GROWTH AND YIELD RESPONSE OF COMMON BEAN (*Phaseolus vulgaris L.*) VARIETIES TO NPSB BLENDED FERTILIZER RATES AT EZHA DISTRICT, SOUTHERN ETHIOPIA

MSc THESIS

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WOLKITE UNIVERSITY
WOLKITE, ETHIOPIA

DECEMBER, 2022

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A THESIS SUBMITTED TO THE
DEPARTMENT OF PLANT SCIENCE,
COLLEGE OF AGRICULTURE AND NATURAL RESUORCE, SCHOOL OF GRADUATE STUDIES
WOLKITE UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN PLANT SCIENCE
(SPECIALIZATION: AGRONOMY)

DECEEMBER, 2022
WOLKITE, ETHIOPIA

THESIS APPROVAL SHEET
WOLKITE UNIVERSITY
SCHOOL OF GRADUATE STUDIES

As Thesis Research Advisor, we hereby certify that we have read and evaluated this thesis prepared under our guidance by Desalegn Kebede Adeba entitled "Growth and Yield Response of Common Bean (*Phaseolus vulgaris L.*) Varieties to NPSB Blended Fertilizer Rates at Ezha District, Southern Ethiopia'' and we recommend that it be submitted as fulfilling the MSc thesis requirement.

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As members of the board of examiners of the MSc thesis open defense examination, we certify that we have read and evaluated the thesis prepared by **Desalegn Kebede Adeba** and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirements for the degree of Master of Science in Agriculture (Agronomy).

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DEDICATION

I dedicate this thesis to my lovely family for their concern, prayer, patience, and encouragement in the success of my life.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis work is my own work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis, and completion of this thesis. All scholarly matter that is included in the thesis has been given recognition through citation. I affirm that I have cited and referenced all sources used in this document. Every serious effort has been made to avoid any plagiarism in the preparation of this thesis.

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BIOGRAPHICAL SKECH

The author, Desalegn Kebede Adeba, was born at Debane near Agena town on March 05, 1987 E.C in Ezha District, Gurage Zone, SNNPR Region, to his father, Mr. Kebede Adeba, and his mother, Mrs. Tirunesh Berta. He attended elementary at Yesray primary school, secondary school at Agena secondary school, and preparatory school at Agena town. And the author joined Adama Science and Technology University from 2005–2007 E.C. and graduated with a BSc degree in natural resource management in July, 2007 E.C. He was employed in the office of Ezha woreda environmental protection and forest office as an expert and also in Ezha woreda urban development and housing office. In December 2013 E.C., he joined the postgraduate program at Wolkite University, School of Graduate Studies, to pursue his studies for the degree of Master of Science in Agronomy.

ACKNOWLEDGMENTS

First and foremost, I would like to thank God and his mother, Saint Virgin Mary, for giving me wisdom, patience, and strength during this thesis preparation and indeed throughout my life. I am highly honored to express my indebtedness and heartfelt appreciation and special gratitude to my major advisor, Dr. Getachew Mekonnen, and co-advisor, Mr. Worku Mengesha, for their unreserved support, sustained guidance, continuous encouragement, constructive criticism, and suggestions throughout the research proposal as well as the thesis manuscript. They efficiently guided me throughout the thesis work, starting from the development of the research proposal and facilitation of technical issues.

My sincere gratitude goes to Wolkite University and Ezha District Administrative Office for sponsoring me to join the MSc Program and providing me with the partial financial support that I needed for conducting the research and writing my thesis and to Melkassa Agricultural Research Institute for providing me with the newly released variety.

I am also grateful to Begenenda fruit farm for providing me experimental fields and other valuable materials during the study. I am indebted to my family and friends as a whole for their encouragement and patience. I am especially very thankful to Mrs. Melis Mare, Abdurahiman Hassen, Andamlak Wolde, Alemu Wegu, Dino Nasir, Remedan Jemal, Girma Zebro, and Marta Gebre, who provided me with various forms of support during my research work and data collection.

ABBREVIATIONS AND ACRONYMS

AGY	Adjusted Grain Yield
ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
CEC	Cationic Exchange Capacity
CSA	Central Statistical Agency
DAP	Di-ammonium phosphate
FAO	Food and Agricultural Organization
GFB	Gross Field Benefit
GLM	General Linear Model
HI	Harvest Index
LSD	Least Significant Difference
MOARD	Minster of Agriculture and Rural Development
NB	Net Benefit
NPSB	Nitrogen, Phosphorus, Sulfur, Boron
OC	Organic Carbon
RCBD	Random Complete Block Design
SAS	Statistical Analysis System
SNNP	Southern Nations and Nationality People
TN	Total Nitrogen
TVC	Total Variable Cost

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Growth and Yield Response of Common Bean (*Phaseolus vulgaris L.*) Varieties to NPSB Blended Fertilizer Rates at Ezha District, Southern Ethiopia

Desalegn Kebede (B.Sc. Natural Resource Management, Adama Science and Technology University)

ABSTRACT

The current average yield of common beans is far less than the national attainable yield in the study area. This is partially due to low soil fertility management and a lack of improved varieties. A field experiment was conducted to evaluate the effect of blended NPSB rates on yield and yield components of common bean varieties, to determine the optimum rate of blended NPSB fertilizer required and the best variety for optimum growth and yield of common bean, and to investigate economically feasible rates of blended NPSB fertilizer for common bean production. The experiment was conducted at Ezha district during 2022 cropping seasons. Treatments consisted of factorial combinations of four common bean varieties (Sab632, Ser119, Ser125, and Bz2) with four NPSB fertilizer rates (0, 50, 100, and 150 kg ha^{-1}) laid out in a randomized complete block design with three replications. Data was collected on growth and yield and yield components and analyzed using SAS (version 9.3). The result showed that NPSB blended fertilizer rate and varieties significantly influenced most of the tested parameters of common bean. The highest days to flowering (51.0), nodule dry weight (3.106), number of pods per plant (17.60), above ground dry biomass (6131.7 kg ha^{-1}), and grain yield (2862.7 kg ha^{-1}) were recorded due to the application of 150 kg of NPSB ha^{-1} for variety Ser119. The highest days to maturity (99.33) and plant height (83.73cm) were recorded from variety Ser125 with a 150 kg NPSB fertilizer application rate. The maximum number of total nodules (73.67), effective nodules (43.55) and the highest harvest index (48.89%) were recorded from variety Ser119 with a 100 kg ha^{-1} NPSB fertilizer application rate. With a 150 kg ha^{-1} NPSB fertilizer application rate, variety Sab632 produced the highest hundred seed weight (42.30). The highest number of seeds per pod (3.76) was recorded from variety Ser125. Net benefit of 81,123.3 birr ha^{-1} was obtained from the treatment combination of 100 kg NPSB ha^{-1} application rate for variety Ser119. Thus, based on the study results, the application of 100 kg NPSB ha^{-1} with variety Ser119 could be recommended to enhance the productivity with the highest net benefits of common bean in the study area. The experiment was done only *at one location and one season therefore it would have to be replicated across location and season to get best conclusive result and sound full recommendation for specific area in order to assure finding of the current study.*

KEYWORDS; Common bean; Blended NPSB; Varieties; Yield; Partial budget

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) belongs to the family members of Leguminosae subfamily Papilionideae (CIAT, 1986). It is a herbaceous annual plant domesticated independently in ancient Meso-America and in the Andes. Now it is grown worldwide for both dry seeds and as a green bean (Shumi *et al*., 2018). It is one of the most essential legume crops grown on all continents of the world, with over 23 million metric tons (MT) of total production, of which 7 million MT were produced in Latin America and Africa (Desta and Ermias, 2019). Most soil types, from light sands to heavy clays, can support the growth of common bean, but friable, deep, and well-drained soils are preferred (Desta and Ermias, 2019), and it grows best in a warm climate with temperatures ranging from 18 to 24 °C (Taminaw and Eman, 2021). It also performs best at the highest nutrient content and pH range of 5.5 to 6.5 (Salcedo, 2008). Common beans have been cultivated as a field crop and are an important food legume produced in Ethiopia (Ali *et al*., 2003). This crop is considered the main cash crop and protein source for farmers in many low and mid-altitude zones of the country (Rahmeto, 2007).

In Ethiopia, common bean is grown predominantly by smallholder producers as an important food crop and source of cash and is one of the fast-expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians (Girma, 2009). In addition to the domestic markets, Ethiopia is also supplying white beans to the export canning industry in the European Union (EU) and other eastern European markets (Desta and Ermias, 2019). Next to faba bean, it ranks second in area of production in Ethiopia (CSA, 2021). It is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enable households to get cash income required to purchase food and other household needs when other crops have not yet matured (Shumi *et al*., 2018).

Nutritionally, common beans contribute greatly to a balanced and healthy diet. This is because the grain has a high protein content and good micro-nutrient concentration. Additionally, their amino acid composition is useful to complement the amino acid profile of cereal proteins. Hence, the common bean is an important crop in addressing the issue of nutrition security in southern Ethiopia, where people's diet is dominated by maize, root, and tuber crops (Walelign, 2015).

Due to early maturity and a moderate degree of drought tolerance, common bean production contributes as food, fodder for livestock, and export commodity, as well as a source of income and employment to a large supply chain and for risk aversion strategies to poor farmers during drought (Tumsa *et al*., 2014). It also provides nitrogen and other soil health benefits under the cropping system to subsequently grown crops (Abebe and Mekonnen, 2019).

Improved common bean production encompasses proper use of different agronomic practices such as improved variety, fertilizer rate, seed rate, spacing, and pesticide application as per recommendations (Mulugeta, 2011).

According to the CSA report, in Ethiopia, common bean is one of the major grain legumes cultivated with its production centered in smallholder farmers and produce low average yields of 1.79 tons ha^{-1}. However, this yield is far less than the attainable yield (2.5-3.6 tons ha^{-1}) under good management conditions (CSA, 2021). The low yield of common bean in Ethiopia is attributed to a number of production constraints, including a lack of improved varieties for various agro-ecological zones; poor agronomic practices such as low soil fertility management; and untimely and inappropriate field operations (Alemitu, 2011).

Ethiopia's common bean is primarily grown in the Eastern, Southern, South Western, and Rift Valley regions (Habte *et al*., 2014). The regional production potential of common bean consists of 38.5% for Oromia, 28.75% for Amhara, 22% for SNNPR and 3.25% for other regions of Ethiopia (CSA, 2021). Accordingly, in 2020/21, the Guraghe zone Administration Agricultural Office reports that the area covered by common bean in the 2020/21 cropping season was 7,922 ha, with an average productivity of 1.85 tons ha^{-1} and a total production of 14,655.7 tons (Guraghe zone Administration Agricultural Office, 2021).

The Agricultural Transformation Agency (ATA) of Ethiopia suggested the general improvement of the soil fertility management system by considering the addition of more nutrients in the fertilizer program. The ATA recommended some blended fertilizers such as NPS, NPSB, NPSBCu, NPSZnBCu, and K fertilizers for crop production in Ethiopia (Desta and Ermias, 2019).

According to Ethiopia's soil fertility status, the soil inventory revealed that the deficiencies of most of the nutrients are widespread in Ethiopian soils (EthioSIS, 2016) and most of the soils are lacking in micronutrients (Cu, B, and Zn) that are required to sustain optimal growth and development of crops because of the long-term frequent cultivation of staple crops (Shiferaw, 2014). Even though NPSB fertilizer is the newly introduced blended fertilizer (MoANR, 2014), there is no national and area specific recommendation for common bean.

Ezha district has the potential for common bean production. According to Ezha district Agriculture office report, the area covered by common bean in the 2014/15 cropping season was 28 ha, with an average productivity of 1.4 tons ha^{-1} and a total production of 39.2 tons. But recently, common bean production in the district has been declining because of different constraints. Among the constraints that account for the low level of productivity and yield of common bean in Ethiopia and even in the Ezha districts are: shortage of high-yielding varieties; inadequate provision of quality common bean seed; insufficient fertilization; inadequate agronomic practices; and postharvest handling techniques are the most important (Ezha woreda agriculture office, 2022).

In addition to the other factors (like disease, low soil fertility), growers’ traditional production practices like inadequate rate of NPSB fertilizer and low yielding varieties result in low production and productivity of the common bean. Smallholder farmers in Ezha district have been using a uniform misunderstanding about common bean’s nutrient requirements, they think fertilizer is not necessary for common bean (own survey, 2021/22). This was initiated to find a specific recommendation of the optimum rate of fertilizer for common bean production in the district to solve the low productivity problem of the crop. And also, smallholder farmers in districts are using the low-yielding red bean varieties for production without considering agro-ecology, soil type, cropping system, and purpose of production. This also initiated to find specific recommendations of best varieties for common production in the district to solve the low productivity problem of common bean.

A recent study showed that the use of blended NPSB fertilizer rate and using the newly released best variety were important to increasing yields of common bean (Fitsum *et al*., 2020). However, the productivity of crops including common bean was much lower than the expected potential. The district's production and average productivity of common beans are very low when compared to the national average; this could be due to inefficient fertilizer use, poor agronomic practices, and planting of low-yielding local varieties (Ezha woreda agriculture office, 2022).

To the best of our knowledge, there is no research conducted in the area that recommends the best varieties and optimum rate of NPSB blended fertilizer rate for common bean. Thus, for the determination of higher yielding common bean varieties, study of crop nutrient sources beyond N and P, especially fertilizers containing S and B, is important to increase common bean productivity.
Therefore, the objectives of this study were:-

- ✓To evaluate the effect of blended NPSB rates on yield and yield components of common bean varieties.
- ✓To determine the optimum rate of blended NPSB fertilizer required and the best performing varieties for optimal growth and yield of common bean.
- ✓To investigate economically feasible treatments of blended NPSB fertilizer and varieties for common bean production.

2. LITERATURE REVIEW

2.1 Origin and Geographical Distribution of Common Bean

Common bean was first originated in Tropical America (Mexico, Guatemala, and Peru), but there are also evidences for its multiple domestication within Central America (Kay, 1979). Domestication occurred independently in South America and Central America/Mexico, leading to two different domesticated gene pools, the Andean and Mesoamerican, respectively (Petry *et al.,* 2015).

Common bean is native to Mexico and Guatemala, where the greater part of the diversity of varieties is found Common bean is the most widely distributed of the related species and has the broadest range of genetic resources. It is frequently used as a food crop throughout the world, especially in Latin America and Africa (Taminaw, 2021). The species was perhaps introduced to the eastern part of Africa by Portuguese traders in the sixteenth century (Wortmann *et al.*, 2004).

2.2 Economic Importance and Production of Common Bean in Ethiopia

Common bean is one of the most important cash crops and sources of protein for farmers in many lowlands and mid-altitude zones of Ethiopia. With regard to the economic importance of common bean, it is used as a source of foreign currency, food crop, means of employment, source of cash, and plays a great role in the farming system (CSA, 2021). The country’s export earnings is estimated to be over 85 % of export earnings from pulses, exceeding that of other pulses such as lentils, faba bean, and chickpea (Taminaw, 2021).

In Ethiopia, common bean ranks third as an export commodity, accounting for approximately 9.5% of total agricultural export value (FAOSTAT, 2010). It is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enables households to get cash income required purchasing food and other household needs when other crops have not yet matured (Taminaw, 2021).

The major common bean producing regions are Oromia, the Southern Nations Nationalities and Peoples Region (SNNPR), and Amhara. Common bean is also one of the most important cash crops and sources of protein for farmers in many lowlands and mid-altitude zones. The country’s export income is estimated to be over 85% of export earnings from pulses, more than that of other pulses such as lentils, faba bean and chickpea (Fissha and Yayis, 2015). The national average yield of common bean in Ethiopia was 1.70 tons ha^{-1} and a total of 520,979.33 tons of yield was produced from 306,186.59 ha of land in the 2017/18 cropping season (CSA, 2018).

There are an extensive range of common bean varieties grown in Ethiopia, including mottled, red, white, and black varieties (Ali *et al*., 2008). The most commercial varieties include pure red and pure white coloured beans, and these are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008).

The major storing and trading sites in the southern Rift Valley area were concentrated in the towns of Sodo, Hawassa, and Shashemene, while the major accumulation centers for white beans were in Nazareth, prior to exportation through Djibouti. There are good prospects that this market will grow as consumers in industrialized countries seek ever more competitive suppliers (Ferris and Kaganzi, 2008).

2.3 Agronomic Requirements of Common Bean

Common bean is a warm-season crop with an optimum temperature of about 24°C. The crop does not tolerate frost or long periods of exposure to near-freezing temperatures at any stage of growth. High temperatures (above 30 ^{o}C) are also not tolerated by common bean, as they can cause flower blasting and bud drop. It requires well-drained soils for germination and it is sensitive to both moisture stress and water logging. Sandy loam, sandy clay loam, or clay loam with a clay content of 15 to 35% are ideal for bean production. With sandy soils, problems of low soil fertility or nematode damage may occur (Gomez, 2004).

Soils of pH 5.5 to 6.5 are suitable for common bean, as the crop is very sensitive to acidic (pH< 5.2) soils (Salcedo, 2008 and Katungi *et al*., 2009). The crop will also not grow well in soils that are compacted, too alkaline or poorly drained. Common bean needs moderate amounts of water (300-600 mm). Adequate moisture during the early part of the season is necessary and essential, especially during the pod filling stage (during and immediately after flowering). During this stage, the soil should not hold less than 60% field capacity to ensure proper moisture availability.

Depending on growth habit type and location, full maturity for dry bean seed types can be attained from 45 to 150 days after emergence. The late-maturing beans were more often indeterminate while the early ones were determinate (Mafuta, 2017).

2.4 Effects of Low Soil Fertility on Common Bean Production

Low soil fertility is a major constraint limiting common bean production in Africa, with 75% of the soil being deficient in phosphorous, 65% of nitrogen and 20% of the soil acidic, causing deficiency of most of the essential nutrients required for common bean production (Kipngetich, 2021).

In Eastern Africa, the primary soil fertility-related problems include low available nitrogen, phosphorous, exchangeable bases and soil acidity (Wortmann *et al*., 2004), caused by continuous cropping, inappropriate cropping systems with little or no input to replenish soil fertility, inadequate resources to allocate to soil improvement by smallholder farmers, increasing population, inadequate supply of organic and inorganic fertilizers, nutrient mining, low nutrient use efficiency, inappropriate fertilizer recommendation and different responses to fertilizers (Rao *et al*., 2016). Due to the continuous cropping among smallholder farmers, nitrogen loss is estimated at 4.4 million tons, phosphorous (P) at 0.6 million tons and potassium (K) at 3 million every year (Kipngetich, 2021).

The declining of soil fertility caused by nutrient mining is the leading cause of decreased yield and low per capita food production in Africa, particularly in Eastern Africa, with an annual loss of 41 kg of nitrogen, 4 kg of phosphorous, and 31 kg of potassium per hectare (Rurangwa *et al*., 2018). Nitrogen, potassium, magnesium, sulfur, calcium, and micronutrients zinc, copper, boron, and molybdenum are among the macronutrients and micronutrients prone to deficiency due to soil degradation, and they affect crop growth, resulting in low production (Kipngetich, 2021).

2.5 Effects of Good Soil Fertility on Common Bean Production

Soil fertility ensures robust plant growth and high yield, and, the application of mineral fertilizers is one of the beneficial ways of increasing soil fertility and crop production. Over the years, there has been an increase in the use of nitrogen, phosphorous, and potassium (Kipngetich, 2021). Common bean is a nutrient demanding crop because of its sensitivity to environmental stresses. One of the significant factors causing low yield in common bean production, is low soil fertility associated with soil acidity, causing nutrient deficiency and limiting plant nutrition, especially available phosphorous and nitrogen (Silva *et al*., 2014).

One way of restoring soil fertility is by applying inorganic fertilizers (Jori, 2014). Nitrogen is one of the most yield-limiting nutrients in agricultural production; it plays an important role in plant biochemistry; it is an essential constituent of the enzyme, nucleic acid, chlorophyll, cell wall, storage of protein, and cellular components (Fageria and Moreira, 2011). Adequate use of nitrogen is fundamental to improving common bean production (Sinclair and Vadez, 2002). Phosphorous is also an important nutrient after nitrogen, is the most abundant element in natural and agricultural soils, and functions in three pools: the soluble pool, the active pool, and the organic pool. It is the second most important essential nutrient after nitrogen (Sanz-saez *et al*., 2017).

Micronutrients are essential plant nutrients required for plant growth in lesser amounts, yet they play a critical role in plant growth, development, and metabolism, while deficiency of micronutrients leads to plant diseases affecting both the quality and quantity of the plant (Tripathi *et al*., 2015). It plays a critical role in improving yield in common bean production by enhancing metabolic and cellular functions like energy metabolism, primary and secondary metabolism, cell protection, gene replication, and hormone perception (Hansch and Mendel, 2009).

There is an indication that the application of micronutrients improves the diversity of microorganisms in the soil, and when applied at the right rate, it enhances microbial colonization, mycorrhizal development, and symbiotic nitrogen fixation, resulting in improved nitrogen fixation in common bean (Kihara *et al*., 2020). The phosphohatase enzyme is essential in the hydrolysis of occluded phosphorous in the soil into inorganic form, which improves the availability of phosphorous for plant growth and development (Margalef *et al*., 2017).

2.6 Effect of Variety on Production of Common Bean

Common bean (Phaseolus vulgaris L.) is an important herbaceous annual grain legume grown throughout the world, primarily as a low-cost protein source for the majority of Sub-Saharan Africans (Mafuta, 2017).

The Ethiopian Institute of Agricultural Research has released and popularized a number of improved varieties (high yielding, disease resistant, and early maturity; varieties meeting the requirements for local consumption and export markets) and management practices since the early 1960s to increase the productivity of common bean. Amanuel and Girma (2018) reported that, the low national yield is related to the low adoption of improved production technologies and a lack of improved varieties.

There are many released and adopted varieties (Hawassa dume, Red Wolayita, Nasir, Ibbado, Awash-1, Awash-2, Ser125, Awash Melka, Ser119, Sab632, Bz2, etc.) of common bean and the potential average yield was 2.6 tons ha^{-1} (MoANR, 2016).

Fitsum *et al.* (2020) reported that the improved common bean varieties (SER-119 and SER-125) had shown better performance in grain yield than the Nasir. Accordingly, the cultivation of common bean with improved varieties has been found more productive, and the yield capacity can be increased by up to 36.15 percent.

According to the report of Abebe and Mokennen (2019), nodulations, plant height, number of pods, seeds per pod, hundred seed weight, grain yield, and harvest index were significantly affected by common bean varieties.

2.7 Fertilizer Requirements of Common Bean

2.7.1 Effect of Nitrogen Fertilizer on Common Bean

Nitrogen fertilizer is very essential for plant growth and development because it participates directly in photosynthesis, it is a basic component of protein (RUBISCO), and it also participates in the activation of enzymes. The rate of side-dressed N fertilization recommended ranges from 20 to 90 kg N ha^{-1}, depending on expected grain yield and the N response class of the soil (Taminaw, 2021).

Common bean N fertilizer requirement depends on soil fertility levels; for low soil nitrogen levels (below 34 kg N ha^{-1}), N fertilizer is generally recommended in order for deficiency indicators not to manifest and for full development up to production. Furthermore, up to 60 kg N ha^{-1} also promotes increased nodule number, mass, and size, giving the highest yields. But, nitrogenous activity declines with applied nitrogen, declining the sink strength and, later, reducing the amount of photo-assimilate partitioned to nodules and grain. Initial application may also result in extreme vegetative growth, leading to delayed flowering, reduced pod set, lower seed yield, and a greater risk of disease infestation (Davis and Brick, 2009).

Common bean requires N in highest amounts because it is a component of proteins, amino acids, and enzymes among other various biological processes therefore the nutrient has a marked effect on crop growth and yield (Soratto *et al.*, 2006). In adequate amounts, nitrogen promotes growth, photosynthesis, nutrient uptake, and improves the immunity of plants to environmental stresses (Wang *et al.*, 2014). In order to increase common bean grain yield with N rates exceeding 100 kg N ha^{-1}. An increase in common bean grain yield with the addition of 120-140 kg N ha^{-1} and attributed this effect to the increase of pods per plant (Soratto *et al.,* 2006).

Common bean grown on N-deficient soils usually responds positively to applied N and the recommendation is to apply N at planting with no reports of yield responses to later applications (top-dressing). Previous surveys estimated that over 60% of the bean production areas in Central, Southern, and Eastern Africa were affected by N deficiency (Vongai, 2018). Furthermore, when compared to other crop legumes, common bean is regarded as a poor nitrogen fixer from the atmosphere. Large N inputs (more than 100 kg

N ha^{-1} $year^{-1}$) would be required to improve bean seed yields above 2,000 kg ha^{-1} per year. Common bean grain yield increased linearly with nitrogen application up to the highest applied nitrogen of 100 kg ha^{-1} and, similarly, common bean grain yield with the addition of a high amount of N ha^{-1} increased the number of pods per plant (Dwivedi *et al*., 1994).

2.7.2 Effect of Phosphorus Fertilizer on Common Bean

Phosphorus deficiency is extensive in regions where the common bean (*Phaseolus vulgaris) is grown*, and apart from nitrogen, phosphorus becomes the second most important nutrient. Phosphorus deficiency is estimated to limit over 50% of common bean productivity (CIAT, 1992). It is essential for root growth and development as well as the production of protein, phytin, and phospholipids in legumes (Rahman *et al*., 2008). The yield of common bean is greatly increased by the application of phosphorus fertilizer (Singh *et al*. 2008). Combined application of phosphorus and rhizobia inoculation increases the grain yield of beans as well as yield parameters (Morad *et al*. 2013).

Application of phosphorus fertilizer has progressive effect on the yield and yield components of common bean revealed that grain weight per plant exhibited a pronounced response to phosphorus application, mean values of grain weight per plant records of 13.0, 17.4 and 20.7 g due to phosphorus fertilization of 0, 50 and 100 kg P_2O_5 ha^{-1}, respectively observed significant increase in grain weight per plant (8.65 g) due to improved P application up to 75 kg P_2O_5 ha^{-1} (Shumi *et al*., 2018).

Legumes, including common bean have high P requirement due to the production of protein having compounds, in which N and P are important constituents, and P concentration in legumes is generally much higher than that found in grasses. High seed production of legumes predominantly depends on the amount of P absorbed. The yield of common bean increases with P application and its nodulation can be improved with the application of phosphorus (Taminaw, 2021).

According to Amare *et al*. (2014), beans respond to the application of phosphorus and production increases proportionally with the increase of phosphorus. The authors also reported that 2326 kg ha^{-1} yield from the rate of 20 kg P2O5 ha^{-1} and 1922 kg ha^{-1} from the control treatment for each variety. Many research indicated that phosphorus availability in the soil is a great limitation for bean production in the tropics (Morgado and Willey, 2003).

Girma (2009) also stated that 69 kg P2O5 ha^{-1} is recommended for common bean production in semi-arid zones of the Central Rift Valley. Fertilizer application in common bean production varies according to production area and soil fertility. The highest total P uptake (32.59 kg ha^{-1}) was reported at 30 kg ha^{-1} and increased with increasing rates of P application, whereas apparent P recovery was found to be highest at 20 kg ha^{-1}. Physiological P use efficiencies of the crop were highest at the rate of 10 kg P ha^{-1}. Therefore, application of 10 kg P ha^{-1} was recommended for better common bean production.

Meseret and Amin (2014) also stated that there was a significant difference among five levels of P fertilizer rates where the maximum (75.5 gm per plant) dry matter yield was reported at an application of P 20 kg ha^{-1}, whereas the minimum (28.9 gm per plant) was recorded from the control. Highest number of seeds per pod (6.46) and seed yield (2.45 t ha^{-1}) were reported from the Awash-Melka variety under irrigation than from other varieties with the application of P-fertilizer (Gebre-Egziabher *et al*., 2014). Varieties such as Awash-1 and Mexican-142 matured earlier (90-94 days) under irrigation than under rain-fed growing conditions. However, application of P-fertilizer was not significant in seeds per pod, seed yield and maturity of the common bean varieties (Gebre-Egziabher *et al*., 2014).

2.7.3 Effect of Sulfur Fertilizer on Common Bean

Sulfur is found in both organic and inorganic forms in the soil. Although the first form represents more than 90% of total S in most soils (Fageria *et al*., 2011), it is the inorganic form (sulfate anion - $SO_4{}^{-2}$) that is absorbed by plants. Thus, the soil's ability to meet the demand for plant nutrients is closely related to the content of soil organic matter and the mineralization of organic S to inorganic forms, such as sulfate. In the soil solution, sulfate is easily leached because it is weakly retained by the coordination mechanism of adsorption, and the sulfate adsorption is higher in clayey soils rich in iron and aluminum oxides (Adriano *et al*., 2017).

Sulfur is one of the essential nutrients for plant growth, and it accumulates 0.2 to 0.5% in plant tissue on a dry matter basis. It is required in the same proportion as phosphorus (Ali *et al*., 2008). Development of the reproductive structure and production of assimilates to fill an economically important sink. Sulfur is one of the crucial plant elements recorded as a secondary nutrient. It is necessary for all plants and is vital for their growth and metabolism.

The application of sulfur at the optimum rate enhances plant height, branches, pods per plant and hundred seed weight in chickpea. Total number of nodules and active nodule significantly increased with application of S up to 20 kg S ha^{-1} for Soybean crop (Ganeshamurthy and Sammi, 2000). It is required in a comparable amount to that of phosphorus. Organic sulfur is present as a heterogeneous mixture form, partly included in microbial biomass and partly in the soil organic matter, and very little is known about the chemical identity of the specific sulfur-containing molecules. Sulfur is associated with the production of crops of superior nutritional and market quality (Ali *et al*., 2008).

The symptoms of sulfur deficiency are similar to those of nitrogen deficiency. But, nitrogen deficiency symptoms first appear in the older leaves; generally, sulfur deficiency symptoms first appear in the younger leaves because sulfur does not easily translocate in the plant. Sulfur-deficient plants are stunted, pale green to yellow in colour, and have elongated thin stems. The deficiency of sulfur may delay maturity in grain crops; interveinal chlorosis may occur (Nebret and Nigussie, 2017).

Root development is restricted, and shoot to root ratios usually decrease for plants grown under sulfur deficiency. Sulfur deficiency can be easily adjusted to root ratios usually decrease for plants grown under sulfur deficiency. Sulfur deficiency can be easily adjusted by the application of chemical fertilizers containing sulfur. Since concentrated fertilizers with low sulfur content are now widely used, sulfur deficiency problems appear more often. As a result, the significant increase in yield obtained with sulfur fertilization appears to be the result of increased sulfur concentrations in various parts of the cluster bean, which helped to maintain the critical balance of other essential nutrients in the plant and resulted in increased metabolic processes in plants (Nebret and Nigussie, 2017).

According to Endrias (2017), sulfur plays a great role when combined with nitrogen and phosphorus fertilizer. He showed that the increase in NPS rate from 0 kg NPS ha^{-1} to 100 kg NPS ha^{-1} increased the number of days required to reach 50% flowering from 39.61 days to 44.11 days and the number of days required to reach physiological maturity from 73.56 days to 76.72 days for common bean.

2.7.4 Effect of Boron Fertilizer

Boron is a micronutrient necessary for plant growth. It plays an important role in cell wall synthesis, sugar transport, cell division, cell development, auxin metabolism, good pollination and fruit set, seed development, synthesis of amino acids and proteins, nodule formation in legumes, and regulation of carbohydrate metabolism. Boron deficiencies occur over a much wider range of soils and crops than do deficiencies are found most often in light soils, low organic matter content and high soil pH levels (Marchner, 1995).

The availability of boron in soil is affected significantly by soil pH. The boron content in legumes is higher than in other species. Boron is mobile in the xylem, but once it reaches the leaves, it becomes immobile. Hence, the first symptoms appear in the young part of the plant. Most of the boron compounds are soluble at low pH, but in the case of sandy soils having low pH, B is lost down the profile by leaching if rainfall is high. It is found primarily in organic matter in surface soil, and as the profile B content decreases, its deficiency results in the formation of a bushy plant with drooping leaves (Muthanna, 2017). Boron plays an essential role in nodulation, cell integrity, carbohydrate transport, and reproductive growth, improving common bean growth (Kipngetich, 2021).

Boron deficiency does not impede common bean development by slowing down activity in the meristematic tissue, but when deficiency is severe, it can kill the growing point because it strongly influences cell division (Oerili and Richardson, 1970).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted from March 25, 2022 to July 29, 2022 at Agujtereh Keble, Ezha district, Gurage zone, SNNPR during the short rainy season, Belg, 2022. The study site is located 186 km away from Addis Ababa, the capital city of Ethiopia, and about 30 km from the capital of the Gurage zone, Wolkite. The area is located between an altitude of 1900–2000 m.a.s.l and approximate geographic coordinates of 8º 12’ 29’’ N latitude and 37º 53’ 74’’E longitude. The annual rainfall is about 1100–2300 mm with a minimum temperature of 11 ^{0}C and maximum of 27 ^{0}C. The major soil type of the study area is vertisols (Ezha woreda Agriculture and natural resource office, 2022).

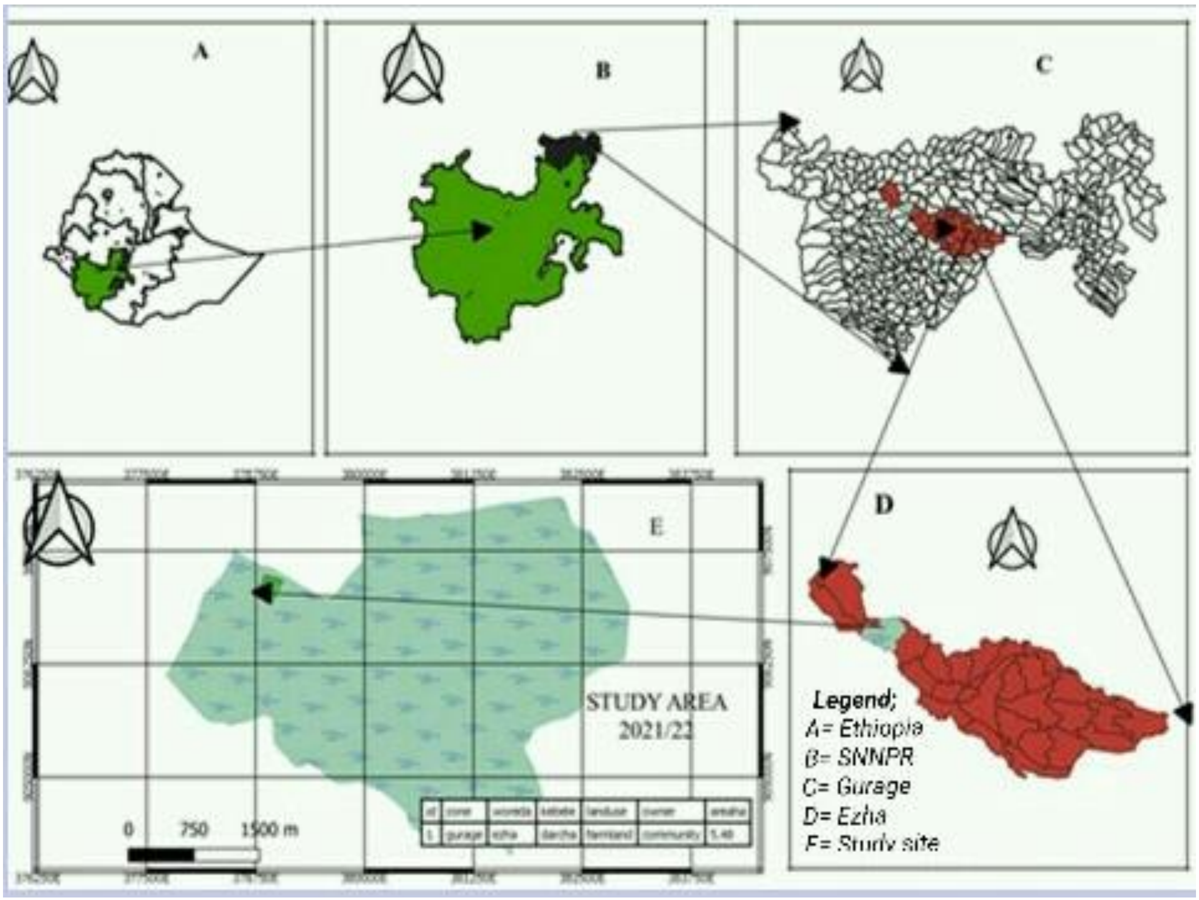

Figure 1 Map showing the study site of Ezha district, Gurage Zone, South Central Ethiopia

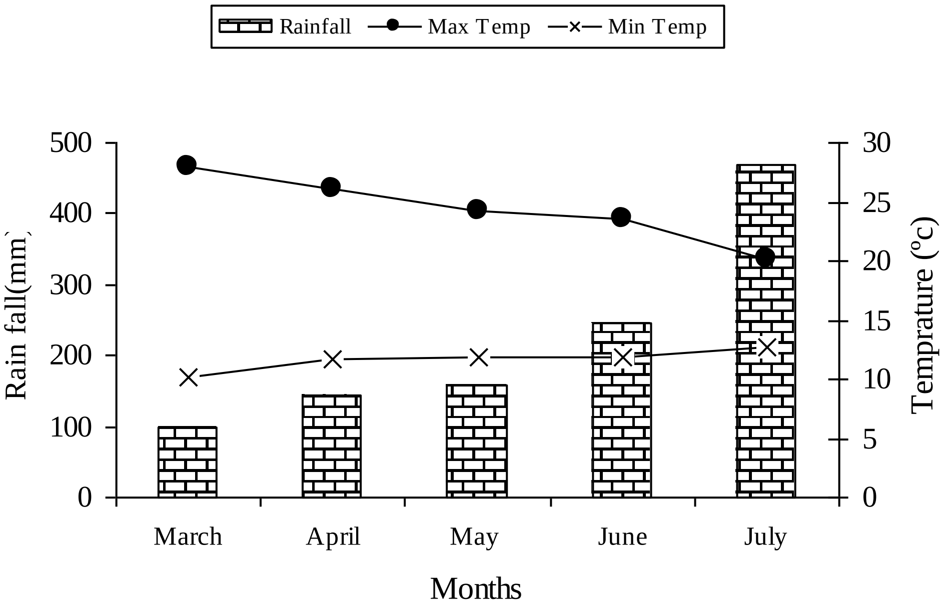

Figure 2 Temperature (^{0}C) and rainfall (mm) condition of experimental site of cropping season

Source: Ethiopian metrological agency, 2022

3.2. Soil Sampling and Analysis

To evaluate the soil fertility status of the study site, a composite soil sample was collected from 10 spots of the experimental site in a zigzag pattern before planting, at a depth of 0–30 cm using a soil auger. Then, the samples were dried in the oven and crushed with mortar and allowed to pass through a sieve size of 2 mm. Particle size distribution (soil texture), soil pH, Cation Exchange Capacity (CEC) (Cmol (+) kg^{-1}), organic carbon (%), available phosphorus [mg/kg (ppm)], total nitrogen (%), available sulfur (ppm) and available boron (ppm) were analyzed at Wolkite and Areka soil laboratories.

The soil pH was determined by a 1:2.5 soil to water ratio using a glass electrode attached to a digital pH meter. The soil textural class was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). The organic carbon of the soil is also determined by the volumetric method based on the oxidation of organic carbon with an acid potassium dichromate (KCO) medium using the Walkley and Black (1934) method.

Total nitrogen was determined according to the modified Kjeldahl method with sulfuric acid by Dewis and Freitas (1984). Available phosphorus (ppm) was determined by Olsen's method (Olsen, 1954). Available sulfur (meq/lS2O4) was determined by the turbdimetric phosphate extraction method (Aaron *et al*., 2008), and available boron was determined using the dilute hydrochloric acid method (Pannamperuma *et al*., 1981). CEC is determined titrimetrically by distillation of ammonia that has been displaced by sodium (Na) (Sahlemedhin and Taye, 2000).

3.3. Experimental Materials

The treatment consisted of four varieties of common bean (Sab632, Ser119, Ser125 and Bz2) and NPSB blended fertilizer was used as inorganic fertilizer at four levels of NPSB blended fertilizer rates. The varieties were obtained from Melkassa Agricultural Research Center. The nutrient compositions of NPSB are 18.9N, 37.7P_2O_5, 6.95S and 0.1B (EthioSIS, 2016).

Table 1 General description of common bean varieties

Variety	Altitude (m) range	Seed Colour	Yield on station (t ha^{-1})	Yield on farm (t ha^{-1})	Year of Release
Sab632 (Tafach)	1450-2000	Speckled	2.2-2.6	1.9-2.4	2015
Ser119	1450-2000	Red	3.3	2.5	2014
Ser125	1450-2000	Red	3.5	2.2	2014
Bz2 (Derash)	1450-1800	Speckled	1.8	1.5	2016

Fitsum *et al*., (2020); MoANR, (2016)

3.4 Treatments and Experimental Design

The treatments consisted of four levels of NPSB inorganic fertilizer (0, 50, 100, 150 kg ha^{-1}) rates and four varieties of common bean (Sab632, Ser119, Ser125, and Bz2), a total of sixteen treatment combinations. The experiment was laid out as a 4x4 factorial arrangement in a randomized complete block design (RCBD) with three replications. The treatments were assigned randomly in each block. The gross plot area was 3.2 m× 2.4 m (7.68m^2) consisting of 8 rows of 2.4 m length. The one outermost row from each side and three plants from both ends of each row were considered as a border, and one row was used for destructive sampling for determining the nodulation parameters and above-ground dry biomass at physiological maturity. Thus, the net plot size was 2m x 1.8m (3.6m^2) with

5 net rows. The spacing between blocks and plots was 1m and 0.5 m, respectively. All the other variables out of the experimental treatments were kept uniform and as per the recommendations.

3.5 Experimental Procedure and Management

The experimental site was ploughed to a depth of 25–30 cm, and the plots were leveled and ridges were made manually. The soil was cleared of unwanted materials and plant residues. The field was divided into three blocks, with sixteen plots in each block. The treatment was assigned to each plot randomly. The spacing between rows and plants was 40 cm and 10 cm, respectively. One seed per hill at the specified spacing was sown at a depth of about 2–5 cm. NPSB fertilizer was hand drilled in rows at the time of sowing. Weeding (2 times) was done at the appropriate time, i.e., the first weeding was done 3 weeks after planting and the second weeding was done before flowering, 5 weeks after planting. All necessary agronomic management was carried out uniformly and properly for each plot, starting from the field preparation to harvesting. When the plant reached physiological maturity, i.e., when the bottom of the common bean pods started to dry, harvesting was done.

3.6 Crop data collection

3.6.1 Phonological and Growth Parameters

Days to 50% flowering: this was determined by counting the number of days from planting to the time when first flowers appeared in 50% of the plants in a plot by counting the number of plants.

Days to physiological maturity: It was determined as the number of days from planting to the time when 90% of the plants in each net plot showed yellowing of the pods. This was done by counting the number of plants.

Number of total nodules per plant: bulk of the roots of 3 randomly taken plants from destructive rows in each plot were carefully exposed at 50% flowering and uprooted for nodulation study. Roots were carefully washed using tap water on a sieve, and nodules were separated and counted.

Effective nodules per plant: For determination of the effective number of nodules, the inside color of nodules was observed by cutting each nodule with the help of a sharp blade, and the pink-colored nodules were considered as effective nodules, while green-colored nodules were considered non-effective.

Nodule Dry Weight (NDW)

The nodules were detached from roots, oven-dried at 70 °C for 24 hours and then weighed to calculate nodules dry weight per plant.

Plant height: it was measured as the height of 10 randomly chosen plants from the ground level to the apex of each plant at the time of physiological maturity from the net plot area.

3.6.2. Yield Parameters

Number of pods plant^{-1}

The number of pods per plant was recorded based on 10 pre-tagged plants in each net plot area at harvest and the average was taken as the number of pods per plant.

Number of seeds pod^{-1}

The total number of seeds in the pods of 10 plants were counted and divided by the total number of pods to find the number of seeds pod^{-1}.

Hundred seed weight (g)

The weight of 100 seeds was determined from each plot using a sensitive balance.

Above-ground dry biomass total

At physiological maturity, 10 plants were randomly taken from the destructive rows of each net plot and used to determine above-ground dry biomass yield, which was measured after oven drying to a constant weight. The dry biomass per plant was then multiplied by the total number of plants per net plot and converted into kg ha^{-1}. This value was used to calculate the harvest index as well.

Grain yield (kg ha^{-1})

Grain yield was determined after threshing the seeds harvested from each net plot. The seed yield was converted to 10% moisture content using a moisture analyzer, and it was converted to kg ha^{-1}.

$$\text{Wf} = \frac{100\text{-MCi}}{100\text{-MCf}}$$

Where; Wf = final weight, MCi = initial moisture content and MCi = final moisture content

Harvest Index (HI)

The harvest index was calculated by dividing grain yield per plot by the total above-ground dry biomass yield per plot multiplied by 100.

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Above ground dry biomass}} \text{ X } 100$$

3.7. Partial Budget Analysis

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

Adjusted grain yield (AGY) (kg ha^{-1}): AGY is the average yield adjusted downwards by 10% to reflect the difference between the experimental yield and the yield of farmers.

Gross field benefit (GFB) (ETB ha^{-1}): GFB is computed by multiplying the field/farm gate price that farmers receive for the crop when they sell it as an adjusted yield. GFB = AGY ×field/farm gate price for the crop.

Total variable cost (TVC) (ETB ha^{-1}) : TVC is calculated by summing up the costs that vary, including the cost of NPSB fertilizers at the time of planting and, according to Ezha, farm daily payment of labor cost for application of NPSB. The costs of other inputs and production practices, such as labor costs for land preparation, planting, weeding, and harvesting, were considered 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 as: NB = GFB – TVC.

3.8. Data Analysis

The data collected and measured parameters from the experiment were subjected to statistical analysis as per the experimental design for each parameter using Statistical Analysis Software (SAS version 9.2) to analyze the data using ANOVA and GLM procedures. The mean separation of significant treatment means was carried out using the least significant difference (LSD) test at a 5 % level of probability (Gomez and Gomez, 1984). Similarly, simple linear correlation analysis was carried out between growth and yield parameters.

4. RESULT AND DISCUSSION

4.1. Physiochemical Properties of the Experimental Site soil

The soil physical and chemical characteristics of the study area are as shown in Table 2. It was 28% clay, 36% silt, and 36% sand, which is a texture under the category of clay loam soil that is suitable for common bean production due to its good ability to retain nutrients and available water. The pH of the soil was 5.7, which is moderately acidic as shown by Marx *et al*. (1996), who classified the soil based on the pH content as strongly acidic (below 5.1), moderately acidic (5.2-6.0), slightly acidic (6.1-6.5), neutral (6.6-7.3), moderately alkaline (7.3-8.4), and strongly alkaline (above 8.5). Common bean grows best in a wide range of soils but it performs best on deep, friable and well aerated soil type with optimum pH range 5.5-6.5 (Salcedo, 2008).

Tekalign *et al*. (1991) classified soil organic carbon (%) as <0.5 very low, 0.5-1.5 low, 1.5-3 medium, and >3 high. The organic carbon content of the study area was high (3.65). According to the OM content rating criteria established by Berhanu (1980) sited in Dagne (2016), soils having less than 0.8% very low, between 0.80% and 2.60% low, between 2.60% medium and > 5.20% rated as high. Thus, organic matter content of the study area was high (6.39%). Tekalign *et al*. (1991) also classified soil nitrogen availability of <0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate, and >0.25% as high. Thus, the nitrogen availability of the study site was high (0.31%). According to the classification of Olsen (1954), available phosphorus <10ppm low, 10-25ppm medium, 25-50 high and >50 were excessive. The result of the study site revealed that the available phosphorus level (3.22mg/kg) was low.

In general, soils high in CEC content are considered agriculturally fertile. According to Landon and Manual (1991), top soil having a CEC greater than 40 meq/100g of soil is rated as very high and 25-40 meq/100g soil as high, 15-25 as medium, 5-15 as low, and < 5 meq/100g of soil as very low in CEC. Thus, the soil of the site had a very high (44 meq/100g soil) CEC. This shows that the soil has the capacity to hold nutrient cations and supply to the crop. Horneck *et al.*, (2011) ratings of Sulphur as <2ppm very low, 2-5ppm low, 5-20 ppm medium, and > 20 ppm high. The available sulfur value of the study area was 18.2 ppm, which is categorized under the medium range.

According to Horneck *et al.,* (2011) rating report, Boron that had <0.2ppm very low, 0.2-0.5ppm low, 0.5-1ppm medium, 1-2ppm high, and >2ppm excessive. The result of the study site showed that the available boron level (0.74ppm) was medium. Thus, according to the soil laboratory results, the soil of the study area was appropriate for common bean production with the application of deficient fertilizers.

Table 2 Result of Selected Physiochemical Properties of Soil of the Experimental Site before sowing

Soil properties	Results	Rating	Reference
Soil particle size			
Clay (%)	28		
Silt (%)	36		
Sand (%)	36		
Textural class	Clay loam		
Soil pH (1:2 H_2O)	5.7	Moderately acidic	Marx *et al*., (1996)
Organic carbon (%)	3.65	High	Tekalign *et al.,* (1991)
Organic matter (%)	6.29	High	Dagne, (2016)
Kjeldahl Nitrogen (%)	0.31	High	Tekalign *et al.,* (1991)
CEC (meq/100g soil)	44	Very high	Landon (1991)
Available Phosphorus (mg/kg soil)	3.22	Low	Olsen *et al*., (1954)
Available Sulphur SO_4 (ppm)	18.4	Medium	Horneck *et al*., (2011)
Available Boron (ppm)	0.74	Medium	Horneck *et al*., (2011)

4.2. Phonological and Growth Parameters

4.2.1. Days to 50% flowering

The analysis of variance revealed that the interaction of varieties and NPSB blended fertilizer rates had highly significantly ($P<0.01$) affected the days to 50% flowering of common bean (Appendix Table 1 and Table 3).

Relatively the longer (51.00) days to flowering was recorded by the interaction of variety Ser119 with highest rate of NPSB (150 kg ha^{-1}) blended fertilizer rates followed by treatment combinations of variety Ser125 with 100 and 150 kg ha^{-1} NPSB (50.67 days) blended fertilizer rates and variety SAB with 150kg ha^{-1} (49.33 days) respectively. However, short days to flowering (38.33 days) were recorded at the treatment combination of the Bz2 variety with 0 kg ha^{-1} NPSB fertilizer rate (Table 3). This means Bz2 variety without fertilizer flowered 12.67 days earlier than the variety Ser119 combined with 150kg^{-1} NPSB. And this showed that planting of common bean by applying more NPSB blended fertilizer has delay the days for flowering, whereas less or no application of fertilizer has shorten the days for flowering of common bean.

The plot that received a high dose of blended NPSB fertilizers for nutrient supply took a longer time to establish and grow than the plots without fertilizer, and variety Bz2 was found to be early flowering as compared to the other varieties across all NPSB fertilizer rates. Prolonged days to flowering at a high rate of N, P, S, and B fertilizer might be associated with the availability of enough nutrients in the soil that lead to the promotion of vegetative growth of the variety, which in turn prolongs days to flowering, and this is due to the delaying effect of nitrogen obtained from NPSB fertilizer. On the other hand, early flowering of a variety with an unfertilized treatment might be due to nutrient deficiencies causing the plant to go into stress, causing the plant to flower early. The difference among the varieties in days to flowering might be due to be genetic differences as common bean has high diversity in such phenological characters.

In agreement with this result, Farkhanda *et al.* (2019) reported that the interaction effect of varieties and NPS blended fertilizer rates had a significant effect on days to 50% flowering on common bean. The variety Long Red Bean with 250 kg NPS ha^{-1} had the longest days to 50% flowering, whereas the variety Kashmir with 0 kg NPS ha^{-1} was the earliest to reach 50% flowering. Endrias (2017) also reported that application of the NPS rate significantly influenced the days to 50% flowering in common bean. Increasing the NPS rate from 0 kg NPS ha^{-1} to 100 kg NPS ha^{-1} increased the number of days required to reach 50% flowering from 42.67 to 49.33 days.

Similarly, the finding of Nuru (2020) who reported that the interaction effect of varieties and NPS blended fertilizer rates had a significant effect on days to 50% flowering on mungbean. The variety Boreda, with a 0 kg ha^{-1} rate, was the earliest to 50% flowering (40.93), while Rasa, with a 150 kg NPS ha^{-1} rate, had the longest days to reach 50% flowering (54.22).

In line with this result, Atinafu (2020) reported that days to 50% flowering were highly significantly affected by the application rates of blended fertilizers on common bean. Increasing the rate of blended NPSB fertilizers from 0 kg ha^{-1} to 200 kg ha^{-1} increased the number of days required to reach 50% flowering from 39.0 days to 46.33 days.

Table 3 Interaction effects of varieties and NPSB fertilizer rates on Days to 50% flowering of common bean

	NPSB (kg ha^{-1})			
Varieties	0	50	100	150
Sab632	42.33^{e}	48.00^{c}	48.33^{bc}	49.33^{abc}
Ser119	48.00^{c}	49.67^{abc}	49.67^{abc}	51.00^{a}
Ser125	45.33^{d}	50.00^{ab}	50.67^{a}	50.67^{a}
Bz2	38.33^{f}	39.67^{f}	38.67^{f}	40.00^{f}
LSD(0.05)		1.93		
CV		2.5		

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.

4.2.2. Days to 90% physiological maturity

The analysis of variance showed that days to 90% physiological maturity were highly significantly ($P<0.01$) influenced by the main effect varieties and NPSB blended fertilizer rates and also their interaction (Appendix Table 1 and Table 4).

The highest rate of NPSB fertilizer rate (150 kg ha^{-1}) resulted in delayed days to maturity within all varieties. Variety Ser125 showed the longest days to physiological maturity (99.33 days) with a combined application of 150 kg NPSB ha^{-1} followed by treatment combinations of variety Ser125 with 100 kg ha^{-1} NPSB (99 days) and variety Ser119 with 150 kg ha^{-1} NPSB (98.67 days) respectively. A relatively short day to physiological maturity (74.66 days) was recorded from the Bz2 variety without NPSB blended fertilizer (Table 4).

The difference in days to maturity might be due to the variations in N, P, S and B availability and genetic differences, as common bean has high diversity in such phenological characters. The delay in days to maturity at the highest blended NPSB fertilizer could also be due to N fertilizer that increasing vegetative growth of the plant.

Similarly, the finding of Farkhanda *et al.* (2019) who reported that the interaction effect of varieties and NPS blended fertilizer rates had significant effect on days to 90% physiological maturity on common bean. Long Red Bean had the longest days to 90% physiological maturity with 250 kg NPS ha^{-1}, while Kashmir had the shortest days to 90% physiological maturity with 0 kg NPS fertilizer. The results of the current study were also in line with the findings of Shumi, (2018), who reported that the delayed physiological maturity of common bean was associated with an increase in NPS fertilizer rates where the highest number of days required to physiological maturity (99.33 days) was recorded for the highest rate of blended NPS application rate (250 kg ha^{-1}) while the shortest days to physiological maturity (91.33 days) was reported with a 0 kg NPS application.

In agreement with this result, Nuru (2020) reported that the interaction effect of varieties and NPS blended fertilizer rates had a significant effect on days to 90% physiological maturity on mungbean. The variety Rasa with 150 kg NPS ha^{-1} had the longest days to 90% physiological maturity (81.22 days), whereas the variety Boreda with 0 kg NPS ha^{-1} rate was the earliest to reach days to 90% physiological maturity (67.93).

Table 4 Interaction effects of varieties and NPSB fertilizer rates on days to 90% physiological maturity of common bean

		NPSB (kg ha^{-1})		
Varieties	0	50	100	150
Sab632	82.67^{f}	94.00^{cde}	94.67^{bcd}	94.33^{bcde}
Ser119	91.66^{de}	97.33^{ab}	97.00^{abc}	98.66^{a}
Ser125	91.33^{e}	98.00^{a}	99.00^{a}	99.33^{a}
Bz2	74.66^{h}	77.00^{gh}	75.67^{h}	79.00^{g}
LSD(0.05)		3.30		
CV		2.197		

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.

4.2.3. Plant height

The analysis of variance showed a highly significant ($p<0.01$) effect of the main factors varieties and NPSB fertilizer rates and a significant ($p<0.05$) effects of their interaction on plant height at physiological maturity (Appendix Table 2 and Table 5).

The application of the highest rate of NPSB fertilizer (150 kg ha^{-1}) produced the highest plant height in almost all varieties of common bean. Variety Ser125 had the highest plant height (83.73 cm) with a combined application of 150 kg NPSB ha^{-1}, followed by the treatment combination of variety Ser125 with 100 kg ha^{-1} (82.1 cm), while Bz2 had the shortest plants (29.266 cm) without NPSB fertilizer application (Table 5). The plant heights of Bz2 and Sab632 varieties were shorter at all fertilizer rates than those of Ser119 and Ser125 varieties.

The increase in plant height in response to the increased blended NPSB application rate might be due to higher N, P, S, and B availability that leads to the maximum vegetative growth of the plants. The integrated actions of fertilizer nutrients significantly affected plant height. Nitrogen helps in chlorophyll formation; phosphorus establishes a strong root system; sulfur enhances the formation of chlorophyll and encourages vegetative growth; and boron plays a vital role in the translocation of photosynthates (Moiruzzaman *et al.*, 2008). The increase in plant height might also be attributed to better root formation due to sulfur, which in turn activated higher absorption of N, P, S, and B from the soil and improved metabolic activity inside the plant.

In agreement with this result, Shumi *et al.* (2018) reported that the interaction of NPS fertilizer rates and varieties had a significant effect on the plant height of common bean. The highest plant height (99.72cm) was observed from Nasir in combination with a 150kg ha^{-1} NPS rate and the shortest plant height (31.08cm) was recorded at variety Ibado in combination with a 0 kg ha^{-1} NPS fertilizer rate.

Similarly, Nuru (2020) reported that the interaction of NPS fertilizer rates and varieties had a significant effect on the plant height of common bean. The highest plant height (104.02 cm) was observed from Red-Wolayita in combination with a 100 kg ha^{-1} NPS rate, and the lowest plant height (45.82 cm) was recorded from the variety Nasir in combination with a 0 kg ha^{-1} NPS fertilizer rate.

In line with this result, Desta and Ermias (2019) also reported that the highest plant height was recorded from the application of 150 kg NPSB ha^{-1}, while the lowest was recorded from a 0 kg NPSB fertilizer rate. Moniruzzaman *et al*., (2008) also found that plant height was significantly increased up to 160 kg N ha^{-1} and that application of phosphorus at the highest level (120 kg P_2O_5) increased plant height in French bean.

Table 5 Interaction effects of varieties and NPSB fertilizer rates on plant height of common bean

	NPSB (kg ha^{-1})			
Varieties	0	50	100	150
Sar632	32.00^{i}	37.80^{h}	48.06^{fg}	47.80^{fg}
Ser119	51.60^{f}	66.00^{d}	76.13^{c}	76.83^{bc}
Ser125	59.53^{e}	79.26^{abc}	82.13^{ab}	83.73^{a}
Bz2	29.26^{i}	44.13^{g}	43.53^{g}	44.20^{g}
LSD(0.05)		5.72		
CV		6.08		

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. Number of total nodules per plant

The analysis of variance showed that the total number of nodules was highly significantly ($p<0.01$) influenced by the main factor varieties and NPSB blended fertilizer rates and the interaction of both (Appendix Table 2 and Table 6).

Variety Ser119 with the combination of 100 kg NPSB ha^{-1} had the highest number of nodules per plant (73.67), followed by treatment combinations of variety Ser119 with 150 kg ha^{-1} NPSB (72.33) and variety Sab632 with 150 kg ha^{-1} NPSB (65.67), respectively. However, Bz2 with no NPSB fertilizer application had the lowest number of nodules (25.77) (Table 6).

The increase in the total number of nodules at 150 kg NPSB ha^{-1} might be due to phosphorus, which is needed in relatively large amounts by legumes for growth and to promote leaf area, biomass, yield, nodule number, and nodule mass in different legumes. In line with this finding, Amare *et al*. (2014) found that nodule number increased significantly with increasing phosphorus levels, with the lowest (12.8) and highest (31.35) numbers in common bean obtained from the control treatment and application of 20 kg ha^{-1} P205 ha^{-1}, respectively. The total number of nodules also increases with the increase in sulfur due to the formation of nitrogenase enzymes that promote nitrogen fixation in legumes. And it also might be the vital role of boron because it is essential for nodule formation in legumes and because it is an essential nutrient for the development of nitrogen-fixing root nodules in legumes.

In agreement with this result, Nuru and Taminaw (2021) reported that the interaction effect of NPS fertilizer rate and variety had a significant effect on the total number of nodules per plant of common bean. The highest number of total nodules (50.80) was observed from the variety Beshbesh in combination with 100 kg NPS ha^{-1} while the variety Tabor, with a 0 kg NPS rate, produced the lowest number of total nodules (6.87). Similarly, Atinafu (2020) also reported that the mean maximum number of nodules per plant of common bean was recorded at 200 kg NPSB ha^{-1} while the minimum number of nodules was recorded at 0 kg NPSB fertilizer application.

In line with this result, Amanuel *et al*. (2018) reported that the interaction of varieties and P rates had a significant effect on the number of nodules per plant of common bean. The maximum number of nodules per plant was recorded for variety Tatu with the application of 69 kg P_2O_5 ha^{-1}, while the minimum number of nodules was recorded for variety Remeda without the application of P_2O_5.

Similarly, Nuru (2020) reported that the interaction effect of NPS fertilizer rate and variety had a significant effect on the total number of nodules per plant of common bean. The highest number of total nodules (68.53) was observed from the variety Nasir in combination with 100 kg NPS ha^{-1} while the variety Red-Wolayita, with a 0 kg NPS rate, produced the lowest number of total nodules (9.87).

Table 6 Interaction effects of varieties and NPSB fertilizer rates on total nodules number of common bean

		NPSB (kg ha^{-1})		
Varieties	0	50	100	150
Sab632	30.00^{fg}	38.00^{def}	61.67^{c}	65.66^{abc}
Ser119	33.11^{efg}	34.78^{efg}	73.67^{a}	72.34^{ab}
Ser125	36.66^{def}	40.67^{de}	62.55^{bc}	61.22^{c}
Bz2	25.77^{g}	45.00^{d}	45.00^{d}	59.22^{c}
LSD(0.05)		10.06		
CV		12.29		

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. Effective nodules per plant

The main factor varieties and NPSB blended fertilizer rates and the interaction of both were found to have a highly significant ($p<0.01$) influence on the number of effective nodules (Appendix Tables 2 and 7).

Variety Ser119 with the combination of 100 kg NPSB ha^{-1} recorded the highest number of effective nodules per plant (43.55), followed by treatment combinations of variety Ser119 with 150 kg ha^{-1} NPSB (42.77) and variety Sab632 with 150 kg ha^{-1} NPSB (40.11), respectively, while the lowest number of effective nodules was recorded from variety Bz2 (15) and variety Sab632 (19.55) of both without NPSB fertilizer application (Table 7).

The increment in the number of effective nodules with the increase in NPSB application up to 100 kg ha^{-1} and 150 kg ha^{-1} NPSB fertilizer might be due to the vital role of phosphorus in increasing the number and size of nodules and the amount of nitrogen assimilated per unit of nodules. In agreement with this result, Bashir *et al*. (2011) reported that phosphorus plays a vital role in increasing root growth and decreasing the time needed for developing nodules to become effective for the benefit of the host legumes. It might also be from increased sulfur application, which might be due to the high dose of sulfur and increasing its availability along with other major nutrients. In legume plants, a high sulfur supply shows greater rates of N2 fixation, and conversely, legumes grown on sulfur poor soils have minimized nitrogen's activity and readily respond to sulfur fertilizers by increasing yield and nitrogen content (Scherer, 2008).

In agreement with this result, China (2018) recorded that the highest number of effective nodules per plant (20.67) was recorded from variety Dhera with the application of 129 kg NPSZnB ha^{-1} while the lowest effective nodule per plant (4.43) was obtained from the interaction of the Natoli variety with a lower fertilizer (64.4 kg) blended NPSZnB ha^{-1} application on chickpea.

Similarly, Wondwosen and Tamado (2017) also reported that the interaction effect of common bean varieties with NP fertilizer rates showed a highly significant ($p<0.01$) on the number of nodules per plant and that the variety Chercher with 36 kg N and 92 kg P2O5 had the highest effective nodules, while Awash Melka with no fertilizer had the lowest effective nodules (19.50).

In line with this result, Hassen (2020) reported that the number of effective nodules per plant increased with the increased rate of blended NPS application. The increase in blended NPS fertilizer from 0 to 200 kg ha^{-1} enhanced the number of effective nodules per plant. The maximum number of effective nodules per plant (33.67) was recorded at a rate of 200 kg NPS ha^{-1} while the minimum number of effective nodules per plant (24.27) was recorded at a rate of 0 kg NPS ha^{-1}.

Table 7 Interaction effects of varieties and NPSB fertilizer rates on number of effective nodule of common bean

	NPSB (kg ha^{-1})			
Varieties	0	50	100	150
Sab632	19.57^{fg}	23.67^{ef}	37.33^{bcd}	40.11^{abc}
Ser119	21.10^{f}	21.44^{f}	43.55^{a}	42.77^{ab}
Ser125	23.66^{ef}	24.33^{ef}	36.89^{cd}	37.11^{bcd}
Bz2	15.00^{g}	28.33^{e}	27.33^{e}	34.23^{d}
LSD(0.05)		5.76		
CV		11.60		

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. Nodule dry weight

The analysis of variance showed that the number of nodules dry weight was highly significantly influenced by the main effects of variety and blended NPSB fertilizer application rates ($p<0.01$) and significantly ($p<0.05$) affected by their interaction (Appendix Table 2 and Table 8).

Variety Ser119 with the combination of 150 kg NPSB ha^{-1} recorded the highest number of nodule dry weight (3.10), followed by treatment combinations of variety Ser119 with 100 kg ha^{-1} NPSB (2.95) and variety Sab632 with 150 kg ha^{-1} NPSB (2.77), respectively, while the lowest number of nodule dry weight was recorded from variety Bz2 (1.26) without NPSB fertilizer application (Table 8).

The increase in the nodule dry weight at 150 kg NPSB ha^{-1} might be due to phosphorus, which is needed in relatively large amounts by legumes for nodule number and effective nodule, which in turn increase nodule weight. In line with this result, Attar *et al. (2012)* reported that various levels of P fertilizer applications significantly affected the nodule dry mass of common bean. The highest nodule dry weight (0.64) was recorded from the application of 90 kg P_2O_5, while the lowest nodule dry weight was recorded from a 0 kg P_2O_5 application.

In agreement with this result, Lake and Jemaludin (2018) found that the highest nodule dry weight was obtained from a 100 kg blended NPSZnB ha^{-1} application rate and the lowest nodule dry weight was recorded from a 0 kg blended NPSZnB application rate on common bean. Similarly, Tesfa (2022) reported that NPS fertilizer had a significant effect on the nodule dry weight of soybean. The maximum nodule dry weight (0.205) was recorded from the application of 150 kg NPS ha^{-1} and the lowest nodule dry weight was recorded from 0 kg NPS ha^{-1}.

In agreement with this result, Rodino *et al*., 2021 found that the highest (18.3) nodule dry weight was obtained from variety PMB-0285 while, the lowest (8.19) nodule dry weight was recorded from variety PMB-0286 of common bean.

Table 8 Interaction effects of varieties and NPSB fertilizer rates on nodule dry weight of common bean

	NPSB (kg ha^{-1})			
Varieties	0	50	100	150
Sab632	1.63^{fgh}	1.66^{fgh}	2.11^{def}	2.77^{abc}
Ser119	1.27^{h}	1.60^{fgh}	2.95^{ab}	3.10^{a}
Ser125	1.27^{h}	1.88^{efg}	1.86^{efg}	2.56^{bcd}
Bz2	1.26^{h}	1.47^{gh}	1.81^{efg}	2.27^{cde}
LSD(0.05)		0.50		
CV		15.37		

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 pods plant^{-1}

The analysis of variance showed a highly significant ($p<0.01$) effect of the main factors varieties and NPSB fertilizer rates and a significant ($p<0.05$) effects of their interaction on number of total pods per plant (Appendix Table 3 and Table 9). These indicated the differential response of varieties to fertilizer rates with regard to the number of pods per plant. The number of pods per plant is known to be determined by several traits, including the number of flowers, the number of branches, and the number of pods set, and this indicates the proportion of flowers that produce pods. Therefore, it is expected that these traits will be highly influenced by fertilizer effects and display differential responses among varieties.

Variety Ser119 with an application of 150 kg blended NPSB ha-1 fertilizer rate scored the highest number of total pods per plant (17.60), followed by Ser119 with 100 kg ha-1 (17.53) and Ser125 with 150 kg ha-1 (16.20) NPSB blended fertilizer rate, respectively, while the lowest number of total pods per plant (5.46) was from variety Sab632 without blended NPSB application rate (Table 9). In most fertilizer rates, the number of pods per plant of the Bz2 and Sab632 varieties was lower than that of the Ser119 and Ser125 varieties.

Increasing the application rate of blended NPSB fertilizer from 0 to 150 kg NPSB ha^{-1} resulted in a progressive increase in the number of pods per plant. The highest number of pods at the highest NPSB (150 kg ha^{-1}) may be attributed to the fact that NPSB promotes common bean establishment, node formation, canopy development, and pod setting, and that the increase in number of pods at this level may be due to various enzymatic activities that controlled flowering and pod formation. This result is in agreement with the finding of Shumi et al. (2018), who reported that increasing the application of blended NPS fertilizer from 0 to 250 kg ha^{-1} increased the number of pods per plant of common bean from 8.7 to 18.5.

This result was also in agreement with the finding of Desta and Ermias (2019), who reported that the interaction effect of varieties and NPSB blended fertilizer rates, had a significant effect on the number of pods per plant. Variety Nassir with 200 kg NPSB ha^{-1} produced significantly the highest number of pods per plant (34.3). In contrast, lowest number of pods per plant was recorded for variety Hawassa-Dume with 50 kg ha^{-1} NPSB fertilizer (12.7).

Similarly, Moniruzzaman *et al.*, (2008) reported that the maximum number of pods per plant (25.49) was obtained with the application of 120-120-60-20-4-1 kg N-P_2O_5-K_2O-Zn-B. Many scientists agree that the increasing number of pods per plant due to the application of phosphorus fertilizer confirms the fact that P fertilizer promotes the formation of nodes and pods in legumes (Hassen, 2020).

In line with this result, Taminaw (2019) also reported that the main effects of varieties, NPS fertilizer rates, and their interaction had a highly significant ($p<0.01$) effect on the number of pods per plant. Variety Awash-melka with 200 kg NPS ha^{-1} produced the highest number of pods per plant (28.4), while variety Awash1 without NPS fertilizer gave the lowest number of pods per plant (13.71).

Table 9 Interaction effects of varieties and NPSB fertilizer rates on number of pod plant^{-1} of common bean

	NPSB (kg ha^{-1})			
Varieties	0	50	100	150
Sab632	5.46^{h}	8.46^{fg}	9.80^{efg}	12.40^{cde}

Ser119	8.20^{gh}	11.93^{cde}	17.53^{a}	17.60^{a}
Ser125	10.40^{defg}	12.13^{cde}	13.46^{bc}	16.20^{ab}
Bz2	8.53^{fg}	12.46^{cde}	11.40^{cdef}	13.06^{cd}
LSD(0.05)		2.95		
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.

4.3.2. Number of seeds pod^{-1}

The analysis of variance showed that the number of seeds per pod was highly significantly ($p<0.01$) affected due to varieties and also significantly ($p<0.05$) affected by NPSB fertilizer rates, but not significantly affected due to the interaction of varieties with blended NPSB fertilizer rates (Appendix Table 3 and Table 10).

The maximum number of seeds per pod (3.76) was recorded for variety Ser125, and it was statistically on par with variety Ser119 (3.74); while the lowest number (3.08) was recorded for variety Bz2 (Table 10). The significant difference among the varieties for seed number pod^{-1} might be attributed to their genetic differences rather than the management, and this could also be attributed to the variation in size of the seeds of the varieties. In line with this, Fageria and Santos (2008) reported that the number of seeds per pod of different common bean varieties varied in the range of 3.1 to 6 and attributed the difference to the genetic variation of varieties.

The highest number of pods per plant (3.70) was obtained with a blended NPSB rate of 100 kg ha^{-1} applied, and it was statistically at par with 100 kg ha^{-1} (3.65), and the lowest (3.14) was recorded at a 0 kg NPSB ha^{-1} rate (Table 10). The increase in the number of seeds per pod with NPSB fertilizer application rates might be due to the fact that P is an essential component in seed formation. Phosphorus plays a vital role in protein synthesis, along with phospholipids and phytin, all of which are important in seed formation and development (Rahman *et al*., 2008).

In agreement with this result, Desta and Ermias (2019), who stated that the application rate of blended NPSB fertilizer had a significant effect on the number of seeds per pod. The highest number of seeds per pod (4.4) was recorded with the application of a 200 kg ha^{-1} NPSB fertilizer rate, while the least (3.8) was recorded without fertilizer application. Similarly, Meseret and Amin (2014) also reported that the number of seeds per pod of common bean was increased from 3.14 to 4.2 with increased levels of P from 0 to 92 kg P2O5 ha^{-1}.

This result was in line with Wondwosen and Tamado (2019), who reported that the number of seed pod-1 was significantly affected due to common bean varieties. The maximum number of seeds per pod (4.65) was recorded from the variety Awash Melka, while the lowest number of seeds per pod (3.98) was recorded from the variety Red-Wolayita.

Table 10 Main effects of varieties and NPSB fertilizer rates on Number of seed per pod of common bean

Treatments	Number of seed per pod
Varieties	
Sab632	3.21^{b}
Ser119	3.74^{a}
Ser125	3.76^{a}
Bz2	3.08^{b}
Mean	3.447
LSD(0.05)	0.413
NPSB rates (kg ha^{-1})	
0	3.14^{b}
50	3.29^{ab}
100	3.70^{a}
150	3.65^{a}
Mean	3.445
LSD(0.05)	0.41
CV	14.36

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.

4.3.3. Hundred Seed Weight (g)

The result of this experiment showed that hundred seed weight was highly significantly ($p<0.01$) affected by the main effects varieties and NPSB fertilizer rates and significantly ($p<0.05$) affected by the interaction of varieties and blended NPSB fertilizer rates (Appendix Table 3 and Table 11).

The highest hundred seed weight (42.3) was recorded from variety Sab632 with a combination of 150 kg NPSB ha^{-1} while the lowest hundred seed weight (25.40) was recorded from variety Ser119 without NPSB fertilizer application (Table 11). This seed weight variation might be due to the genetic constituents of plant varieties that determine the size of grain and nutrients (N, P, S, and B) in critical growth periods of plants, which were improved at the optimum level of blended NPSB fertilizer rates. Similarly, according to Mfilinge *et al.* (2014), the P-fertilized crop produced more pods per plant, which were better filled with heavier seed than the control. The increase in hundred seed weight might also be attributed the presence of a difference in seed size among common bean varieties, as hundred seed weight increases with increasing seed size.

In line with this finding, Farkhanda (2019) reported that Long Red Bean with 200 kg NPS ha^{-1} had the heaviest seed weight (54.33 g), while Nasir with 50 kg blended NPS application rates had the lightest seed weight. The increase in hundred seed weight as a result of P application might also be attributed to the important role the nutrient plays in the vegetative growth of crops, leading to increased seed size (Zafar *et al*., 2013).

In agreement with this result, Habtamu *et al*., (2017) also reported that the interaction effect of varieties and NP fertilizer rate had a significant effect on the hundred seed weight of common bean. Variety Deme with the highest NP rate (46 kg ha^{-1} of P2O5 and 41 kg ha^{-1}of N) scored the maximum hundred seed weight (54.2), while the minimum was recorded from variety Awash with the lowest NP rate (0 kg ha^{-1}).

Similar findings were reported by Teame *et al*., (2020), who showed that the highest hundred seed weight (28.43 g) was recorded in the Nasir variety with a combination of 20 x 45 kg ha^{-1} PS rate, whereas the lower hundred seed weight (24.20 g) was obtained from Awash-Melka in the treatment combination of 30 x 60 kg ha^{-1}.

Table 11 Interaction effects of varieties and NPSB fertilizer rates on hundred seed weight of common bean

	NPSB (kg ha^{-1})			
Varieties	0	50	100	150
Sab632	41.27^{ab}	41.47^{ab}	40.46^{b}	42.30^{a}
Ser119	25.40^{h}	25.63^{gh}	26.06^{efgh}	26.04^{efgh}
Ser125	25.76^{fgh}	26.67^{efg}	26.70^{ef}	26.85^{e}
Bz2	33.93^{d}	34.11^{d}	35.48^{c}	35.83^{c}
LSD(0.05)		1.04		
CV		2.0		

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.

4.3.4. Above-ground dry biomass

The analysis of variance computed for above ground biomass yield showed a highly significant ($p<0.01$) difference for all the main effects and a significant ($p<0.05$) differences for the interaction (Appendix Table 4). These indicated the differential response of varieties towards a fertilizer rates with regard to the performance of above ground biomass yield. It is known that above ground biomass yield is a constituted from several traits and genes; such as plant height, number of pods, leaf number and size, grain yield and straw yield. That indicates the involvement of many parameters for its manifestation. Therefore, it is expected that this parameter to be highly influenced by fertilizer effects and display differential responses among varieties.

Ser119 variety, with an application of 150 kg blended NPSB ha^{-1} scored significantly the highest above ground dry biomass (6131.7 kg ha^{-1}). It was statistically par with variety Ser125 with a 150 kg NPSB fertilizer rate (6106.7 kg ha^{-1}) and followed by treatment combinations of variety Sab632 with 100 kg ha^{-1} NPSB (5840 kg ha^{-1}) and variety Ser119 with 100 kg ha^{-1} NPSB (5838.3 kg ha^{-1}), while the lowest above ground dry biomass (3106.7 kg ha^{-1}) was recorded from variety Bz2 with a 0 kg blended NPSB ha^{-1} application rate (Table 12).

The results generally showed an increase in biomass production with an increase in the rate of blended NPSB in most of the bean varieties. The increase in above-ground dry biomass of the varieties across blended NPSB might be attributed to the fact that the higher availability of nitrogen significantly increased plant height, the number of pods per plant, and the overall vegetative growth of the crop, which contributed to higher above-ground dry biomass.

In agreement with this result, Asmachew *et al*., (2022) reported that the interaction of varieties and NPSZnB fertilizer rates had a significant effect on the above-ground dry biomass of soybean. Planting variety Pawe-03 with the application of a 200 kg ha^{-1} blended NPSZnB fertilizer rate gave the highest (6944.44kg ha^{-1}) above ground dry biomass yield, while the lowest (2874.60kg ha^{-1}) above ground dry biomass was recorded when variety Pawe-01 was planted with a 0 kg application of fertilizer.

In conformity with this result, Shumi (2018) reported the highest above-ground dry biomass (10278 kg ha^{-1}) was recorded from variety Angar in combination with 250 kg NPS ha^{-1}, whereas the lowest above-ground dry biomass (4045 kg ha^{-1}) was obtained from variety Nasir under the 0 kg NPS rate.

Table 12 Interaction effects of varieties and NPSB fertilizer rates on AGDBM of common bean

		NPSB (kg ha^{-1})		
Varieties	0	50	100	150
Sab632	3246.7^{f}	4318.3^{e}	5840^{ab}	5796.7^{abc}
Ser119	4403.3^{e}	5373.3^{bcd}	5838.3^{ab}	6131.7^{a}
Ser125	4365^{e}	5098.3^{d}	5813.3^{ab}	6106.7^{a}
Bz2	3106.7^{f}	4186.7^{e}	4528^{e}	5276.7^{cd}
LSD(0.05)		533.96		
CV		6.45		

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. Grain yield

The analysis of variance showed that the grain yield was highly significant ($p<0.01$) influenced by the main effects of varieties and blended NPSB fertilizer rates and their interaction (Appendix Table 4 and Table 13).

Variety Ser119 with 150 kg NPSB ha^{-1} produced 66.25% (1897 kg ha^{-1}) more yield than variety Bz2 without fertilizer application, and it was statistically equivalent with variety Ser119 with 100 kg NPSB fertilizer rate (2849.3 kg ha^{-1}); it was followed by the treatment combination of variety Ser125 with 150 kg NPSB ha-1 (2802.4 kg ha^{-1}). while the lowest grain yield (966.1 kg ha^{-1}) was recorded from variety Bz2 with a 0 kg ha^{-1} NPSB fertilizer rate, and this was also followed by variety Sab632 (994.1 kg ha^{-1}) without NPSB fertilizer application (Table 13).

This might be due to the genetic variation within common bean varieties. Grain yield increased significantly as NPSB fertilizer rate was increased. This might be due to increased nutrient uptake and better growth due to the synergetic effect of the nutrients, which enhanced yield and yield components at the highest NPSB rate. The contribution of this balanced NPSB fertilizer was great in order to increase yield components through higher uptake of all nutrients and increased translocation of assimilates from source to sink. The number of pods per plant and the number of seeds per pod are associated with grain yield; the variety with a higher number of pods and seeds per pod significantly contributes to a higher grain yield.

According to this experiment, it was concluded that using blended nutrients with supplementary nitrogen is more effective than using single elements as fertilizer in order to get a high grain yield. In agreement with the result of this study, Hassen (2020) observed significant variations due to the interaction effect of variety and blended NPS fertilizer rates on common bean grain yield. Variety Fadis, with the application of 150 kg ha^{-1} fertilizer, recorded the highest seed yield (2565 kg ha^{-1}), while the lowest grain yield (1383 kg ha^{-1}) was recorded from variety Babile with a 0 kg NPS ha^{-1} application rate.

In agreement with these results, Asmachew *et al*., (2022) also reported that different rates of blended NPSZnB fertilizer rates, varieties, and interaction effects of NPSZnB rates and varieties had highly significant effects on the seed yield of soybean. The maximum grain yield (2876.98 kg ha^{-1}) was produced when the Pawe-03 variety was planted with the application of 100 kg ha^{-1} NPSZnB fertilizer, while the minimum grain yield (1030.16 kg ha^{-1}) was recorded when the Pawe-01 variety was planted with nil fertilizer applications.

In line with this result, Kawte *et al*., (2020) reported that the interaction effect of mung bean varieties and blended NPS fertilizer was significant on grain yield. The maximum grain yield (1244.7 kg ha^{-1}) was recorded for variety N-26 at 150 kg ha^{-1}, while the lowest grain yield (655.7 kg ha^{-1}) was recorded for Shewarobit at a 0 kg rate of NPS. Similarly, in agreement with this result, Negash and Rezene (2015) also reported that the application of NP (27 kg N and 69 kg P2O5) had a significant effect on the grain yield of common bean.

Table 13 Interaction effects of varieties and NPSB fertilizer rates on grain yield of common bean

		NPSB (kg ha^{-1})		
Varieties	0	50	100	150
Sab632	994.1^{h}	1461.1^{g}	2481.9^{bc}	2459.1^{bc}
Ser119	1367.4^{g}	2168.8^{cd}	2849.3^{a}	2862.7^{a}
Ser125	1453.6^{g}	1949.6^{de}	2751.7^{ab}	2802.4^{a}
Bz2	966.1^{h}	1595.5^{fg}	1574^{fg}	1826.2^{ef}
LSD(0.05)		319.97		
CV		9.73		

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. Harvest Index (HI)

Harvest index is the ratio of grain yield to total dry biomass and is a measure of reproductive efficiency. The result of this experiment showed that the harvest index was significantly ($p<0.05$) influenced by the interaction of varieties and blended NPSB fertilizer rates (Appendix Table 4 and Table 14).

The highest harvest index (48.79%) was recorded from the Ser119 variety with the application of 100 kg ha^{-1} followed by treatment combinations of variety Ser125 with 100 kg ha^{-1} NPSB (47.32%) and variety Ser119 with 150 kg ha^{-1} NPSB (46.79%), respectively, whereas the lowest harvest index (30.91%) was obtained from variety Sab632 without the application of NPSB fertilizer (Table 14). The variation in harvest index could be due to synergetic effect of blended fertilizer and genetic variability of varieties in response to blended fertilizer; higher grain yield at higher fertilizer rate. From this investigation we can conclude that increased rate of blended NPSB fertilizer can increases ratio of harvest index which indicates the higher production of grain yield.

In agreement with this result, Uddin *et al*., (2020) reported that the interaction of variety and boron had a significant effect on the harvest index of French bean. The variety Bahri Jharseem-3 had the highest harvest index (37.19) when fertilized with 1.5 kg of boron ha-1.Whereas the minimum harvest index (30.68%) was recorded from Bahri Jharseem-1, which was not fertilized with boron (0 kg ha^{-1}). Similarly, in line with this result, Shumi (2018) reported that the interaction of varieties and blended NPS fertilizer rates had a significant effect on the harvest index of common bean. The highest harvest index (53%) was recorded for variety Angar with an application of blended NPS fertilizer at 150 kg ha^{-1}.

In conformity with this result, Wondwosen and Tamdo (2017) also reported that the highest harvest index (49%) was obtained from variety Awash1 with the application of 18 kg P: 46 kg P2O5 ha^{-1}, whereas the lowest harvest index (26%) was recorded from the Chercher variety without fertilizer application.

Table 14 Interaction effects of varieties and NPSB fertilizer rates on Harvest index of common bean

Treatments		harvest index (%)		
Varieties	0	50	100	150
Sab632	30.91^{f}	33.86^{def}	42.50^{abc}	42.43^{abc}
Ser119	31.12^{f}	40.46^{bcd}	48.89^{a}	46.79^{ab}
Ser125	33.27^{ef}	38.35^{cde}	47.32^{a}	45.91^{ab}
Bz2	31.34^{f}	38.10^{cde}	34.76^{def}	34.56^{def}
LSD(0.05)		6.6		
CV		10.26		

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

The correlation between growth and yield components of common bean as influenced by the application of blended NPSB fertilizers was computed and its results are shown in Table 15. The present study indicated that Plant height was highly significantly and strong positively correlated with number of pod per plant (r=0.84***), number of seed per plant (r=0.82***), hundred seed weight (r=0.79***), grain yield (r=0.67***), nodule dry weight and above ground dry biomass (r=0.40**) and also significantly and positively correlated with total number of nodule (r=0.30*) and effective nodule number (r=0.29*). Days to maturity highly significantly and negatively correlated with total number of nodules (r=-0.56*). Total number of nodule was highly significantly and positively correlated with effective nodule number (r=0.98***) and nodule dry weight (r=0.71***), above ground dry biomass (r=0.49**), number of pod per plant (r=0.42*), number of seed per plant (r=0.43*), hundred seed weight (r=0.41*) and grain yield (r=0.36*). Similarly, effective nodule per plant was highly significantly and positively correlated with nodule dry weight (r=0.74***) and above ground dry biomass (r=0.53***) and also significantly and positively correlated with number of pod per plant (r=0.41*), number of seed per plant (r=0.42*), hundred seed weight (r=0.39*) and grain yield (r=0.37*). Nodule dry weight was highly significantly and positively correlated with number of pod per plant (r=0.53***), grain yield (r=0.70***) and above ground dry biomass (r=0.69***) and negatively correlated with harvest index.

Similarly, number of pod per plant was highly significantly and strong positively correlated with number of pod per plant (r=0.84***), number of seed per plant (r=0.98***), hundred seed weight (r=0.83***), grain yield (r=0.78***) and above ground dry biomass (r=0.60***). Number of seed per pod was highly significantly and strong positively correlated with hundred seed weight (r=0.83***), grain yield (r=0.74***) and above ground dry biomass (r=0.61***). In agreement with this study, Amanuel *et al. (2018)* obtained a highly significant and positively correlated number of pods per plant, and similarly, the number of seeds per pod showed a positive and highly significant correlation with grain yield and above ground dry biomass.

Growth parameters and yield components contributed to grain yield increment because grain yield was found to be highly significantly and positively correlated with plant height (r=0.67***), nodule dry weight (r=0.70***), number of pod per plant (r=0.78***), number of seed per plant (r=0.74***), hundred seed weight (r=0.68***), and above ground dry biomass (r=0.59***), total number of nodule (r=0.36*), effective nodule per plant (r=0.37*). In line with this result, Beruktawit *et al. (*2012) reported that grain yield was highly correlated with the number of pods per plant, number of seeds per plant, above ground dry biomass, and hundred seed weight. Similarly, Atinafu (2020) reported a comparable investigation in which he found a highly significant and positive relationship between grain yield, above-ground dry biomass, plant height, hundred seed weight, number of pods per plant, number of seeds per pod, days to flowering and maturity, number of total nodules per plant, and number of effective nodules per plant.

Table 15 Simple correlation coefficient (r) of growth and yield parameters of common bean in Ezha district

	DF	DM	PH	TNPP	ENPP	NDW	NPPP	NSPP	HSW	GY	AGDBM	HI
DF	1											
DM	0.00^{NS}	1										
PH	0.00^{NS}	0.00^{NS}	1									
TNPP	0.0054^{NS}	-0.56***	0.30*	1								
ENPP	0.00^{NS}	-0.054***	0.288*	0.98***	1							
NDW	-0.0021^{NS}	0.031^{NS}	0.40**	0.71***	0.74***	1						
NPPP	-0.0047^{NS}	-0.12^{NS}	0.84***	0.42*	0.41*	0.53***	1					
NSPP	0.041^{NS}	-0.16^{NS}	0.82***	0.43*	0.42*	0.52**	0.98***	1				
HSW	0.105^{NS}	-0.23^{NS}	0.79***	0.41*	0.39*	0.46**	0.83***	0.83***	1			
GY	-0.11^{NS}	0.19^{NS}	0.67***	0.36*	0.37*	0.70***	0.78***	0.74***	0.68***	1		
AGDBM	0.028^{NS}	-0.08^{NS}	0.40**	0.49**	0.53***	0.69***	0.60***	0.61***	0.53**	0.59***	1	
HI	-0.025^{NS}	-0.32^{NS}	0.06^{NS}	-0.39**	-0.42*	-0.75***	-0.07^{NS}	-0.06^{NS}	-0.018^{NS}	-0.46**	-0.47**	1

***= very highly significant, **= highly significant, *= significant, NS= none significant, DF= Days to 50% flowering, DM = Days to 90% physiological maturity, PH= Plant height, TNPP = Total nodule number per plant, ENPP= effective nodule number per plant NDW=nodule dry weight, NPPP= number of pod per plant, NSPP = Number of seeds per pod, HSW= Hundreds seed weight, GY= grain yield, AGDBM= Above Ground Biomass yield, and HI= Harvest index

4.5. Partial Budget Analysis

The partial budget analysis of the 16 treatments is shown in Table 15. Based on this result, the highest net benefit of 81,123.3 Birr ha^{-1} was obtained from the treatment combination of 100 kg NPSB ha^{-1} application rate for variety Ser119 followed by the treatment combination of Ser119 with 150 kg ha^{-1} NPSB blended fertilizer (79,408.51 Birr ha^{-1}). On the other hand, the lowest net benefit (18,129.07 Birr ha^{-1}) was obtained from variety Bz2 with a 0 kg ha^{-1} NPSB blended fertilizer rate (Table 14). Therefore, the most productive and attractive variety with NPSB fertilizer application rate for producers or farmers with a higher net benefit was Ser119, with a 100 kg NPSB ha^{-1} fertilizer application rate. In agreement with this result, Desta and Ermias (2019) obtained the highest net benefit of 28,635.3 Birr with the application of 100kg NPSB ha^{-1} for common bean.

Table 16 Summary of partial budget analysis of response of common bean varieties to the application of NPSB fertilizer

Treatment		AGY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})
Variety	NPSB (kg ha^{-1})				
Sab632	0	894.713	35,788.457	16,650.00	19,138.45
	50	1314.96	52,598.364	19,250.00	33,348.36
	100	2233.72	89,348.92	21,450.00	67,898.92
	150	2213.167	88,526.574	23,650.00	64,876.57
Ser119	0	1230.647	49,225.83	16,650.00	32,577.83
	50	1951.88	78,075.123	19,250.00	58,825.12
	100	2564.33	102,573.303	21,450.00	81,123.30
	150	2576.46	103,058.519	23,650.00	79,408.51
Ser125	0	1308.243	52,329.63	16,650.00	35,679.63
	50	1754.63	70,185.154	19,250.00	50,935.15
	100	2476.52	99,060.802	21,450.00	77,610.80
	150	2522.193	100,887.809	23,650.00	77,237.80
Bz2	0	869.477	34,779.074	16,650.00	18,129.07
	50	1435.95	57,438	19,250.00	38,188
	100	1416.33	56,653.2	21,450.00	35,203.2
	150	1643.58	65,743.2	23,650.00	42,093.2

Where; AGY =Adjusted Grain Yield, GFB = Gross Field Benefit, TVC =Total Variable Cost, NB=Net Benefit and ETB = Ethiopian Birr. Cost of NPSB = 44.00 ETB kg^{-1}*, Farm gate price of Common bean = 40.00 ETB kg*$^{-1}$ *and Labor cost = 150.00 ETB day*$^{-1}$*.*

5. SUMMARY AND CONCLUSION

Common bean is among the most important pulse crops cultivated in Ethiopia. It is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enable households to get the cash income required to purchase food and other household needs when other crops have not yet matured. However, the current national average yield of common beans is far less than the attainable yield. This is partly due to low soil fertility management and a lack of improved varieties. Thus, a field experiment was conducted during the 2022 cropping season to evaluate the growth and yield response of common bean varieties to blended NPSB fertilizer rates at Ezha district, Gurage zone of Southern Ethiopia.

Almost all parameters were significantly and highly significantly influenced by the interaction of both factors. Days to flowering, days to physiological maturity, total nodule per plant, effective nodule per plant and seed yield were highly significantly ($p<0.01$) affected due to the interaction of both factors while, plant height, nodule dry weight, number of pod per plant, hundred seed weight, above ground dry biomass and harvest index were significantly affected by the interaction of both factors but, number of seed per pod was not significantly affected by the interaction of varieties and NPSB fertilizer rates.

The application of 150 kg of NPSB ha^{-1} resulted in the highest days to flowering (51.0), nodule dry weight (3.106), number of pods per plant (17.60), AGDBM (6131.7 kg ha^{-1}), and seed yield (2862.7 kg ha^{-1}) for variety Ser119. The maximum days to maturity (99.33) and plant height (83.73cm) were recorded from variety Ser125 with a 150 kg NPSB fertilizer application rate. The highest number of total nodules (73.67), effective nodules (43.55) and the highest harvest index (48.89%) were recorded from variety Ser119 with a 100 kg ha^{-1} NPSB fertilizer application rate.

The highest hundred seed weight (42.30) was recorded from variety Sab632 with 150 kg ha^{-1} NPSB fertilizer application rate. The highest number of seeds per pod was recorded from variety Ser125.

Most of the crop parameters considered were significantly and positively correlated with each other as a result of the applied NPSB blended fertilizer. The result indicated that grain yield was found to be highly significantly and positively correlated with plant height, number of pods per plant and above ground dry biomass.

The economic analysis showed that the highest net benefit of 81,123.30 birr ha^{-1} was obtained from the treatment combination of 100 kg NPSB ha^{-1} application rate for variety Ser119. Thus, it can be concluded from the result of the present study that the use of Ser119 variety with the application of 100 kg NPSB ha^{-1} could be recommended to enhance the productivity of common bean in the study area. However, the results of the present study need to be validated and proven in the same agro-ecologies and seasons with further experiments.

6. REFERENCES

Aaron S., Tening F., Tchunentu F. and Gwanpua B. (2008) Suitability of different extractants and Turbidimetric reagents in quantitative of sulfate-sulfer in south western Cameroon. Journal of the Cameroon academy of sciences vol 7 No 3.

Abebe A. and Mekonnen Z. (2019). Common Bean (*Phaseolus Vulgaris L.*) Varieties Response to Rates of Blended NPKSB Fertilizer at Arba Minch, Southern Ethiopia. Advanced Crop Science Technology v.7: 429.

Adriano S., Luis F. and Leonardo C. (2017). Common bean grain yield as affected by sulfur fertilization and cultivars Rev. Ceres, Viçosa, v. 64, n.5, p. 548-552.

Alemitu M. (2011). Factors affecting adoption of improved haricot bean varieties and associated agronomic practices in Dale woreda, SNNPRS M.Sc. Thesis, Hawassa University, Hawassa, Ethiopia.

Ali K., Gemechu A., Beniwal M., Makkouk S. and Halila M. (2003). Food and forage legumes of Ethiopia; Progress and prospects on food and forage legume proceeding of the workshop, 22-26, Addis Ababa, Ethiopia.

Ali R., Khan M. and Khat R. (2008). Response of rice to different sources of sulfur (S) at various levels and its residual effect on wheat in rice-wheat cropping system. Application in common bean in a no-tillage system communications Beans (Phaseolus) spp.–model food legumes. Plant and Soil, 252, 55-128.78 39:581-583.

Amanuel A. and Girma A. (2018). Production Status, Adoption of Improved Common Bean (Phaseolus vulgaris L.) Varieties and Associated Agronomic Practices in Ethiopia. J Plant Sci Res. 2018;5(1): 178.

Amanuel A., Amisalu N. and Merkeb G. (2018). Growth and yield of common bean (*Phaseolus vulgaris* L.) cultivars as influenced by rates of phosphorus at Jimma, Southwest Ethiopia. Journal of Agricultural Biotechnology and Sustainable Development. Vol. 10(6), pp. 104-115, June 2018 DOI: 10.5897/JABSD2018.0312 Article Number: 3D343E557179 ISSN 2141-2340

Amare G., Demelash A. and Ayele T. (2014). The response of haricot bean varieties to different rates of phosphorus at Arba Minch, Southern Ethiopia. Journal of Agricultural and Biological Science, 9(10): 344-350.

Asmachew A., Yayeh B. and Dereje A. (2022) Response of yield and quality of soybean (*Glycine max L.*) Merrill] varieties to blended NPSZnB fertilizer rates in Northwestern Ethiopia. Contents lists available at ScienceDirect Heliyon journal homepage: www.cell.com/heliyonBahir Dar University, College of Agriculture and Environmental Science, P.O. Box 5501, Bahir Dar, Ethiopia

Atinafu T. (2020). Effect of Types And Rates of Blended Fertilizers On Selected Chemical Soil Properties and Yield of Common Bean (*Phaseolus Vulgaris L.*) in Debub Ari District, Southern Ethiopia Msc Thesis. Haramaya University, Haramaya.

Attar H., Blavet D., Selim E., Abdelhamid M. and Drevon J. (2012). Relationship between phosphorus status and nitrogen fixationby common beans (*Phaseolus vulgaris L.*) under drip irrigation International Journals of Environmental Science Technology v. 9:1–13

Bashir K., Ali S. and Umari A. (2011). Effect of different phosphorus levels on xylem sap components and their correction with growth variables of Mash bean. Sarhad Journal of Agriculture 27(4):10-20.

Beruktawit M., Tamada T., Nigussie D. (2012). Response of common bean (Phaseolus Vulgaris L.) cultivars with different growth habits to plant density at Haramaya, Eastern Ethiopia. 29 p.

Bouyoucos G. (1962). Hydrometer method improved for making particle size analyses of soils. Journal of Agronomy, 54 (5) pp., 464-465.

Buttery B. (1969). Analysis of the growth of soybeans as affected by plant population and fertilizer. Canadian Journal of Plant Sciences 49:675-684

China G. (2018). Response of Chickpea (*Cicer Arientinum L.*) Varieties to Blended NPSZNB Fertilizer Application in Ada'a-Liban District, Central Ethiopia. Msc. Thesis

CIAT (Centro Internacional de Agricultural Tropical) (1986). The cultivated species of Phaseolus; study guide to be used as a supplement to the audio tutorial unit on the same topic Production: Fernando Fernandez O., Cali, Colombia. CIAT 52 p. (Series 04EB 09.02).

CIAT (Centro Internacional de Agricultural Tropical), (1992). Constraints to and opportunities for improving bean production. A planning document 1993–98. An achievement document 1987–92, CIAT, Cali Colombia.

CSA (Central Statistical Agency) (2017). Agricultural sample survey, area and production of temporary crops, private holdings for the 2016/2017, Meher season. Statistical Bulletin No. 584. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). (2018). Report on area and production of major crops (Private Peasant Holdings, Meher Season), The Federal Democratic Republic of Ethiopia (FDREP). Addis Ababa, Ethiopia 1:10-29.

CSA (Central Statistics Agency) (2021). *Crop and livestock utilization*. The Federal Democratic Republic of Ethiopia Central Statistical Agency Volume VII report on private peasant holdings, Meher season (Vol. 7).

Dagne Chimdessa (2016). Soils characteristics in maize based farming system of western Oromia, Ethiopia. Journal of Energy and Natural, 5(4): 37-46.

Davis J. and Brick M. (2009). Fertilizing Dry Beans. Colorado State University Available.

Desta A. and Ermias E. (2019). Effect of NPSB Fertilizer Rates on Growth, Yield, and Yield Components of Haricot Bean (*Phaseolus vulgaris L.*) Varieties at Mid-altitude of Hadiya, Ethiopia. International Journal of Applied Sciences: Current and Future Research Trends (IJASCFRT) v. 4, No 1, pp 12-29

Dewis J. and Freitas F. (1984). Physical and chemical methods of soil, and water analysis, 51– 106. New Delhi, India: Oxford and IBH.

Dwivedi D., Singh H., Shahi K. and Rai J. (1994). Response of French bean (*Phaseolus vulgaris L.*) to population density and nitrogen levels under mid upland situation in north-east alluvial plains of Bihar. Indian Journal of Agronomy 39:581-583.

Endrias C. (2017). Effect of Nitrogen-Phosphorus-Sulfur-Blended Fertilizer and Rhizobium Inoculation on Yield Components and Yield of Common Bean (Phaseolus vulgaris L.) Varieties at Bolosso Bombe District, Southern Ethiopia. MS thesis, Haramaya University, Haramaya, Ethiopia.

EthioSIS (Ethiopia Soil Information System), (2016). Soil Fertility Status and Fertilizer recommendation atlas of SNNPRS, Ethiopia. Ministry of Agriculture and natural resource (MoANR) and Agricultural Transformation Agency (ATA).

Fageria N. and Santos A. 2008b. Yield physiology of dry bean. Journal Plant Nutrition, 31:983–1004.

Fageria N. and Moreira A. (2011). Advances in Agronomy. In Donald, L. (Ed.). The Role of Mineral Nutrition on Root Growth of Crop Plants (1st ed., pp. 251-331). Academic press.

Fageria N., Baligar V. and Jones C. (2011). Growth and mineral nutrition of field crops. 3ª ed. Boca Raton, CRC Press. 586 p.

FAOSTAT (Food and Agriculture Organization) (2010). At www.fao.org.

Farkhanda K., Niamat U., Imran U., Sami U., Abdulaziz K., Tehseen A. and Abdur R. (2019) Impact of NPS fertilizer on the yield and yield components of Common Bean varieties in rainfed conditions of Pakistan. International Journal of Agriculture and Biological Sciences- ISSN (2522-6584), Ghazi University, Dera Ghazi Khan, Pakistan; 5 Department of Horticulture, Faculty of Agriculture, Gomal University, D. I. Khan.

Ferris S. and Kaganzi E. (2008). Evaluating marketing opportunities for haricot beans in Ethiopia. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper7. ILRI (International Livestock Research Institute), Nairobi, Kenya 68 pp.

Fisseha N. and Yayis R. (2015). Nitrogen and phosphorus fertilizers rate as affecting common bean production at Areka, Ethiopia. Journal of 178 Afr. J. Plant Sci. Agriculture and Crops 1(3):33-37

Fistum M., Gemechu G. and Belay R. (2020). Evaluation of Newly Released Common Bean Varieties through On-Farm Demonstrations in ATJK and Shalla Districts of Oromia Regional State, Ethiopia Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center Volume 6, Issue 1, PP 43-48, ISSN No. 2454–622.

Ganeshamurthy A. and Sammi R. (2000). Effect of Integrated Use of Farmyard Manure and Sulfur in a Soybean and Wheat Cropping System on Nodulation, Dry Matter Production and Chlorophyll Content of Soybean on Swell-Shrink Soils in Central India. Journal of Agronomy and Crop science, 185(2): 91-97.

Gebre-Egziabher M., Hadush T. and Fetien A. (2014). Agronomic performance of some haricot bean varieties (*Phaseolus vulgaris L.*) with and without phosphorus fertilizer under irrigated and rain fed conditions in the Tigray and Afar regional states, northern Ethiopia. Momona Ethiopian Journal of Science, 6(2):95-109.

Girma A. (2009). Effect of NP fertilizer and moisture conservation on the yield and yield components of haricot bean (*Phaseolus vulgaris L.*) in the Semi-arid zones of the Central Rift Valley in Ethiopia. Advances in Environmental Biology 3(3):302-307.

Gomez O. (2004). Evaluation of Nicaraguan common bean (*Phaseolus vulgaris L.*) landraces Doctoral thesis, Department of ecology and crop production sciences Uppsala, Swedish University of Agricultural Sciences. ISSN 1401-6249 ISBN 91-576-6762-4

Habtamu A., Berhanu A. and Tamado T. (2017). Response of Common Bean (*Pharsalus vulgaris L.*) Cultivars to Combined Application of Rhizobium and NP Fertilizer at Melkassa, Central Ethiopia. *International Journal of Plant & Soil Science 14(1): 1-10, 2017; Article no.IJPSS.30864 ISSN: 2320-7035*

Habte E, Gebeyehu S, Tumsa S, Negash K (2014) Decentralized common bean seed production and delivery system. Melkassa agricultural research center, Ethiopian institute of agricultural research, Ethiopia.

Hansch R. and Mendel R. (2009). Physiological functions of mineral micronutrients (cu, Zn, Mn, Fe, Ni, Mo, B, Cl). Current Opinion in Plant Biology, 12(3), 259-266.

Hassen A. (2020) Response of Common Bean (*Phaseolus Vulgaris L.*) Varieties To Rate of Blended NPS Fertilizer In Jarso District, East Hararghe, Haramaya University, Msc Thesis.

Horneck D., Sullivan D., Owen J. and Hart J. (2011). Soil test interpretation guide.

Jori E. (2014). Soil fertility constraints for the production of common bean (Phaseolus vulgaris L.) in the Usambara Mountains of northern Tanzania. Applied Environmental Geosciences VU University MSc. Thesis Applied Environmental Geosciences

Katungi E., Farrau A., Chiano J., Sperting L. and Beebe S. (2009). Common bean Eastern and Southern Africa: A situation and outlook analysis. CIAT, Cali.

Kawte K., Dereje Sh. and Mesfin B. (2020). Performance of mung bean (*Vigna radiata L.*) varieties at different NPS rates and row spacing at Kindo Koysha district, Southern Ethiopia, Cogent Food & Agriculture, 6:1, 1771112, DOI: 10.1080/23311932.2020.1771112

Kay D. (1979). Food Legumes. Tropical Product Institutes. 56/62 Gray's lnn Road London. p. 25.

Kihara J., Bolo P., Kinyua M., Rurinda J. and Piikki K. (2020). Micronutrient deficiencies in African soils and the human nutritional nexus: opportunities with staple crops. Environmental Geochemistry and Health, 42(3), 1-19.

Kipngetich C. (2021). Response of common bean (*Phaseolus vulgaris L.*) to lime and customized micronutrient fertilizer in Nandi County, M.Sc. Thesis, Egerton University, Kenya.

Lake M. and Jemaludin S. (2017). The Response of Common Bean (*Phaseoluse Vulgaris L.*) to Various Levels of Blended Fertilizer. International Journal of Research in Agriculture and Forestry Volume 5, Issue 7, 2018, PP 15-20 ISSN 2394-5907 (Print) & ISSN 2394-5915

Landon J. and Manual B. (1991). A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Hong Kong: Longman Scientific and Technical Group Ltd.

Mafuta N. (2017). Effect of spatial arrangement and variety on performance of common bean (*Phaseolus Vulgaris L.*) in Western Kenya, M.Sc. Thesis, University of Eldoret, Kenya.

Marchner H. (1995). Mineral nutrition of higher plants. Sand Diego: Academic press inc

Margalef O., Sardans J., Fernánde M., Molowny R., Janssens I., Ciais P., Goll D., Richter M., Obersteiner M., Asensio D., and Peñuelas J. (2017). Global patterns of phosphatase activity in natural soils. Scientific Reports, 7(1), 1-13.

Marx E., Hart J. and Stevens R. (1996). Soil test interpretation guide.pp.1-7 Oregon State University 2nd edition.

Meseret T. and Amin M. (2014). Effect of Different Phosphorus Fertilizer Rates on Growth, Dry Matter Yield and Yield Components of Common Bean (*Phaseolus vulgaris L.*) World Journal of Agricultural Research; 2(3):88-92.

Mfilinge A., Kevin M. and Patrick A. (2014). Effects of *Rhizobium* inoculation and supplementation with P and K, on growth, leaf chlorophyll content and nitrogen fixation of bush bean varieties. American Journal of Research Communication; 2(10):49-87.

MoANR (2014). Directory of Released Crop Varieties and Their Recommended Cultural Practices. Addis Ababa, Ethiopia.

MoANR (Ministry of Agriculture and Natural Resource). (2016). CROP VARIETY REGISTER ISSUE No. 19. MoANR Plant Variety Release, Protection and Seed Quality Control Directorate. Addis Ababa, Ethiopia.

Moniruzzaman M., Islam M. and Hasan H. (2008). Effect of NPKS Zn and B on yield attributes and yields of French bean in South Eastern Hilly Region of Bangladesh. Journal of Agriculture & Rural Development, 6(1): 75-82.

Morad M., Sara S., Alireza E., Reza C. and Mohammad D. (2013). Effects of seed inoculation by Rhizobium strains on yield and yield components in common bean cultivars (*Phaseolus vulgaris L.*). International Journal of Biosciences, 3, 134-141.

Morgado L. and Willey R. (2003). Effects of plant population and nitrogen fertilizer on yield and efficiency of maize-bean intercropping. Pesquisa Agropecuária Brasileira, 38(11):1257-1264.

Mulugeta A (2011). Factors affecting adoption of improved haricot bean varieties and associated agronomic practices in Dale woreda. SNNPRS M.Sc. Thesis in Plant Sciences (Agronomy), Hawassa University, Hawassa, Ethiopia, Africa.

Muthanna M., Singh A., Tiwari A., Jain V. and Padhi M. (2017). Effect of boron and sulphur application on plant growth and yield attributes of potato (*Solanum tuberosum L.*). International Journals of microbiology, 6.

Nebret T. and Nigussie D. (2017). Effect of Nitrogen and Sulfur Application on Yield Components and Yield of Common Bean (*Phaseolus Vulgaris L.*) in Eastern Ethiopia. Academic Research Journal of Agricultural Science and Research Vol. 5(2), pp. 77-89, DOI: 10.14662/ARJASR2016.053

Negash F. and Rezene Y. (2015) Nitrogen and phosphorus fertilizers rate as affecting common bean production at Areka, Ethiopia. Journals of Agricultural Crops 1: 33-37.

Nuru S. (2020) Effect of Blended NPS Fertilizer and Rhizobium Inoculation on Yield Components and Yield of Common Bean (*Phaseolus Vulgaris L.*) Varieties at Mekdela District, South Wollo, Ethiopia. Academic Journal of Research and Scientific Publishing Vol 2 Issue 18 www.ajrsp.com 115 ISSN: 2706-6495

Nuru S. (2020) Effects of NPS Fertilizer Rates on Growth, Yield and Yield Components of Mungbean (*Vigna radiata L.*) Wilczek] Varieties under Irrigation at Gewane, Northeastern Ethiopia. International Journal of Research in Agricultural Sciences Volume 7, Issue 5, ISSN: 2348 – 3997

Nuru S. and Taminaw Z. (2021) Response of Some Common Bean Varieties to Different Rates of Nitrogen, Phosphorus, Sulfur Fertilizers and Rhizobium Inoculation on

Nodulation, Yield, Yield Attributing Traits. International Journal of Research in Agricultural Sciences Volume 7, Issue 6, ISSN: 2348 – 3997

Oerili J and Richardson W. (1970). The mechanism of boron immobility in plants. Physiol. Plant. 23: 108-116.

Olsen S. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture; Washington.

Petry N., Boy E., Wirth J. and Hurrell R. (2015). The Potential of the Common Bean (*Phaseolus vulgaris* L.) as a Vehicle for Iron Biofortification. Journal of Nutrients Production in Africa, Central International Agricultural Tropical phosphorus application on vertisols at Haramaya University, 133

Ponnamperuma F., Cayton M. & Lantin,R. (1981). Dilute hydrochloric acid as an extractant for available zinc, copper and boron in rice soils. Plant Soil 61, 297–310.

Rahman M., Bhuiyan M., Satradhar G. and Paul A. (2008). Effect of phosphorus, molybdenum and Rhizobium inoculation on yield and yield attributes of mungbean. International Journal of Sustainable Crop Production. 3(6), 26-33.

Rahmeto N. (2007). Determinants of Adoption of Improved Haricot Bean Production Package in Alaba Special Woreda, Southern Ethiopia. A Thesis Submitted to the Department of Rural Development and Agricultural Extension, School of Graduate Studies at Haramaya University, Ethiopia

Rao I., Miles J., Beebe S. and Horst W. (2016). Root adaptations to soils with low fertility and aluminium toxicity. Annals of Botany, 118(4), 593-605..

Rodino A., Riveiro M. and De Ron A. (2021) Implications of the Symbiotic Nitrogen Fixation in Common Bean under Seasonal Water Stress. Agronomy, 11, 70. https://doi.org/10.3390/ agronomy11010070, Spain.

Rurangwa E., Vanlauwe B. and Giller K. (2018). Benefits of inoculation, P fertilizer and manure on yields of common bean and soybean also increase yield of subsequent maize. Agriculture, Ecosystems and Environment, 261(8), 219-229.

Sahlemedhin S. and Taye B. (2000). Procedures for soil and plant analysis. Technical paper, (74), p.110.

Salcedo J. (2008). Regeneration guidelines: common bean. In: Dulloo M., Thormann I., Jorge M. and Hanson J., editors. Crop specific regeneration guidelines [CD-ROM]. CGIAR System-wide Genetic Resource Programme, Rome, Italy. 9 pp.

Sanz-Saez A., Morales F., Arrese C. and Aranjuelo I. (2017) P Deficiency: A Major Limiting Factor for Rhizobial Symbiosis. In: S. Sulieman (Ed) Legume Nitrogen Fixation in Soils with Low Phosphorus Availability. Springer.

Scherer H. (2008). Impact of sulfur on N 2 fixation of legumes. In Sulfur assimilation and abiotic stress in plants (pp. 43-54). Springer, Berlin, Heidelberg.

Shiferaw H. (2014). Soil Fertility Status and Fertilizer Recommendation for Ethiopian Agricultural Land. Paper presented at the In Ethiopian Economic Association Conference, Addis Ababa, Ethiopia.

Shumi D., Alemayehu D., Afeta T. and Debelo B. (2018). Response of Common bean (*Phaseolus vulgaris L.*) Varieties to Rates of Blended NPS Fertilizer in Adola District, Southern Ethiopia. J Plant Biol Soil Health; 5(1): 11.

Silva D., Esteves J., Messias U., Teixeira A., Gonçalves J., Chiorato.D. and Carbonell S. (2014). Efficiency in the use of phosphorus by common bean genotypes. Scientia Agricola, 71(3), 232-239.

Sinclair T. and Vadez V. (2002). Physiological traits for crop yield improvement in low Nitrogen and Phosphorous environments. Plant and Soil, 245(1), 1-15.

Singh R., Gupta S. and Yadav A. (2008). Effect of levels and sources of phosphorus and PSB on growth and yield of blackgram. Legume Research, 31(2), 139-141.

Soratto R., Carvalho M. and Arf O. (2006). Nitrogen in Coverage in common bean grown in no-tillage. Revista Brasileira de Ciencia do Solo, 30, 259-266.

Taminaw Z. (2019). Effects of NPS fertilizer rates on growth, yield components and yield of common bean (*Phaseolus vulgaris L.*) varieties under irrigation at gewane, north-eastern Ethiopia. MSc Thesis School of Plant Science Haramaya University, Haramaya PP(34-75)

Taminaw Z. (2021). Review on effect of N and P fertilizer rates on yield and yield components of common bean (*Phaseolus vulgaris L.*) varieties. International Journal of Research in Agronomy; 4(1): 32-40 E-ISSN: 2618-0618.

Taminaw Z. and Eman H. (2021). Review on effects of phosphorus fertilizer rates on growth, yield components and yield of common bean (*Phaseolus vulgaris L.*) Journal of Current Research in Food Science 2021; 2(1): 34-39 best review

Teame G., Dejene K., Mengistu Z. and Araya T. (2020). Effects Of Combined Application of Phosphorus And Sulfur Fertilizers On Agronomic Traits And Protein Content f Supplementary Irrigated Haricot Bean (*Phaseolus Vulgaris L.*) Varieties In Raya

Valley, Northern Ethiopia. African Journals of Food Agricultural Nutrition Development ; 20(1): 15383-15401 Doi: 10.18697/Ajfand.89.17500

Tekalign T., Haque I. and Aduayi E. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Tesfa I., Nandeshwar B., Kinde L., and Tolera A., (2022) Response of soybean (*Glycine max*) varieties ‘Katta’ and ‘Korme’ to NPS fertilizer rates at Western Ethiopia. Res. Crop. 23 (1) : 100-109 (2022) DOI : 10.31830/2348-7542.2022.015

Tripathi D., Singh S., Singh S., Mishra S., Chauhan D. and Dubey N. (2015). Micronutrients and their diverse role in agricultural crops: Advances and future prospective. Acta Physiologiae Plantarum, 37(7), 1-14.

Tumsa K., Buruchara R. and Beebe S. (2014). Common bean strategies and seed roadmaps for Ethiopia.

Uddin F., Mira H., Sarker U. and Akondo M. (2020). Effect of variety and boron fertilizer on the growth and yield performance of French bean (*Phaseolus vulgaris L.*). Archives of Agriculture and Environmental Science, 5(3): 241-246, https://dx.doi.org/10.26832/24566632.2020.050302

Vongai C. (2018). Response of Common bean (*Phaseolus VulgarisL.*) to rhizobia inoculation, nitrogen and phosphorus application and residual benefits to maize on smallholder farms in Eastern Zimbabwe. M.Sc. Thesis, University of Zimbabwe

Walelign Worku, 2015. Haricot Bean Production Guide: with emphasis on southern Ethiopia (English version). p-3

Walkley A. and Black I. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science, 37(1): pp.29-38.

Wang Y., Liu T., Ren X., Li R., Zhang M. and Yousaf L. (2014). Establishment method affects oilseed rape yield and the response to nitrogen fertilizer. Agronomy Journal, 106, 131–42.

Wondwosen W. and Tamado T. (2017). Yield Response of Common Bean (*Phaseolus vulgaris L.*) Varieties to Combined Application of Nitrogen and Phosphorus Fertilizers at Mechara, Eastern Ethiopia. Journal of Plant Biology & Soil Health Vol.:4, Issue:2.

Wortman C., Kirkby R., Eledu C. and Allen D. (2004). Atlas of Common Bean *(Phaseolus vulgaris* L.*)* Production in Africa. International Center for Tropical Agriculture.

Zafar M., Abbasi M. and Khaliq A. (2013). Effect of different phosphorus sources on the growth, yield, energy content and phosphorus utilization efficiency in maize at Rawalako Azad Jammu and Kashmir, Pakistan. Journal of Plant Nutrition 36:1915-1934.

7. APPENDIX

7.1 List of Tables in the Appendix

Appendix Table 1. Mean squares of analysis of variance for phonological and growth parameters of common bean affected by varieties and NPSB fertilizer rates

		Means squares	
Sources of variation	DF	DF	DPM
Replication	2	1.52	1.33
Variety	3	281.41**	1070.35**
NPSB fertilizer rates	3	41.96**	147.69**
Variety x NPSB rates	9	4.78**	12.08**
Error	30	1.34	3.93
CV (%)		2.5	2.197

DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= significant at 1% level of significance; DFF= Days to 50% flowering; DPM= Days to physiological maturity

Appendix Table 2. Mean squares of analysis of variance for phonological and growth parameters of common bean affected by varieties and NPSB fertilizer rates

		Means squares			
Sources of variation	DF	PH	TNPP	ENPP	NDW
Replication	2	5.67	2.43	4.06	0.14
Variety	3	4005.36**	196.85**	77.06**	0.57**
NPSB fertilizer rates	3	1037.21**	3117.52**	986.74**	4.16**
Variety x NPSB rates	9	35.79*	147.92**	54.29**	0.27*
Error	30	11.75	36.39	11.93	0.091
CV (%)		6.08	12.29	11.60	15.37

DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= significant at 1% level of significance; PH= Plant height; TNPP= Total nodule per plant; ENPP= Effective nodule per plant; NDW= Nodule dry weight

Appendix Table 3. Mean squares of analysis of variance for yield components of common bean affected by varieties and NPSB fertilizer rates

Sources of variation	DF	Means squares		
		NPPP	NSPP	HSW
Replication	2	4.55	0.046	0.91
Variety	3	53.88**	1.47**	659.18**
NPSB fertilizer rates	3	97.15**	0.91*	2.83**
Variety x NPSB rates	9	7.04*	0.33ns	0.89*
Error	30	3.12	0.24	0.39
CV (%)		14.95	14.36	2.0

DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= significant at 1% level of significance; NPPP= Number of pod per plant; NSPP= Number of seed per pod; HSW= Hundred seed weight

Appendix Table 4. Mean squares of analysis of variance for yield and yield components of common bean affected by varieties and NPSB fertilizer rates

Sources of variation	DF	Means squares		
		AGDBM	GY	HI
Replication	2	51301.56	33785.17	14.89
Variety	3	3485059.03**	1736714.02**	134.77**
NPSB fertilizer rates	3	9952914.58**	4385552.92**	344.72**
Variety x NPSB rates	9	248019.68*	153288.74**	35.25*
Error	30	102536.01	35818.90	15.84
CV (%)		6.45	9.72	10.26

DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= significant at 1% level of significance; AGDBM= Above ground dry biomass; SY= Seed yield; HI= Harvest index