2021). Many farmers are unable to compensate for such losses, which resulted in negative nutrient balances (Erkossa et al., 2022). Thus, the supply of adequate and balanced nutrients is one way of achieving high bread wheat grain yield. Adequate and timely application of fertilizer should be aligned with fertilizer-responsive varieties. This is directly associated with the amount of yield harvested and thereby its end quality. Besides genetic and environmental factors, crop management factors like fertilizer application determine productivity.

2.5. Soil Fertility and Soil Nutrient Depletion in Ethiopia

Soil fertility is the status or the inherent capacity of the soil to supply nutrients to plants in adequate amounts and in suitable proportions. According to modern usage, soil fertility is the capacity of the soil to produce crops of economic value and to maintain the health of the soil without deterioration. The study of soil fertility involves examining the forms in which plant nutrients occur in the soil, how these become available to the plant, and the factors that influence their uptake (Shireen et al., 2018). The annual per-hectare net loss of nutrients is

estimated to be at least 40 kg N, 6.6 kg P, and 33.2 kg K (Scoones and Toulmin, 1999). In Ethiopia, the soil depletion rate of macronutrients, N, P, K was 122, 13, and 82 kg ha⁻¹ year⁻¹, respectively (Abebe et al., 2022). Hence, soil fertility reduction is one of the leading production constraints, particularly in sub-Saharan areas (Wawire et al., 2021).

On the other hand, soil degradation is the most serious bio-physical constraint limiting crop productivity in Ethiopia (Abebe et al. 2022). The loss of soil nutrients in Ethiopia is related to cultural practices such as low fertilizer use, removal of vegetative cover (such as straw or stubble), and burning of plant residues or the annual burning of vegetation on grazing land (Debele et al., 2021). However, many soils in the highlands of Ethiopia are poor in available plant nutrients and organic matter content (Belay et al., 2022). Thus, the application of balanced and combined plant nutrients is very important for the better crop productivity and sustaining food security among the smallholder farmers.

2.6. Role of Individual Plant Nutrients on Growth and Yield of Bread Wheat Varieties

2.6.1. Nitrogen

Nitrogen (N) is the most abundant mineral nutrient in plants. It constitutes 2–4% of plant dry matter. All vital processes in plants are associated with protein, of which N is essential for plant growth as it is a constituent of all proteins and nucleic acids. It is an integral component of many essential plant compounds such as amino acids which are building blocks of all proteins including enzymes, nucleic acids, and chlorophyll (Grzyb et al., 2021). It is the key nutrient input for achieving higher yields of wheat. Wheat is very sensitive to insufficient N and very responsive to N fertilization. It plays a central role in plant biochemistry and occupies a conspicuous place in the plant metabolism system (Leghari et al, 2016). A low

supply of N has a profound influence on crop growth and may lead to great loss in grain yield (Anas, 2020). Since it is present in many essential compounds, it is not surprising that growth without added N is slow in plants.

Moreover, N plays a key role in agriculture by increasing of crop yield (Anas, 2020). According to Grzyb et al. (2021), the most important role of N in the plant is its presence in the structure of protein and nucleic acids which are the most important building and information substances from which the living material or protoplasm of the very cell is made. Nitrogen not only enhances the growth of the crops but also improves the bread wheat yield (Derebe et al., 2022). Consequently, to get more crop production, N application is indispensable. Plants require N in the largest amounts among the soil nutrients for growth and development.

2.6.2. Phosphorus

Phosphorus (P) has great importance in plant nutrition. It involves in the processes of energy transformations, genetic inheritance, protein synthesis and cell division. Moreover, P enhances root development and strengthening of straw, affects flowering, fruiting, seed formation and crop maturation. In line with this, the availability of P in soil is affected by different factors like soil reaction and climate. In Ethiopia P application as fertilizer is important in increasing crop production of bread wheat. Based on the various findings of P fertilization results, the yield and yield components of bread wheat increased with increasing P fertilizer application rates (Assefa et al., 2021).

Adequate P nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth, particularly development of lateral roots and fibrous

rootlets. Ibrahim (2022), reviewed different reports and stated that the availability of soil P is influenced by soil reaction, soil type, amount and forms of P as well as many other factors. Oxisols high in iron oxides and aluminum oxides, and many sandy soils low in humus content, for instance, have low available P (Johan et al., 2021). Addition of organic matter indirectly reduces P adsorption by inhibiting aluminum oxide and to a certain extent Fe-oxide crystallization, while the addition of manure and fertilizer phosphorous reduces phosphorous fixation by increasing the saturation of adsorption sites.

According to Johan et al. (2021) in acid soils with high Al and Fe contents, phosphoric acid and soluble P fertilizer transformed into insoluble forms of P so quickly that plants can derive very little from P fertilized treatments. Johan et al. (2021) indicated that at pH lower than 5.5, the retention results largely from the reactions with Fe, Al and their hydrous oxides resulting into low forms of available P. At pH higher than 7.0, high concentration of Ca, Mg and their carbonates cause precipitation of the added phosphorus and reduce the availability of P.

2.6.3. Sulfur

Sulfur (S) is a macronutrient required for the proper growth and development of plants. It is increasingly being recognized as the fourth major plant nutrient after N, P and potassium (K) in crop production. It is reported to be a macro-nutrient that is taken up by grain crops in amounts similar to and sometimes beyond those of P, 10–30 kg ha⁻¹, and is considered to be one of the most limiting nutrient elements for crop production (Weil et al., 2011).

Sulfur is essential for the growth and development of all crops, without exception. It is a constituent of three S-containing amino acids (cysteine, cystine and methionine), which are

the building blocks of protein. It is also a key ingredient in the formation of chlorophyll and about 90% of plant S is present in these amino acids (Chowdhury et al., 2020).

It is usually present in relatively small amounts in soils in the available forms (Weil et al., 2011) and also reported that at the lowest S rate, N uptake was 42%, but increased to 70% as S fertilizer was increased. It enhances other nutrients use efficiency and ranks second only to N in importance for optimum crop yield and quality (Assefa et al., 2022), also stated that S application from the leaf had a minimum effect on the grain yield of bread wheat. Addition of S to a calcareous soil may result in a decline in soil pH and consequently may increase availability of micronutrients like B (Tabak et al., 2020).

2.7. Effect of Blended Fertilizer on Growth and Yield of Bread Wheat Varieties

The application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation (Amalfitano et al., 2017). Abebual *et al*, (2019) reported that increasing blended fertilizer, N,P, S, Zn and B, significantly increase plant growth and development of wheat. Blended fertilizer supply had also a marked effect on the aboveground biomass, grain yield, and straw yield. It enhances sustainable production and provides nutrient needs to crops according to their physiological requirements and expected yields (Abebaw and Hirpa, 2018).

According to Deriba et al. (2019), days to heading, days to maturity, spike length, seeds spike⁻¹, thousand kernel weights and straw yield were significantly affected by the main effect of varieties and blended fertilizer rates. The same author also reported that application of 300 kg and 200kg of NPSB blended fertilizer showed a higher yield for Wane and Kingbird variety respectively.

Increased application of blended NPS fertilizers, increased the yield and yield components of bread wheat like plant height, spike length, number of tillers per square meter and number of kernels per spike (Bereket et al., 2014). The experiment conducted by Mathwos (2022), in the Asossa area also showed that the highest grain yield (3.54 t ha^{-1}) was recorded from application of 200 kg ha^{-1} NPSZnB with Kingbird variety as compared with other varieties. Accordingly, the higher grain yield was obtained from Wane (4236 kg ha^{-1}) variety at 300 kg NPSB fertilizer treatment; but in Kingbird (3737 kg ha^{-1}) at 200 kg NPSB fertilizer treatment with supplementary urea was the best one. Furthermore, Tilahun et al. (2021) also reported that increasing the rates of blended NPS fertilizer from 0 to 100 kg ha^{-1} and N from 0 to 92 kg ha^{-1} showed consistent increase of grain yield of bread wheat while the yield became declined at maximum application rates of both fertilizers. Similarly, Haji et al. (2020) in Wondo district of west Arsi zone indicated that application of 150 kg ha^{-1} NPSB blended fertilizer along with 100 kg ha^{-1} urea improved most of the growth, yield and yield components of wheat.

Previous fertilizer research work in Ethiopia has been focused on N and P fertilizer sources under different soil types and various climatic conditions, while very limited work has been reported with other essential macro- and micro-nutrients (K, S, Fe, Zn, B, etc.). Understanding plant nutrients requirement of a given area has a vital role in enhancing crop production and productivity on a sustainable basis. Nevertheless, increasing crop yields through the application of N and P alone can deplete other nutrients (Liu et al., 2021).

3. MATERIALS AND METHODS

3.1. Discription of Study Area

A field experiment was conducted in the Gorche district in Sidama regional state during the 2021 cropping season. The area is located 6°52'30" North latitude and 38°35'30" East longitude and an altitude of 2620 masl. The experimental site is 45 km away from Hawassa, the capital city of the region. The mixed crop-livestock production system is the main agricultural activity in the study area. The highland mixed crop-livestock production system is largely based on the intensive cultivation of cereals, pulses, tubers, and vegetables.

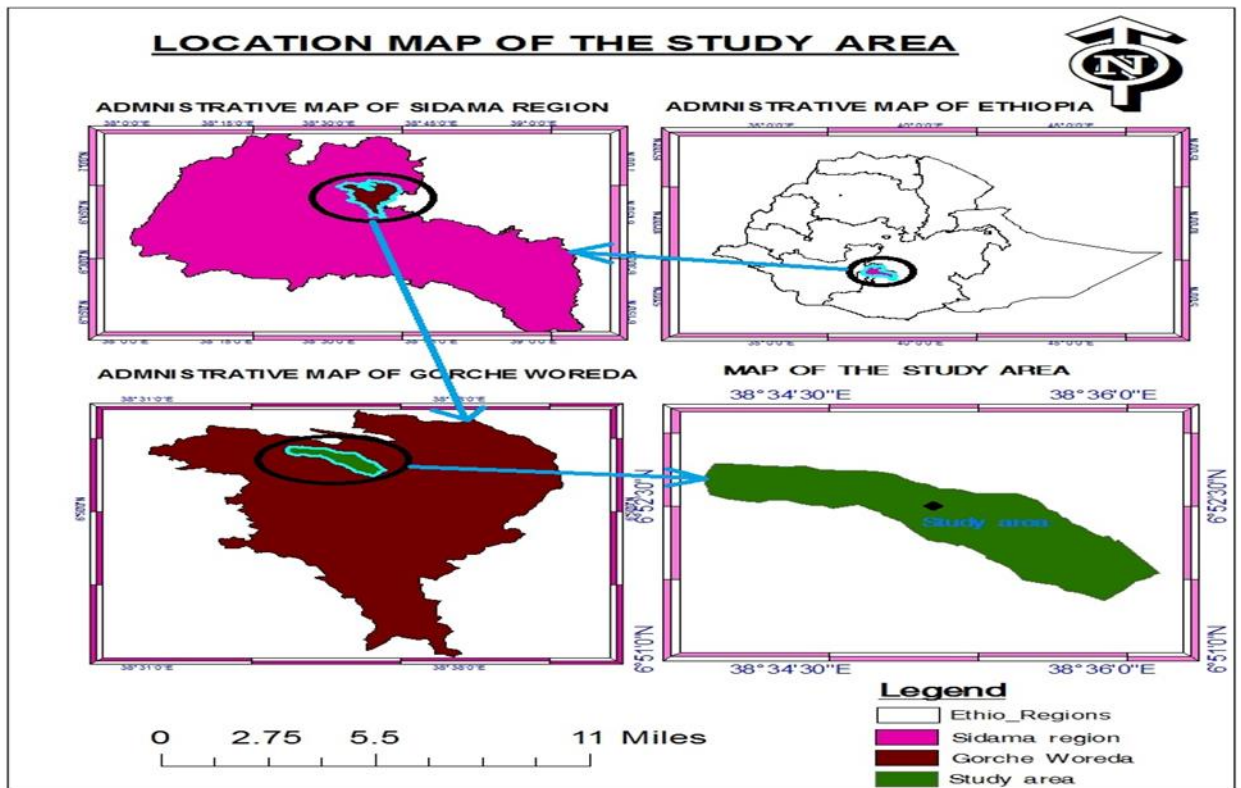


Figure 1. Map of the Study area

According to Ethiopian traditional agro-ecological classification, the area is grouped under dega with the major soil type Vertisols and the most dominate land cover taken by cultivated land. The annual rainfall and annual minimum and maximum temperatures of the study area are 1324.3mm, 8.16 and 22.2°C, respectively, whereas mean relative humidity is 65% (SRSSoA, unpublished data). The site receives the highest rainfall in the main rainy seasons (June to September) and accounts for 66% of the annual rainfall and the lowest in the short rainy season (February to May) (Figure 2). The highest rainfall received in the month of July and August coincides with the planting and crop establishment time for bread wheat.

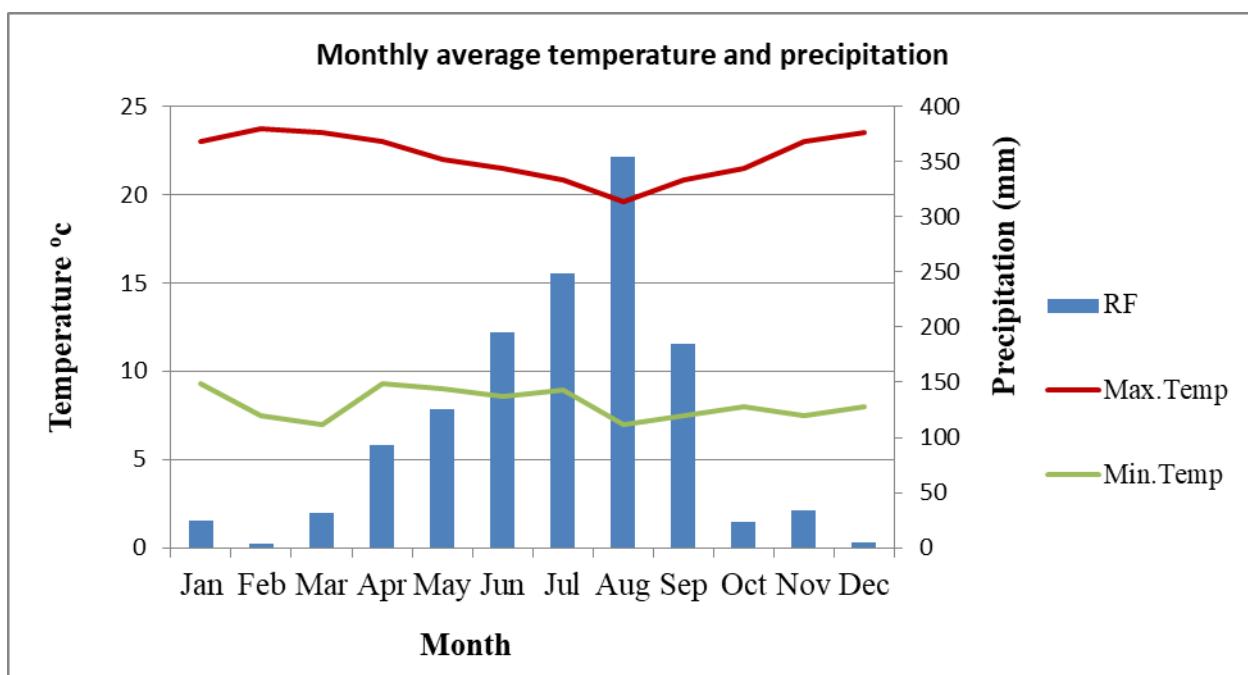


Figure 2. Mean monthly Rainfall, Max temp, Min temperature of the study area.

Source: - (Gorche Woreda Agriculture and Natural resource management office data, 2021).

3.2. Source of Experimental Materials

Three bread wheat varieties namely Wane, Kingbird, and Hidase were used as experiment materials. The varieties were obtained from the Worabe Agricultural Research Center (WARC). NPS fertilizers having 19% N, 38 % P₂O₅ and 7% S nutrient ratio were applied at planting time for the experiment. The recommended amount of Urea (46% N) was uniformly applied to all the plots. It was applied in two split half at planting and half at tillering stage of bread wheat in the presence of soil moisture to avoid the potential loss of N into the atmosphere.

3.3. Treatments and Experimental Design

The treatments studied consists of three bread wheat varieties (Wane, Kingbird and Hidase) and four rates of blended fertilizer (0, 50, 100 and 150 kg NPS ha⁻¹). The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangement with three replications. The total treatment combinations consist of a total of 12 treatments. The gross plot size was 20 rows per plot of four -meter length (4 m×3 m =12 m²) and the net plot/ harvestable rows consist of 18 with 3.4 m length (3.4 m×3 m=10.2 m²). The spacing between rows, plots and blocks were 0.20, 0.5 and 1 m, respectively. Wheat plants in the two outer most rows on both sides of a plot as well as 0.10 m on each end of central rows were considered as border plants and not considered for data collection.

3.4. Experimental Procedures

The experimental field was prepared following conventional tillage practice ploughed by local plough (Maresha). Fine seedbeds was prepared and leveled manually and rows made across each plot. After the layout, the plots were leveled manually; each treatment was assigned randomly to the experimental plots within a block.

NPS fertilizer was applied at planting time using basal application for all treatments according to the randomizations. Application of N fertilizer in the form of urea at the rate of 100 kg ha^{-1} , out of this $1/2$ (50kg) was applied at sowing for all treatments except the control and the remaining $1/2$ (50kg) was applied after 35 days planting of the experiment to avoid N losses by leaching. All agronomic practices such as weeding, cultivation, rouging and pest control were carried out accordingly. Weeds were removed from the experimental plots by hand weeding. Lately emerging grasses and off-type plants rouged to avoid interference with the wheat cultivars. All other recommended cultural practices were done as per the recommendation to the area.

3.5. Soil Sampling and Analysis

Before planting, soil samples were randomly taken from the experimental field at a depth of 0 to 30 cm using an auger and the samples were mixed thoroughly and reduced to produce a representative one-kg composite sample. The sample was air-dried and ground to pass 2 and 0.5 mm sieves (for total N) and analyzed for soil textural class (sand, silt, and clay), soil pH, total N, available P, available S, organic carbon (OC), and CEC. Soil texture was determined by the Bouyous hydrometer method (Bouyous, 1951). The soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil-to-water ratio using a pH

meter. Available phosphorus (P) was determined by the Olsen method using ammonium fluoride as an extractant and measuring the concentration of the nutrient at 880 nm (Olsen et al., 1954). Soil OC was determined by the Walkley-Black wet digestion method (Walkley and Black, 1934). Total N was determined by the wet oxidation procedure of the Kjeldhal method (Bremner, 1965). Cation exchange capacity (CEC) was determined with an ammonium acetate-saturated sample using sodium (Na) from percolating sodium chloride (NaCl) solution to replace the ammonium ions. The displaced ammonium was measured using the modified Kjeldahl procedure and was reported as CEC.

3.6. Data Collection and Measurements

3.6.1. Phenological parameters

Days to 50% heading: it was recorded as the number of days from sowing to the time when the plants were reached heading based on visual observation.

Days to 90% maturity: it was determined as the number of days from sowing to the time when the plants reached 90% maturity based on visual observation.

Plant height (cm): it was measured at physiological maturity from the soil surface to the top of the spike excluding awns on ten randomly pre-tagged selected plants from the central unit area. The total measured plant height was summed together and divided by the number of plants to get the height per plot.

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

3.6.2. Yield and yiled components

Numbers of effective tillers plant⁻¹: were counted from ten randomly selected plants at the physiological maturity stage.

Number of kernels spike⁻¹: it was determined from 10 randomly selected spikes from the net plot areas.

Thousand kernel weight: it was determined based on the weight of 1000 seeds sampled from the bulk grain yield of each treatment by counting on an electronic seed counter and their weight taken with an electronic balance and adjusted at 12.5% grain moisture content.

Above ground dry biomass (t ha⁻¹): at maturity, the whole plant parts, including leaves and stems, and seeds from the net plot area were harvested and after drying, the biomass was measured. The complete drying was determined by obtaining constant weight.

Grain yield: it was measured from the harvested central unit areas of 2 m². Grains were cleaned following harvesting and threshing, weighed using electronic balance, and adjusted to 12.5% moisture content.

Straw yield: it was calculated as the difference between above-ground biomass and grain yield.

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

$$\text{HI} = \frac{\text{Economic yield}}{\text{Biological yield(AGP)}} \times 100\%$$

3.7. Statistical Analysis

The collected data were subjected to the analysis of variance (ANOVA) using the SAS computer package version 9.0 (SAS Institute, 2002). Statistically significant treatment means were separated using the List Significance Difference (LSD) test at a 5% probability level. Pearson's correlation coefficients were also calculated to establish relationships between plant growth, grain yield and yield components.

3.8. Partial Budget Analysis

To consolidate the analysis of the variance of the agronomic data, economic analysis was analyzed for each treatment. For the economic evaluation, cost and return were calculated according to the procedure given by CIMMTY, (1988). The actual bread wheat yield was adjusted downward by 10% to reflect the difference between the experimental bread wheat yield and the bread wheat yield that farmers would expect to get from the same treatment (CIMMTY, 1988).

The mean grain yield of the treatments was used in partial budget analysis (CIMMTY, 1988). The field price of 1 kg of bread wheat that the farmers received by selling their crops was taken as the market price of bread wheat at the Gorche market near the experimental site. The total variable cost included the cost of NPS fertilizer, seed price, and labor as the sum of all cost that was variable or specific to treatment against the control. Dominance analysis and marginal rate of return (%) were used to evaluate the economic performance of treatments and net return was calculated by subtracting the total variable cost from the gross benefit. The minimum accepted marginal rate of return used in this study was assumed to be 100% for the farmer's recommendation domain. Finally, the treatment that gave the maximum net benefit

with a marginal rate of return was selected. The economic analysis was based on the formula developed by (CIMMTY, 1988) and given as follows.

Gross average yield (kg ha⁻¹) (AvY): is an average yield of each treatment

Adjusted yield (AjY): is the average yield which was adjusted downward by a 10%.

$$AjY = AvY - (AvY * 0.1)$$

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield.

$$GFB = AJY * \text{field/farmer gate price of a crop}$$

Total cost: is the cost of input that were used for the experiment as mean current prices of Urea, seeds, strain and labor for application were considered per hectare. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, crop protection, and harvesting were assumed to remain the same among treatments.

Net benefit (NB): was calculated by subtracting the total costs from gross field benefits for each treatment. $NB = GFB - TC$

Marginal rate of return: percent marginal rate of return was calculated as changes in net benefit (raised benefit) dividing by changes in cost (raised cost).

$$MRR (\%) = (\text{change MB} / \text{change MC}) * 100$$

4. RESULTS AND DISCUSSION

4.1. Physical and Chemical Properties of Soil before Planting

The physical and chemical properties of the soil before planting in the experimental area are presented in Table 1. Soil texture is one of the inherent soil properties less affected by management and determines nutrient status and organic matter content. The results of soil analysis for soil texture revealed that the soil of the study site was clay loam in texture with a proportion of 33, 36, and 31% of sand, silt, and clay, respectively. Which is in the suitable range for bread wheat production (Zenebu et al., 2018). The soil of the study site was moderately acidic in reaction with a pH (H₂O 1:25) value of 5.28. The soil of the study sites had total N, available P, available S, organic carbon (OC), and CEC of 0.14%, 9.0 mg kg⁻¹, 19.35 ppm, 2.3% and 23.0 cmol (+) kg⁻¹, respectively.

The total N content of the soil was within the range of low according to Havlin et al. (1999), who classified the range of total N < 0.1, 0.1– 0.15, 0.15 – 0.25, and > 0.25% as very low, low, medium and high, respectively. According to Olsen et al. (1954), P content (mg kg⁻¹) <5 is very low, 5 – 15 is low, 15 – 25 is medium and >25 is high. Therefore, the available P in the soil at the experimental site (9.0 mg kg⁻¹) was in the low range. Landon (1991) classified the soil OC content as 1 – 2, 2 – 4, and 4 – 6% which were rated as low, medium, and high, respectively. Thus, the soil at the experimental site had medium soil OC content of 2.3%. The CEC is an important parameter of soil because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching (Kumari and Mohan, 2021). According to Landon (1991), the soil CEC ranges of 5 – 15, 15 – 25, and 25 –

40 cmol (+) kg⁻¹ were rated as low, medium, and high, respectively. Based on these ratings, the CEC value of 23.0 cmol (+) kg⁻¹, before planting, was in the medium range.

Overall, pre-planting soil analysis results indicated that the area has a deficiency of nutrients to support potential wheat production. This is probably due to low productivity of farmers cultivar in use and continuous cropping with little or no inputs of fertilizers resulting in reduced soil fertility in the area. Therefore, the application and identification of optimum plant nutrients are needed to obtain optimum crop yields to sustain food security among smallholder farmers.

Table 1. Physico-chemical properties of the experimental soil before planting

pH	Total N (%)	Available P (mg kg ⁻¹)	Available S (mg kg ⁻¹)	Organic C (%)	CEC (cmol (+) kg ⁻¹)	Sand (%)	Silt (%)	Clay (%)	Textural class
5.28	0.14	9.0	19.35	2.3	23.0	33.0	36.0	31.0	Clay loam

4.2. Effect of NPS-Fertilizer on Phenological Traits of Bread Wheat Varieties

4.2.1. Days to 50% heading

The main effects of varieties and NPS rates were highly significant ($P < 0.01$) on days to 50% heading while the interaction of the factors was non-significant (Appendix Table 1). Longer days to 50% heading (69.00 days) were recorded for a variety of Wane that produced heading 4.58 days later than the variety Kingbird (64.42 days) (Table 2). However, there were no marked differences between bread wheat varieties Hidase and Wane in days to 50% heading. The difference among the varieties in days to heading might be due to genetic differences as bread wheat has high diversity in such phenological parameters. In line with this result, Aliyi (2020) reported highly significant differences in the number of days required to reach 50%

flowering among three wheat varieties. Similarly, varietal differences among bread wheat with respect to heading was reported by Abdulkerim et al. (2015).

Likewise, increasing NPS application from 0 – 150 kg ha⁻¹ prolonged the time required to attain 50% heading of the bread wheat where the earliest heading (63.0 days) was recorded with 0 kg NPS ha⁻¹ which was 8.55 days earlier than 150 kg NPS ha⁻¹ fertilizer (71.55 days) (Table 2). However, the number of days required for heading did not show a significant difference for a plot that received 50 and 100 kg NPS ha⁻¹. The delay in heading with the higher NPS rates might be attributed to the increased rate of N in the blended fertilizer which has a great role in vegetative growth (Delesa et al., 2022). The addition of N and P fertilizers might have contributed to the availability of soil nutrients to plant growth whereby the N fertilization delayed days to heading (Taminaw, 2019). Similarly, Aga and Geleta (2020) reported that the improved vegetative growth and delayed 50% heading when the fertilizer rate increases. Moreover, Diriba et al. (2019) reported a significant effect of blended fertilizer on number of days to heading, and the longest days to heading was observed at 300 kg NPSB ha⁻¹ application with supplementary urea.

Table 2. Main effect of NPS rates on phenological parameters of bread wheat varieties, during 2021 cropping season

Treatments	Days to 50% heading	Days to 90% maturity
<i>Variety</i>		
Wane	69.00 ^a	114.25 ^a
Kingbird	64.42 ^b	107.08 ^b
Hidase	68.92 ^a	114.17 ^a
LSD 0.05	2.16	3.57
<i>NPS kg ha⁻¹</i>		
0	63.00 ^c	104.56 ^c
50	66.55 ^b	110.56 ^b
100	68.67 ^b	113.44 ^b
150	71.55 ^a	118.78 ^a
LSD 0.05	2.49	4.12
CV%	3.79	3.77

Means in columns followed by the same letters are not significantly different as judged by LSD test at 5% level of significance; CV: Coefficient of Variation

4.2.2. Days to 90 % physiological maturity

The analysis of variance revealed that the main effects of varieties and NPS fertilizer rates had highly significantly ($P < 0.001$) effects on days to 90% physiological maturity while the interaction of both factors had non-significant effects (Appendix Table 1).

The number of days required to 90% physiological maturity varied from 107 – 114 among bread wheat varieties (Table 2). Variety Wane had the longest days to reach 90%

physiological maturity (114.25 days), and it was statistically at par with Hidase (114.17 days), whereas the variety Kingbird was the earliest to reach 90% physiological maturity (107.08 days). The observed variations might be attributed to genotypic differences of the respective varieties as phenological characteristics are genetically controlled. This result was in line with the findings of Khan et al. (2020) who reported significant differences among bread wheat varieties in the number of days to reach physiological maturity. Melaku (2019) also reported significant variation among bread wheat varieties to reach physiological maturity.

Likewise, the result revealed that increasing NPS application from 0 – 200 kg ha⁻¹ prolonged the time required to attain 90% physiological maturity (Table 2). Delayed days to maturity were observed in plots that received 150 kg NPS ha⁻¹, but the number of days required for days to maturity did not show a significant difference with a plot that received 50 and 100 kg ha⁻¹ NPS. The delay in days to maturity at the highest NPS rate could be due to the fact that N fertilization increases the vegetative growth of plants. The longer maturity periods might also have been caused by the promoted vegetative growth due to an enhanced supply of N through NPS fertilizer application (Taminaw, 2019). The result of this study is in agreement with the findings of Melaku (2019), who indicated a significant influence of blended NPS fertilizer on days to physiological maturity of the bread wheat. Similarly, Tagesse et al. (2018) stated that the application of blended NPS fertilizer had a significant effect on the days to physiological maturity of bread wheat. Moreover, Abebaw and Hirpo (2018) reported prolonged vegetative growth of wheat due to the application of blended fertilizer (macro and micro) and urea.

4.3. Effect of NPS-Fertilizer on Growth Parameters of Bread Wheat Varieties

4.3.1. Plant height

Main effects of varieties and NPS fertilizer rate had a highly significant ($P < 0.001$) effect on the plant height of bread wheat. However, their interaction effect did not show a significant ($P > 0.05$) effect on plant height (Appendix Table 2).

Among the varieties, the tallest plant height (72.56 cm) was recorded from the variety Hidase followed by the variety Wane. Whereas, the shortest plant height (66.92 cm) was recorded by the King bird variety (Table 3). The differences in plant height among the varieties could be attributed to the difference in their genetic makeup or cell division rate that results in changes in plant height of different varieties. The result was also in agreement with the results of Abdulkarim et al. (2015) who reported that tallness in wheat plants is mostly associated with the genetic makeup of the variety such as root growth, nutrient absorption, and nutrient translocation in cell division, and elongation. Similarly, Abdunasir (2021) reported that the height of the crop was mainly regulated by the genetic makeup of a genotype.

With respect to the fertilizer effect, the tallest plant height (76.72 cm) was recorded from 150 kg NPS ha⁻¹ fertilizer rate which was followed by 100 kg NPS ha⁻¹ fertilizer rate (73.73 cm) while the shortest plant height (59.62 cm) was recorded from the control (Table 3). The increase in plant height with the increment of the rates of NPS fertilizer might be due to the fact that N, P, and S nutrients are involved in vital plant functions and contribute to enhanced growth in the height of the crop. Moreover, the increase in plant height with the increased NPS application rate indicates maximum vegetative growth of the plants under higher N and S availability and P also plays a pivotal role in early root proliferation that might increase the

nutrient uptake of the plant consequently resulted in increased vegetative growth (Taminaw, 2019;). In agreement with this result, Abebaw and Hirpa (2018) reported the highest plant height due to the application of blended fertilizer at 150 kg ha⁻¹. Similarly, other researchers report improved plant height of cereal crops due to applied blended fertilizers (Diriba et al., 2019).

Table 3. Main effect of NPS rates on growth parameters of bread wheat varieties, during 2021 cropping season

Treatments	Plant height (cm)	Spike length (cm)
<i>Variety</i>		
Wane	69.92 ^b	6.98 ^b
King bird	66.92 ^c	6.88 ^b
Hidase	72.56 ^a	7.29 ^a
LSD 0.05	1.87	0.23
<i>NPS kg ha⁻¹</i>		
0	59.62 ^d	6.34 ^c
50	69.11 ^c	6.90 ^b
100	73.73 ^b	7.35 ^a
150	76.72 ^a	7.61 ^a
LSD 0.05	2.16	0.27
CV%	3.16	3.94

Means in columns followed by the same letters are not significantly different as judged by LSD test at 5% level of significance; CV: Coefficient of Variation

4.3.2. Spike length

Spike length is one of the most important yield components of wheat, which contributes to high grain yield. The main effect of varieties and blended NPS fertilizer rates had a highly

significant ($P < 0.001$) effect on spike length; however, the interaction effect between the two factors did not show a significant effect on the spike length (Appendix Table 2).

Among the varieties, Hidase produced the longest spike of 7.29 cm, while Kingbird produced the shortest spike length of 6.88 cm, followed by Wani (6.98 cm) (Table 3). The differences in spike length could be due to the genetic makeup of the variety to produce longer spikes. This result is in line with the finding of Habtamu and Ahadu (2019) who reported differences in spike length among varieties due to the differences in their genetic makeup. Similarly, Aman et al. (2018) also reported that the varietal difference in spike length is governed by the genetic makeup of the genotype on the ability to perform yield. Moreover, several other authors reported differences among the varieties regarding to the spike length (Aliyi, 2019; Abdunasir, 2021).

Regarding the fertilizer effect, increasing the rate of blended NPS increased spike length. Accordingly, the longest spike (7.61 cm) was recorded at the rate of 150 kg ha⁻¹ of blended NPS, whereas the shortest spike (6.3 cm) was obtained from the control treatment (Table 3). Such increment of spike length with the application of blended fertilizer might be due to P fertilizer which increases early root development and tillering which contributes to the spike length increment. Moreover, NPS fertilizer had the ability to increase spike length positively (Aliyi, 2019). In agreement with this result, Tilahun et al. (2021) also reported that increased spike length due to increased NPS and N from zero to the highest in bread wheat. Moreover, these results also agreed with the findings of Aliyi (2019); Abdunasir (2021), who reported that increasing NPS fertilizer application improved the spike length of bread wheat.

4.4. Effect of NPS-Fertilizer on Yield and Yiled Components of Bread Wheat Varieties

4.4.1. Numbers of effective tillers plant⁻¹

Analysis of variance revealed that the main effect of varieties and blended NPS fertilizer application rate were highly significant ($P < 0.001$) on the numbers of tillers plant⁻¹; however, the interaction effect between the two factors did not show a significant effect on the numbers of tillers plant⁻¹ (Appendix Table 3).

Of the three varieties, the highest number of effective tillers plant⁻¹ (4.41) was produced from the variety Hidase. Whereas, the lowest number of effective tillers plant⁻¹ (3.87) was produced by the Wane variety. Statistically, there was no significant difference between Wame and Kingbird varieties on effective tillers plant⁻¹ (Table 4). The differences in the number of tillers produced by the wheat varieties could be attributed to genetic makeup (Habtamu and Ahadu, 2019). The current study also agrees with Harinder and Sudhir (2022), observed the varietal differences with respect to tillering capacity in rice crops. Similarly, Aliyi (2019) also reported that significant difference in the bread wheat varieties in the number of total tillers and productive tillers. The varieties which had more productive tillers produced more grain yield. This would be due to the number of productive tillers, which is an important yield component that directly contributes to the final grain yield of the crop.

Regarding the fertilizer effect, increasing the rate of blended NPS increased effective tillers plant⁻¹. The highest number of effective tillers plant⁻¹ were observed in plots that received 150 kg NPS ha⁻¹, but the number of effective tillers plant⁻¹ did not show a significant difference with a plot that received 50 and 100 kg NPS ha⁻¹. The lowest number of effective tillers plant⁻¹ were recorded in plots that received 0 kg NPS ha⁻¹ (Table 4). The increase in the number of

effective tillers in response to increasing rate of blended NPS fertilizer may indicate the importance of the availability of balanced nutrients for better growth and development of the plant (Abdunasir, 2021). Moreover, the highest number of effective tillers at the highest rates of blended NPS might be due to the rapid conversion of synthesized carbohydrates into protein and thus increase in the number and size of growing cells, finally resulting in an increased number of tillers. This result is in line with the result of Muzayin (2020), who reported that the highest number of productive tillers (451.7 m^{-2}) was produced by plants treated with the highest application of $200 \text{ kg NPSB ha}^{-1}$. Dinkinesh et al. (2020) also reported the highest number of tillers plant^{-1} of bread wheat due to the application of 183 kg NPSB for the Mangudo variety indicating the positive role of the high rate of nitrogen for tillering. Similarly, Aga and Geleta (2020) also reported an increased number of productive tillers in response to the increased rates of NPSZnB and UREA fertilizers may be attributed to the synergic roles in enhancing productive tillers production by the plant. In addition, Tagesse et al. (2018) reported that the application of blended NPS fertilizer had a significant effect on both the total and productive number of tillers of bread wheat, as reported that the application of blended fertilizer increases total productive tillers plant^{-1} .

4.4.2. Number of kernels spike⁻¹

The yield potential of the wheat spike is determined by the kernels spike^{-1} , which is an important yield component of grain yield. The analysis of variance revealed that the main effects of varieties and blended NPS fertilizer rates had a highly significant ($P < 0.001$) effect

on kernels spike⁻¹. However, the interaction between the two factors was not significant (Appendix Table 3).

Among the varieties, the Hidase variety produced the maximum number of kernels spike⁻¹ (41.25), whereas the minimum number of kernels spike⁻¹ (37.41) was produced by the variety Kingbird (Table 4). Number of kernels spike⁻¹ is related to the number of spikelets spike⁻¹, the number of florets spikelet⁻¹ as well as the efficiency of pollination and seed development in florets. This may be due to different varieties may have different yield-performing abilities genetically. In agreement with this result Dinkinesh et al. (2020) reported highly significant differences among the tested cultivars for the number of kernels spike⁻¹. Similarly, Tefera et al. (2021) were seen significant differences among the wheat varieties for the number of kernels spike⁻¹.

Regarding the fertilizer effect, the highest number of kernels spike⁻¹ (43.22) was produced from the highest rate of blended NPS fertilizers (150 kg ha⁻¹), whereas the minimum number of kernels per spike (35.22) were produced from plots without fertilization (Table 4). Such response can be attributed to the adequate N availability which might facilitate the tillering ability of the plants, resulting in a greater spike population (Muzayin, 2020). Moreover, the increased number of kernels spike⁻¹ with an increased rate of NPS might be due to the P effect since it plays an important part in many physiological processes that occur within developing kernels and is involved in enzymatic reactions in the plant and in the development of kernels (Aliyi, 2020). Dinkinesh et al. (2020) also reported that increasing the rates of NPS increased the number of kernels spike⁻¹ in bread wheat where the maximum number of kernels spike⁻¹ (42.7) was produced at the highest rate of NPSB fertilizers 183 kg ha⁻¹, whereas the minimum number of kernels spike⁻¹ (30.3) was produced at nil NPSB rate. Similarly, Usman et al.

(2020) reported the maximum number of wheat kernels spike⁻¹ with the application of NPSB fertilizer at the rate of 150 kg ha⁻¹.

Table 4. Main effect of NPS rates on yield and yield Components of bread wheat varieties, during 2021 cropping season

Treatments	Number of effective tillers plant⁻¹	Number of kernels spike⁻¹	Thousand kernels weight (g)
<u>Variety</u>			
Wane	3.87 ^b	39.33 ^b	36.75 ^b
King bird	3.98 ^b	37.41 ^c	36.33 ^b
Hidase	4.42 ^a	41.25 ^a	38.91 ^a
LSD 0.05	0.27	1.27	1.19
<u>NPS kg ha⁻¹</u>			
0	3.38 ^c	35.77 ^d	33.77 ^d
50	3.98 ^b	37.55 ^c	35.22 ^c
100	4.16 ^b	40.77 ^b	38.77 ^b
150	4.84 ^a	43.22 ^a	41.55 ^a
LSD 0.05	0.31	1.47	1.38
CV%	7.93	3.83	3.8

Means in columns followed by the same letters are not significantly different as judged by

LSD test at 5% level of significance; CV: Coefficient of Variation

4.4.3. Thousand kernel weight

The analysis of variance revealed that a thousand kernel weight was highly significantly ($P < 0.001$) affected by the main effect of variety and NPS fertilizer rates. However, the interaction effects of variety and blended NPS fertilizer on thousand kernel weight were found non-significant (Appendix Table 3).

Among the varieties, Hidase had the highest thousand kernels weight (38.91 g), while variety Kingbird recorded significantly the lowest thousand kernels weight of 36.33 g with a non-significant difference with varieties Wane (Table 4). Such variation in thousand kernels weight among varieties might be related to a good grain filling period and favorable environmental conditions, which increases a thousand kernel weights among the varieties (Usman et al., 2020). In line with this result, a significant variation in thousand kernels weight was reported by Dinkinesh et al. (2020). In addition, Muzayin (2020) reported a significant difference in thousand kernels weight among varieties that ranged from 37.91 to 40.28g. Similarly, Abdunasir (2021) reported a thousand kernel weight that ranged from 38.63 to 44.59 g for wheat varieties.

Regarding the fertilizer rate effect, the highest thousand kernel weight (41.55 g) was recorded from the NPS fertilizer rate of 150 kg ha⁻¹ while the lowest thousand kernel weight (33.77 g) was obtained from the control treatment (Table 4). In general, the result revealed that significantly increased a thousand kernels weight with increasing rates of blended NPS fertilizer. The increase in the thousand kernels' weight with increased rates of NPS fertilizer rates might be due to the provision of adequate and balanced nutrients which enhanced the accumulation of assimilate in the grains, resulting in good grain filling and the development of

heavier kernels. The current results are in line with Aga and Geleta (2020), who reported that an increase in the application of fertilizer rate had a positive impact on the yield component of wheat, especially on thousand kernel weight. Similarly, Abdunasir (2021) also reported that a thousand kernels' weight increased with the increase in NPS rate up to 150 kg ha⁻¹. Moreover, Aliyi (2020) reported that increasing the NPS rate from 0 to 200 kg ha⁻¹ increased a thousand kernels weight of bread wheat by about 15.9%.

4.4.4. Above ground dry biomass

The analysis of variance revealed that the main effects of variety and blended NPS fertilizer highly significantly ($P < 0.01$) affected the above-ground dry biomass yield of bread wheat. Likewise, their interactions also significantly ($P < 0.05$) affected the above-ground dry biomass of bread wheat (Appendix Table 3).

The highest aboveground dry biomass yield (13690 kg ha⁻¹) was recorded for variety Hidase at 150 kg NPS ha⁻¹ followed by the same variety at 100 kg NPS ha⁻¹. On the other hand, the lowest aboveground dry biomass yield (7167 kg ha⁻¹) was recorded for the variety Kingbird without NPS fertilizer application (Table 5). The increase in aboveground dry biomass at the highest rates of NPS might have resulted from improved root growth and increased uptake of nutrients favoring better growth and delayed senescence of leaves of the crop due to the synergetic effect of the nutrients. In agreement with the current study, Jasemi et al. (2014) reported that both vegetative growth and biological yield have much dependence on the consumption of chemical fertilizers, and their application led to an increased biological yield of wheat. Similarly, Bekalu and Mamo (2016) also reported that increasing N rates from 23 to 69 kg ha⁻¹ increased the aboveground dry biomass of wheat by about 22.6%. Likewise,

Wakene et al. (2014) stated that the supply of P₂O₅ at a rate of 69 kg ha⁻¹ in wheat was found to be adequate to produce maximum aboveground dry biomass. Yasir et al. (2015) also reported the maximum aboveground dry biomass of wheat with the application of 140 kg N ha⁻¹ at sowing and 20 kg S ha⁻¹ at anthesis.

Table 5. Interaction effects of the NPS fertilizer rates and varieties on above ground dry biomass yield of wheat

Blended NPS fertilizer rates (kg ha ⁻¹)	Varieties		
	Wane	Kingbird	Hidase
0	7656 ^{ij}	7167 ^j	8406 ^{hi}
50	9139 ^{fgh}	8928 ^{gh}	10037 ^{de}
100	9873 ^{def}	9593 ^{efg}	11923 ^b
150	11183 ^{bc}	10613 ^{cd}	13690 ^a
LSD (5%)	869.53		
CV %	5.21		

4.4.5. Grain yield

The main goal of crop production is to increase economic yield, which is a complex function of individual yield components in response to the genetic potential of the varieties and inputs used. The analysis of variance revealed that the grain yield was highly significantly ($P < 0.001$)

affected by the main effect of variety and NPS fertilizer rates. However, the interaction effects of both factors on grain yield were found non-significant (Appendix Table 3).

Of the three varieties, the great grain yield ($2884.4 \text{ kg ha}^{-1}$) was recorded from the variety Hidase. Whereas, the lowest grain yield ($2438.4 \text{ kg ha}^{-1}$) was produced by the Kingbird variety. Statistically, there was no significant difference between Hidase and Wane varieties on grain yield (Table 6). The differences in yield among the test varieties may be due to their differences in yield potential due to genetic makeup and their varying adaptability to the environment. Moreover, such a yield difference might be due to the high tillering capacity and its genetic potential of the variety Hidase. The current result agrees with the finding of Aliyi (2020) who reported a significant variation in the performance of bread wheat varieties on seed yield. Similarly, Diriba et al. (2019) also reported a marked difference among the wheat varieties.

Regarding the fertilizer rate effect, the highest grain yield ($3363.0 \text{ kg ha}^{-1}$) was recorded from the NPS fertilizer rate of 150 kg ha^{-1} while the lowest grain yield ($1417.1 \text{ kg ha}^{-1}$) was obtained from the control treatment. Statistically, there was no significant difference between 100 kg ha^{-1} and 150 kg ha^{-1} on grain yield (Table 6). The highest grain yield at the highest NPS rate might have resulted from improved root growth and increased uptake of nutrients and better growth due to the synergistic effect of the three nutrients which enhanced yield components and yield. The result agreed with the findings of Yasir et al. (2015), who reported that the combined application of N with S fertilizers increases the net photosynthetic rate in crop plants, which in turn increases their grain yield of the plants. Similarly, Aga and Geleta (2020) also found that the grain yield of wheat increased with increase in fertilizer rate up to a certain level. Likewise, Habtegebrial et al. (2013) reported the optimum grain yield for two

bread wheat varieties by the application of 100 kg N ha⁻¹; coupled with 20 kg S ha⁻¹, beyond which the yield increase was non-significant, suggesting that higher N rates are avoided. Furthermore, Mulugeta et al. (2017) reported that the application of nutrients like K, S, Zn, Mg, and B significantly increased grain yield and yield component of bread wheat as compared to the control (no fertilizer).

Table 6. Main effect of NPS rates on grain yield, straw yield and harvest index of bread wheat varieties, during 2021 cropping season

Treatments	Grain yield (kg ha⁻¹)	Straw yield (kg ha⁻¹)	Harvest index
<i>Variety</i>			
Wane	2720.1 ^a	6742.5 ^b	28.21 ^a
King bird	2438.5 ^b	6636.9 ^b	26.23 ^b
Hidase	2884.4 ^a	8129.4 ^a	25.83 ^b
LSD 0.05	178.44	496.10	1.97
<i>NPS kg ha⁻¹</i>			
0	1417.1 ^c	6326.0 ^c	18.28 ^b
50	2744.5 ^b	6623.4 ^c	29.32 ^a
100	3199.5 ^a	7263.5 ^b	30.65 ^a
150	3363.0 ^a	8465.5 ^a	28.78 ^a
LSD 0.05	206.04	572.85	2.27
CV%	7.86	8.17	8.71

Means in columns followed by the same letters are not significantly different as judged by LSD test at 5% level of significance; CV: Coefficient of Variation

4.4.6. Straw yield

The straw yield of cereal crops is an important agronomic parameter that is sensitive to the nutrient level of soil or the nutrient applied from external sources. Analysis of variance revealed that the main effects of variety and blended NPS fertilizer rates had a highly significant ($P < 0.001$) effect on straw yield; however, the interaction effect of both factors did not show a significant effect on the straw yield (Appendix Table 3).

Among the varieties, the Hidase variety produced the highest straw yield ($8129.4 \text{ kg ha}^{-1}$), whereas the lowest straw yield ($6636.9 \text{ kg ha}^{-1}$) was produced by the variety Kingbird (Table 7). Statistically, there was no significant difference between Wane and Kingbird varieties on straw yield (Table 6). The differences in straw yield might be due to the inherent differences among the varieties in the yield components like the number of tillers plant^{-1} , number of kernels spike^{-1} , and thousand kernels weight. This could help to understand farmers' preference for the Hidase variety for animal feed. In line with this study, Usman et al. (2020) also found that lower straw yield from the variety Kingbird as compared with Hidase and Huluka variety. Moreover, several other authors reported differences among the varieties regarding to the straw yield (Aliyi, 2019; Abdunasir, 2021).

Regarding the fertilizer effect, the highest straw yield ($8465.5 \text{ kg ha}^{-1}$) was recorded from the NPS fertilizer rate of 150 kg ha^{-1} while the lowest straw yield ($6326.0 \text{ kg ha}^{-1}$) was obtained from the control treatment. Statistically, there was no significant difference between 0 kg ha^{-1} and 50 kg ha^{-1} on straw yield (Table 6). The marked improvement in straw yield in response to the highest application rate of blended NPS fertilizer might have resulted in increased uptake of nutrients and better growth favored due to the synergistic effect of the three nutrients

produced higher plant population which enhanced growth and yield components there by resulting in the highest above ground biomass yield (Aliyi, 2019). The current result agrees with the finding of Abdunasir (2021), who reported a higher straw yield (6692 kg ha^{-1}) under a higher blended NPS rate (200 kg ha^{-1}), whereas the lowest straw yield (5663 kg ha^{-1}) was noted in response to the application of zero level of blended NPS fertilizer rates. Similarly, Abdulkerim et al. (2015) also reported increased straw yield with increasing fertilizer rates.

4.4.7. Harvest index

Harvest index is the relationship of the economic yield to the total or biological yield expressed as a coefficient of effectiveness. Analysis of variance showed that the harvest index was significantly ($P < 0.05$) affected by both the main effects of variety and blended fertilizer rates. However, the interaction effect of the variety and NPS fertilizer was not significant (Appendix Table 3).

The variety Wane had a greater mean harvest index (28.21) than Hidase (25.83) and Kingbird (26.23) varieties (Table 6). The differences among the varieties for harvest index could be due to their differences in genetic makeup. In line with the current study, Abdulkerim et al. (2015) reported significant varietal differences in the harvest index in bread wheat varieties. Moreover, several other authors reported differences among the varieties regarding to the harvest index (Aliyi, 2019; Abdunasir, 2021).

Regarding blended NPS fertilizer rates, the maximum harvest index (28.78) was obtained from the application of 150 kg ha^{-1} blended NPS, while the lowest harvest index (18.28) was recorded from the control plot (Table 6). However, there was no significant difference among NPS fertilizer rates. There was a numerical increment in the harvest index from control to 100

kg NPS fertilizer then starts to diminish, which might be due to an increment in N which contributes more for vegetative growth grain yield. The maximum harvest index at the highest blended NPS rate could be attributed to greater photo assimilate production and its greatest partitioning into grains as compared to partitioning into the straw, hence, proportionally higher grain yield than vegetative biomass yield. In line with this result, Aga and Geleta (2020) reported that the highest harvest index at 100 kg NPSZnB ha⁻¹ and the lowest harvest index at control plots.

4.5. Relationship between Wheat Yield and Yield Components

Significant positive correlation of grain yield with all the yield and yield components were observed which indicates that grain yield consistently increased with increasing characteristics of all yield related crop parameters, with the exception of straw yield which not significantly correlated (Table 7). Positive and significant correlations was observed between grain yield and with plant height ($r = 0.52^{**}$), productive tillers ($r = 0.45^*$), spike length ($r = 0.49^*$), kernel spike⁻¹ ($r = 0.37^*$), above ground dry biomass ($r = 0.43^*$), and harvest index ($r = 0.62^{**}$). In line with these findings, Tewodros and Haile (2020) revealed that harvest index (0.813) and biological yield (0.804) exerted high and favorable direct effects on grain yield. In addition, such a positive and significant relationship among the parameters measured reveals the existence of a true relationship between these parameters and grain yield. Moreover, the positive association of these parameters with grain yield might be attributed to the higher rate of photosynthetic assimilation as biomass increased due to plant height and enhanced photosynthate partitioned to kernels that increased their weight and thereby harvest index. This suggested that improvement of biomass would result in a substantial increment in grain yield that could be used in the selection of genotypes for high grain yield under optimum

conditions. In line with this study, Gashaw et al. (2020) also reported significant and positive associations of grain yield with the plant height, above-ground dry biomass yield, and harvest index of wheat. Teklay and Girmay (2016) also reported a strongly significant and positive correlation of grain yield with plant height, panicle length, panicle seed weight, and straw yield for teff.

Table 7. Pearson Correlation coefficient (r) between mean of total biomass, grain yield, straw weight and other parameters of wheat grown under blended fertilizers.

	PH	TL	SL	KPS	BM	GY	STY	HI
PH	1.00							
TL	0.71*	1.00						
SL	0.80*	0.76*	1.00					
KPS	0.85***	0.73*	0.82*	1.00				
BM	0.84*	0.86*	0.84*	0.83***	1.00			
GY	0.52*	0.45*	0.49*	0.37**	0.43**	1.00		
STY	0.76*	0.80*	0.77*	0.79***	0.95***	0.15 ^{ns}	1.00	
HI	-0.21 ^{ns}	-0.29 ^{ns}	-0.25 ^{ns}	-0.32**	-0.40**	0.62***	-0.64***	1.00

Where: * = Correlation is significant at the 0.05 level, *NS=Non Significant, PH= Plant Height, SL= Spike Length, TNT= Total Number of Tillers, TL= Number of Tiller, BM = Biomass Yield, GY = Grain yield, STY= Straw Yield, HI= Harvest Index.

4.6. Partial Budget Analysis

A cost-benefit analysis was done to determine the relative economic returns on the applied treatments using the prevailing market prices. Experimental yields are often higher than the yields that farmers could expect using the same treatments; hence, in economic calculations, the yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988).

In the current study, Hidase varieties gave an economic benefit of (99367.6) birr ha⁻¹ with a marginal rate of return (13281.2%) at 100 kg NPS ha⁻¹ fertilizer rate but an economic benefit of (101131.89) birr ha⁻¹ was obtained for the variety Hidase at 150 kg NPS ha⁻¹ with marginal rate of return (196) (Table 9). According to CIMMYT (1988) suggestion, the minimum acceptable marginal rate of return should be more than 100%. Application of 150 kg ha⁻¹ NPS fertilizer with Hidase variety gave unacceptable range with marginal rate of return (20.8%). Therefore, Hidase variety at 100 kg NPS ha⁻¹ was economical and recommended for the production of bread wheat in the study area and other areas with similar agroecological conditions.

Table 8. Economic analysis (partial budget and dominance) of the effects of blended fertilizer (NPS) rates on bread wheat varieties at Gorche district in 2021 cropping season

Treatments		AGY	ASY	Income			TVC	NB	MRR
Variety	NPS			AGY	ASY	GFB			
Wane	0	1303.74	5586.3	39112.2	2793.15	41905.35	4700	37205.35	-
King bird	0	1107.54	5343.3	33226.2	2671.65	35897.85	4750	31147.85	D
Hidase	0	1414.98	6150.6	42449.4	3075.3	45524.7	4775	40749.7	
Wane	50	2455.02	5769.9	73650.6	2884.95	76535.55	5600	70935.55	
Kingbird	50	2301.3	5733.9	69039	2866.95	71905.95	5650	66255.95	D
Hidase	50	2653.74	6379.2	79612.2	3189.6	82801.8	5675	77126.8	
Wane	100	2897.46	5988.6	86923..8	2994.3	89918.1	6500	83418.1	
Kingbird	100	2588.76	6045.3	77662.8	3022.65	80685.45	6550	74135.45	D
Hidase	100	3152.52	7578	94575.6	3789	98364.6	6575	91789.6	
Wane	150	3136.23	6928.2	94086.89	3464.1	97550.99	7400	90150.99	D
Kingbird	150	2781.27	6770.7	83438.1	3385.35	86823.45	7450	79373.45	D
Hidase	150	3162.51	9154.4	94875.3	4577.2	99452.5	7475	91977.5	

Where, AGY = adjusted grain yield; ASY = adjusted straw yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha-1 = Ethiopian Birr per hectare; D = dominated treatments. Market price of wheat = 30.00 ETB kg-1; Cost of NPS= 18 kg-1; Cost of Urea =14.5ETB kg -1; cost of straw = 0.5 ETB kg -1 or 1 quintals=50 ETB.

Table 9. Economic analysis (partial budget and Marginal rate of return) of the effects of blended fertilizer (NPS) rates on bread wheat varieties at Gorche district in 2021 cropping season

Treatment		AGY	ASY	Income			TVC	NB	MRR
Variety	NPS			AGY	ASY	GFB			
Wane	0	1303.74	5586.3	39112.2	2793.15	41905.35	4700	37205.35	-
Hidase	0	1414.98	6150.6	42449.4	3075.3	45524.7	4775	40749.7	4725.8
Wane	50	2455.02	5769.9	73650.6	2884.95	76535.55	5600	70935.55	3658.89
Hidase	50	2653.74	6379.2	79612.2	3189.6	82801.8	5675	77126.8	8255
Wane	100	2897.46	5988.6	86923.8	2994.3	89918.1	6500	83418.1	762.58
Hidase	100	3152.52	7578	94575.6	3789	98364.6	6575	91789.6	11162
Hidase	150	3162.51	9154.4	94875.3	4577.2	99452.5	7475	91977.5	20.87

5. SUMMARY AND CONCLUSION

Bread wheat is one of the major staples and strategic food security crop in Ethiopia. However, wheat yield in Ethiopia and the study area is low as compared to the attainable yield because wheat production is constrained by both biotic and abiotic factors such as diseases, insect pests, moisture stress, low soil fertility, inappropriate and imbalanced fertilizer application, inadequate improved bread wheat varieties and poor agronomic practices are among the major challenges responsible for the low productivity of bread wheat in the study area. So use of optimum and balanced fertilizer and appropriate variety are essential to boost the productivity of wheat. Thus, the current study was conducted in the Gorche district of Sidama Regional State to determine optimum NPS fertilizer rates on growth, yield, and yield components of bread wheat varieties.

The treatments studied consists of three bread wheat varieties (Wane, Kingbird and Hidase) and four rates of blended fertilizers (0, 50, 100 and 150 kg NPS ha⁻¹). The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangement with three replications. The total treatment combinations consist of a total of 12 treatments.

The results revealed that day to emergence was not significantly affected by variety, different rates of NPS blended fertilizer, and their interaction. However, days to heading, days to maturity, plant height, spike length, effective tillers, kernel spike⁻¹, straw yield, and grain yield were significantly influenced by the main effects of variety and blended NPS fertilizer, while most of these parameters were not significantly influenced by their interaction, except above-ground dry biomass.

Among the varieties, the Hidase variety showed superior performance for most of agronomic characteristics. The observed significant differences among the wheat varieties could be attributed to their differences in genotypes. Similarly, the application of different rates of NPS had a significant effect on all agronomic traits of wheat. In this study, the application of NPS fertilizer improved vegetative growth and delayed the physiological maturity of bread wheat, which could be due to the physiological effect of N. The highest plant height, number of tillers, spike length, thousand kernel weights, above-ground biomass, and straw yield in the main effect were recorded from higher (150 kg NPS ha⁻¹) fertilizer application.

Regarding the grain yield, increasing NPS fertilizer rates from 0 to 150 kg ha⁻¹ resulted in a significant increase in bread wheat yield. However, the bread wheat yield obtained at NPS rates 100 and 150 kg ha⁻¹ did not show statistically significant differences with each other. Moreover, the Hidase variety at 100 kg ha⁻¹ was found to be better in terms of economical feasibility. Therefore, the Hidase variety and application of 100 kg NPS ha⁻¹ were recommended for the study area. However, as the experiment was conducted only for a single season, the repeat of the study is suggested for more seasons around the Gorche area and similar agroecology.

6. REFERENCES

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7. APPENDICES

Appendix table 1. Mean square of phenological parameters

Source of variation	Mean squares			
	DF	Days to 50% emergence	Days to 50% heading	Days to 90% physiological maturity
Replication	2	2.53	11.86	33.25
Varieties (V)	2	0.86 ^{ns}	82.53 ^{***}	203.08 ^{***}
NPS	3	0.52 ^{ns}	116.82 ^{***}	316.26 ^{***}
V*NPS	6	1.38 ^{ns}	2.34 ^{ns}	7.34 ^{ns}
Error	22	2.38	6.53	17.80
CV (%)		20.71	3.79	3.77

Appendix table 2. Mean square of growth parameters

Source of variation	Mean squares		
	DF	Plant height (cm)	Spike length (cm)
Replication	2	23.95	0.38
Varieties (V)	2	95.61 ^{***}	0.55 ^{***}
NPS	3	502.35 ^{***}	2.78 ^{***}
V*NPS	6	8.75 ^{ns}	0.11 ^{ns}
Error	22	4.87	0.08
CV (%)		3.16	3.94

Appendix table 3. Mean square of yield and yield components

Source of variation	Mean squares							
	DF	Effective tillers plant ⁻¹	Kernels spike ⁻¹	Thousand kernel weight (g)	Above ground dry biomass (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index
Replication	2	0.27	7.00	11.583	767247	91648	467761	3.132
Varieties (V)	2	1.01 ^{***}	44.08 ^{***}	23.083 ^{***}	1.263E+07 ^{***}	610061 ^{***}	8324281 ^{***}	19.540 [*]
NPS	3	3.28 ^{***}	99.03 ^{***}	111.037 ^{***}	2.688E+07 ^{***}	7005858 ^{***}	8094469 ^{***}	293.148 ^{***}
V*NPS	6	0.17 ^{ns}	2.12 ^{ns}	2.565 ^{ns}	823992 [*]	19500 ^{ns}	804760 ^{ns}	5.537 ^{ns}
Error	22	0.11	2.27	2.008	263692	44417	343340	5.425
CV (%)		7.93	3.83	3.80	5.21	7.86	8.17	8.71

Appendix table 4. Mean Monthly Meteorological Data of the Study Area during the experimental year (2021).

2021 Cropping year			
Month	Max temp(0C)	Min temp(0C)	Rainfall(mm)
January	23	9.3	25
February	23.7	7.5	3.5
March	23.5	7	31.5
April	23	9.3	93.5
May	22	9	125
June	21.5	8.6	195
July	20.8	8.9	249
August	19.6	7	354
September	20.8	7.5	185
October	21.5	8	23.5
November	23	7.5	34.5
December	23.5	8	4.8
Total	265.89	97.6	1324.3
Mean	22.15	8.13	

Source: - Gorche woreda Agricultural and Natural Resource management office.

8. BIOGRAPHICAL SKETCH

The author was born on December 24, 1992, in Shebedino district, Dila Afarara Kebele of the former SNNPRS, now Sidama Regional State, Ethiopia. He attended elementary and secondary education at Dila Afarara. Secondary and preparatory education at Leku Secondary and Yirgalem secondary and Preparatory School.

He then joined Hawassa University in 2010 and graduated with BSc in Plant Sciences on July 14, 2012. After graduation, he joined the Shebedino district Agricultural office in October 2012 and worked for about five years in the position of an Agronomy expert until he joined the school of graduate studies at Hawassa University in October 2018 G.C to pursue MSc studies in the field of Agronomy.