# EFFECT OF BLENDED NPSB FERTILIZER RATES ON YIELD AND YIELD COMPONENTS OF MAIZE *(ZEA MAYS L.)* VARIETIES AT ENORE ENER DISTRICT, CENTERA, ETHIOPIA

**MSC. THESIS**

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Wolkite University
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# Effect of Blended NPSB Fertilizer Rates on Yield and Yield Components of Maize *(Zea mays* L.*)* Varieties at Enore Ener District, Central, Ethiopia

Thesis Submitted to School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science in Plant Science (Specialization: Agronomy)

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## WOLKITE UNIVERSITY

## SCHOOL OF GRADUATE STUDIES

We here by certify that we have read and evaluate this Thesis titled “**Effect of Blended NPSB Fertilizer Rates on Yield and Yield Components of Maize (Zea mays L.) Varieties at Enore Ener District, Central, Ethiopia** prepared under our guidance by Lijwork Nigatu Amerga. We recommend that the Thesis shall be submitted as fulfilling the requirements for the award of Master of Science in Agronomy.

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As members of the Board of the Examiners of the Master of Science Thesis open defense examination, we have read and evaluated this Thesis prepared by **Lijwork Nigatu Amerga** and examined the candidate. We hereby certify that, the thesis is accepted for fulfilling the requirements for the award of the degree of science (MSc.) in Agronomy.

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# DEDICATION

To my wife, daughters, and family, thank you for your unwavering support and encouragement that made this thesis possible.

# DECLARATION

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# BIOGRAPHICAL SKECH

Lijwork Nigatu Amerga was born on December 13, 1983 G.C in Shanka *Kebele* near Gunchire town, Ethiopia, where he was born on December 13, 1983 G.C. He completed his elementary and secondary education at Gunchire Elementary and high schools. Driven by his interest in Plant Sciences, he pursued a BSc degree at Wolaita Sodo University (2002-2004 G.C.) and later a Master of Science in Agronomy at Wolkite University (commenced December 2013 E.C.). His professional experience includes roles in the Enore Ener District Agriculture Office and the Enore Ener District Youth Sport, Enterprise and Industry Development and Livestock and Fishery Head Office.

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| ATA | Agricultural Transformation Agency |
| ATP | Adenosine triphosphate |
| CIMMYT | Centro International Mejoramiento Maize Y Trigo |
| CSA | Central Statistical Agency |
| FAO | Food and Agricultural Organization |
| GFB | Gross Field Benefit |
| GLM | General Linear Model |
| LSD | Least Significant Difference |
| MOARD | Minister of Agriculture and Rural Development |
| NPSB | Nitrogen, Phosphorus, Sulfur, Boron |
| OPVs | Open-pollinated varieties |
| PAR | Photo Synthetically Active Radiation |
| RCBD | Random Complete Block Design |
| SAS | Statistical Analysis System |

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## ABSTRACT

*Maize, a staple cereal crop in Ethiopia,* suffers *from low productivity in the study area due to poor soil fertility, limited fertilizer use, and low-yielding varieties. To address this, a field experiment was conducted during the 2021/2022 bulge cropping season in Enore Ener district, Central Ethiopia. The study evaluated the effects of blended NPSB fertilizer rates on yield and yield components of three maize varieties (BH-540, BH-546, and BH-661). The experiment also aimed to identify economically viable NPSB fertilizer application rates. Treatments consisted of factorial combinations of the three varieties and four NPSB fertilizer rates (0, 50, 100, and 150 kg ha-*$^{1}$*) arranged in a randomized complete block design with three replications. Data on maize phenology, growth, yield, and yield components were collected and analyzed using SAS software (Version 9.3).The results showed a significant interaction between maize varieties and NPSB fertilizer rates for most parameters. The result revealed that, BH-661 with 150 kg ha-*$^{1}$* NPSB achieved the tallest in plant height (291.33 cm), maximum leaf area (7229.7 cm2), and highest leaf area index (4.3). Application of 150 kg ha-*$^{1}$* NPSB fertilizer with variety BH-546 also produced the most ears per plant (2.3) and most grains per ear (6432.7). Moreover, the application of 150 kg ha-*$^{1}$* NPSB fertilizer with variety BH-546 resulted in the highest grain yield (9,366.7 kg ha-*$^{1}$*) and the greatest net benefit (211,865.55 Birr ha-*$^{1}$*) Hence applying 150 kg ha-*$^{1}$* NPSB fertilizer with variety BH-546 is optimal for maximizing yield and net benefit in the study area., Nevertheless further research is needed across locations and seasons for robust recommendations to the region.*

**Key-words:** Grain Yield, NPSB fertilizer, Partial budget, Varieties

# 1. INTRODUCTION

Maize (*Zea mays* L.) belongs to the tribe *Maydae*, family *Poaceae*, and originated in Central America. It was introduced to West Africa in the early 1500s by Portuguese traders and later to Ethiopia during the 1960s to 1970s. Today, it is one of the most important food crops worldwide, growing in various environmental conditions between 50° latitude north and south of the equator (FAO, 2020). In Ethiopia, maize is a major food crop, leading in volume of production and productivity, with an average yield of 3.67 tons per hectare (CSA, 2021). However, the national crop productivity remains low at 1.7 tons per hectare (FAOSTAT, 2020), compared to the reported 4.7 tons per hectare from on-farm trials (IFPRI, 2010) and the world average yield of 5.21 tons per hectare (FAO, 2020).

Maize is unparalleled to other crops due to its adaptability to diverse environments and its multiple end uses as human food, livestock feed, and an important component in various industrial products. It also serves as a model organism for biological research worldwide (Shiferaw et al., 2011). Globally, maize production reaches approximately 1016.73 million metric tons annually, making it the highest among major staple cereals (FAOSTAT, 2018).

Maize faces challenges in sustaining production and productivity in Ethiopia, primarily due to poor soil fertility (Tolessa et al., 1994; Abebayehu et al., 2011). Recent studies in southern Ethiopia also confirmed lower productivity levels compared to the national average in maize production (Tadesse et al., 2021). It is also a vital field crop in Ethiopia, with a significant area coverage, production, and economic importance. In the 2015/2016 cropping season, approximately 2,111,518.23 hectares of land were dedicated to maize cultivation, yielding an estimated production of no less than 71,508,354.11 quintals (CSA, 2022/23). Maize grows across diverse ecological zones in Ethiopia, ranging from sea level to over 3000 meters above sea level, including moisture deficit semi-arid lowlands, mid-altitude and highlands, and moisture surplus areas.

The mid-altitude regions in western, southern, eastern, and central Ethiopia, along with the low-altitude areas in the southwestern parts of the country, are well-known maize agro-ecologies. These regions benefit from warm temperatures, sufficient rainfall, and relatively fertile soils, providing favorable conditions for maize cultivation (Worku et al., 2012). However, the full potential of maize productivity in Ethiopia has not been fully exploited. Challenges such as site-specific fertilizer recommendations, improved varieties, knowledge gaps among farmers, suboptimal plant population per hectare, inadequate seed rates, and disease and pest management hinder the realization of maize's productivity potential (CSA, 2021). The adoption of adaptive cultivation practices, including fertilizer application, maize varieties, sowing time, sowing density, and row and plant spacing, can improve maize grain yield (Pasuquin et al., 2014). Increased use of improved maize varieties, mineral fertilizers, and enhanced extension services are key factors contributing to accelerated maize productivity in Ethiopia (Tsedeke et al., 2015).

Being an exhaustive crop with high genetic potential, maize absorbs a significant amount of nutrients from the soil during different growth stages. Among the nutrients Nitrogen is a vital plant nutrient and a major factor determining maize yield. It is essential for plant growth, constituting one to four percent of the plant's dry matter (Jeet et al., 2012). Improved maize hybrids are also required to increase production per unit area, particularly considering changing climatic conditions and emerging biotic stresses (Jeet et al., 2012).

The development of a soil fertility map by the Agricultural Transformation Agency (ATA, 2016) led to the recommendation of blended fertilizers containing N, P, S, B, Zn, and Cu for the South Nation Nationalities and People Regional State (EthioSIS, 2016). Soil sample results from cultivated land in 32 kebeles of Enore Ener District indicated nutrient deficiencies, including N, P, S, and B, which negatively affect crop production in the study area (EthioSIS, 2016). Additionally, there is a lack of research findings on the effect of blended NPSB fertilizer on maize yield in the study area, highlighting the need for investigation. Poor soil fertility, including nitrogen, phosphorus, sulfur, and boron deficiencies, contributes to the low productivity of maize crops (CSA, 2021). Therefore, understanding the effect of blended NPSB fertilizer on maize yield is crucial for improving productivity and addressing nutrient deficiencies in the study area.

### General Objective

- ✓ To evaluate the effect of Blended NPSB fertilizer rates on yield and yield components of maize and recommend economically optimum rate for the study area.

### Specific objectives

- ✓ To determine effect of NPSB rates on yield and yield components of maize varieties.
- ✓ To investigate the interaction effect of NPSB fertilizer and varieties on maize yield.
- ✓ To determine economic feasibility rates of NPSB fertilizer on yield of maize varieties

# 2. LITRATURE REVIEW

## 2.1. Origin, Domestication and Distribution of Maize

The center of origin of maize is the Mesoamerican region, probably in the Mexican highlands, from where it spread rapidly (Hailare, 2000) Archaeological records and phylogenetic analysis suggest that domestication began at least 6,000 years ago (Piperno and Flannery, 2001; Matsuoka *et al*, 2002). It was first cultivated in the area of Mexico more than 7,000 years ago, and spread throughout North and South America (Hailare, 2000).

World production of white maize is currently estimated to be around 65 to 70 million tons. Through the individual geographical regions of the developing countries, white maize production has a greatest importance in Africa. The main white maize producers in Africa include Kenya, Tanzania, Zambia and Zimbabwe (Kidist, 2013). In Ethiopia, maize production is of recent history. It was probably introduced to this country from Kenya during the 17th Century (Marco, 2014).

## 2.2. Maize Production in Ethiopia

Maize was one of the most important cereal crops in Ethiopia, ranking second in area coverage and first in total production (CSA, 2017). Although it is one of the strategic crops for the achievement of food security in the country, more than 90% of the production is handled by small scale farmers under rain fed growing conditions (CSA, 2022/23). About 40% of the total maize growing area is also located in low moisture stress areas, where it contributes less than 20% to the total annual production (Mandefro *et al*, 2002). The low yield in these areas, like other Sub-Saharan African countries, is mainly attributed to recurrent drought, low levels of fertilizer use and low adoption of improved varieties (CIMMYT and IITA, 2010).

Ethiopia was one of the main maize producers from Africa. It was the second most widely cultivated crop in Ethiopia and grown under diverse agro-ecologies and socioeconomic conditions, typically under rain fed production (FAO Stat, 2020). Ethiopia has doubled its maize productivity and production in 2016, 2017 and 2018.The yield, currently estimated more than 3.6, 3.7, and 3.8 metric tons/ha and area harvest is more than 2.1, 2.1, and 2.2 million ha in 2016, 2017 and 2018 respectively (FAO Stat, 2020).

It was the second most widely cultivated crop in Ethiopia and were grown under diverse agro-ecologies and socioeconomic conditions (Tsedeke *et al*, 2017). Also Ethiopia's leading the second cereal crops producer in terms of production, produced in by 11,475,499 million farmers across of 2,274,305.93 hectares land and 96,357,345.00 quintals (CSA, 2019/20).

In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands (Kebede et al., 1993). It is one of the important cereal crops grown in the country. The total annual production and productivity exceed all other cereal crops, though it is surpassed by teff in area coverage (Benti *et al,* 1997). Therefore, considering its importance in terms of wide adaptation, total production and productivity, maize is one of the high priority crops to feed the increasing population of the country.

On the half-hectare demonstration plots of (Sasakawa Global 2000 SG-2000) and the similar government extension program, hybrids gave an average yield of 5-6 t ha-$^{1}$ in potential areas. This represents a 250% increment over the average yield obtained by traditional practices in the country (Benti *et al,* 1997 and Simons et al., 2014). Increased the average productivity of maize from 3.4 ton per hectare in 2015 to 5.o ton per hectar in 2020 and increased the total volume of produce from 7.2million tons in 2015 to 10.9 million ton by the year 2020 (MoA, 2016).

## 2.3. Factors Affecting Maize Production

The most important farmers production constraints in maize farming, as revealed by the farmers were, high input prices; especially fertilizers and seed, disease, low soil fertility, limited access to improved seed, Insect pests, adoption of communication technologies, access to roads, animal clinics, and credit and financial institutions positively impacted productivity (Nikhith *et al.*,2016).

Appropriate use of fertilizers, knowledge about micro-nutrients and recommended agronomic packages like use of high yielding varieties were almost not sufficient. Similarly, there was much room for improvement in getting farmers to adopt and implement the recommended package of agronomic management methods including proper tillage and land preparation, row planting, maintaining the right planting depth, plant population, time and frequency of weeding, and proper time of harvesting are also factors affecting maize production (ATA, 2013).

## 2.4. Botanical Description of Maize

Maize (*Zea mays* L.) was a thick-stemmed annual grass, usually with a single stem, one to four meters tall, with one or more tillers. It was monoecious and diclinous, with male and female inflorescences born separately on the same plant. It was among the most human-modified crops on earth. It’s wild relative with a very small rachis that breaks at maturity to release 10 to 12 seeds enclosed in capsules.

Selection produced a maize plant that can grow up to 5 m high, with a rachis on a single branch that contains as many as 800 - 1,000 kernels covered by modified leaves (husks) that protect the kernels from desiccation.

## 2.5. Agronomic Practice for Maize production

The most important agronomic practices for production of maize include, field preparation, fertilizer application, proper seed rate, proper spacing, sowing in proper time , appropriate weed management and timely harvesting are critical in production of maize (Amit *et al,* 2014). Plough the soil for formation of favorable condition for root development and expose to different pathogens to sun light and reduces risk of soil borne diseases (Anonymous, 2016).

## 2.6. Ecological Requirements of Maize

Maize grows well in a wide range of environments, but the interaction between the environments and genotype is critical to its production (Otung, 2014). These agro ecologies differ in altitude, annual rainfall, temperature, relative humidity, and latitude. The factors determining the growth and final yield of maize (*Zea mays* L.) are climate, soil, fertilizer and crop management. An average summer temperature of 20°C to 21° C seems to be the most favorable for maximum yield of maize. The annual precipitation where corn is grown ranges from 250 mm to more than 5000 mm in the tropics (Edward, 1992).

Maize were produced under diverse agro - ecologies ranging from an elevation of 1600 to 3000 masl and from high moisture to moisture stress areas due to the availability of different maize cultivars developed being tailored for each condition (ESA, 2014). It responds to higher temperatures, the threshold temperature for seed germination was about 10° C. The crop is relatively sensitive to cool temperatures, and it does not acclimatize to low temperatures as do most cool-season crops. Temperatures of 5° to 7° C may be followed by photo-inhibited physiological damage that may reduce photosynthetic rates for several days (Trayer, 2001).

As a C4 plant, maize responds well to both high temperatures and intense sunlight. Well-watered maize plants reach maximum leaf photosynthesis rates at midday temperatures of 32° to 35° C. Photosynthetic rates of sun-adapted maize do not saturate until light intensity approaches full sunlight. Because photosynthetic captured sunlight energy were the primary driving force for maize growth and yield, excessive cloudiness and short days tend to lower maize yields (Trayer, 2001). Maize was water efficient, to obtain high yield it requires a considerable amount of water. Seasonal water uses were about 500 to 600 mm in temperate areas and up to 1200 mm or more under irrigation in dry climates. Under rain fed conditions, which were the most common production system, plant water was supplied by seasonal rainfall and stored soil water. Hence, deep soils and those with high organic matter content which store much more plant available water are considered the most suitable for maize production (Nafziger, 2009).

Maize thrives well in most soils, as far as they are deep (more than 1 meter) and fertile, and have a good water holding capacity. Maize grows best on sandy clay (loams), loamy and siltyclay soils; it is less adapted to compact clays and sands (Purseglove, 1976).

Major soil factor is soil water storage, and this is determined by texture and structure. Available soil moisture is a major element of success in rain-fed maize production, particularly where the rains are not uniformly distributed over the season. In this case, the plant has to rely on the moisture stored in the root zone to overcome the temporary water deficit (Purseglove, 1976).

## 2.7. Effect of Variety on Production of Maize

Improved varieties play a great role in increasing maize productivity on currently cultivated land (Mosisa *et al,* 2009). The amount of improved seed and the extent of area under application are increasing from year to year. The use of these improved seeds still remains very low and has not been widely practiced by small holder farmers. From the total area under improved seed allocated to cereals about 83% covered by maize (*Mosisa et al*, 2009).

The amount of improved seed ha-$^{1}$ (improved seed application rate) for this major cereal crop is increasing from year to year. The application rate for maize seed was 0.24 quintal ha-$^{1}$ of cultivated land (CSA, 2015). The best hybrid cultivars produce high yielding, uniform crops under favorable soil and climatic conditions while maintaining better yields than older hybrids or open-pollinated varieties under unfavorable conditions. Improved seeds are utilized in 31 percent of fields with maize (CSA, 2017).

### 2.8. Nutrient Requirement for Maize production

Nutrient requirements of crops depend on yield level, crop species, cultivar or genotypes within species, soil type, climatic conditions and soil biology. Hence soil, plant and climatic factors and their interactions are involved in determining plant nutrient requirements. In addition to this, the economic value of a crop and the socioeconomic conditions of the farmer also are important factors in determining the nutrient requirements of a crop. Diagnostic techniques for nutritional disorders are the methods for identifying nutrient deficiencies, toxicities or imbalances in the soil-plant system (Fageria *et al*, 2011).

#### 2.8.1. Response of maize to nitrogen fertilizer

Maize (*Zea mays* L.) is second most important crop after rice. It was grown in 0.9 million ha with the production of 2.3 million ton (t) and Productivity of 2.56 t/ha and Ecologically, it was commonly cultivated in mid hills and high hills and was mostly grown under rain fed conditions, mostly on marginal land with very little use of commercial fertilizers (MoALD, 2018).

Nitrogen is referred as the primary macronutrients because of the probability being deficient in plants and their large quantities taken up from the soil relative to other essential nutrients. It was an important component of proteins, enzymes, and vitamins in plants and central part of the essential photosynthetic molecule and chlorophyll (Jat *et al*, 2013).

The response of maize plant to application of nitrogen fertilizers varies from variety to variety, location to location and also depends on the availability of the nutrients and previous findings indicated that the increase in maize grain yield after nitrogen fertilization were largely due to an increase in the number of ears per plant, increase in total dry matter distributed to the grain and increase in average ear weighing (Onasanya *et al*, 2009).

Grain yield, days to flowering, plant height, ear height, kernel rows per ear, number of kernels per row, ear length and thousand grain weight significantly affected due to growing seasons and split applications of nitrogen (Adhikari *et al*, 2016).

The lack of nitrogen reduces the growth of the plants and lower yields. On the contrary, when optimum levels of nitrogen are used, higher yields are produced due to the larger leaf area and the proper growth of the plant. In addition to its function in the creation of green tissue, nitrogen plays a very important role in the development of the ear and kernel (Ciampitti and Vyn, 2010).

### 2.8.2. Response of maize to phosphorus fertilizer

Maize was an exhaustive crop taking nutrients from the soil during its growth. The newly evolved high yielding varieties of maize are more fertilizer responsive and their yield potential can be exploited through judicious use of fertilizer. Phosphorus (P) is one of the most important essential plant nutrients in crop production( Ozanne ,1980) reported that P is indispensable for all forms of life because of its genetic role in ribonucleic acid and function in energy transfers via adenosine tri-phosphate. After nitrogen; P has a more widespread influence on both natural and agricultural ecosystems than any other essential plant element (Brady and Weil, 2002 and Fageria, 2009).

Phosphorus is another essential nutrient required to increase maize yield. Consequently, the lack of phosphorus is as important as the lack of nitrogen in limiting maize performance. Phosphorus was claimed to be the second most important plant growth limiting nutrient (Tisdale *et al,* 1995). It makes about 0.2-0.5% of the plant’s dry weight and it to be involved in several physiological and biochemical processes of plants; being components of membranes, chloroplasts and mitochondria and constituent of sugar and played a crucial role in energy transfer reactions and metabolic processes in plant maturity, fruit setting, and seed production (Brady and Weil, 2002).

It also important plant nutrient in maize production as it requires adequate supply of nutrients for good growth and high yield. In maize production, phosphorus was a major yield determining factor and its availability in sufficient quantity was essential for optimum maize growth and yields (Epstein and Bloom, 2005).

### 2.8.3. Response of maize to sulfur fertilizer

Maize (*Zea mays* L.) was one of the most important food grains and extensively grown worldwide for food and also as a source of raw material for manufacturing of several products such as corn sugar, corn flakes, corn oil, and corn protein. Among them sulfur was one of the essential nutrients for plant growth and yield. Maize requires sulphur in amounts similar to phosphorus. It has specific functions during plant growth, metabolism, and enzymatic reactions and it requires for the synthesis of sulfur-containing amino acids such as cystine, cysteine, and methionine.

Sulfur (S) was a constituent of the amino acids cysteine and methionine and hence, part of proteins that play an important role in the synthesis of vitamins and chlorophyll in the cell. Deficiency of either nitrogen or sulfur limits protein production of the plant. Sulfur fertilization is most critical for oil, protein synthesis and improvement of quality of produce by their enzymatic and metabolic efforts (Singh *et al,* 1981). A deficiency of S causes plants to be uniformly chlorotic, stunted, and thin stemmed, Growth is retarded and, consequently, yield is reduced (Sakal *et al,* 2000).

### 2.8.4. Response of maize to boron fertilizer

Boron (B) was an essential element for the normal growth and development of higher plants (Camacho *et al,* 2008). Many physiological and biochemical processes such as sugar transport, cell wall synthesis, lignification's of cell wall structure, membrane integrity, carbohydrate, RNA, IAA and phenol metabolisms, in plants are directly or indirectly regulated by the boron (Cakmak and Romheld 1997). Boron deficiency is one of the most widespread micronutrient deficiencies in crops in the world and leads to heavy losses in yield. In soil deficiency of boron is most prevailed due to its easily leachable property under high rainfall conditions (Camacho *et al,* 2008).

Boron deficiency has been reported to result in considerable yield reduction in maize (Rashid, 2005). Rashid (2006) estimated a substantial potential net economic benefit from the use of B fertilizers in B deficient crops. Boron requirement is generally higher for reproductive development than for vegetative growth in plants (Dell and Huang 1997). (Agarwala *et al*, 1981) showed delayed emergence of tassels and lack of sporogenous tissue and formation of stem nodes in place of stamens in B deficient maize. Requirement of B for pollen fertility has been demonstrated because poor in vitro germination of pollen grains in the absence of B has been observed in maize (Agarwala *et al,* 1981).

Boron is one of the most commonly deficient micronutrients in agriculture, with reports of deficiencies in 132 crops and in 80 countries and its deficiency results in the general stunting of the young plants due to shortening of the internodes; leaves of young plants fail to emerge, and death of growing point may occur and these deficiencies typically result from boron leaching (Welch *et al*, 1991). Boron's widespread role within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, and regulation of plant hormone levels (Marschner, 1995).

In B-deficient maize, poor grain-setting can result in barren cobs, and this was attributed by the silks being non-receptive. For an open pollinated crop with separated female and male inflorescences like maize, knowing precisely how Boron deficiency affects functions of the two reproductive organs and the rest of plant parts were useful for targeting the management of Boron deficiency through its sensitive diagnosis and timely application of foliar Boron (Jamjod *et al,* 2004).

### 2.8.5. Effect of NPSB fertilizer rate on phenology, growth, yield component and yield of maize varieties

A balanced use of NPSB has a remarkable influence on maize growth and yield. Chemical fertilizers are used in modern agriculture to correct known plant-nutrient deficiencies; to provide high levels of nutrition, which aid plants in withstanding stress conditions; to maintain optimum soil fertility conditions; and to improve crop growth and yield. Adequate fertilization programmers' supply the amounts of plant nutrients needed to sustain optimum net returns. In essence, fertilizers are used to make certain that soil fertility is not a limiting factor in crop production (Shiferaw *et al*, 2018).

Balanced nutrition is an essential component of nutrient management and plays a significant role in increasing crop production and its quality. For the major processes of plant development and yield formation the presence of nutrients like N, P, S and B etc. in balanced form is essential. Applying the deficient soil nutrients N, P, S and B, indicated in them soil fertility map of Hawassa zuriya was improved maize yield. Research finding in Hawassa zuriya showed that NPSB (115 kg N + 39 kg P + 17 kg S + 1.7 kg B ha-$^{1}$) compared to NPS fertilizer treatments, while the lowest yield was recorded from the control plots (Shiferaw *et al*, 2018).

The Ethiopian soil information system (EthioSIS), a project launched by the Ethiopian Government's Agricultural Transformation Agency (ATA) in 2012, is a detailed soil map providing up-to-date soil fertility data. The information's revealed that in addition to nitrogen and phosphorus, sulfur and boron deficiencies are widespread in Ethiopian soils, while some soils are also deficient in potassium, copper, manganese, and iron (EthioSIS, 2013; 2014; 2015; Lelago et al., 2016), which all potentially grasp back crop productivity despite continued use of N and P fertilizers as per the blanket recommendation. Fertilizer recommendation for crops in the country has until recently focused on Nitrogen and Phosphorus macronutrients only, but future gains in food grain production will be more difficult and expensive considering the increasing problem of multi soil nutrient deficiencies. After the soil fertility map was developed by Agricultural Transformation Agency (ATA) in 2016, 13 blended fertilizers containing N, P, S, B, Zn, and Cu in different mix forms have been recommended for South

According to the soil map of Enore Ener woreda (EthioSIS, 2016), soil sample results from cultivated land of 42 kebeles of the woreda showed that up to 5 kebeles including the study area soils have N, P, S, and B nutrients deficiencies, which decreases crop production in some amount in the study area. In addition to this, there is limited empirical information on the effect of blended NPSB fertilizer on maize yield in association with their improved varieties in the study area. Thus there is a need to investigate the effects of blended Nitrogen, Phosphorus, Sulphur, and Boron (NPSB) fertilizer in the performance of different improved maize varieties

On growth, yield, and yield components of the crop. So far research carried out in many localities across Ethiopia in previous years also recommended different rates of P and N in accordance to crop and soil types. Also, blended fertilizer significantly increased the Yield of maize crops as compared to the recommended NP fertilizers (Chimdessa, 2016). The application of deficient soil nutrients such as Nitrogen, phosphorus, sulfur, and boron improves the grain and biological yield of maize crops (Shiferaw et al., 2018). However, there is limited information regarding the performance of different maize varieties at different rates of NPSB fertilizer levels in the study area as described in EthioSIS (2016).

# 3. MATERIALS AND METHODS

## 3.1. Description of the Study Area

The experiment was conducted at Workat *Kebele*, Enore Ener district, Gurage zone, Central, Ethiopia during 2021/22 *Belg* cropping season. The study site is located 189 km away from Addis Ababa, Ethiopia, and about 30 km from Wolkite, the capital of the Gurage zone. It has an altitude ranges from 1956-2200 m.a.s.l and approximate geographic coordinates of 8º 14’ 30’’ N latitude and 37 º 56’ 30’’ E longitudes.

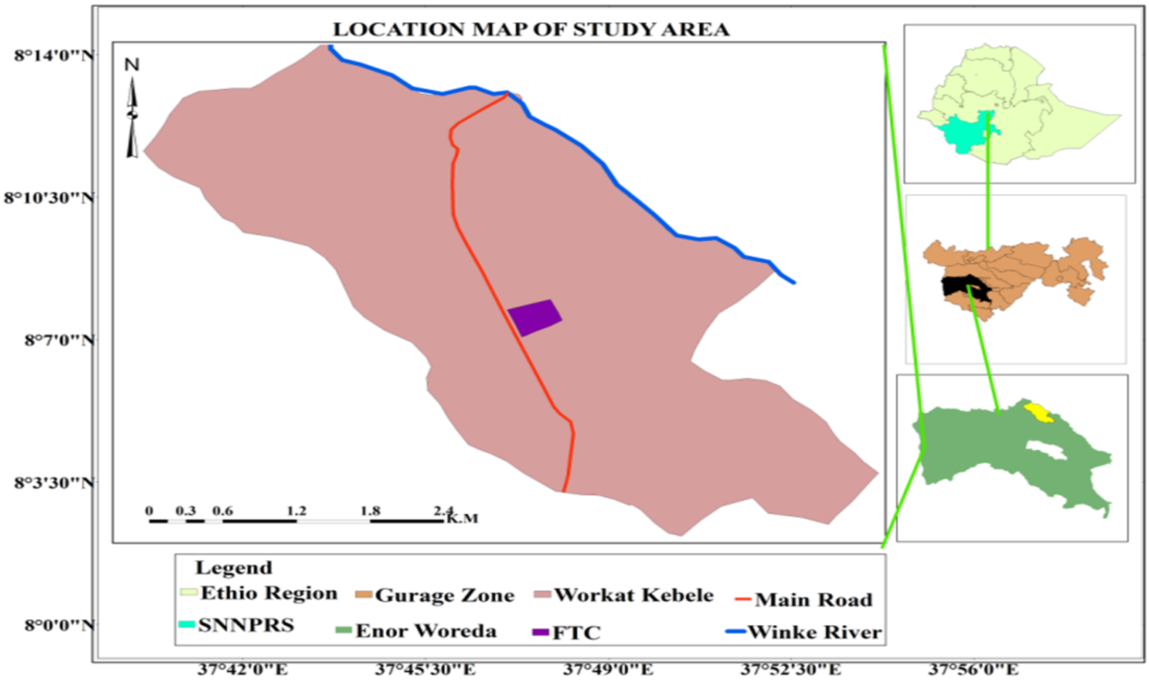

Figure 1.Map of the study area

The area receives an annual rainfall of approximately 1100–2300 mm with a minimum temperature of 17°C and a maximum of 21°C. According to the Enore Ener District Agriculture and Natural Resource Office (2022), the major soil type in the study area is Vertisols.

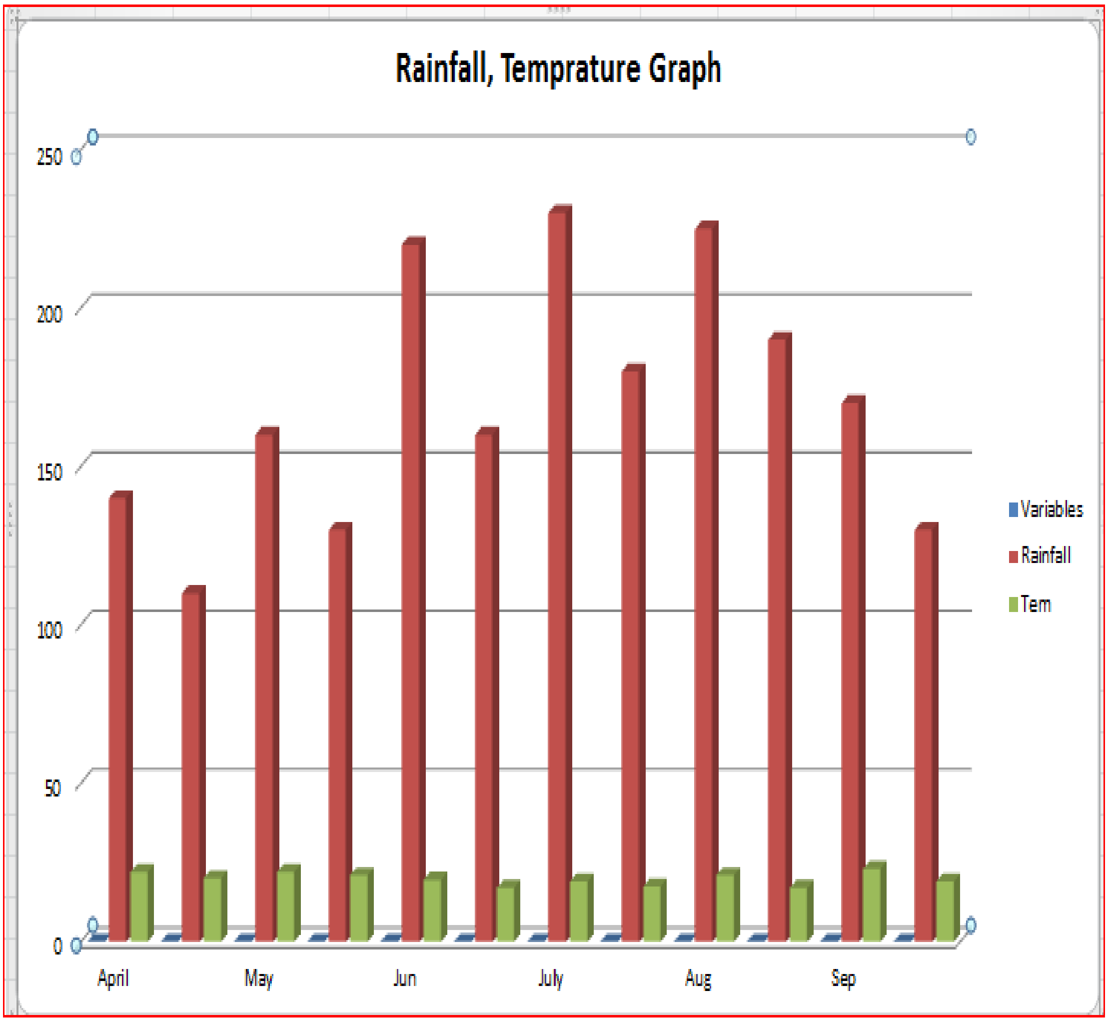

Figure 2.Rainfall (mm) and Temperature of experimental site

Source: Ethiopian metrological agency, (2022)

### 3.2 Soil Sampling and Analysis

The soil samples were collected randomly from the surface layer (0-20 cm) depth using an auger in a zigzag pattern before planting. About 1 kg of the composite sample was collected, air-dried on a shelf in a soil sample drying room, and then ground using a pestle and mortar under shade. The sample was sieved through a 2mm diameter sieve mesh analysis.

The soil was measured for soil textural class, pH, cation exchange capacity (CEC), organic carbon (%), available phosphorus (mg/kg), total nitrogen (%), available sulfur (mg/kg), and available boron. The soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH was measured in a 1:2.5 soil-to-water ratio using a glass electrode attached to a digital pH meter (Walkley and Black, 1934).

Soil organic carbon was determined by the wet digestion method (Walkley and Black, 1934). After air drying, the soil was ground to pass through a 0.5mm diameter sieved.

Cation exchange capacity (cmol (+)/kg) was determined by leaching the soil sample with 1M ammonium acetate, followed by washing with ethanol. The adsorbed ammonium was then replaced by sodium (Na). The CEC was determined titrimetrically by distillation of ammonia displaced by sodium (Sahlemedhin and Taye, 2000).

Total nitrogen (%) was also determined from the soil sample passing through a 0.5 mm diameter sieve using the Kjeldahl method (Jackson, 1974). Available phosphorus in the soil was determined by the Bray II (Bray and Kurtz, 1945) extraction method. Available sulfur (meq/L SO42-) was determined by the mono-calcium phosphate extraction method (Hoeft et al, 1973), and available boron was determined using the hot water method (Havlin et al, 1999).

### 3.3. Description of Experimental Materials

### 3.3.1. Crop materials

The maize varieties BH-540, BH-546, and BH-661, released by the Bako Agricultural Research center were used as test crops. These varieties are adapted to the agro-ecology of the study area.

Table 1: Maize varieties for the study

| Variety | released year | Altitude (m) | Rainfall(mm) | Days to maturity | Seed color | Yield(tone/ha) | |
|---|---|---|---|---|---|---|---|
| | | | | | | On Research station | On farmers field |
| BH-540 | 1995 | 1000-2000 | 1000-1200 | 145 | Red | 8.0-9.0 | 5.0-6.5 |
| BH-546 | 2013 | 1000-2000 | 1000-1200 | 145 | White | 8.5-9.5 | 5.5-7.0 |
| BH-661 | 2011 | 1600-2200 | 1000-1500 | 160 | White | 9.0-12.0 | 6.5-8.5 |

**Source:** MoARD, (2016)

### 3.3.2. Fertilizer materials

The recommended dose of urea (46% N) was applied uniformly to all plots. The blended NPSB fertilizer containing 18.9% N, 37.7% $P_2O_5$, 6.95% S, and 0.1% B (ATA, 2016) was used according to the specified treatment rates for maize productivity (EthioSIS, 2016).

### 3.4. Treatment and Experimental Design

The treatments consisted of four levels of blended NPSB fertilizers (0, 50, 100, 150 kg ha- $^{1}$) rates and three varieties of maize (BH-540, BH-546, and BH-661), for a total of twelve treatment combinations. The experiment was laid out a 3x4 factorial arrangement in a randomized complete block design (RCBD) with three replications. 75 by 25 cm inter and intra row spacing is used for plant population. The treatments were assigned randomly in each block. The gross plot area was 4.5 m× 3.5 m (15.75 m2) consisting of 6 rows. The one outermost row from each side and two plants from both ends of each row were considered as a border. Thus, the net plot size was 3x2.5 m (7.5 m2). The spacing between blocks and plots was 1m and 0.5 m, respectively.

### 3.5. Experimental Procedure and Management

The experimental field was ploughed to a depth of 30-50 cm using an oxen plow to achieve a fine tilth. The plots were then leveled manually. The site was cleared of all unnecessary materials and plant residues. The experimental field was divided into three blocks, with twelve (12) plots in each replication. Based on the design, a field layout was created, and each treatment was assigned randomly within a block following the method described by Gomez and Gomez (1984). Seeds were planted manually in rows with 75 cm x 25 cm spacing on May 10, 2022. The total NPSB fertilizers were applied at sowing and from 150kg/ha-$^{1}$ urea fertilizer one-third were used at the time of sowing, while the remaining two-thirds of the urea were applied at 35 days after sowing. The first weeding was done one month after planting, and the second weeding was done before tasseling. All necessary agronomic practices (e.g., weeding, insect pest control (stalk borer) by using 1 litter Diaznol chemicals/ ha-$^{1}$) were carried out uniformly and properly for each plot at the right time and place, starting from field preparation to harvesting. Harvesting was done manually when the crop reached physiological maturity.

## 3.6. Data collected

### 3.6.1. Phenological and growth parameters

**Days to 50% tasseling:** The number of days from planting until 50% of the tassels in each sample plot emerged was recorded and analyzed using the method described by Murphy et al. (1996).

**Days to 50% silking:** The number of days from planting until 50% of the silks in the sample plot emerged was recorded and analyzed using the method described by Murphy et al. (1996).

**Days to maturity:** The number of days from planting to when 90% of the plants became dry and collapsed at the neck was counted. The mean values were computed and used for further analysis.

**Plant height (cm):** The height from the soil surface to the base of the tassel of ten randomly selected maize plants from the net plot area (3 m x 2.5 m) was measured at plant physiological maturity. The average plant height was used for analysis.

**Leaf area ($cm^2$):** The leaf area of randomly selected ten plants per plot at time of 5% silking was measured using the formula LA = W x L x 0.75, as suggested by Francis et al. (1969), where:

LA = leaf area ($cm^2$)
W = maximum leaf width (cm)
L = maximum leaf length (cm)
0.75 = correction factor for maize
Leaf area index (LAI): The ratio of the leaf area to the ground area was calculated using the formula LAI = leaf area/ground area (Radford, 1967).

### 3.6.2. Yield components and yield

**Number of ears per plant:** was measured from randomly sampled plants and count number of ear from plant in each sample plot taken to average and divide the number of plant the result were analyzed properly (Lakew et al., 2016).

**Ear-length (cm):** It was measured from the point where the ear attaches to the stem to the tip of the ear from randomly selected plants in the central net plot at the crop harvest.

**Ear-Diameter (mm)** was measured the diameter ears of each sampled plants.

Number of grain rows per ear: was measured by counting the number of grain rows per ear of randomly selected sampled plants.

**Number of grains per ear:** counting the number of grains that is found ear of sampled plants then the results was analyzed (Lakew et al., 2016).

**Hundred-grain weight (gram):** One hundred seeds were randomly sampled from the bulk harvest and weighed using an analytical balance. The weight was then adjusted to a 12.5% moisture level.

**Total above-ground dry biomass yield (kg ha-$^{1}$):** Plants were harvested from each net plot, sun-dried to a constant weight, and then weighed. The results were converted to kilograms per hectare.

**Grain yield (kg ha-$^{1}$):** The central rows of each plot were harvested, sun-dried, and threshed. The grain yield obtained from each plot was weighed using an electronic balance and converted to kg/ha.

**Harvest index (%):** The ratio of grain yield to total above-ground dry biomass yield and multiplied by 100% was calculated at harvest in each plot (Huehn, 1993). The formula used was:

HI = (Grain yield / Total above-ground dry biomass) x 100%

### 3.7. Partial Budget Analysis

An economic analysis was conducted using a partial budget procedure described by CIMMYT (1988). The cost of NPSB fertilizer and the labor costs involved in its application were considered as variable costs. Net benefits and other economic analysis parameters were calculated using the formulas developed by CIMMYT (1988) as follows:

**Adjusted grain yield (AGY) (kg ha-$^{1}$):** AGY is the average yield adjusted downwards by 10% to account for the difference between the experimental yield and the yield typically achieved by farmers under real-world conditions.

**Gross field benefit (GFB) (ETB ha-$^{1}$):** GFB is calculated by multiplying the adjusted yield by the field/farm gate price that farmers receive when they sell the crop.

GFB = AGY × Field/farm gate price (source: local market survey or specify source)

**Total variable cost (TVC) (ETB ha-$^1$):** TVC is calculated by summing the variable costs, including the cost of NPSB fertilizers at the time of planting and the daily labor cost for NPSB application according to the prevailing rates in Enore. The costs of other inputs and production practices, such as labor costs for land preparation, planting, weeding, and harvesting, were assumed to be the same for all treatments or plots.

**Net benefit (NB) (ETB ha-$^1$):** NB is calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment: NB = GFB – TVC.

### 3.8. Data Analysis

The data collected from the experiment were analyzed using the statistical software SAS version 9.3. Analysis of variance (ANOVA) was performed to assess the significance of treatment effects. Mean separation for significant treatment effects was performed using the least significant difference (LSD) test at a 5% level of probability (Gomez and Gomez, 1984). Additionally, simple linear correlation analysis was conducted to explore relationships between growth and yield parameters.

# 4. RESULTS AND DISCUSSION

## 4.1. Physicochemical Properties of Experimental Soil before Planting

The physicochemical properties of the soil in the study area are presented in Table 2. The soil texture was determined to be sandy loam, with 15% clay, 27% silt, and 57% sand content. This soil texture is favorable for maize production, as it allows for good nutrient retention and water availability.

The pH of the soil was measured to be 6.2, indicating a slightly acidic nature. According to Tisdale et al. (2002), soil pH ranges can be classified as strongly acidic (5.1-5.5), moderately acidic (5.6-6.0), slightly acidic (6.1-6.5), and neutral (6.6-7.3). Hence, the pH value of the study area is considered ideal for maize production, as maize generally thrives within a pH range of 5-8 (Martin, 1993).

The organic carbon content of the soil in the study area was determined to be 7.254%. According to London (1991), soil organic carbon levels can be categorized as <2% (very low), 2-4% (low), and >4% (high). The organic carbon content of 7.254% indicates a high level in the soil, which is beneficial for nutrient availability and soil fertility.

The total nitrogen content of the soil was found to be 0.625%. London (1991) classifies soil total nitrogen levels as <0.1% (very low), 0.1-0.2% (low), and >0.25% (high).The measured total nitrogen content of 0.625% falls within the high category, indicating good nitrogen availability for plant uptake and growth.

The available phosphorus level in the soil was determined to be 18.2 mg/kg, categorizing it as medium according to Tekalign et al. (1991). The classification ranges for available phosphorus are <10 ppm (low), 11-31 ppm (medium), 32-56 ppm (high), and >56 ppm (very high). The medium level of available phosphorus suggests that adequate phosphorus is present in the soil for maize production.

The cation exchange capacity (CEC) of the soil was measured to be 34 meq/100g soil, which falls within the very high category according to Landon and Manual (1991). CEC values greater than 40 meq/100g soil are rated as very high, while 25-40 meq/100g soil is considered high. Soils with high CEC are agriculturally fertile as they have the capacity to retain and supply nutrient cations to crops.

The available sulfur content in the soil was determined to be 22 mg/kg, indicating a medium range according to EthioSIS (2014). The classification ranges for available sulfur are <10 ppm (very low), 10-20 ppm (low), 20-80 ppm (medium), 80-100 ppm (optimum), and >100 ppm (very high). The medium sulfur content in the study area revealed favorable for production the production of maize.

The available boron level in the soil was measured to be 0.84 ppm, categorizing it as medium according to Johnson and Fixen (1990). Boron levels below 0.5 mg/kg are considered low, 0.5-1.0 mg/kg as medium, and above 1.0 mg/kg as adequate. The medium boron content indicates that the soil has sufficient boron for crop production, although the application of blended fertilizers containing boron may be necessary to further enhance crop production and boron content in the soil.

Overall, the physicochemical analysis of the soil in the study area revealed favorable soil properties for maize production, including a sandy loam texture, slightly acidic pH, high organic carbon and total nitrogen levels, medium available phosphorus, very high CEC, medium sulfur availability, and medium boron content. These findings provide important baseline information for understanding the nutrient status of the soil and guide appropriate fertilizer management practices for sustainable maize production in the study area.

## 4.2. Phenological and Growth Parameters

### 4.2.1. Days to tasseling

The analysis of variance revealed a significant ($P<0.01$) influence of the interaction effects between NPSB fertilizer levels and maize varieties on days to tasseling (Appendix Table 1).The shortest and longest durations to tasseling were recorded as 91.00 and 111.67 days with control treatments of BH-540 and BH-546 with 150kg/ha-$^{1}$ maize varieties respectively (Table 3)

The application of blended NPSB fertilizer levels resulted in delaying tasseling compared to the control treatments, which is divergent with varieties. This may be due to the increased rate of NPSB fertilizers promotes rapid growth and development of the crop, leading to earlier tassel formation.

This finding is consistent with the study conducted by Dagne (2016), who reported a significant difference in the number of days to 50% tasseling with the application of blended fertilizer rates on maize varieties. Additionally, Amjed et al. (2013) indicated that nitrogen (N) and sulfur (S) significantly affected the number of days to tasseling with different maize varieties. These results align with the findings of Orkaido (2004), who reported that the application of different rates of phosphorus (P) a highly significant on the number of days to tasseling with maize varieties. Similarly, Abeba (2012) and Dawadi and Sah (2012) reported a high significant effect of maize varieties on the number of days to tasseling. In contrast, Khan et al. (2014) reported that N and P levels had a non-significant effect on the number of days to tasseling.

Overall, the results indicated that the interaction between NPSB fertilizer levels and maize varieties significantly influenced the number of days to tasseling. The application of blended fertilizer resulted in earlier tasseling, highlighting the importance of fertilizer management in promoting the growth and development of maize crops

Table 2: Interaction effect of NPSB fertilizer rates and improved varieties of maize on days to

| Treatments | NPSB fertilizer Rates (kg ha-1) | | | | |
|---|---|---|---|---|---|
| Varieties | 0 | 50 | 100 | 150 | Mean |
| BH-540 | $91.0^{g}$ | $95.33^{f}$ | $97^{ef}$ | $98^{def}$ | 95.33 |
| BH-546 | $97.00^{ef}$ | $99.33^{cde}$ | $100.33^{bcde}$ | $111.67^{a}$ | 102.1 |
| BH-661 | $99.00^{cdef}$ | $101.67^{bcd}$ | $102.67^{bc}$ | $103.67^{b}$ | 101.75 |
| Mean | 95.66 | 98.77 | 100 | 104.44 | 99.7 |
| LSD (0.05) | | 3.92 | | | |
| CV (%) | | 2.31 | | | |

*LSD= Least significance difference; CV= Coefficient of variation; Means in the column within a parameter followed by the same letter(s) are not significantly different at 5% level of significance.*

### 4.2.2. Days to silking

The analysis of variance indicated that highly significant (P<0.01) effect on the interaction between blended NPSB fertilizer and maize variety on the number of days to silking (Appendix Table 1). The longest duration to silking (128.33 days) was observed when the combined application of 150 kg ha-$^{1}$ NPSB fertilizer rate with BH-661 maize variety. On the other hand, the shortest duration to silking (102 days) was recorded when the control treatments with BH-540 maize variety (Table 4). Generally, the duration to silking was delayed when no NPSB fertilizer was applied across different maize varieties.

This can be attributed to the higher application of NPSB, which promoted vegetative growth of plant organs and thus prolonged the time taken for the crop to reach the silking stage in different maize varieties. The positive interaction of boron (B) in the blended fertilizer also contributed to this effect.

These findings are consistent with the study conducted by Dagne (2016), which reported a significant difference in the number of days to silking in maize with the application of blended fertilizer. They also align with the results of Dawadi and Sah (2012), Abeba (2012), and Amona (2014), who reported that the application of different rates of blended NPSB fertilizer levels were highly significant effect of maize variety on the number of days to silking. Similar results were reported by Takele et al. (2017), showing that the day of silking was significantly affected by the N fertilizer rate on different maize varieties. Additionally, Amjed et al. (2013) reported highly significant effects of nitrogen (N) and sulfur (S) on the number of days to silking on different maize varieties. Furthermore, Orkaido (2004) found that the application of phosphorus (P) had a highly significant influence on the number of days to silking on different maize varieties. In contrast, Khan et al. (2014) reported non-significant effects of nitrogen (N) and phosphorus (P) levels, as well as their combined effect, on the number of days to silking.

Table 3: Interaction effect of NPSB fertilizer rates and improved varieties of maize on days to silking:

| Treatments | | NPSB fertilizer Rates (kg ha-$^{1}$) | | | |
|---|---|---|---|---|---|
| Varieties | 0 | 50 | 100 | 150 | Mean |
| BH-540 | $102.00^{g}$ | $106.00^{f}$ | $111.00^{def}$ | $117.3^{bcd}$ | 109.1 |
| BH-546 | $109.00^{ef}$ | $109.67^{ef}$ | $110.33^{def}$ | $121.33^{abc}$ | 112.6 |
| BH-661 | $114.33^{cde}$ | $119.00^{bc}$ | $123.33^{ab}$ | $128.33^{a}$ | 121.24 |
| Mean | 108.44 | 111.55 | 114.8 | 122.32 | 114.27 |
| LSD (0.05) | | 7.06 | | | |
| CV (%) | | 3.68 | | | |

*LSD= Least significance difference; CV =Coefficient of variation; Means in the column within a parameter followed by the same letter(s) are not significantly different at 5% level of significance*

### 4.2.3. Days to physiological maturity

The analysis of variance revealed a highly significant ($P < 0.01$) influence of the interaction between NPSB fertilizer and maize varieties on the number of days to physiological maturity (Appendix Table 1). The longest duration to maturity (168.33 days) was observed with BH-661 maize variety when applied at a rate of 150 kg ha-$^{1}$ NPSB fertilizer. Conversely, the earliest duration to maturity (142.33 days) was recorded with the BH-540 maize variety in the control plots (Table 5). The use of blended fertilizer was associated with vigorous and rapid growth, leading to accelerated maturity of maize crops. This effect may be attributed to the presence of boron (B) fertilizer in the blended fertilizer, which contributed to the hastening of maturity.

These findings are consistent with the study conducted by Dagne (2016), which reported a significant difference in the number of days to maturity of maize with the application of blended fertilizer.

Table 4: Interaction effect of NPSB fertilizer rates and improved varieties of maize on days to physiological maturity

| Treatments | NPSB fertilizer rates (kg ha-$^{1}$) | | | | |
|---|---|---|---|---|---|
| Variety | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 142.33$^{e}$ | 145.33$^{de}$ | 146.33$^{de}$ | 148.66$^{d}$ | 145.66 |
| BH-546 | 144$^{de}$ | 145.33$^{de}$ | 151.00$^{de}$ | 158.67$^{c}$ | 149.75 |
| BH-661 | 156.00$^{c}$ | 161.33$^{bc}$ | 164$^{ab}$ | 168.33$^{a}$ | 162.4 |
| Mean | 147.4 | 150.6 | 153.7 | 158.5 | 152.55 |
| LSD (0.05) | | 2.8 | | | |
| CV (%) | | 2.53 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.2.4. Plant height

The statistical analysis of the data demonstrated a highly significant ($P < 0.01$) effect of the interaction between NPSB rates and maize varieties on plant height (Appendix Table 2).The BH-661 variety exhibited the tallest plant height (291.33 cm) when combined with an application of 150 kg ha-$^{1}$ NPSB, which was at par with BH-661 variety with 100 kg ha-$^{1}$ NPSB, resulting in a plant height of 269.00 cm. In contrast, the BH-540 variety displayed the shortest plant height (147.33 cm) when no NPSB fertilizer was applied (Table 6).

The increase in plant height in response to higher blended NPSB application rates can be attributed to the enhanced availability of nitrogen (N), phosphorus (P), sulfur (S), and boron (B), which support maximum vegetative growth. Nitrogen aids in chlorophyll formation, phosphorus contributes to the establishment of a strong root system, sulfur promotes chlorophyll formation and vegetative growth, and boron plays a crucial role in the translocation of photosynthesis within the plant (Moiruzzaman et al., 2008). Additionally, the improved root formation due to sulfur may have facilitated increased absorption of N, P, S, and B from the soil, enhancing metabolic activity within the plant.

These findings align with the study conducted by Dagne (2016), who reported a significant increase in plant height with the application of blended fertilizer compared to recommended NP fertilizers and the control in maize varieties. Similar results were reported by Dawadi and Sah (2012), Tolera et al. (2017), and Tamene et al. (2018), who observed a significant increase in plant height in maize variety with higher N application rates. Soomro et al. (2011) and Saleem et al. (2016) found that boron (B) application significantly increased plant height. Khan et al. (2014) also reported an increase in plant height with higher N and P rates. Likewise, Rafiq et al. (2016) demonstrated that plant height of maize significantly increased with the application of both sulfur (S) and nitrogen (N) levels. Consistent with these results, Masood et al. (2011) reported a significant effect of different phosphorus (P) levels on maize plant height.

Table 5: Interaction effect of NPSB fertilizer rates and improved varieties of maize on plant height

| Treatments | NPSB fertilizer Rates (kg ha-$^1$) | | | | |
|---|---|---|---|---|---|
| Varieties | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 147.33$^{e}$ | 168.67$^{cde}$ | 170.17$^{cde}$ | 185.17$^{c}$ | 167.8 |
| BH-546 | 150.75$^{de}$ | 166.33$^{cde}$ | 174.00$^{cd}$ | 178.00$^{c}$ | 167.27 |
| BH-661 | 168.67cde | 250.00$^{b}$ | 269.00$^{ab}$ | 291.33$^{a}$ | 244.75 |
| Mean | 155.5 | 195 | 201.4 | 218.1 | 192.5 |
| LSD (0.05) | | 23.8 | | | |
| CV (%) | | 7.27 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance*

### 4.2.5. Leaf area

The analysis of variances revealed a significant ($P < 0.01$) interaction effect between NPSB fertilizer rates and maize variety on leaf area (Appendix Table 2). The BH-661 variety exhibited the highest leaf area (7129.7 cm$^2$) when combined with an application rate of 150 kg ha-$^1$ NPSB. On the other hand, the control treatment with BH-661 maize variety had the lowest leaf area (2787.7 cm$^2$). Increasing NPSB rates from 0 to 150 kg ha-$^1$ resulted in an increase in leaf area for all treatments, however the magnitude varied with varieties this can be attributed to the positive effect of NPSB fertilizer on the photosynthetic rate, leading to enhanced dry matter accumulation and expansion of leaves. The blended fertilizer contributed to improve crop growth and development in maize.

These findings are consistent with previous studies by Dagne (2016) who reported a significant increase in leaf area with the application of blended fertilizer in maize crops. Orkaido (2004) found that leaf area was significantly affected by the application of nitrogen (N) and phosphorus (P). Muammad et al. (2003) observed a progressive increase in leaf area with higher levels of phosphorus (P). Amjed et al. (2013) also reported a significant effect on leaf area with the application of nitrogen (N) and sulfur (S).

The variation in leaf area among maize varieties in response to NPSB application can be attributed to their genetic potential and plant characteristics. Certain varieties may have wider and longer leaves, allowing them to capture more solar radiation and produce more carbohydrates. Tolera et al. (2017) also reported that maize varieties significantly affected the mean leaf area.

Table 6: Interaction effect of NPSB fertilizer rates and improved varieties of maize on leaf area

| Treatments | NPSB fertilizer Rates (kg ha-$^1$) | | | | |
|---|---|---|---|---|---|
| Varieties | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 3906.7$^b$ | 3958.3$^b$ | 4157.7$^b$ | 4266.7$^b$ | 4172.35 |
| BH-546 | 4105$^b$ | 4131.7$^b$ | 4143.3$^b$ | 4160$^b$ | 4135 |
| BH-661 | 2787$^b$ | 4300$^b$ | 4922$^b$ | 7229.7$^a$ | 4809.67 |
| Mean | 3599.5 | 4130 | 4407.6 | 5218.8 | 4338.9 |
| LSD (0.05) | | 1054.6 | | | |
| CV (%) | | 14.38 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance*

### 4.2.6 Leaf area index

The statistical analysis of the result revealed a highly significant ($P < 0.01$) interaction effect between blended NPSB fertilizer rates and maize variety on leaf area index (Appendix Table 2). The BH-661 variety, combined with an application rate of 150 kg ha-$^1$ NPSB fertilizer, recorded the highest LAI value of 4.3, while the BH-546 variety with control treatments had the lowest LAI value of 2.13 (Table 8).

The increase in LAI can be attributed to improved leaf expansion in maize varieties as a result of increased NPSB rates, or the application of NPSB may have contributed to larger leaf size, enabling better light capture for photosynthesis.

These findings are consistent with previous studies (Tolera et al. (2017) Idoko et al. (2018) who reported significant effects of maize varieties on LAI. Abeba (2012) observed an increasing trend in LAI in maize with higher rates of N fertilizer application and the use of hybrid maize varieties. Kidist (2013) found that LAI increased as N rates increased, as nitrogen improves the greenness of vegetation and leads to higher LAI. Thirupathi et al. (2016) also reported an increase in LAI with higher nitrogen levels. Vijaya et al. (2018) observed similar results with the application of nitrogen and phosphorus levels.

Table 7: Interaction effects of NPSB fertilizer rates and improved varieties of maize on leaf

| Treatments | NPSB fertilizer rates (kg ha-$^{1}$) | | | | |
|---|---|---|---|---|---|
| Variety | 0 | 50 | 100 | 150 | Mean |
| BH-540 | $2.38^{cd}$ | $2.4^{cd}$ | $2.42^{cd}$ | $2.46^{cd}$ | 2.4 |
| BH-546 | $2.13^{b}$ | $2.43^{cd}$ | $2.86^{c}$ | $3.53^{b}$ | 2.7 |
| BH-661 | $2.4^{cd}$ | $2.46^{cd}$ | $2.56^{cd}$ | $4.3^{a}$ | 2.9 |
| Mean | 2.2 | 2.4 | 2.6 | 3.3 | 2.6 |
| LSD (0.05) | | 0.35 | | | |
| CV (%) | | 13.38 | | | |

area index

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3. Yield Parameters

#### 4.3.1. Number of ears per plant

The statistical analysis of the data indicated a significant interaction effect between blended NPSB fertilizer rates and maize variety on the number of ears per plant (Appendix Table 3). The BH-546 variety, combined with an application rate of 150 kg ha-$^{1}$ NPSB fertilizer, recorded the highest (2.3) number of ears per plant. On the other hand, the BH-540 variety with control treatments had the lowest (1.00) number of ears per plant (Table 9). This suggests that the combination of higher NPSB fertilizer rates and specific maize varieties led to an increase in the number of ears per plant.

Table 8: Interaction effects of NPSB fertilizer rates and improved varieties of maize on number of ears per plants

| Treatments | NPSB fertilizer rates (kg ha-$^1$) | | | | |
|---|---|---|---|---|---|
| Variety | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 1.00$^{e}$ | 1.15$^{de}$ | 1.18$^{de}$ | 1.23$^{de}$ | 1.14 |
| BH-546 | 1.23$^{de}$ | 1.43$^{cd}$ | 1.93$^{b}$ | 2.3$^{a}$ | 1.7 |
| BH-661 | 1.19$^{de}$ | 1.21$^{de}$ | 1.23$^{de}$ | 1.58$^{c}$ | 1.3 |
| Mean | 1.1 | 1.2 | 1.4 | 1.7 | 1.4 |
| LSD0.05 | | 0.32 | | | |
| CV% | | 13.96 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3.2. Ear length

The main effects of variety and NPSB fertilizer were found to have a significant ($P < 0.01$) effect on ear length, but their interaction did not significantly affect this parameter (Appendix Table 2).

Increasing application rates of NPSB fertilizer led to a consistent increase in ear length. The shortest ear length of 16.11 cm was observed in the control plots, while the longest ear length of 22.06 cm was recorded with a fertilizer rate of 150 kg ha-$^1$ NPSB, followed by 100 kg ha-$^1$ NPSB at 21.58 cm (Table 10).The trend indicated that ear length decreased with lower NPSB fertilizer rates, suggesting that higher NPSB rates had a favorable the increasing in ear length. This increase in ear length might be attributed to the positive effect of NPSB fertilizer on photosynthetic assimilate production and its distribution to the stems.

When we see the varieties the highest ear length (22.3) cm was obtained from the variety BH-661 and lowest ear length (17.97) cm was scored from BH-540 maize variety. (Table 10).Different varieties have shown different performance on their ear length and this could be due to their inherent genetic characteristics, leaf area, and growth potential, as noted by Buriro et al. (2015).

This finding is consistent with the research conducted by Dagne (2016), which reported that the application of blended fertilizer significantly increased ear length in maize.

Additionally, variations in ear length among maize varieties can be attributed to genetic potential, plant characteristics, and nutrient uptake capabilities.

### 4.3.3. Ear diameter

The main effects of variety and NPSB fertilizer rates were found to have a highly significant ($P < 0.01$) effect on ear diameter (Appendix Table 3). However, their interaction did not significantly ($P < 0.001$) affect this parameter.

Increasing NPSB fertilizer application rates consistently resulted in larger ear diameters. The shortest ear diameter of 31.83 mm was observed in the control treatments, while the longest ear diameter of 49.55 mm was recorded with a fertilizer rate of 150 kg ha-$^{1}$ NPSB, followed by 100 kg ha-$^{1}$ NPSB at 43.11 mm (Table 10).The trend indicated that ear diameter decreased with lower NPSB fertilizer rates, suggesting that higher NPSB rates had a favorable impact on ear diameter.

When we see the varieties the highest ear diameters were (46.91) cm was recorded from the variety BH-546 and lowest ear diameter (38.04) cm was obtained from BH-661 maize variety. (Table 10).These differences in ear diameter suggest the presence of genetic variation among the maize varieties. This finding aligns with previous studies by Tasisa Temesgen (2019), who reported significant differences among maize varieties for both ear length and diameter, highlighting the influence of growth factors and genetic variation on ear morphology.

### 4.3.4. Number of grain rows per ear

The main effects of blended NPSB fertilizer rates and varieties had a significant ($P < 0.01$)effect on the number of grain rows per ear, but their interaction did not significantly affect this parameter (Appendix Table 3).The lowest number of grain rows per ear (10.44), was observed in the control treatments, while the highest number of grain rows (14.22), was recorded with a fertilizer rate of 150 kg ha-$^{1}$ NPSB, followed by 100 kg ha-$^{1}$ NPSB at 13.33 (Table 10).The trend indicated that the number of grain rows per ear decreased with lower NPSB fertilizer rates, suggesting that higher NPSB rates had a favorable effect on grain rows in maize.

However comparing to the variety the higher number of grain rows per ear was (13.33) recorded from maize variety BH-546 followed by BH-661 (12.33) number of grain rows per ear were recorded, whereas the lowest number of grain rows per ears (18.83) were recorded with maize variety of BH-540.

Table 9: Main effects of varieties and NPSB fertilizer rates on ear length, ear diameter and number of grain rows per ear of maize during 2022 main cropping season

| Treatments | Ear-Length (cm) | Ear-Diameter (mm) | No. of grain rows per ear |
|---|---|---|---|
| NPSB Rates (kg ha-$^{1}$) | | | |
| 0 | 16.11$^{b}$ | 31.83$^{d}$ | 10.44$^{d}$ |
| 50 | 19.25$^{a}$ | 41.00$^{c}$ | 12.00$^{c}$ |
| 100 | 21.58$^{a}$ | 43.11$^{b}$ | 13.33$^{b}$ |
| 150 | 22.06$^{a}$ | 49.55$^{a}$ | 14.22$^{a}$ |
| LSD0.05 | 3.02 | 4.79 | 0.57 |
| Variety | | | |
| BH-540 | 17.97$^{b}$ | 39.16$^{b}$ | 11.83$^{b}$ |
| BH-546 | 18.94$^{b}$ | 46.91$^{a}$ | 13.33$^{a}$ |
| BH-661 | 22.33$^{a}$ | 38.04$^{b}$ | 12.33$^{b}$ |
| LSD0.05 | 2.6 | 4.15 | 0.65 |
| CV (%) | 15.67 | 11.86 | 5.39 |

*Where, EL= Ear length; ED=Ear diameter; NGRPE=Number of grain rows per ear; LSD (0.05) = Least significant difference at 5% level CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3.5. Number of grains per ear

The number of grains per ear in maize was significantly ($P < 0.01$) influenced by both the main effects of NPSB fertilizer rates and varieties and their interaction (Appendix Table 3).The application of blended fertilizer had a highly significant effect on the number of grains per ear in maize. The maximum number of grains per ear (6432.7) was observed with the application of 150 kg ha-$^{1}$ NPSB blended fertilizer in combination with the BH-546 variety. On the other hand, the minimum number of grains per ear (2483.3) was recorded in the control treatment with the BH-540 maize variety.

The statistical analysis indicated that increasing NPSB fertilizer rates had a positive effect on the number of grains per ear across all maize varieties. This finding suggests that the application of NPSB blended fertilizer, particularly at higher rates, can significantly increase the number of grains per ear in maize. It highlights the importance of fertilizer management in enhancing grain yield potential.

Table 10: Interaction effects of NPSB fertilizer rates and improved varieties of maize on number of grains per ear

| Treatments | NPSB fertilizer rates (kg ha-$^1$) | | | | |
|---|---|---|---|---|---|
| Variety | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 2483.3$^{e}$ | 3660.0$^{d}$ | 3857.3 $^{d}$ | 5929.3$^{ab}$ | 3982.5 |
| BH-546 | 3866.3$^{d}$ | 5018.7$^{bc}$ | 5611.3$^{ab}$ | 6432.7$^{a}$ | 5232.3 |
| BH-661 | 4532.0$^{cd}$ | 4556.0$^{cd}$ | 4557.3.0$^{cd}$ | 4564.0$^{cd}$ | 4552.3 |
| Mean | 3627.2 | 4411.5 | 4675.2 | 5642 | 4588.9 |
| LSD0.05 | | 952.2 | | | |
| CV% | | 12.25 | | | |

*LSD (0.05) = Least significant difference at 5% level CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3.6. Hundred-kernel weight

The Stastical analysis showed that hundred kernel weights was significantly (P < 0.01) influenced by the main effects of maize varieties and NPSB fertilizer rates, however, the main their interaction was found to be non-significant (Appendix Table 4).

Improved maize varieties showed a significant increase in hundred-kernel weight. The maximum hundred-kernel weight of 38.64 g was recorded in the BH-540 maize variety, followed by the BH-661 maize variety at 33.14 g. On the other hand, the BH-546 variety had the minimum hundred-kernel weight of 32.41 g (Table 12).

When we see the effect of blended NPSB fertilizer on hundred kernel weight, the lowest hundred kernel weight (31.47) gram was recorded from the control treatments, while the highest hundred kernel weight (37.13) gram, was recorded with a fertilizer rate of 150 kg ha-$^1$ NPSB (Table 12).

This finding aligns with the results reported by Idoko et al. (2018), who found that maize varieties significantly influenced on hundred-kernel weight. Amona (2014) also reported similar results that significant effect of NPSB fertilizer rates and its interaction on hundred-kernel weight.

Table 11: Main effects of varieties and NPSB fertilizer rates on hundred kernel weights of maize

| Treatments | Hundred kernel weights (gram) |
|---|---|
| NPSB rates (kg ha-$^1$) | |
| 0 | 31.47$^b$ |
| 50 | 35.7$^{ab}$ |
| 100 | 33.14$^{ab}$ |
| 150 | 37.133$^a$ |
| LSD0.05 | 5.07 |
| Variety | |
| BH-540 | 38.64$^a$ |
| BH-546 | 32.41$^b$ |
| BH-661 | 34.62$^{ab}$ |
| LSD (0.05) | 4.39 |
| CV (%) | 14.95 |

*LSD (0.05) = Least significant difference at 5% level CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3.7. Total above-ground dry biomass yield

The total above-ground dry biomass yield was significantly ($P < 0.01$) influenced by the interaction effect of NPSB fertilizer rates and maize varieties (Appendix Table 4).

The highest total above-ground dry biomass yield (33,240kg ha-$^1$) was achieved with the BH-540 maize variety and a fertilizer rate of 150 kg ha-$^1$ NPSB. In contrast, the lowest biomass yield of 24,067 kg ha-$^1$ was observed in the control plots with the BH-540 maize variety (Table 13).

This finding indicated that different maize varieties responded differently to fertilizer rates in terms of above-ground biomass yield. The above-ground biomass yield is influenced by various traits and genes, such as plant height, number of ears, leaf number and size, grain yield, and straw yield. Therefore, the manifestation of above-ground biomass yield involves multiple parameters, and its response to fertilizer effects can vary among varieties.

The increase in above-ground dry biomass yield with higher NPSB fertilizer rates can be attributed to factors such as increased plant height and leaf area index, which enable plants to accumulate more biomass. Similar studies have shown that higher biomass yields in maize were obtained when higher amounts of NPSB fertilizer were applied, compared to lower fertilizer rates (Shiferaw et al., 2018).These results align with the findings of Kene (2015), Takele et al. (2017), and Tamene et al. (2018), who reported significant influences of N rates on the biological yield of maize.

Table 12: Interaction effects of varieties and NPSB fertilizer rates on above ground biomass yield of maize

| Treatments | | NPSB fertilizer rate (kg ha-$^{1}$) | | | |
|---|---|---|---|---|---|
| Variety | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 24,067$^{d}$ | 27,403$^{bc}$ | 30,200$^{ab}$ | 33,247$^{a}$ | 28,729.25 |
| BH-546 | 28,000$^{b}$ | 28,427$^{b}$ | 28,600$^{b}$ | 28,600$^{b}$ | 28,406.75 |
| BH-661 | 24,100$^{d}$ | 24,350$^{cd}$ | 24,477$^{cd}$ | 24,667$^{cd}$ | 24,398.5 |
| Mean | 25,389 | 26,726.7 | 27,759 | 28,838 | 27,178.2 |
| LSD (0.05) | | 3.07 | | | |
| CV (%) | | 6.68 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3.8. Grain yield

The grain yield of maize, which is the ultimate outcome influenced by various physiological and biochemical processes, was significantly ($P < 0.01$) influenced by the interaction effect of NPSB fertilizer rates and maize varieties (Appendix Table 4).

The application of blended fertilizer had a highly significant ($P < 0.01$) effect on grain yield. The maximum grain yield of 9,366.7 kg ha-$^{1}$ was attained with the BH-546 maize variety at a fertilizer rate of 150 kg ha-$^{1}$ NPSB. On the other hand, the control treatments with the BH-540 maize variety resulted in the minimum grain yield of 3,166.7 kg ha-$^{1}$ (Table 14).

The statistical analysis indicated that increasing NPSB fertilizer rates had the potential to increase grain yield in all maize varieties, although there was variation in yield among the varieties. This variation in grain yield can be attributed to genetic differences within the maize varieties.

The increase in grain yield with higher NPSB fertilizer rates can be attributed to factors such as increased nutrient uptake and improved plant growth due to the synergistic effect of the nutrients. The balanced NPSB fertilizer played a significant role in increasing yield components by promoting nutrient uptake and translocation of assimilates from source to sink.

The higher grain yield obtained from improved maize varieties at higher NPSB rates can be attributed to their superior yield components and the need for nutrient supplementation for maize production through blended fertilizer.

Similar results have been reported Shiferaw et al. (2018), Dawadi and Sah (2012) and Masood et al. (2011) who have observed significant increases in grain yield with the application of blended fertilizers, higher N and P rates, S and N levels, varying levels of P, and B application in maize.

Table 13: Interaction effects of varieties and NPSB fertilizer rates on grain yield of maize

| Treatments | NPSB fertilizer rates (kg ha-$^{1}$) | | | | |
|---|---|---|---|---|---|
| Variety | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 3,166.7$^{i}$ | 4,600$^{fg}$ | 5,233.3$^{e}$ | 6,966.6$^{c}$ | 4,991.65 |
| BH-546 | 4,066.7$^{gh}$ | 5,000$^{ef}$ | 6,766.6$^{c}$ | 9,366.7$^{a}$ | 6,300 |
| BH-661 | 3,733.3$^{hj}$ | 4,730$^{ef}$ | 6,160$^{d}$ | 8,230$^{b}$ | 5713.3 |
| Mean | 3655.6 | 4776.7 | 6053.3 | 8187.8 | 5668.4 |
| LSD (0.05) | | 0.28 | | | |
| CV (%) | | 7.4 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3.9. Harvest index

The harvest index (HI), which represents the ratio of grain yield to total above-ground biomass, is a measure of reproductive efficiency is significantly (P < 0.01) influenced by the interaction effect of both NPSB fertilizer rates and varieties of maize.( Appendix Table 4).

The highest harvest index of 33.2% and 32.8% were observed in the combination of the BH-661 and BH-546 maize varieties with an application of 150 kg ha-$^{1}$ NPSB fertilizer, respectively (Table-15). On the other hand, the lowest harvest index of 12.8% was recorded in the BH-540 maize variety with control treatments (no fertilizer application) (Table 15). In general, the harvest index increased with higher NPSB fertilizer rates across different maize varieties. A higher harvest index suggests a greater proportion of dry matter allocated to grain production, which can be attributed to increase the genetic potential of maize varieties.

Similar studies conducted by Dawadi and Sah (2012) have reported highly significant effects of maize varieties on the harvest index. Kene (2015) and Takele et al. (2017) also found that the maximum harvest index was achieved with the highest N application rates.

Furthermore, Inamullah et al. (2011) observed significant effects of N on the harvest index of maize hybrids. Muhammad et al. (2003) reported significantly higher harvest index values in response to P application rates of 100 and 150 kg ha-$^{1}$. Amjed et al. (2013) also found significant effects of N and S on the harvest index value.

Table 14: Interaction effects of varieties and NPSB fertilizer rates on harvest index of maize

| Treatments | | NPSB fertilizer rates (kg ha-$^{1}$) | | | |
|---|---|---|---|---|---|
| Variety | 0 | 50 | 100 | 150 | Mean |
| BH-540 | 12.8$^{f}$ | 16.8$^{ef}$ | 17.3$^{cd}$ | 20.95$^{c}$ | 16.9 |
| BH-546 | 14.5$^{f}$ | 17.6$^{de}$ | 23.7$^{b}$ | 32.8$^{a}$ | 22.15 |
| BH-661 | 15.2$^{ef}$ | 19.6$^{c}$ | 24.7$^{b}$ | 33.2$^{a}$ | 23.2 |
| Mean | 14.2 | 18 | 21.9 | 28.9 | 20.75 |
| LSD (0.05) | | 2.26 | | | |
| CV (%) | | 6.43 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.4. Correlation Analyses among Growth and Yield Parameters

Simple correlation analysis was done to assess the association of various agronomic characters and NPSB fertilizer level and variety of maize. The correlation between growth and yield components of maize as influenced by the application of blended NPSB fertilizers was computed and its results are shown in Table 16.

The present study indicated that Leaf area indicated highly significantly positive association with leaf area index (r=0.87**), ear ear-diameter (r=0.75**), number of grain rows per ear (0.77**), number of grains per ear(r=0.5**), grain yield(r=0.57**), and harvest index (r=0.75**) and significantly positive correlation with total above ground biomass yield(r=0.39*),but it is insignificantly negative correlation hundred kernel weights(r=0.126).

Ear length showed highly significantly positive correlation with number of grain rows per ear (r=0.54**), number of grains per ear (r=0.61**), grain yield (r=0.66**) and harvest index (r=0.8**) but it is negatively correlated to total above ground dry biomass (r=-0.22).

Number of grain rows per ear showed highly significantly positive correlation with number of grains per ear (r=0.65**), grain yield (r=0.65**) and harvest index (r=0.77**) and insignificantly positive correlation with above ground biomass yields (r=0.16) but insignificantly negative correlation with hundred kernel weights (r=-0.06).

Number of grains per ears showed highly significantly positive correlation with number of grain rows per ear (r=0.65**), grain yield (r=0.88**) and harvest index (r=0.84**) but insignificantly positive correlation with hundred kernel weights (r=0.09) but insignificantly negative correlation with total above ground biomass (r= -0.27).

Number of grains per ears showed highly significantly positive correlation with number of grain rows per ear (r=0.65**), grain yield (r=0.88**) and harvest index (r=0.84**) but insignificantly positive correlation with hundred kernel weights (r=0.09) but insignificantly negative correlation with total above ground biomass (r= -0.27).

Grain yield indicated highly significantly positive association with leaf area (r=0.57**), leaf area index (r=0.65**), ear length (r=0.66**), ear diameter (r=0.84**), number of ears per plant (r=0.73**), number of grain rows per ear(0.654**), number of grains per ear(r=0.88**) and harvest index (r=0.92**) and significantly positive correlation with days to silking(r=0.37*), days to maturity(r=0.5**) and plant height (0.38*) but it is insignificantly positive correlation with days to tasseling(r=0.26), and hundred kernel weights(r=0.124).

Harvest index showed highly significantly positive association with days to silking (0.43**), days to physiological maturity (0.71**), plant height (0.58**), leaf area (r=0.754**), leaf area index (r=0.826**), ear length (r=0.8**), ear diameter (r=0.69**), number of ears per plant (r=0.65**), number of grain rows per ear(r=0.77**), number of grains per ear (0.841**) and grain yield (r=0.92**) and insignificantly positive correlation with hundred kernel weights (0.045).

Table 15: Simple correlation coefficient (r) of growth and yield parameters of Maize in Enore Ener district:

| Variables | DT | DS | DM | PH | LA | LAI | EL | ED | NEPP | NGRPE | NGPE | HKW | GY | TADBM | HI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DT | 1 | | | | | | | | | | | | | | |
| DS | 0.0284 | 1 | | | | | | | | | | | | | |
| DM | 0.083 | 0.68** | 1 | | | | | | | | | | | | |
| PH | -0.008 | 0.64** | 0.88** | 1 | | | | | | | | | | | |
| LA | 0.169 | 0.65** | 0.90** | 0.79** | 1 | | | | | | | | | | |
| LAI | 0.07 | 0.57** | 0.87** | 0.78** | 0.87** | 1 | | | | | | | | | |
| EL | -0.27 | 0.56** | 0.76** | 0.75** | 0.75** | 0.83** | 1 | | | | | | | | |
| ED | 0.39* | 0.14 | 0.18 | 0.1 | 0.29 | 0.39* | 0.466* | 1 | | | | | | | |
| NEPP | -0.16 | 0.09 | 0.2 | 0.04 | 0.4* | 0.47** | 0.35* | 0.77** | 1 | | | | | | |
| NGRPE | -0.09 | 0.37* | 0.62** | 0.56** | 0.77** | 0.69** | 0.54** | 0.6** | 0.82** | 1 | | | | | |
| NGPE | -0.28 | 0.26 | 0.43** | 0.28 | 0.5** | 0.59** | 0.61** | 0.84** | 0.7** | 0.65** | 1 | | | | |
| HKW | -0.25 | -0.13 | -0.09 | -0.002 | -0.126 | -0.15 | 0.038 | 0.11 | -0.126 | -0.06 | 0.09 | 1 | | | |
| GY | 0.26 | 0.37* | 0.5** | 0.38* | 0.57** | 0.65** | 0.66** | 0.84** | 0.73** | 0.65** | 0.88** | 0.124 | 1 | | |
| TADBM | -0.29 | -0.015 | -0.38* | -0.35* | 0.39* | 0.35* | -0.22 | -0.22 | 0.45** | 0.16 | -0.27 | 0.13 | 0.26 | 1 | |
| HI | -0.17 | 0.43** | 0.71** | 0.58** | 0.75** | 0.82** | 0.8** | 0.69** | 0.65** | 0.77** | 0.84** | 0.045 | 0.92** | -0.09 | 1 |

DT= days to tasseling, DS= days to silking, DM = days to maturity, PH= plant height, LA=leaf area, LAI=leaf area index, EL= ear length, ED= ear diameter, NEPP= number of ears per plant, NGRPE= number of grain rows per ear, NGPE= number of grains per ear, HKW= hundred kernels weight, TADBM= total above dry biomass, GY=grain yield, HI=harvest index, **=highly significant, *=significant, NS=non-significant.

### 4.5. Partial Budget Analysis

Table 17 presents the results of the partial budget analysis for the 12 treatments. The treatment combination of 150 kg ha-$^{1}$ NPSB fertilizer application rate for the BH-546 maize variety yielded the highest net benefit of 211,865.55 Birr per hectare. The second-highest net benefit of 176,188.45 Birr per hectare was obtained from the treatment combination of the BH-661 variety with 150 kg ha-$^{1}$ NPSB blended fertilizer.

On the other hand, the lowest net benefit of 14,559.5 Birr per hectare was observed in the variety BH-540 with control treatments (no fertilizer application). The control treatments of the BH-546 variety resulted in a net benefit of 32,568.45 Birr per hectare (Table 17). Based on these findings, the most productive and economically attractive combination for producers or farmers, with the highest net benefit, was the BH-546 maize variety with a 150 kg ha-$^{1}$ NPSB fertilizer application rate. This combination yielded the highest return on investment and is recommended for maximizing profitability in maize production.

Table 16: Summary of partial budget analysis of response of maize varieties to the application of NPSB fertilizer

| Variety | Treatments NPSB (ha-$^{1}$) | AGY (kg ha-$^{1}$) | AGY(kg ha-$^{1}$) | GFB(ETH ha-$^{1}$) | TVC(ETB ha-$^{1}$) | NB(ETB ha-$^{1}$) |
|---|---|---|---|---|---|---|
| BH-540 | 0 | 3,160 | 2,844 | 101,540 | 86,980.5 | 14,559.5 |
| | 50 | 4,600 | 4,140 | 148,900 | 89,190.5 | 59,709.5 |
| | 100 | 5,230 | 4,707 | 170,745 | 91,400.5 | 79,344.5 |
| | 150 | 6,960 | 6,264 | 227,240 | 91,110.5 | 136,129.5 |
| BH-546 | 0 | 4,066.7 | 3,660.03 | 130,101.05 | 87,055.5 | 43,045.55 |
| | 50 | 5,000 | 4,500 | 161,500 | 89,265.5 | 72,234.5 |
| | 100 | 6,766.7 | 6,090.03 | 219,151.05 | 91,475.5 | 127,675.55 |
| | 150 | 9,366.7 | 8,430.03 | 303,051.05 | 91,185.5 | 211,865.55 |
| BH-661 | 0 | 3,733.3 | 3,359.97 | 119,598.95 | 87,030.5 | 32,568.45 |
| | 50 | 4,733.3 | 4,259.97 | 153,098.95 | 89,240.5 | 63,858.45 |
| | 100 | 6,166.7 | 5,550.03 | 200,251.05 | 91,450.5 | 108,800.55 |
| | 150 | 8,233.3 | 7,409.97 | 267,348.95 | 91,160.5 | 176,188.45 |

# 5. SUMMARY AND CONCLUSION

Maize is a crucial cereal crop in Ethiopia due to its high production and cash income generation for households. However, the national and regional average grain yields are below the global average due to factors such as poor soil fertility management and a lack of improved varieties. To address these challenges, a field experiment was conducted in Enore Ener district, Gurage zone, Southern Ethiopia, during the 2022 cropping season to evaluate the growth and yield components of maize varieties with blended NPSB fertilizer rates.

The interaction of maize varieties and blended NPSB fertilizer rates had a significant impact on almost all parameters studied. Days to tasseling, days to silking, days to physiological maturity, plant height, leaf area, leaf area index, number of ears per plant, number of grains per ear, total above-ground dry biomass, grain yield, and harvest index were significantly affected by the interaction effect of NPSB fertilizer and varieties. However, ear length, ear diameter, number of grain rows per ear, and hundred kernel weights were not significantly influenced by the interaction effects.

The application of 150 kg NPSB per hectare resulted in the highest values for days to maturity, plant height, leaf area, leaf area index, and harvest index in the BH-661 variety. The variety BH-546 achieved the highest number of ears per plant, number of grains per ear, and grain yield, while the variety BH-540 had the highest total above-ground dry biomass. The BH-540 variety had the maximum hundred kernel weight, while the BH-546 variety had the highest number of grain rows per ear and ear diameter. The BH-661 variety exhibited the longest ear length.

Most of the crop parameters showed significant positive correlations with each other due to the application of NPSB blended fertilizer. Grain yield was highly correlated with leaf area, leaf area index, ear length, ear diameter, number of ears per plant, number of grain rows per ear, number of grains per ear, and harvest index.

The economic analysis revealed that the treatment combination of 150 kg NPSB per hectare for the BH-546 variety resulted in the highest net benefit of 211,865.55 birr per hectare. Therefore, it can be concluded that the use of the BH-546 variety with a 150 kg NPSB per hectare application rate is recommended to enhance maize productivity in the study area. However, further experiments are needed to validate and confirm these results in the same agro-ecological conditions and seasons.

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# 7. APPENDIX

Appendix table 1: Mean squares of analysis of variance for phonological parameters of maize affected by varieties and NPSB fertilizer rates.

| Source of variation | Mean squares | | | |
|---|---|---|---|---|
| | DF | DT | DS | DPM |
| Replication | 2 | 12.11 | 21.028 | 67.03 |
| Variety | 2 | 59.11** | 673.36*** | 2582.03*** |
| NPSB fertilizer rates | 3 | 92.69*** | 156.85** | 688.07*** |
| Variety x NPSB fertilizer | 6 | 35.88** | 215.76*** | 148.21*** |
| Error | 22 | 5.38 | 17.39 | 15.54 |
| CV% | | 2.31 | 3.68 | 2.53 |

*DF=degree of freedom; ns= non-significant; *= significant at 5% level of significance;**= highly significant at 1% level of significance ***=very highly significant at 1% level of significance; DT= Days to tasseling; DS= Days to silking; DPM= Days to physiological maturity*

Appendix table 2: Mean squares of analysis of variance for growth and yield components Parameters of maize affected by varieties and NPSB fertilizer rates.

| Source of variation | Mean squares | | | | |
|---|---|---|---|---|---|
| | DF | PH | LA | LAI | EL |
| Replication | 2 | 470.1 | 432053 | 0.3 | 8.45 |
| Variety | 2 | 23832.5*** | 1867733* | 0.81*** | 62.82** |
| NPSB | 3 | 6234.9*** | 3886762** | 2.31*** | 66.56** |
| Variety x NPSB | 6 | 1751.1** | 2970564** | 0.65** | 1.61ns |
| Error | 22 | 197.6 | 387910 | 0.13 | 9.58 |
| CV% | | 7.27 | 14.38 | 13.38 | 15.67 |

*DF=degree of freedom; ns= non-significant; *= significant at 5% level of significance;**= highly significant at 1% level of significance ***=very highly significant at 1% level of significance; PH= Plant height; LA= Leaf area; LAI= Leaf area index; EL= Ear length*

Appendix table 3: Mean squares of analysis of variance for yield components of maize affected by varieties and NPSB fertilizer rates.

| Source of variation | Mean squares | | | | |
|---|---|---|---|---|---|
| | DF | ED | NEPP | NGRPE | NGPE |
| Replication | 2 | 13.00 | 0.017 | 4.33 | 245581 |
| Variety | 2 | 280.18** | 1.08*** | 15.25$^{ns}$ | 4697744** |
| NPSB fertilizer rates | 3 | 483.3*** | 0.53*** | 54.62*** | 6202163*** |
| Variety x NPSB fertilizer | 6 | 3.34$^{ns}$ | 0.14** | 15.76 $^{ns}$ | 1725905** |
| Error | 22 | 24.09 | 0.03 | 3.5 | 316223 |
| CV% | | 11.86 | 13.96 | 15.41 | 12.25 |

*DF=degree of freedom; ns= non-significant; *= significant at 5% level of significance;**= highly significant at 1% level of significance ***=very highly significant at 1% level of significance; ED= Ear diameter; NEPP= Number of ears per plants; NGRPE= Number of grain rows per ear; NGPE= Number of grains per ear.*

Appendix table 4: Mean squares of analysis of variance for yield and yield components and yield of maize affected by varieties and NPSB fertilizer rates.

| Source of variations | Mean square | | | | |
|---|---|---|---|---|---|
| | DF | HKW | TAGBM | GY | HI |
| Replication | 2 | 16.75 | 3.66 | 0.14 | 5.26 |
| Variety | 2 | 51.9 $^{ns}$ | 15.87* | 34.04*** | 384.4*** |
| NPSB fertilizer rates | 3 | 139.05$^{*}$ | 69.85*** | 5.15*** | 126.99*** |
| Variety x NPSB fertilizer | 6 | 27.22$^{ns}$ | 15.3** | 0.56** | 21.7*** |
| Error | 22 | 26.9 | 3.29 | 0.1 | 1.78 |
| CV% | | 14.95 | 6.68 | 7.4 | 8.43 |

*DF=degree of freedom; ns= non-significant; *= significant at 5% level of significance;**= highly significant at 1% level of significance ***=very highly significant at 1% level of significance; HKW= Hundred kernel weight; TAGBM= Total above ground biomass; GY= Grain yield; HI= Harvest index*

Appendix table 5: Selected physico-chemical properties of the soil of the experimental site before planting.

| Soil parameters | Results | Rating | Reference |
|---|---|---|---|
| Particle distribution | | | |
| Sand (%) | 57 | | |
| Silt (%) | 28 | | |
| Clay (%) | 15 | | |
| Textural *class* | Sandy loam | | |
| $P^H$ | 6.2 | Slightly acidic | ( Tisdale *et al*, 2002) |
| Total nitrogen (%) | 0.625 | High | (Landon,1991) |
| Available phosphorus (mg/kg) | 18.2 | Medium | ( Tekaligne *et al*,1991) |
| Available sulfur (mg/kg) | 22 | Medium | ( EthioSIS ,2014) |
| Available boron (mg/kg) | 0.84 | Medium | (Johnson and Fixon,1990) |
| Organic carbon (%) | 7.254 | High | ( Landon,1991) |
| CEC (cmol (+)/kg) | 34.00 | High | ( Landon,1991) |