**SCHOOL OF GRADUATE STUDIES**

# EFFECT OF BLENDED NPSB FERTILIZER RATES ON YIELD AND YIELD COMPONENTS OF MUNG BEAN VARIETIES IN CHEHA DISTRICT, GURAGE ZONE, CENTRAL ETHIOPIA

**MSc THESIS**

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# Effect of Blended NPSB Fertilizer Rates on Yield and Yield components of Mung bean Varieties in Cheha District, Gurage Zone, Central Ethiopia

**A Thesis Submitted to the Department of Plant Sciences, College of Agriculture and Natural Resource in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agronomy**

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**June 2024**

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# WOLKITE UNIVERSITY
# SCHOOL OF GRADUATE STUDIES
# APPROVAL SHEET

We hereby certify that we have read and evaluated this Thesis entitled **"Effect of NPSB Fertilizer Rate on Yield and Yield Components of Mung bean Varieties in Cheha District, Ethiopia"** prepared under our guidance by Tigist Fentahun Meharie. We recommend that the thesis shall be submitted as fulfilling the requirements for the award of MSc. Degree in Agronomy.

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Final approval and acceptance of the Thesis is contingent up on the submission of its final copy to the council of postgraduate program (CPGS) through the candidates department or school graduate committee (DGC or SGC).

# DEDICATION

I dedicate this thesis to my beloved family and friends whose unwavering support and sacrifices made this achievement possible.

# STATEMENT OF THE AUTHOR

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

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# BIOGRAPHICAL SKETCH

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| ATA | Agricultural Transformation Agency |
| CEC | Cation Exchange Capacity |
| CSA | Central Statistical Agency |
| EARO | Ethiopian Agricultural Research Organization |
| ECX | Ethiopian Commodity Exchange |
| EEPA | Ethiopian Export Promotion Agency |
| LSD | Least Significant Difference |
| MARC | Melkassa Agricultural Research Center |
| MoARD | Ministry of Agriculture and Rural Development |
| MoSHE | Ministry of Science and Higher Education |
| NPSB | Nitrogen, Phosphorus, Sulfur and Boron |
| RCBD | Randomized Complete Block Design |
| SAS | Statistical Analysis System |

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# Effect of NPSB Fertilizer Rate on Yield and Yield Components of Mung bean (*Vigna radiata* L.) Varieties in Cheha District, Gurage Zone, Central Ethiopia


## ABSTRACT

*Mung bean (Vigna radiata L.), is a recently introduced grain legume crop with high potential uses and export demand. However poor crop management practices, including improper NPSB fertilization rate and absence of improved varieties contributed to low productivity in the study area. Hence a field experiment was conducted in Cheha district, Gurage Zone to evaluate the effect of blended NPSB fertilizer rates on the yield and yield components of mung bean varieties. The experiment was laid out in a randomized complete block design with three replications. There were 16 treatment combinations, comprising two mung bean varieties (NVL-1 and Rasa) and eight blended NPSB fertilizer rates (0, 25, 50, 75,100, 125, 150 and 175 kg $ha^{-1}$). The results showed that the highest values for most growth parameters and yield components were obtained with the application of 175 kg $ha^{-1}$ NPSB. Results from the main effect of NPSB fertilizer rates indicated that the highest values for plant height (75.83), total number of branches (8.43), total number of nodules (22.91 and 22.6), number of effective nodules (13.41and 13.01) hundred seed weight (35.5g) and above ground dry biomass (5606.3 kg $ha^{-1}$) were obtained. The interaction between variety and NPSB rate significantly influenced several growth and yield traits. The combination of Rasa variety with 175 kg $ha^{-1}$ NPSB resulted in the highest days to 50% flowering (55.66 days),days to 90% physiological maturity (88.33 days), number of pod per plant (31), number of seed per pod (13.91), grain yield (1403.33 kg $ha^{-1}$) and harvest index (24.97%).The partial budget analysis indicated that the combination of rasa variety with 175 kg $ha^{1}$ NPSB gave the highest net benefit (48,928 Birr $ha^{-1}$) with 1113.2% marginal rate of return. Therefore, the use of 175 kg $ha^{-1}$ NPSB fertilizer with Rasa variety are recommended for optimal mung bean yield and economic benefit in the study area and similar agro ecology. These findings provide valuable insights for farmers and researchers to enhance mung bean production and address yield limitations in Ethiopia. However, since the result is only on one season and one location, further research is recommended to be carried out across more seasons and locations.*



**Keywords:** Grain yield, Mung bean, NPSB Fertilizer, Variety

# 1. INTRODUCTION

## 1.1. Background of the study

Mung bean (*Vigna radiata* L.) is a major pulse crop farmed in tropical and subtropical regions all over the world (Kumari *et al*., 2012). It is a widely distributed, herbaceous and annual legume crop used primarily by traditional farmers (Ali *et al*., 2010). The crop is characterized by fast growth under warm conditions, low water requirement and excellent soil fertility enhancement via nitrogen fixation (Yagoob and Yagoob, 2014). Its requirement in growing areas where the rainy season is short and its wide adaptability together with its digestibility makes mung bean to be cultivated all over the world. Nearly all 90%, of the world's mung bean production comes from Asia (Astanakulov, 2022). As Somta and Srinives (2007) reported the crop is utilized in several ways; seeds, sprouts and young pods are all consumed and provide a rich source of amino acids, vitamins and minerals. The grain contains 24.2% protein, 1.3% fat and 60.4% carbohydrate (Hussain *et al*., 2011).

Mung bean has low in calories and rich in fiber and easily digestible crop without cause flatulence as happens with many other legumes (Minh, 2014). According to Itefa (2016) at present mung bean cultivation spreads widely in Africa, South America, Australia and in many Asian countries. Currently, the crop has been cultivated and familiarized in different regions of Ethiopia like Oromia, South People Nations and Nationalities, Tigray and Amhara National Region.

It is mainly cultivated in North Shewa, Harerge, Illubabor, Gamo Gofa, South Wollo, Tigray, Gondar, and in some districts of Benshangul Gumuz Reginal State (CSA, 2018). The crop is also produced in moisture stress areas of the country such as Gofa, Konso, South Omo Zone, and Konta special district (Wedajo, 2015). As Asfaw *et al.* (2012) reported in Ethiopia mung bean is mostly grown by smallholder farmers under drier marginal environmental condition and the production capacity is lower than other pulse crops.

For resource poor farmers in Ethiopia, mung bean is mainly used as food, but growing it for income generation can also be important. The optimum temperature range for good production of mung bean ranges from 27 - 30 $^{0}$C. The temperature necessities always stay above 15 $^{0}$C and the crop requires from 90–120 days for maturity. It is a short maturity and drought resistance crop, which conferees its adaptation to adverse environmental conditions and successfully grows in rain fed areas (Anjum *et al*., 2006). Furthermore, it is adaptable for the semiarid and arid areas due to its short growing cycle (Kidane, 2010) which may be related to attainment of the required degree days to reach maturity in a short period of time due to high temperature condition. The world mung bean production coverage is worth around 7.3 million ha and an average of 5.3 million tons of mung bean is harvested from it (Domingo, 2023).

It is an important pulse crop for smallholders that has gained attention and announced as sixth export commodity (ECX, 2014). In Ethiopia, mung bean is produced at about 56,015.65 ha with total production of 571, 58.788 ton and the average productivity of 1.02 t ha$^{-1}$ (CSA, 2022). The area coverage of the crop in the SNNPRS is estimated to be 224.4 ha, and the average productivity is 0.9 t ha$^{-1}$, which is far below the potential yield level of 1.5 t ha$^{-1}$ (MoA, 2011). Ethiopian agricultural production enhancement and export augment strategy delineate pulses including mung bean as strategically important crops to the nation's development in the agriculture sector. Because pulses including mung bean are the third agricultural export commodity after coffee and oilseeds and play a pronounced role in the economic development of the country (Nair, 2020).

In Ethiopia, this crop might be a promising source of human and animal food due to the high levels of minerals and vitamins (Tensay, 2015). Farmers used mung bean in bordering areas to make the soil fertile without providing fertilizer on the land. So, farmers regard mung bean as traditional crop and cultivated by traditional farming (Tensay, 2015). As Abayomi *et al*. (2008) reported the root nodules of mung bean fix atmospheric nitrogen. Nitrogen is an important mineral whose nutritional management requires special attention due to its diverse roles in plant physiology and metabolites biosynthesis, as well as its dynamics in soil (Souri *et al*., 2019). Nitrogen application increased the seed yield of mung bean, which was related

to higher number of pods per plant, number of seeds per pod and hundred seed weight (Mozumder *et al*., 2003). Phosphorus is also a component of nucleic acids that promotes root growth and increases nodule activity in plants. For instance,

Phosphorus application on leguminous crop improves yield components and yield of green gram grain yield, number of branches, number of pods plant$^{-1}$, number of seeds pod$^{-1}$ and hundred seed weight considerably as compared with treatments given no phosphorus (Amanullah and Stewart, 2013). Sulfur is recently identified to be low in most soils (ATA, 2015). The effect of boron on yield of mung bean was found to be positive and significant (Mathew *et al*., 2013). Both macronutrients and micronutrients increase nitrogen (N) fixation and the growth of mung bean plant. Like other legumes, it requires nutrients like nitrogen, phosphorus and sulfur for growth and development (IFPRI, 2010; Arians, 2012).

Low productivity of mung bean in Ethiopia as compared to the production reported in other countries around the globe might be attributed to low soil fertility, which is also attributed to the limited use of inorganic fertilizer (Asrate *et al*., 2012). Despite all of the benefits, mung bean production faces a number of challenges. These include poor selection of bean seeds, poor quality of seeds, soil degradation, poor husbandry practices, and postharvest losses (AOATM, 2011). The farmers have a less awareness for the application of fertilizers for mung bean production in Ethiopia as well as in the study area. Due to limited research results, the farmers in the study area in particular and the country in general lack information on optimal rate of blended fertilizers like NPSB, inappropriate selection of variety and variety-specific recommendations of fertilizer rates. Given these problems, this research was initiated to select adaptable mung bean varieties with optimum NPSB rate to be applied in the study area.

## 1.2. Statement of the Problem

Mung bean production in study area faces significant challenges, including inadequate use of fertilizer and absence of improved varieties. Several factors contributed to this issue, including biological and non-biological limitations. Fertilizer management in particular plays, a crucial role in mung bean growth and yield.

As Asrate *et al*. (2012) highlight additional challenges such as limited farmer experience, restricted use of modern inputs and inappropriate agronomic practices like imbalanced fertilizer application and a lack of suitable varieties contributed to low production and productivity in Ethiopia. Farmers in the study area often fail to follow recommended rates and timings, opting to grow mung beans on marginal and less productive land. Therefore, the optimum rate of blended fertilizers necessary for mung bean production in Ethiopia's SNNPR has to be determined and more research is needed.

However poor agronomic practices currently limit crop yield potential. Furthermore, due to limited research results, the farmers in the study area (Buchach kebele) in particular and the country in general lack of information on optimal rate of newly introduced blended fertilizers like NPSB, inappropriate variety selection and variety-specific recommendations of fertilizer rates. Therefore this study aims to investigate the effects of different blended NPSB fertilizer rates and varieties influencing mung bean output and productivity with in the study area (Buchach kebele).

## 1.3. Objectives

### 1.3.1. General Objective

To enhance the production and productivity of mung bean through determining optimal blended NPSB fertilizer rate in Cheha district, Gurage Zone.

### 1.3.2. Specific Objectives

- ✓ To evaluate the effect of NPSB fertilizer rate on growth and yields of mung bean in the study area.
- ✓ To determine the economic feasibility of NPSB fertilizer rate and variety of mung bean production in Cheha district.

# 2. LITRETURE REVIEW

## 2.1. Botanical Description of Mung Bean Crop

The mung bean plant is an annual, erect or semi-erect; reaching a height of 0.15-1.25m (FAO, 2012). It is slightly hairy with a well-developed root system. Wild types tend to be prostrate while cultivated types are more erect. The stems are many-branched, sometimes twining at the tips. Mung bean is described as the binomial name *Vigna radiata* which belongs to the angiosperm dicot crops with family Fabaceae. It is deep rooted much branched with long petioles. The leaves are alternate, trifoliolate with elliptical to ovate leaflets, 5-18cm long 3-15 cm broad. The inflorescence is an axillary raceme with a peduncle 2 to 13cm long. The flowers are papillonaceous, pale yellow or greenish in colour (Sehrawat *et al*., 2013).

The pods are long, cylindrical, hairy and pending. They contain small, ellipsoid or cube-shaped seeds (Lambrides *et al*., 2006). The seeds are variable in colour: they are usually green but can also be yellow, olive, brown, purplish brown or black, mottled or ridged. It is early maturing crop, Special features include high yield, good nutritive value, the earliness and drought resistant features, the reasonable cost of production and the ability to stimulate striga without being parasitized. Cultivated types are generally green or golden and can be shiny or dull depending on the presence of a texture layer (Lambrides *et al*., 2006). It is one of the most important edible legume crops, grown on more than 6 million ha worldwide (about 8.5% of the global pulse area) and consumed by most households in Asia. Due to its characteristics of relatively drought-tolerant, low-input crop, and short growth cycle, the mung bean is widely cultivated in many Asian as well as in dry regions of southern Europe and warmer parts of Canada and the United States (Dahiya *et al*., 2015).

## 2.2. Origin and Distribution of Mung bean

According to Chadha (2010) Mung bean originated in India or the Indo-Burmese region where it has been cultivated for several millenaries. It spread in early times to most other Asian countries, and more recently also to other continents. The primary genetic diversity and center of origin for mung bean was the central Asian region with India having the widest diversity of domesticated varieties, and wild relatives (Altaf, 2009). It is widely grown in Southeast Asia, Africa, South America and Australia and has been identified as high yielding pulse crop (SADAFF, 2010). The short duration it needs to grow and its wide adaptability together with the easier way of its digestibility makes mung bean cultivation to spread all over the world (Wedajo, 2015). At present mung bean cultivation spreads widely because of its superior digestibility in Africa, South America, Australia and in many countries, and has been identified as high yielding pulse crop (Wedajo, 2015).

Mung bean agriculture has grown all over the world due to the short time it takes to grow and its extensive adaptability, as well as the ease with which it may be digested (Chadha, 2010). As Wedajo (2015) reported Mung bean widely grown south and south-east Asia, over 80% of the mung bean is produced in South Asia. The short duration it needs to grow and its wide adaptability easier way together with its digestibility makes mung bean cultivate all over the world. Currently, green gram is the most important seed legume in Thailand and the Philippines; it ranks second in Sri Lanka and third in each of India, Burma, Bangladesh and Indonesia (Shanmugasundaram, 2001). In India, mung bean is cultivated either summer spring or rainy season, also grown in South India (Sehrawat *et al*., 2013). It has been introduced in different regions of Ethiopia like Shewa, Hararge, Ilubabor, Gamogofa, Tigray and Gondar (Keating *et al*., 2011). In southern Ethiopia, Farmers in some moisture stress areas (Gofa, Konso, south Omo zone and Konta) have been producing mung bean to supplement their protein needs and also effectively use scanty rainfall ( Asrate *et al*., 2012).

## 2.3. Nutritional Value of Mung bean

Mung bean have a high nutritional value due to amino acids, ash, crude protein and crude lipid occupy an important source of food (Ullah *et al*., 2014). The plant is rich in terms of essential oil acid, high fiber content, protein and minerals such as phosphorus, calcium and vitamins like other legumes. Moreover, energy value of the plant is higher than other legumes. Researches focused on their functional characteristics increases their usage as a food supplement in food industry (Shaheen *et al*., 2014).

Mung bean is an important crop with high digestion ratio, easy transportation and storage, soil improving characteristics while it is a less cultivated legume crop in global term. Besides these, mung bean can be used in health care especially as an anticancer food which makes it as a functional food (Sehrawat *et al*., 2020). It is a pulse or food legume crop used primarily as dried seeds and occasionally as forage or green pods and seeds for vegetables (Tomooka, 2002). Dried seeds may be eaten whole or split, cooked, fermented, milled and ground into flour. It can also be made into products like soups, porridge, confections, curries, bread, biscuits and alcoholic beverages (Sehrawat *et al*., 2013). In western cultures, mung bean sprouts are popularly used as afresh salad vegetable (Lambrides, 2007).

Mung bean is an important cash crops serving as a source of income and foreign currency in the world (Somta and Srinives, 2007). It is an important legume crop and considered the most economically important Vigna crop. In developing countries, mung bean is consumed as dry seeds, fresh green pods, or leaves and seeds as vegetables due to its high protein, vitamin, and mineral content (Das *et al.*, 2014; Tang *et al.*, 2014). It is an important pulse crop in Asia because of its high protein content and ability to improve soil fertility (Asim *et al*., 2006).

## 2.4. Climatic Requirement of Mung bean

Mung bean is a warm season crop requiring 90-120 days of frost-free conditions from planting to maturity. The optimum temperature range for growth is between 27 °C and 30 °C (Asfaw *et al.*, 2012). Seed can be planted when the minimum temperature is above 15 °C.

It performs in fertile, sandy loam soils with excellent internal drainage and a pH of 5 to 7.2. On more alkaline soils, it can show severe iron chlorosis signs and certain micronutrient deficits because it does not tolerate saline soils (SADAFF, 2010). Mung beans are responsive to daylight length. Short days result in early flowering, while long days result in late flowering.

However, mung bean varieties differ in their photoperiod response. It is considered to be heat and drought tolerant. As Asfaw *et al*. (2012) reported, in Ethiopia mung bean is mostly grown by smallholder farmers under drier marginal environmental condition and the production capacity is lower than other pulse crops.

## 2.5. Production and Importance of Mung bean

Mung bean has the capacity to fix atmospheric nitrogen which rehabilitates the soil fertility status, use of land and water resources (Nawale, 2001). The majority of a crop is exported with Taiwan, the Philippines, the United States and the United Kingdom being the top destinations. Mung bean demand is expanding rapidly in the global import-export industry (Zhichao *et al*., 2018).

Mung bean production is mainly (90%) situated and produced in Asia in which India is the largest producer with more than 50 % of world production and consumes almost its entire production. China produces large amounts of mung beans next to India, which represents 19 % of its legume production. Mung bean cultivation is gaining popularity day by day among the farmers and Ethiopia's mung bean export has grown slightly to 1363 tons in 2002 from 822 tons in 2001 (MOARD, 2008). It is grown in lower, drier and warmer areas of Ethiopia (Itefa, 2016).

Its cultivation is gaining popularity from time to time among the farmers and Ethiopia's mung bean export has grown slightly from year to year. Though its production in Ethiopia is very negligible when it is compared to other pulse crops, small holder farmers in drier marginal environments grow mung bean and it has been an important grain legume for resource poor farmers in these areas (Itefa, 2016). Mung bean is a grain legume grown by

small holder farmers in drier marginal environments, and it has been an essential grain legume for resource poor farmers in these areas, despite its low productivity in Ethiopia when compared to other pulse crops (Itefa, 2016).

## 2.6. Nutrient Requirements of Mung bean

### 2.6.1. Nitrogen

Nitrogen is an important major nutrient element for plant. For mung bean, it is more useful because it is the main component of amino acids as well as proteins. Adequate supply of nitrogen is essential for normal growth and yield (Mozumder *et al*., 2003). It is an essential nutrient that needed to grow plants that large amount of it needed for plant growth that its deficiency in the soil is usually common. Soil mineral fertilizers in agricultural systems are important institutions because the need for food plants resolves in the shortest possible time (Azadi *et al.,* 2013). Nitrogen and phosphorus are essential and present in high levels in mung bean and play important roles in its growth, development, high yield and significantly affect many mung bean traits (Hussain *et al*., 2011).

Micronutrients increase the nodulation and nitrogen fixation of mung bean plants. Nitrogen is an important major nutrient element for plant. For legumes, it is more useful because it is the main component of amino acids as well as proteins. Adequate supply of nitrogen is essential for normal growth and yield. Nitrogen containing fertilizers are essential for crops as source of proteins and play beneficial roles on crop performance, which contribute for maximizing production (Davis *et al*., 2009). Fertilizers like, Nitrogen is an important mineral whose nutritional management requires special attention due to its diverse roles in plant physiology and metabolites biosynthesis, as well as its dynamics in soil (Noroozlo *et al*., 2019).

As the plant grows, the rhizobia increases and its ability to fix atmospheric N improves however, during the late growth period, rhizobia activity is inhibited if excess N fertilizer is applied. When soil N levels are low the application of a small amount of N fertilizer induces rhizobia formation and promotes the growth of strong mung bean seedlings. During the early growth stages before the branches develop, mung bean cannot efficiently fix atmospheric N

because it has few or no rhizobia. The efficient fertilizer management is the important factor that greatly affects the growth attributes and yield of this crop. Nitrogen is perhaps the single most important factor limiting the crop yields. Increasing the application of N fertilizer during the early growth period promotes vegetative growth and creates conditions favoring high yield (Yanni *et al*., 2001).

Different levels of nitrogen showed significantly increased on grain yield of mung bean (Rahman, 2015). Nitrogen deficiency reduces the number of branches plant$^{-1}$, plant height, stem diameter and pod length (Mainul *et al*., 2014). It also reduces early vigor and the crop yield reduces accordingly. Moreover, research studies have revealed that mung bean yield and quality could be improved by the use of balanced fertilizers (Aslam *et al*., 2010). There is an exigency in the country to increase the mung bean yield through proper soil fertility management practices especially nitrogen.

### 2.6.2. Phosphorus

Phosphorus is a critical nutrient element for plant growth, since it is involved in cellular energy transfer, respiration and photosynthesis. The application of P might have improved the nutritional environment in rhizosphere as well as in plant system leading to increased uptake and translocation of nutrients in reproductive structures which led to higher content and uptake. Adequate P availability improves the nodule number and N content in the tissues of mung bean (Bashir *et al*., 2011). Such positive effects of a high P supply on nodule development are associated with the essential function of P in energy metabolism (Tang *et al*., 2001). Among the soil nutrient elements, phosphorus is the second most essential nutrient after the nitrogen.

It is one of the three macro nutrients that plants must be obtain from the soil. It is a major component of compounds whose functions relate to growth, root development flowering and ripening (Sompong *et al*., 2010). P fertilizer promotes root growth, diseases resistance, drought tolerance and enhances nutrient and water absorption in the seedlings after they have depleted their endosperm reserves. According to Sadeghipour *et al*. (2010) revealed that the highest seed yield of mung bean was obtained at highest rate phosphorus fertilizer. Since

mung bean is a new and very economical crop for our country, we have to develop appropriate agronomic package like fertilizer rate determination.

But rate of fertilizer recommendation is affected by different factors like, soil type, available nutrient in the soil, climatic factors and other environmental factors. Phosphorus is essential and present in high levels in mung bean and plays important roles in its growth, development, high yield and significantly affects many mung bean traits (Hussain *et al*., 2019).

As in Kahn *et al*. (2004) disclosed the yield of different crops have been noticed from the soil application of the deficient macronutrient, therefore the poor availability of phosphorus fertilizer is one of the major causes depressing the productivity of the crops. Phosphorus and other micronutrients enhance biological activity especially nitrogen fixation in order to enhance plant height, number of nodules per plant, number of pods per plant, and straw quality (Kumar *et al*., 2012). Many researches on legume indicated that phosphorus availability in the soil is a great limitation for bean production in tropics (Gifole *et al*., 2011). According to Sign *et al*. (2014) reported that growth parameters such as branches plant$^{-1}$, leaves plant$^{-1}$, leaf area index, plant dry matter accumulation and yield components such as pods length, pods plant$^{-1}$ and 100 seed weight were significantly affected by supplied Phosphorus rates. The grain yield of mung bean is also significantly improved due to successive increase in Phosphorus levels up to 40 kg ha$^{-1}$ (Kumar *et al*., 2017).

### 2.6.3. Sulphur

It is involved in various metabolic and enzymatic processes including photosynthesis, respiration and legume Rhizobium symbiotic N fixation (Rao *et al*., 2001). Sulphur is also an important nutrient for plant growth and its uptake by plants accounts 9 to 15% of nitrogen uptake. It has long been recognized as an essential element for plant and ranks in importance with nitrogen and phosphorus. The legume crops are more susceptible for Sulphur deficiency. Since mung bean is a legume crop it is quite likely that likely that it may respond Sulphur. It is recently identified to be low in most soils (ATA, 2015). Therefore, Sulfur is

among the sixteen essential elements which are important for many reactions and functions in Sulfur plays a remarkable role in protein metabolism and it is required for the synthesis of proteins, vitamins and chlorophyll (ATA, 2015).

Moreover sulphur containing amino acids such as methionine, cysteine and cystine which are essential components for proteins (Kumar *et al*., 2012). It also an essential plant nutrient for higher pulse production and has been recognized as fourth major essential plant nutrient because of its widespread deficiency in many crops (Singh, 2001). Sulphur deficiency symptoms are like those of nitrogen. However nitrogen deficiency symptoms first appear in the older leaves generally, sulphur deficiency symptoms first appear in the younger leaves because sulphur does not easily translocate in the plant. Sulphur deficient plants are stunted, pale green to yellow in colour, have elongated thin stems and lack vigor, may delay maturity in grain crops and also interveinal chlorosis may occur. Root development is restricted and shoot to root ratios usually decrease for plants grown under sulphur deficiency. Deficiency of Sulphur has long been recognized as limiting nutrient for crop production (Yasmin *et al*., 2007).

Organic Sulphur must be mineralized to sulfate to be taken up by crop plants. The lower the organic matter content of the soil the more likely Sulphur deficiency is to occur. Sulphur promotes the formation of legume nodules and stimulates the production of seeds. With the application of S up to 20 kg $ha^{-1}$, the total number of nodules and active nodules increased significantly (Ganeshamurthy *et al.*, 2000). Formation of nodule was increased due to sulphur application in black gram and involved in the formation of nitrogenase enzyme known to promote nitrogen fixation in legumes (Varin *et al*., 2010) examined whether the effect of sulphate addition on N fixation resulted from a stimulation of host plant growth, a specific effect of sulphur on nodulation, or a specific effect of sulphur on nodule metabolism.

The increased yield under sulphur application might be ascribed to increased pods per plant and seed per pod along with heavier grains. Therefore significant improvement in yield obtained under sulphur fertilization seems to result from increased concentration of sulphur in various parts of cluster bean that helped to maintain the critical balance of other essential

nutrients in the plant and resulted in increased metabolic processes in plants (Sharma and Singh, 2005).

### 2.6.4. Boron

Boron ranks third among the micronutrients and has a chief role in the plant cell wall and membrane constancy. Boron application maximizes the light interception ratio, biomass production, leaf area index, net assimilation rate, crop growth rate and seed yield in pulses (Kumar *et al*., 2012). The micronutrient especially Boron plays an important role in plant nutrition and recognized as major yield limiting factor in mung bean (Ali *et al.* 2004). It helps in chlorophyll synthesis as well as involved in carbohydrates metabolism. The most important role of boron is to activate the germination of pollen, accelerates the growth of pollen tube and increases the number of flowers and fruits formation. So, there is an ample scope of increasing the yield of mung bean per unit area by using balanced fertilization including sulphur and boron.

The influence of boron application also observed significant in mung bean by increased seed yield (1.55 t $ha^{-1}$) at boron level 1.5 kg $ha^{-1}$ (Alam and Islam, 2016). Boron is one of the essential micronutrients required for plant growth and productivity. It plays an important role in cell wall synthesis, RNA metabolism and root elongation as well as phenol metabolism. Foliar application of boron resulted increase in the number of pods, increased the number of seed $plant^{-1}$ and seed yield of mung bean and other pulse crops. It is a micronutrient essential for normal growth of pollen grains, sugar translocation and movement of growth regulators within the plant. Boron's involvement in hormone synthesis and translocation, carbohydrate metabolisms and DNA synthesis probably contributed to additional growth and yield (Hamasa and Putaiah, 2012).

Due to B deficiency plants manifest restricted growth of terminal buds with necrosis, shortened internodes and lateral branching which gives the plants a bushy appearance. Under severe stress, boron deficient plants may develop chlorosis, drop their flower buds and fail to develop seeds. The leaves become thickened, deformed and brittle, petiole and stem organs may crack and root may exhibit discoloration and rot. The deficiency of boron retards sugar formation and translocation. It also plays an important role in flowering and fruit setting

process, N metabolism and hormonal action (Shil *et al*., 2007). Boron fertilizer increased the root nodulation through better root development and more nutrient availability, resulting in vigorous plant growth and dry matter accumulation leading to flowering, fruiting and pod formation. The effect of boron on yield of mung bean was found to be positive and significant (Mathew *et al*., 2013).

## 2.7. Response of Mung bean Varieties to NPSB Fertilizer Application

Varieties of mung bean differ in their growth, development and yield performance in relation to rates of blended NPSB fertilizer. The growth, yield components of mung bean varieties is increase with increasing application rates of blended fertilizer. Interaction of varieties with NPSB fertilizer rate showed significant effect on days to 50% flowering, days to 90% physiological maturity, number of pod per plant, number of seeds per pod and grain yield of mung bean (Wondwosen *et al*., 2019). This is might be due to various enzymatic activities which controlled flowering and pod formation.

Accordingly, maturity date prolonged following the increase in the level of NPSB, which might be related to role of N in the NPSB that enhanced vegetative growth. According to Dereje *et al*. (2020) it is observed that N improved luxuriant vegetative growth, thereby delaying maturity in mung bean. Results indicated that branch number was notably affected by the interaction of NPSB rates and varieties. Due to genetically different characteristics of varieties, and increased NPSB fertilizer rate can enhance crop growth. The amounts of total branches per plant were increased due to increased application of blended NPSB fertilizer. This implies that higher vegetative growth was formed when there is higher availability of nutrients supplied from blended NPSB fertilizer. Increased number of branch plant$^{-1}$ was formed for the fact that vigorous growth by the plants is a result of better photosynthetic activities with adequate availability of nutrients at vegetative growth stages (Dereje *et al*., 2020).

Introduction of high yielding varieties and increased cropping intensity requires heavy applications of N and P fertilizers. The management of fertilizer is one important factor that greatly affects the growth and yield of the crop. Moreover, appropriate management practice that combines high yielding varieties with balanced fertilizers can increase the seed yield to

great extent since higher productivity can be achieved through a combination of an ideal cultivar associated with proper environment and appropriate agronomic practices. Research results revealed that mung bean yield and quality could be improved by the use of balanced fertilizers (Wondwosen *et al*., 2015). As Hamza *et al*. (2016) concluded that mung bean can respond significantly to P and B combination in growth parameters like plant height, number of branches plant$^{-1}$, and pods plant$^{-1}$ due to its short duration mung bean can fit in as a cash crop between major cropping seasons.

## 2.8. Effect of Varieties on Yield and Yield Component of Mung bean

Varieties of mung bean differ in their growth, development and maturity time. The significant differences in days to 90% Physiological Maturity among mung bean varieties (MOARD, 2011). This difference might be attributed by genotypic differences of the respective varieties and rates of NPSB application (Wondwosen *et al*., 2019). Similarly mung bean varieties have significant difference number of pod per plant. The highest number of pods per plant for variety Rasa might be due to varietal characteristics as individual varieties have different growing habit. Moreover, the supply of adequate nutrients might have facilitated the production of primary branches, secondary branches and plant height which might in turn have contributed for the production of higher number of pods per plant (Wodajo, 2015).

This highest number of pod at the highest rates of NPSB might be attributed by the fact that NPS enhance establishment of beans, promote the formation of nodes, canopy development and pod setting. And also the increase in number of pods with these levels might be due to various enzymatic activities which controlled flowering and pod formation. The increase in number of pods per plant occurs due to the increased leaf area with additional N being associated with more reproductive nodes. A greater leaf area also results in a corresponding increase in assimilate supply which has been reported to determine pod number in legumes. Corroborating this result reported that number of pod per plant increased with increase in N rate in legumes. It also reported that the number of pods per plant of mung bean increased with N doses (Amany, 2007).

Grain yield is the result of dry matter production and its transformation in to economic value that takes place in the plant system. There was significant difference on grain yield with the varietal effect on tested mung bean varieties.

# 3. MATERIALS AND METHODS

## 3.1. Description of the Study Area

The field experiment was conducted in Cheha district, Buchach kebele, Gurage zone, Central Ethiopia during the main cropping season. Cheha is one of the districts in the Gurage Zone. Located at 170 km South West Addis Ababa and 15 km South East Wolkite city, the Zonal capital. Geographically, it lies at coordinates of 80 12’54’’N and 37 48’30’’E with an altitude of 1929 m.a.s.l. The rainfall pattern in the study area is unimodal (having one district in wet season). Vertisols are the dominant soil type, as reported by Alemayehu (2015). The district has diverse agro-ecological zones: 9 % dry-land (kola), 71 % mid-land (Woina dega) and 20 % highland (Dega).

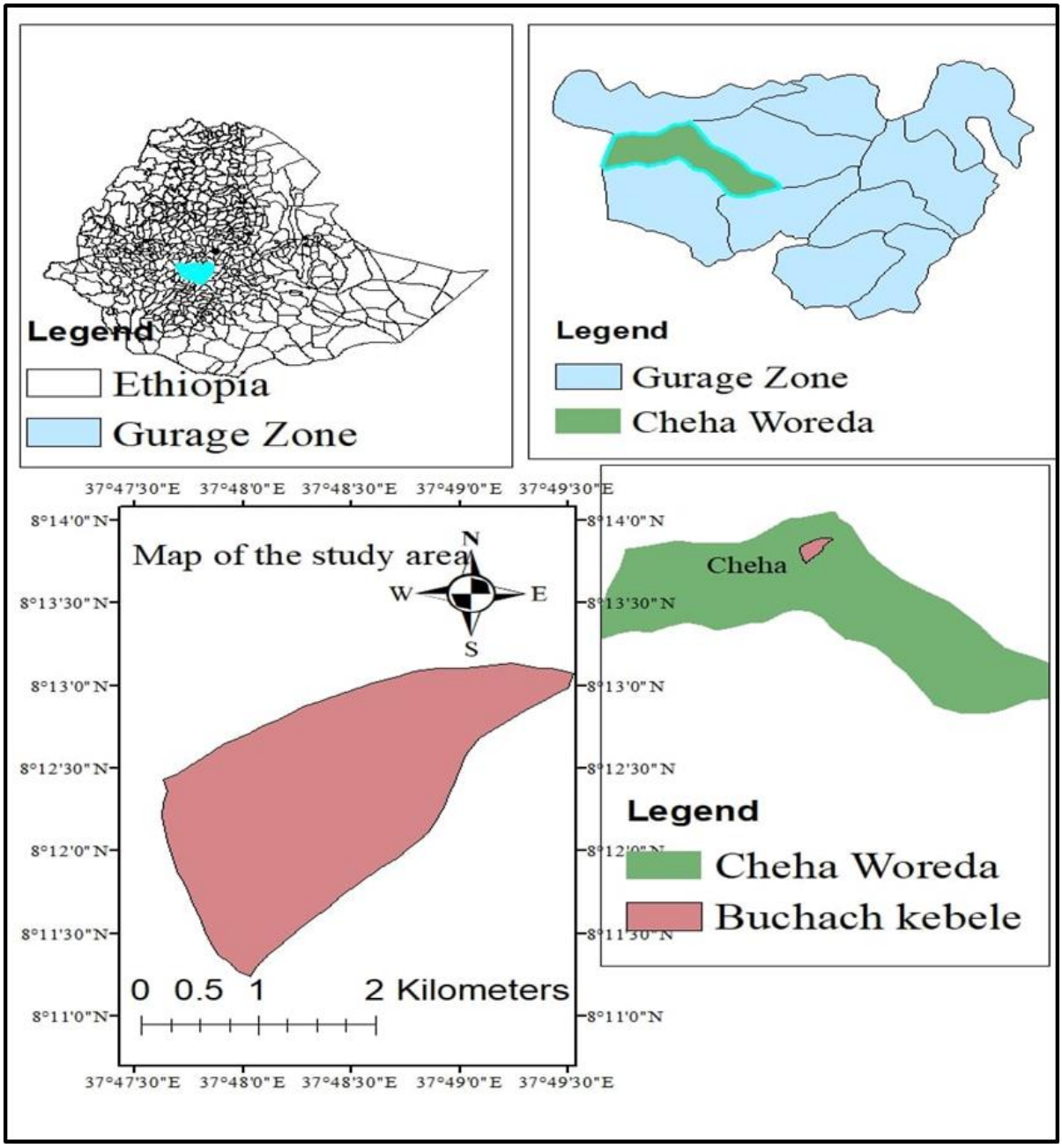


Figure 1. Map showing the study area

Agriculture and related agribusiness trade are the primary economic activities in the district. Enset (false banana) serve as the staple crop, alongside maize, wheat, barley, chickpea, yam, kale and others. Teff, niger seed, and coffee are the major cash crops grown in the area (CWANRO (Cheha Woreda Agriculture and Natural Resource Office), 2020)).

According to the 10 years (2012-2022) ) meteorological data obtained from Southern Nation, Nationality and Peoples' Region State Meteorological Agency and Emdibir sub-station, the mean annual rainfall; annual mean minimum and maximum temperatures of the study area were 105.5 mm, 10.5C$^0$ and 24.62C$^0$ respectively (Figure 2).

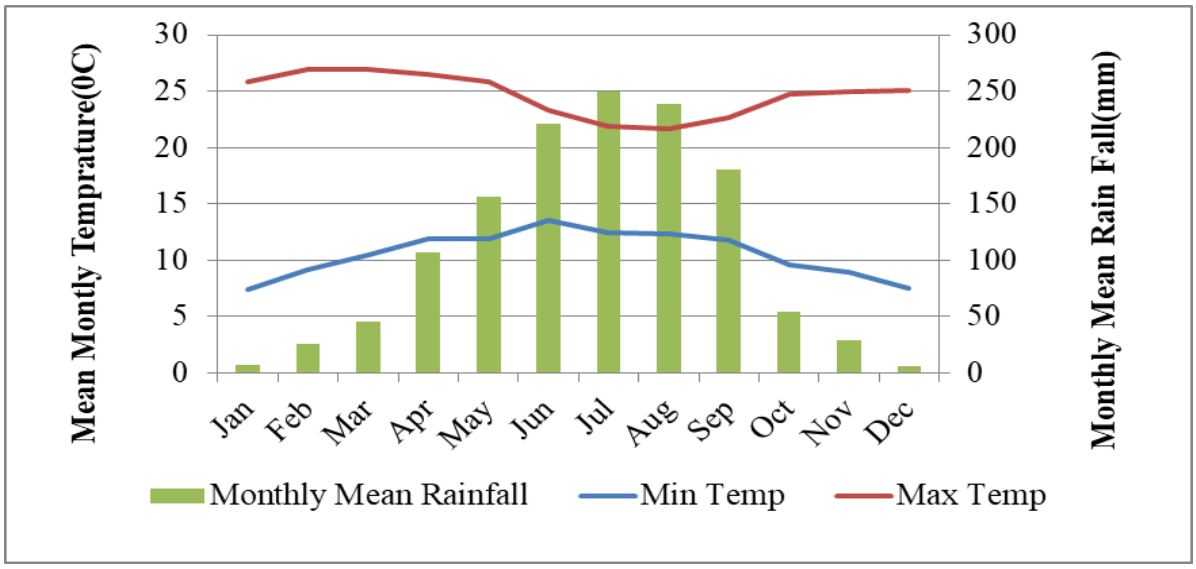



Figure 2. Mean monthly minimum and maximum temperatures and rainfall of study area.

## 3.2. Soil Sampling and Analysis

To determine physiochemical properties of the soil, a composite soil sample was collected from the entire experimental area. Then sub-samples were taken from a depth of 0 -20cm using a soil auger following a zigzag pattern. The collected samples were air-dried at room temperature in a shaded area and ground to pass through a 2 mm sieve. The thoroughly mixed sample was then reduced to a representative composite sample of approximately 1 kg. This composite sample was placed in a polythene bag. The following physiochemical analysis, particle size distribution (soil texture), pH, total N, available P, available S, available B, organic carbon, Cation Exchange Capacity (CEC) were analyzed at Wolkite soil laboratory using standard procedures.

Soil particle size distribution was determined by Bouyoucos hydrometer method Bouyoucos (1962). The soil pH was measured in the supernatant suspension of a 1:2.5 soil water ratios using an electrode pH meter Van Reeuwijk (2002). The cation exchange capacity (CEC) was determined by ammonium acetate method Sahlemedhin and Taye (2000). Organic carbon content (%) of the soil was determined by Walkley and Black wet oxidation method Walkley and Black (1934). The total N content (%), available phosphorus [(mg/kg ppm)], available Sulphur [(mg/kg ppm)] and available boron [(mg/kg ppm)] of soil sample were determined the Kjeldahl procedure Jackson (1958), Olsen *et al.* (1954) mono-calcium phosphate extraction method Hoeft *et al*. (1973) and hot water method Havlin *et al*. (1999) respectively.

## 3.3. Experimental Materials

**Seeds:** Two Mung-bean varieties, NVL-1 and Rasa (previously referred to as N-26), were obtained from Melkassa Agricultural Research Center (MARC, 2020). These varieties were chosen for their high yield potential to the study area agro-ecological conditions (Table 1).

**Fertilizer:** Blended NPSB fertilizer, containing of (18.9% of N, 37.7% of $P_2O_5$, 6.95% of S and 0.1% of B), was used as the fertilizer source. It was obtained from the Plant Science Department of Wolkite University. This fertilizer is widely adapted for in Ethiopia.

Table 1. Description of mung bean varieties used for the study

| Name of variety | Year of Release | Rainfall (mm) | Altitude | Maturity time | Yield kg ha$^{-1}$ (research) | Yield kg ha$^{-1}$ (Farmers Field) | Breeder/ Maintainer |
|---|---|---|---|---|---|---|---|
| NVL-1 | 2014 | 350-550 | 990-1600 | 65-80 | 1500 | 1000 | MARC |
| N-26 | 2011 | 350-550 | 990-1600 | 65-80 | 1500 | 1000 | MARC |

Source: Melkassa Agricultural Research Center (MARC, 2020)

## 3.4. Treatments and Experimental Design

The treatments consisted of a factorial combination of eight NPSB fertilizer rates (0 kg ha$^{-1}$ as control, 25, 50, 75, 100,125,150 and 175 kg ha$^{-1}$) and two mung bean varieties (NVL-1 and Rasa (N-26)), were included. The experiments were laid out in Randomized Complete

Block Design (RCBD) in a factorial arrangement with three replications. Each block had sixteen plots corresponding to all sixteen treatment combinations.

The gross size was 3.2 m wide and 2 m long (6.4 $m^2$) with eight plants per row. To minimize border effects, the outermost rows on both sides and ends of each plot were designated as border plants and excluded from data collection. This resulted in a net plot size of 2.4 m by 1.8 m (4.32 $m^2$) with six rows for data collection. Plots were spaced 0.5 meters apart, with 1 meter separating blocks. The treatments were randomly assigned to plots with in each block using a lottery method. Seeds were sown based on the recommended seed rate as one seed per hole with in a spacing 0.4 meters between rows and 0.1 meters between plants with each row. This resulted in twenty plants per row and a total population of 160 plants per plot.

Table 2.Treatment combinations

| Variety | Fertilizer rates (kg $ha^{-1}$) | Treatment combination |
|---|---|---|
| NVL-1 (V1) | 0(NPSB0) | V1NPSB0 |
| | 25(NPSB1) | V1NPSB1 |
| | 50(NPSB2) | V1NPSB2 |
| | 75(NPSB3) | V1NPSB3 |
| | 100(NPSB4) | V1NPSB4 |
| | 125(NPSB5) | V1NPSB5 |
| | 150(NPSB6) | V1NPSB6 |
| | 175(NPSB7) | V1NPSB7 |
| N-26 (V2) | 0(NPSB0) | V2NPSB0 |
| | 25(NPSB1) | V2NPSB1 |
| | 50(NPSB2) | V2NPSB2 |
| | 75(NPSB3) | V2NPSB3 |
| | 100(NPSB4) | V2NPSB4 |
| | 125(NPSB5) | V2NPSB5 |
| | 150(NPSB6) | V2NPSB6 |
| | 175(NPSB7) | V2NPSB7 |

## 3.5. Management of Experimental Plots

The experimental field was undergone through preparation to ensure a good seedbed. Three passes with a tractor were made achieve affine tilth at a depth of 25-30cm. The plots were then manually leveled and cleared of debris and unwanted plant residues. Following the designated layout based on randomized complete block design (RCBD) with three replications, the field was divided into blocks and individual plots.

Sowing was conducted following recommended seed rates for the chosen mung bean varieties (NVL-1 and Rasa). The required amount of NPSB fertilizer, as per the treatment allocation, was applied at planting time. Weed control was carried out manually throughout the growing season as needed for each treatment. All other essential agronomic practices, from field preparation to harvest, were uniformly applied to all plots according to recommended practices for mung bean at each growth stage. Weeding was performed three times, while harvesting and threshing were done manually. Harvest timing coincided with physiological maturity, indicated by the drying of the lower mung bean pods (EARO, 2006).

## 3.6. Data collection and Measurement

The phenological parameters, growth and yield related parameters of mung bean were collected from the central rows of each plot using standard procedures.

### 3.6.1. Phenological Parameters

**Days to 50% flowering:** The number of days taken from planting until 50% of the plants in the plot displayed flowers was recorded.

**Days to 90 % physiological maturity:** The number of days from planting to the time when 90% of the plants exhibited leaf senescence and pods began to yellow was recorded.

### 3.6.2. Nodulation and Growth Parameters

**Number of total nodule per plant:** Six plants were randomly uprooted plants from each plot, destructive rows, at the 50% flowering stage. The total number of nodule per plant was determined by counting, and the average was taken.

**Number of effective nodule per plant:** The interior color of each nodule from the six sampled plants was examined by cutting them with a sharp blade. Pink-colored nodules were classified as effective and counted to determine the average number of effective nodules per plant.

**Nodule dry weight per plant (g/plant):** Nodules collected from six plants were oven-dried at 65°C for 48 hours until a constant weight was achieved. The average dried weight was recorded as the nodule dry weight per plant.

**Plant height (cm):** Ten plants were randomly chosen from the central rows of each plot at harvest. Their height measured from the ground to the top of the main plant using a meter stick, and averaged to represent plant height per plant.

**Number of total branches**: The average number of total branches from the ten randomly selected plants with in the net plot area was recorded at the physiological maturity stage.

### 3.6.3. Yield and Yield Components

**Number of Pods per Plant:** Ten plants were randomly tagged in each net plot area at harvest. The average number of pods per plant was calculated from the total number of pods of these plants.

**Number of seeds per pod:** The total number of seeds in the pods from ten plants was counted and divided by the total number of pods to determine the average number of seeds per pod.

**Hundred seed weight (g):** Was determined by weighing 100 selected dry seeds from the harvested net plot using a sensitive balance and the weight adjusted to 10 % seed moisture content.

**Above-ground dry biomass yield (kg $ha^{-1}$):** Plants harvested from the net plot area at physiological maturity were sun-dried to a constant weight and then converted to kg $ha^{-1}$.

It was taken and measured from the net plot harvestable area before threshing after sun drying for two weeks till it attains constant weight.

**Grain yield (kg ha$^{-1}$):** The crop from the net plot area was harvested, threshed and adjusted at 10% moisture content before being converted to kilograms per hectare to represent grain yield.

**Harvest index (%):** The harvest index was calculated by dividing the grain yield by the total above- ground dry biomass yield, multiplied by 100.

## 3.7. Data Analysis

Data analysis was performed using the Statistical Analysis Software (SAS) version 9.4 (SAS, 2011). Analysis of variance (ANOVA) was conducted using the procedures outlined by Gomez and Gomez (1984) with a general linear model (GLM) procedure within SAS. For parameters with statistically significant differences ($p < 0.05$) identified by the F-test, treatment means were compared using the least significant difference (LSD) test at a 5% significance level. Additionally, Pearson correlation analysis was carried out using SAS software to assess correlations between the various parameters studied.

## 3.8. Partial Budget Analysis

A partial budget analysis was conducted to evaluate the economic viability of different treatment combinations (NPSB fertilizer rates and mung bean varieties). This method considers the variable costs and net benefits associated with each treatment (CIMMYT, 1988). Fertilizer application cost (200 birr/day), NPSB fertilizer cost (40 birr/kg), mung bean seed cost (40 birr/kg) were used to obtain variable cost for this analysis. Cost and benefit calculations (per hectare, Ethiopian Birr (ETB)). Cost of blended NPSB fertilizer (based on mean market price at planting) and cost of mung bean seed (based on variety).

**Gross field benefit (GFB):** Adjusted grain yield (AGY) x field/farm gate price for mung bean grain.

**Adjusted grain yield (AGY):** was calculated by deducting 10% from the average yield to account for the difference between experimental and farmers yield.

**Total variable cost (TVC):** Sum of the cost of NPSB fertilizer, application cost and mung bean seed. Costs of other inputs and practices (land preparation, planting, weeding, harvesting, threshing) were assumed to be the same for all treatments.

**Net benefit (NB):** Difference between gross field benefit and total variable cost (GFB – TVC).

**Marginal rate of return (MRR):** [(Change in net benefit) / (Change in total variable cost)] x 100.

# 4. RESULTS AND DISUSSIONS

## 4.1. Soil Physico chemical Properties of the Experimental Site

The physio-chemical properties of the soil at the experimental site, buchach kebele were analyzed before planting, and the results are presented in Appendix Table 1. The soil analysis indicated that the particle size distribution was 11% sand, 21% silt, and 68% clay, classifying the soil textural class is clay. The pH of the soil was 5.7, which is moderately acidic as described by Tekalign *et al*. (1991). This pH range is suitable for most legume crops, including mung beans, which can grow in soils with pH ranging from 5.0 to 8.0.

Other soil chemical properties analyzed before sowing revealed the following values: 2.1% organic carbon (OC) content, 44.8 cmol (+) $kg^{-1}$ cation exchange capacity (CEC), 0.16% total nitrogen, 2.69 mg $kg^{-1}$ available phosphorus, 6.34 mg $kg^{-1}$ available sulfur, and 0.443 mg $kg^{-1}$ (ppm) extractable boron. These values indicate that the experimental soil had low organic carbon (OC) content, very high cation exchange capacity (CEC), low total nitrogen, very low available phosphorus, low available sulfur, and low extractable boron, according to (Landon, 1991; Hazelton and Murphy, 2007; Landon, 1991; Olsen *et al*., 1954; Lewis, 1999; Reisenauer *et al*., 1973), respectively (Appendix Table 1).

Therefore, based on the soil analysis, it is recommended to add nitrogen, phosphorus, sulfur, and boron-containing fertilizers such as NPSB to fulfill the crop's nutrient requirements and improve soil fertility.

## 4.2. Effects of Varieties and NPSB Fertilizer rates on Phenological Parameters of Mung bean

### 4.2.1. Days to 50 % flowering

The analysis of variance showed that both variety and NPSB fertilizer rate had a highly significant effect ($p < 0.001$) on days to 50% flowering of mung bean. The interaction between the variety and NPSB fertilizer rate also had a significant effect ($p < 0.05$) (Appendix Table 2).

Among the varieties Rasa with rate of 175 kg $ha^{-1}$ NPSB had the longest duration to reach 50% flowering, taking approximately 55.66 days, on the other hand variety NVL-1 application of 25 kg $ha^{-1}$ NPSB had the earliest to flower, taking around 26.33 days (Table 3). This indicates that Rasa is a late-flowering variety, while NVL-1 is an early-maturing variety. The variation in flowering time can be attributed to the specific characteristics of each variety. Additionally, the delayed flowering observed with increased NPSB fertilizer rates could be due to the effect of nitrogen from the blended NPSB fertilizer, which may have caused a delay in flowering by promoting vegetative growth.

This delay in flowering due to nitrogen fertilization has been reported in previous studies by (Nuru, 2020). It is also possible that the stimulatory effect of phosphorus on growth hormones contributed to early flowering in mung bean, as phosphorus has been shown to induce early flowering in common bean. The application of sulfur (S) in combination with NP fertilizer can enhance metabolic activity and nutrient utilization, favoring vegetative growth (Kawte *et al*., 2020).

Table 3. Interaction effects of variety and blended NPSB fertilizer rates on days to 50% flowering of mung bean

| Variety | NPSB (kg ha$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 125 | 150 | 175 |
| NVL-1 | 31.66$^{fg}$ | 26.33$^{g}$ | 33$^{f}$ | 33$^{f}$ | 41.66$^{cd}$ | 46.33$^{bc}$ | 48$^{b}$ | 47$^{bc}$ |
| Rasa | 32$^{f}$ | 35$^{ef}$ | 35$^{ef}$ | 40$^{de}$ | 42$^{cd}$ | 45.33$^{bcd}$ | 49$^{b}$ | 55.66$^{a}$ |
| Mean | 40.08 | | | | | | | |
| LSD (0.05) | 5.4 | | | | | | | |
| CV (%) | 8.08 | | | | | | | |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

### 4.2.2. Days to 90% Physiological Maturity

The analysis of variance indicated that both the NPSB fertilizer rates and varieties had a highly significant effect ($p < 0.01$) on the days to 90% physiological maturity of mung bean. Additionally, their interaction also had a significant effect ($p < 0.05$) on this parameter (Appendix Table 2).

Among the varieties, Rasa (N-26) with a rate of 175 kg ha$^{-1}$ NPSB had the longest duration to reach 90% physiological maturity, taking approximately 88.33 days. It was statistically similar to the variety Rasa with 150 kg ha$^{-1}$ NPSB, which took around 87.6 days. On the other hand, the variety Rasa with no NPSB fertilizer applied had the shortest duration to reach 90% physiological maturity, taking approximately 40 days (Table 4). This indicates that Rasa (N-26) is a late-maturing variety, while NVL-1 is an early-maturing variety.

The variation in maturity time can be attributed to the specific characteristics of each variety and the addition of nitrogen, phosphorus, sulfur, and boron from the blended NPSB fertilizer. The results clearly show that the days to maturity were prolonged with increasing levels of NPSB fertilizer rates, as reported by Nuru (2020). The delay in maturity at the highest NPSB fertilizer rate is likely due to the promotion of vegetative growth by nitrogen fertilization. As Thies *et al*. (2009) also reported that the appearance of phenological stages and the growth period increased with higher nitrogen fertilizer levels in chickpea and soybean, respectively.

Phenological characteristics are genetically controlled, and individual varieties have different growth habits, flowering times, and days to maturity (Nuru, 2020). The prolonged maturity date with increasing levels of NPSB fertilizer can be attributed to the role of nitrogen in the NPSB blend, which enhances vegetative growth, as reported by Mota *et al*. (2021). According to Kawte *et al*. (2020), nitrogen improves luxuriant vegetative growth, thereby delaying maturity in mung bean. However, a study by Tadesse and Dechassa (2017) on common bean reported no significant effect of sulfur application on days to maturity.

The days to 90% physiological maturity in mung bean were influenced by both the NPSB fertilizer rates and the varieties. The specific characteristics of each variety and the presence of nitrogen, phosphorus, sulfur, and boron from the NPSB fertilizer played a role in determining the time to reach physiological maturity. The increase in NPSB fertilizer rates generally resulted in a delay in maturity, likely due to the promotion of vegetative growth by nitrogen fertilization.

Table 4. Interaction effects of variety and blended NPSB fertilizer rates on days to 90% flowering of mung bean

| Variety | NPSB (kg $ha^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 125 | 150 | 175 |
| NVL-1 | $45^{ef}$ | $46.6^{ef}$ | $54.33^{de}$ | $60.33^{cd}$ | $63.6^{cd}$ | $65.3^{cd}$ | $68.3^{bc}$ | $68.3^{bc}$ |
| Rasa | $40^{f}$ | $54.66^{de}$ | $54.66^{de}$ | $61.66^{cd}$ | $64^{cd}$ | $79.3^{ab}$ | $87.6^{a}$ | $88.33^{a}$ |
| Mean | 60.66 | | | | | | | |
| LSD (0.05) | 12.81 | | | | | | | |
| CV (%) | 12.26 | | | | | | | |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

## 4.3. Effects of Varieties and NPSB Fertilizer rates on Nodulation and Growth Parameters of Mung bean

### 4.3.1. Number of total and effective nodules per plant

The analysis of variance showed that the number of total and effective nodules in mung bean were highly significantly ($p<0.01$) influenced by the main effect of NPSB fertilizer rates. While the main effects of varieties and their interaction were non-significant (Appendix Table 2).

The highest number of total nodules (22.91 and 22.61) and effective nodules (13.41 and 13.01) per plant were recorded with the application of 175 and 150 kg $ha^{-1}$ NPSB fertilizer rate respectively, which were at par with 125,100,75 and 50 kg $ha^{-1}$ NPSB fertilizer rate.

On the other hand the lowest numbers of total nodules (11.18) and effective nodules (5.55) were observed with no fertilizer applied (0 kg $ha^{-1}$) (Table 5). The increase in total and effective number of nodules can be attributed to the application of NPSB fertilizer, which stimulates nodule formation of mung bean. Application of blended NPSB fertilizers significantly increased the number of nodules was due to better root development associated with increased availability of these nutrients.

The applications of small doses of starter nitrogen stimulate nodule formation and increased the number of active nodules, as reported by Deresa (2018). The highest number of total and effective nodules per plant was obtained from application of inorganic fertilizer (Ganeshamurthy *et al*. 2000; Murat *et al*., 2009; Nebret *et al*., 2017). The increased number of total and effective nodules with the increase in NPSB application up to 200 kg $ha^{-1}$ NPSB might be due to the vital role of phosphorus in increasing the number and size of nodule and the amount of nitrogen assimilated per unit of nodules (Deresa, 2018).

Furthermore, phosphorus plays a vital role in promoting plant and root growth, reducing the time required for developing nodules to become active for the benefit to the legume, as reported by Bashir *et al*. (2011). Additionally, Amare *et al*. (2014) also reported a significant increase in nodule number with increasing levels of phosphorus in common bean. Similarly,

Scherer *et al*. (2006) also reported that application of sulphur increased nodule formation in black gram, as sulphur involved in the formation of nitrogenous enzyme known to promote nitrogen fixation in legumes.

Table 5. Main effects of NPSB fertilizer rates on numbers of total and effective nodules per plant of mung bean

| Treatment | Number of Total nodules | Number of Effective Nodules |
|---|---|---|
| NPSB rate (kg $ha^{-1}$) | | |
| 0 | $11.18^{c}$ | $5.55^{d}$ |
| 25 | $15.78^{bc}$ | $7.95^{cd}$ |
| 50 | $17.46^{ab}$ | $9.41^{bc}$ |
| 75 | $18.76^{ab}$ | $9.86^{bc}$ |
| 100 | $19.61^{ab}$ | $11.28^{ab}$ |
| 125 | $21.18^{ab}$ | $11.66^{ab}$ |
| 150 | $22.61^{a}$ | $13.01^{a}$ |
| 175 | $22.91^{a}$ | $13.41^{a}$ |
| Mean | 18.69 | 10.27 |
| LSD(0.05) | 5.48 | 2.47 |
| CV (%) | 24.89 | 20.46 |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

### 4.3.2. Nodule dry weight per plant

The nodule dry weight per plant of mung bean was significantly influenced by both the varieties and NPSB fertilizer rates. While, their interaction effects were not significant (Appendix Table 2). The highest nodule dry weight per plant (0.17 and 0.168g) were recorded with the application of 175 and 150 kg $ha^{-1}$ NPSB fertilizer, which was statistically at par with 125 kg $ha^{-1}$ NPSB (0.155g), at par with 125 kg $ha^{-1}$ NPSB fertilizer. On the other hand, the lowest nodule dry weight per plant (0.14g) was observed in the control group with no fertilizer application applied (0 kg $ha^{-1}$) (Table 6).

The increase on nodule dry weight attributed to the presence of phosphorus found in the NPSB fertilizer which promotes the development of extensive root systems and good nodule development. Similar findings were reported by Arebu *et al*. (2019), observed the highest nodule dry weight (0.27 g plant$^{-1}$) from 46 kg $P_2O_5$ ha$^{-1}$ and the lowest (0.08 g plant$^{-1}$) in control group. The reduction in nodule dry weight with increased phosphorus deficiency could be due to limited growth, development, and dry matter accumulation by the plant. Similarly, Melkamu (2019) observed the highest nodule dry weight with the application of inorganic fertilizers and the lowest in the control group. The application of NPSB fertilizer, particularly at higher rates, resulted in increased nodule dry weight per plant of mung bean.

Table 6. Main effects of NPSB fertilizer rates and varieties on nodule dry weight per plant of mung bean

| Treatment | Nodule dry weight per plant |
|---|---|
| NPSB (kg ha$^{-1}$) | |
| 0 | 0.13$^{c}$ |
| 25 | 0.14$^{bc}$ |
| 50 | 0.142$^{bc}$ |
| 75 | 0.147$^{b}$ |
| 100 | 0.149$^{b}$ |
| 125 | 0.155$^{ab}$ |
| 150 | 0.168$^{a}$ |
| 175 | 0.17$^{a}$ |
| Mean | 0.15 |
| LSD (%) | 0.02 |
| Varieties | |
| NVL-1 | 0.154a |
| Rasa | 0.146$^{a}$ |
| LSD (%) | 0.015 |
| CV | 8.59 |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

### 4.3.3. Plant Height and Number of total branches

Plant height and total number of branches of mung bean plant were highly significantly ($p<0.01$) influenced by the main effects of NPSB fertilizer rate. While, the main effect of varieties and their interaction were not significant for both parameters (Appendix Table 2).

The tallest plant height (75.83 cm) was recorded from 175 kg $ha^{-1}$ NPSB fertilizer rate which was at par with 150,125 and 100 kg $ha^{-1}$NPSB. Similarly the maximum numbers of total branches (8.43) were obtained from plots treated with 175 kg $ha^{-1}$ NPSB which was at par with 150 and 125 kg $ha^{-1}$ NPSB treatments. On the other hand, the shortest plant height (48.1 cm) and the minimum number of total branches (3.66) were found from the control treatment (0 kg $ha^{-1}$) (Table 7).

The increase in plant height and the total number of branches per plant with higher NPSB fertilizer rates can be attributed to the involvement of nitrogen, phosphorus, sulfur and boron nutrients in vital plant functions, which contribute to enhanced vegetative growth of the crop. The increment in the number of total branches with increased phosphorus rate can be attributed to the importance of phosphorus in cell division, which contributes to increased plant height and branch formation. Similar findings were reported by Tesfaye *et al*. (2007), who found that phosphorus application increased plant height and the number of branches in mung bean. Similarly, Moniruzzaman *et al*. (2007) also reported a significant increase in the number of branches per plant with increased nitrogen application in legumes.

The increased plant height and total number of branches can be attributed to better photosynthetic activities resulting from adequate nutrient availability during the vegetative growth stages, as reported by Kawte *et al*. (2020). The current results are consistent with (Mahmood *et al*., 2003), who reported increased plant height and total number of branches in mung bean with inorganic fertilizer application. Additionally, Deresa *et al*. (2018) reported maximum plant height and total number of branches with the maximum rate of NPSB application (150 kg $ha^{-1}$ NPSB) in common bean.

Table 7. Main effects of NPSB fertilizer rates on plant height and number of total branches per plant of mung bean

| Treatment | Plant height (cm) | Number of Total Branches |
|---|---|---|
| NPSB rate (kg $ha^{-1}$) | | |
| 0 | $48.1^{e}$ | $3.66^{e}$ |
| 25 | $58.1^{d}$ | $3.95^{e}$ |
| 50 | $65.98^{cd}$ | $4.5^{de}$ |
| 75 | $66.85^{bcd}$ | $5.4^{cde}$ |
| 100 | $69.96^{abc}$ | $5.98^{bcd}$ |
| 125 | $71.8^{abc}$ | $6.53^{abc}$ |
| 150 | $75.5^{ab}$ | $7.86^{ab}$ |
| 175 | $75.83^{a}$ | $8.43^{a}$ |
| Mean | 66.51 | 5.79 |
| LSD(0.05) | 8.87 | 1.94 |
| CV (%) | 11.31 | 28.54 |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

## 4.4. Effect of Varieties and NPSB Fertilizer rates on Yield and Yield Components of Mung bean

### 4.4.1. Number of Pods per Plant

The number of pods per plant of mung bean was found to be highly significantly ($p < 0.001$) affected by the main effects of blended NPSB fertilizer rate and varieties. The interaction effect of main factors had also significant ($p<0.05$) (Appendix Table 3). Variety Rasa (N-26) combined with the application of 175 kg $ha^{-1}$ NPSB fertilizer produced the highest number of pods per plant (31).While variety NVL-1 without NPSB fertilizer application produced the lowest number of pods per plant (9.91) (Table 8).

The higher number of pods per plant in variety Rasa could be attributed to its specific varietal characteristics, as individual varieties can exhibit variations in their growth habits and response to NPSB fertilizer rate. Adequate nutrient supply, facilitated by the NPSB fertilizer, may have contributed to the production of primary and secondary branches as well as increased plant height, leading to a higher number of pods per plant (Nuru, 2020). The availability of NPSB nutrients may have promoted branch production and better canopy coverage, resulting in a higher number of pods per plant (Habtamu *et al*., 2021).

Similar findings were reported by Mourice *et al*. (2012), who found a significant effect of nitrogen fertilizers on the number of pods per plant in legumes, with the maximum number of pods per plant (25.49) observed. The addition of NPSB fertilizer provides immediate nutrient supply to the plants, enhancing photosynthetic activities, improving vegetative growth and development, and ultimately increasing pod production through translocation (Mota *et al*., 2021). Additionally, Yin *et al*. (2018) reported a significant effect of NP fertilizers on pod production per plant in mung bean, with the maximum number of pods per plant (30.45) obtained with the application of 52.5 kg N $ha^{-1}$ and 26 kg $P_2O_5$ $ha^{-1}$. Similarly, Amany (2007), Shubhashree (2007) and Dereje *et al*. (2015) reported an increase in the number of pods per plant with increased NP fertilization in legumes.

Table 8. Interaction effects of variety and blended NPSB fertilizer rates on number of pods per plant of mung bean

| Variety | NPSB (kg $ha^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 125 | 150 | 175 |
| NVL-1 | $9.91^{e}$ | $13.21^{de}$ | $13.74^{cde}$ | $17.65^{bcd}$ | $17.83^{bc}$ | $18^{bc}$ | $18.85^{b}$ | $20.16^{b}$ |
| Rasa | $13.53^{cde}$ | $17.91^{bc}$ | $18.41^{b}$ | $18.83^{b}$ | $19.15^{b}$ | $19.16^{b}$ | $19.83^{b}$ | $31^{a}$ |
| Mean | 17.95 | | | | | | | |
| LSD (0.05) | 4.49 | | | | | | | |
| CV (%) | 15.02 | | | | | | | |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

### 4.4.2. Number of seeds per pod

The number of seeds per pod in mung bean was significantly affected by the main effects of NPSB fertilizer rates ($p < 0.001$), varieties ($p<0.05$) and their interaction ($p<0.05$) (Appendix Table 3). Variety Rasa combined with the application of 175 kg $ha^{-1}$ NPSB fertilizer produced the highest number of seeds per pod (13.91) which was at par with 150 kg $ha^{-1}$ NPSB fertilizer (12.49) while variety NVL-1 without NPSB fertilizer application produced the lowest number of seeds per pod (4.43) (Table 9).

The increase in the number of seeds per pod with increased NPSB rates in both varieties can be attributed to the higher vegetative growth and improved branching, which leads to increased number of seeds per pod production and. The increment in the number of seeds per pod with increasing NPSB fertilizer application rates can be attributed to the fact that phosphorus is an essential component in seed formation. Adequate nutrient supply may have facilitated vegetative growth, which in turn contributed to the production of a higher number of seeds per pod (Khan *et al*., 2012). Nuru (2020) also observed the highest number of pods at the highest NPSB rates (150 kg $ha^{-1}$), which can be attributed to the promotion of bean establishment, node formation, canopy development, and pod setting through NPSB fertilizer application.

These results are consistent with the findings of Mulu, (2019), who reported a significant interaction effect of NPSB fertilizer rates and mung bean varieties on the number of seeds per pod, with the maximum number of seeds per pod (8.84) obtained at 150 kg $ha^{-1}$ NPSB for variety Rasa (N-26). The combination of photosynthesis, nitrogen function, phosphorus's seed formation ability and the metabolic energy ability of sulfur and boron likely contributed to the highest number of seeds per pod (Islam *et al*., 2017). Baza (2019) also observed significant variation in number of seeds per pod due to effect of NPSB fertilizer of mung bean.

Table 9. Interaction effects of variety and blended NPSB fertilizer rates on number of seeds per pod of mung bean

| Variety | NPSB (kg ha$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 | 125 | 150 | 175 |
| NVL-1 | 4.43$^{j}$ | 4.96$^{ij}$ | 5.93$^{ghij}$ | 7.48$^{defg}$ | 8.43$^{def}$ | 9.13$^{cde}$ | 9.46$^{cd}$ | 10.75$^{bc}$ |
| Rasa | 5.35$^{hij}$ | 5.4$^{hij}$ | 6.66$^{fghi}$ | 7.18$^{efgh}$ | 7.66$^{defg}$ | 8.5$^{def}$ | 12.49$^{ab}$ | 13.91$^{a}$ |
| Mean | 7.98 | | | | | | | |
| LSD (0.05) | 2.05 | | | | | | | |
| CV (%) | 15.45 | | | | | | | |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

### 4.4.3. Hundred Seed Weight

The hundred seed weight in mung bean was significantly ($p<0.05$) affected by the NPSB fertilizer rate, while the main effects of varieties and their interaction did not show significant effects (Appendix Table 3).

The maximum hundred seed weight (35.53 and 34.11g) was recorded at the application of 175 and 150 kg ha$^{-1}$ NPSB fertilizer, respectively which was at par with to all treatment except the application of 25 kg ha$^{-1}$ NPSB and control treatment. The lowest hundred seed weight (21.6g) was observed in plots without NPSB fertilizer application (0 kg ha$^{-1}$ NPSB) (Table 10). As the rate of NPSB fertilizer increased, the hundred seed weight also increased proportionally. This might be because nutrient use efficiency by crop was enhanced at optimum level of NPSB since grain weight indicates the amount of resource utilized during critical growth periods. The increase in hundred seed weight with higher rates of NPSB fertilizer can be attributed to the high nitrogen and phosphorus requirement of legumes, including mung bean, as phosphorus is a major storage component in seeds (Habtamu *et al*., 2021).

Similar findings were reported by Nuru (2020) in mung bean research conducted in Ethiopia. Nutrient use efficiency by the crop may also be enhanced with increasing levels of NPSB, as

seed weight reflects the amount of resources utilized during critical growth periods, in addition to the supply of phosphorus that promotes seed formation (Habtamu *et al*., 2021). Additionally, the improved growth and development of crop plants due to sulfur supply and nitrogen uptake may have increased assimilate supply to the seeds, resulting in increased seed weight (Tairo *et al*., 2013; Tesfaye, 2015). Studies on soybean and common bean reported by Tairo *et al*. (2013) and Tesfaye (2015), respectively, also reported an increase in hundred seed weight with increased NPSB fertilizer application.

Table 10. Main effects of NPSB fertilizer rates on hundred seed weight and above ground dry biomass of mung bean

| Treatment | Hundred Seed Weight (g) | Above Ground Dry Biomass (kg ha$^{-1}$) |
|---|---|---|
| NPSB rate (kg ha$^{-1}$) | | |
| 0 | 21.61$^{c}$ | 3901$^{d}$ |
| 25 | 23.26$^{bc}$ | 4691.2$^{c}$ |
| 50 | 27.83$^{abc}$ | 4811.5$^{bc}$ |
| 75 | 28.16$^{abc}$ | 5172$^{abc}$ |
| 100 | 31$^{ab}$ | 5329.2$^{ab}$ |
| 125 | 31.21$^{ab}$ | 5344.5$^{a}$ |
| 150 | 34.11$^{a}$ | 5510$^{a}$ |
| 175 | 35.53$^{a}$ | 5606.3$^{a}$ |
| Mean | 29.09 | 5045.7 |
| LSD(0.05) | 8.16 | 525.5 |
| CV (%) | 23.80 | 8.83 |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

### 4.4.4. Above-ground dry biomass Yield

The above-ground dry biomass yield of mung bean crop was highly significantly ($p<0.01$) affected by the main effect of NPSB fertilizer application rate, while the main effects of varieties and their interaction did not show significant effect on dry biomass yield (Appendix Table 3).

The highest dry biomass yield (5606.3 kg $ha^{-1}$) was obtained at the application rate of 175 kg $ha^{-1}$ NPSB, which was statistically similar to the yield obtained at the application rate of 150 and 125 kg $ha^{-1}$ NPSB and which was at par with the application rate of 100 and 75 kg $ha^{-1}$ NPSB. The lowest dry biomass yield (3901 kg $ha^{-1}$) was recorded in the control treatment (0 kg $ha^{-1}$) without NPSB fertilizer application (Table 10). This indicates that the above-ground dry biomass production increased as the NPSB application rates increased from the lowest to the highest rate.

These findings are consistent with the results reported by Deresa *et al*. (2018) in common bean, where above-ground dry biomass showed a significant linear response to the application of different levels of NPSB compared to the control treatment. The increased in biomass yield of cultivars across blended NPS rates could be attributed to the fact that the enhanced availability of N significantly increased plant height, number of pods per plant and to the overall vegetative growth of the plants that contributed to higher aboveground dry biomass yield (Deresa *et al*., 2018). Similar results were reported by Girma (2009) in common bean, where an increment in biological yield was observed with increased rates of NP fertilizers. Wondwosen and Tamado (2019) reported that total dry matter production per plant increased significantly due to increased nitrogen application.

### 4.4.5. Grain yield

The grain yield of mung bean was highly significantly ($p < 0.001$) affected by the main effect of NPSB fertilizer rate and varieties, and their interaction (Appendix Table 3). Variety Rasa (N-26) combined with the application rate of 175 kg $ha^{-1}$ NPSB fertilizer produced the highest grain yield (1403.3 kg $ha^{-1}$) (Table 11). On the other hand, variety NVL-1 without NPSB fertilization resulted in the lowest grain yield (410 kg $ha^{-1}$).

Planting Rasa variety with 175 kg $ha^{-1}$ NPSB application increased the grain yield of mung bean by 70.78% compared to growing NVL-1 variety without NPSB fertilization. The differences in grain yield among mung bean varieties can be attributed to their varietal genetic characteristics as individual have different growing habits. The highest grain yield was achieved through the highest application of NPSB fertilizer.

They play a critical role in chlorophyll formation and protein synthesis, directly increasing plant protein content and ultimately boosting yield (Sadeghipour *et al*., 2010). In line with the present findings, (Mulu, 2019) reported that the grain yield of mung bean is significantly affected by the interaction of mung bean varieties and blended NPSB rate. Sadeghipour *et al*. (2010), who found highly significant interaction effects of nitrogen and phosphorus levels on seed yield of mung bean. Singh *et al*. (2017) also reported that the application of phosphorus and sulfur can maximize mung bean production.

Phosphorus is known to stimulate root development and seed formation (Havlin *et al*., 2004). Similarly, Yayis (2015) reported that the application of nitrogen and phosphorus significantly improved grain yield in beans.

Table 11. Interaction effects of variety and blended NPSB fertilizer rates on grain yield (kg ha-1) and harvest index (%) of mung bean

| Treatments | | Variables | |
|---|---|---|---|
| Varieties | NPSB (kg $ha^{-1}$) | Grain yield (kg $ha^{-1}$) | Harvest index (%) |
| NVL-1 | 0 | $410^{i}$ | $11.1^{de}$ |
| | 25 | $426.6^{i}$ | $10.5^{e}$ |
| | 50 | $480^{hi}$ | $9.86^{e}$ |
| | 75 | $532.67^{gh}$ | $10.16^{e}$ |
| | 100 | $610^{fg}$ | $11.97^{de}$ |
| | 125 | $726.67^{e}$ | $13.18^{cd}$ |
| | 150 | $833.33^{cd}$ | $14.98^{c}$ |
| | 175 | $1013.3^{b}$ | $18.12^{b}$ |
| Rasa | 0 | $505^{hi}$ | $12.28^{de}$ |
| | 25 | $532.3^{gh}$ | $10.11^{e}$ |
| | 50 | $618.3^{fg}$ | $13.56^{cd}$ |
| | 75 | $680^{ef}$ | $13.40^{cd}$ |
| | 100 | $763.3^{de}$ | $13.76^{de}$ |
| | 125 | $910^{c}$ | $17.73^{b}$ |
| | 150 | $1100^{b}$ | $20.19^{b}$ |
| | 175 | $1403.3^{a}$ | $24.97^{a}$ |
| Mean | | 721.56 | 14.12 |
| LSD (0.05) | | 100.75 | 2.6 |
| CV (%) | | 8.37 | 11.04 |

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of Variation. Means in the table followed by the same letters are not significantly different at 5% level of significance

### 4.4.6. Harvest index

The harvest index of mung bean crop was highly significantly ($p < 0.001$) influenced by the main effects of NPSB fertilizer rate and varieties, as well as their interactions (Appendix Table 3).

The highest harvest index (24.97%) was recorded for variety Rasa combined with the application of 175 kg $ha^{-1}$ NPSB fertilizer, while the lowest harvest index (9.86%) was observed for variety NVL-1 combined with the application of 50 kg $ha^{-1}$ NPSB fertilizer (Table 11). This difference in harvest index can be attributed to the effect of increased NPSB rates on the translocation of dry matter from the vegetative parts of the plant to the economic yield. Additionally, genotypic differences among the mung bean varieties in terms of grain yield and above-ground dry biomass can also contribute to variations in harvest index. This finding is consistent with the study conducted by Nuru (2020), which reported an increase in harvest index with an increase in NPSB fertilizer rate from 0 to 150 kg $ha^{-1}$ NPSB.

The low harvest index observed in some treatments is due to the enhancement of biomass yield more than seed yield. This result aligns with the findings of (Mulu, 2019), who reported the maximum harvest index values in the N-26 variety with increased NPSB fertilizer application compared to the control treatments. (Malik, 2003) also reported an increase in the harvest index of mung bean in response to the addition of nitrogen and phosphorus. Similarly, Mulu (2019) reported that the maximum harvest index was obtained from the N-26 variety at an NPSB rate of 150 kg $ha^{-1}$, followed by the same variety N-26 (39.05%) at a rate of 100 kg $ha^{-1}$ NPSB.

## 4.5. Correlation analysis

The correlation analysis indicated that grain yield was highly significantly ($p < 0.001$) and positively correlated with days to maturity ($r = 0.85^{**}$), number of total branches ($r = 0.78^{**}$), number of total nodule ($0.70^{**}$), number of effective nodule ($0.55^{**}$) and number of pod per plant ($0.66^{**}$) and number of seed per pod ($0.77^{**}$) and had non-significant correlated with days to flowering ($0.17^{ns}$).

The study showed that most of the traits were positively correlated with each other while some others are in a negative correlation especially days to flowering had shown mostly negative correlation with the traits correlated. These indicated that the yield increase is mainly attributed to an increase in biomass yield and pod number and moderately attributed to branches, pod length, number of seed per pod,  In consistence with this finding, Canci and

Toker (2014) was reported that grain yield was significantly and moderate positively correlated with the biological yield (r = 0.688), pods per plant (r = 0.682), plant height (r = 0.602), branches per plant (r = 0.585) and pod number (r = 0.510) of mung bean. It is also clearly observed that the increment in grain yield under this experiment due to NPSB blended fertilizer application has resulted from improvement in the number of primary branches per plant and number of seeds per pod which is supported by the positive and significant relationship of grain yield (Table 12).

Table 12. Simple correlation coefficient among different measured traits

| | DF | DPM | NTB | NTN | NEN | NDW | NPPP | NSPP | HSW | AGDB | GY | HI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DF | 1 | | | | | | | | | | | |
| DPM | 0.01$^{ns}$ | 1 | | | | | | | | | | |
| NTB | 0.12$^{ns}$ | 0.87$^{**}$ | 1 | | | | | | | | | |
| NTN | -0.15$^{ns}$ | 0.79$^{**}$ | 0.75$^{**}$ | 1 | | | | | | | | |
| NEN | -0.24$^{ns}$ | 0.73$^{**}$ | 0.59$^{**}$ | 0.71$^{**}$ | 1 | | | | | | | |
| NDW | 0.18$^{ns}$ | 0.74$^{**}$ | 0.67$^{**}$ | 0.64$^{**}$ | 0.57$^{**}$ | 1 | | | | | | |
| NPPP | 0.10$^{ns}$ | 0.66$^{**}$ | 0.55$^{**}$ | 0.49$^{**}$ | 0.48$^{**}$ | 0.66$^{**}$ | 1 | | | | | |
| NSPP | 0.36$^{**}$ | 0.74$^{**}$ | 0.72$^{**}$ | 0.51$^{**}$ | 0.41$^{**}$ | 0.71$^{**}$ | 0.69$^{**}$ | 1 | | | | |
| HSW | -0.05$^{ns}$ | 0.73$^{**}$ | 0.66$^{**}$ | 0.67$^{*}$ | 0.54$^{**}$ | 0.56$^{**}$ | 0.66$^{**}$ | 0.60$^{*}$ | 1 | | | |
| AGDB | 0.17$^{ns}$ | 0.68$^{**}$ | 0.74$^{**}$ | 0.61$^{**}$ | 0.54$^{**}$ | 0.58$^{**}$ | 0.50$^{**}$ | 0.61$^{**}$ | 0.59$^{**}$ | 1 | | |
| GY | 0.17$^{ns}$ | 0.85$^{**}$ | 0.78$^{**}$ | 0.70$^{**}$ | 0.55$^{**}$ | 0.77$^{**}$ | 0.66$^{**}$ | 0.77$^{**}$ | 0.67$^{*}$ | 0.72$^{**}$ | 1 | |
| HI | -0.07$^{ns}$ | 0.54$^{**}$ | 0.46$^{**}$ | 0.33$^{*}$ | 0.36$^{**}$ | 0.34$^{*}$ | 0.35$^{**}$ | 0.37$^{**}$ | 0.34$^{**}$ | 0.26$^{*}$ | 0.36$^{**}$ | 1 |

DF= days to flowering, DPM= days to physiological maturity, PH= plant height, NTB= number of total branches index, NTN=number of total nodule, NEN= number of effective nodule, NDW= nodule dry weight, NPPP= number of pod per plant, NSPP= number of seed per pod, HSW= hundred seed weight, AGBM= above-ground dry biomass, GY= grain yield, HI= harvest index

## 4.6. Partial budget analysis

The partial budget analysis revealed that the treatment with the highest net benefit (48,928 Birr $ha^{-1}$) and marginal rate of return (1113.2%) was obtained from the Rasa variety with an application rate of 175 kg $ha^{-1}$ of NPSB fertilizer. Whereas the lowest net benefit (15,860 Birr $ha^{-1}$) obtained from NVL-1 variety with an application rate of 25 kg $ha^{-1}$ of NPSB fertilizer (Table 13). According to the suggestion by CIMMYT (1988), the minimum acceptable marginal rate of return should be higher than 100%. Therefore, the results indicate that this treatment is economically feasible. Furthermore, there was a general increase in the cost-benefit ratio as the level of blended NPSB fertilizer increased. This suggests that higher fertilizer application rates can lead to greater economic returns. This treatment demonstrated the highest net benefit and a favorable marginal rate of return, making it a promising choice for farmers.

Table 13. Partial budget analysis of blended NPSB fertilizer rates and varieties of mung bean

| Treatments | | AY (kg $ha^{-1}$) | AGY (kg $ha^{-1}$) | TVC (birr $ha^{-1}$) | GFB (birr $ha^{-1}$) | NB (birr $ha^{-1}$) | MRR (%) |
|---|---|---|---|---|---|---|---|
| NVL-1 | 0 | 410 | 409.9 | 0 | 16,396 | 16,396 | - |
| | 25 | 426.6 | 426.5 | 1,200 | 17,060 | 15,860 | D |
| | 50 | 480 | 479.9 | 2,200 | 19,196 | 16,996 | 113.6 |
| | 75 | 532.6 | 532.5 | 3,200 | 21,300 | 18,100 | 110.4 |
| | 100 | 610 | 609.9 | 4,200 | 24,396 | 20,196 | 316 |
| | 125 | 726.6 | 726.5 | 5,200 | 29,060 | 23,860 | 366.4 |
| | 150 | 833.3 | 833.2 | 6,200 | 33,328 | 27,128 | 326.8 |
| | 175 | 1013.3 | 1013.2 | 7,200 | 40,528 | 33,328 | 620 |
| Rasa | 0 | 505 | 504.9 | 0 | 20,196 | 20,196 | - |
| | 25 | 532.3 | 532.2 | 1,200 | 21,288 | 20,088 | D |
| | 50 | 618.3 | 618.2 | 2,200 | 24,728 | 22,528 | 244 |
| | 75 | 680 | 679.9 | 3,200 | 27,196 | 23,996 | 146.8 |
| | 100 | 763.3 | 763.2 | 4,200 | 30.528 | 26,328 | 233.2 |
| | 125 | 910 | 909.9 | 5,200 | 36,396 | 31,196 | 486.8 |
| | 150 | 1100 | 1099.9 | 6,200 | 43,996 | 37,796 | 660 |
| | 175 | 1403.3 | 1403.2 | 7,200 | 56,128 | 48,928 | 1113.2 |

Where; AY= actual yield, AGY=adjusted grain yield downwards by10%, TVC= total variable cost, NB= net benefit, MRR= marginal rate of return, D= dominated treatment, price of blended NPSB cost= 40 birr/kg, price of mung bean variety= 40 birr/kg, price of labour cost=200 birr/day

# 5. CONCLUSIONS AND RECOMMENDATIONS

## 5.1. Conclusions

In the present study almost all the tested nodulation, growth and yield components influenced by that of variety and blended NPSB fertilizer. Likewise, the interaction effect of variety and NPSB fertilizer influenced a number of traits like days to 50% flowering, days to 90% physiological maturity, number of pods per plant, number of seeds per pod, grain yield and harvest index of mung bean. The Rasa variety at 175 kg $ha^{-1}$ NPSB produced the longest flowering and physiological maturity times (55.66 and 88.33 days respectively), the most pods per plant (31), number of seeds per pod (13.91), grain yield (1403.3kg $ha^{-1}$) and the highest harvest index (24.97%). Similarly the highest plant height (75.83cm), number of total branches (8.43), number of total nodules (22.9), number of effective nodules (13.41), hundred seed weight (35.53 kg $ha^{-1}$) and aboveground dry biomass (5606.3 kg $ha^{-1}$) were recorded under 175 kg $ha^{-1}$ NPSB fertilizer.

Moreover the present study confirmed that increasing rate of Blended NPSB fertilizer from 0 to 175kg $ha^{-1}$ in all parameters. Generally the improved varieties used in the present study performed well in all parameters of mung bean, where Rasa variety recorded the highest grain yield with application rate of 175 kg $ha^{-1}$ (1403.3 kg $ha^{-1}$) which is increased the grain yield by 70.78% as compared to the control (zero fertilizer). Application of 175 kg $ha^{-1}$ with Rasa variety obtained the highest net benefit (48,928 Birr $ha^{-1}$) with a marginal rate of return (1113.2%) which is economically feasible for mung bean production in the study area.

## 5.2. Recommendations

Based on the results of the present study, it is recommended that NPSB fertilizer at the rate of 175 kg $ha^{-1}$ with Rasa variety are economically feasible and profitable for the production of mung bean in the study area and similar agroecology. However, the present study was conducted in for a season and at one location, therefore further multi-seasons and multi-locations studies are required in order to give comprehensive and strong recommendation for wide range of agro ecologies for mung bean production.

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# 7. APPENDICES

Appendix Table 1. Soil physico chemical properties of the experimental site

| Soil characters | Unit | Values | Rating | References |
|---|---|---|---|---|
| Sand | % | 11 | - | - |
| Silt | % | 21 | - | - |
| Clay | % | 68 | - | - |
| Textural class | - | Clay | - | - |
| PH (H2O) | - | 5.7 | Moderately acid | (Tekalign *et al*., 1991) |
| Organic carbon | % | 2.1 | Low | (Landon, 1991) |
| CEC | Cmol (+) $kg^{-1}$ | 44.8 | Very high | (Hazelton and Murphy, 2007) |
| Total nitrogen | % | 0.16 | Low | (Landon, 1991) |
| Available phosphorus | Mg $kg^{-1}$ | 2.69 | Very low | (Olsen *et al*., 1954) |
| Available sulphur | Mg $kg^{-1}$ | 6.34 | Low | (Lewis, 1999) |
| Available boron | Mg $kg^{-1}$ | 0.443 | Low | (Reisenauer *et al*., 1973) |

Appendix Table 2. Mean square values for phenological, nodulation and growth parameters

| | | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Source of variation | D.F | DF | DPM | PH | NTB | NTN | NEN | NDW |
| Replication | 2 | $31.64^{ns}$ | $322.14^{**}$ | $181.51^{*}$ | $3.95^{ns}$ | $8.34^{ns}$ | $35.52^{**}$ | $0.00004^{ns}$ |
| NPSB rate | 7 | $376.23^{**}$ | $1022.42^{**}$ | $529.48^{**}$ | $18.51^{**}$ | $91.42^{**}$ | $41.97^{**}$ | $0.0012^{*}$ |
| Variety | 1 | $140.08^{**}$ | $630.75^{**}$ | $177.1^{ns}$ | $6.45^{ns}$ | $11.6^{ns}$ | $3.52^{ns}$ | $0.0007^{*}$ |
| NPSB*Variety | 7 | $25.03^{*}$ | $137.17^{*}$ | $12.18^{ns}$ | $0.51^{ns}$ | $0.22^{ns}$ | $0.51^{ns}$ | $0.0004^{ns}$ |
| Error | 30 | 10.51 | 59.07 | 56.61 | 2.73 | 21.65 | 4.41 | 0.00017 |

Where, D.F= degree of freedom, DF= days to flowerings, DPM= days to physiological maturity, PH= plant height, NTB= number of total branches, NTN= number of total nodule, NEN= number of effective nodule, NDW= nodule dry weight

Appendix Table 3. Mean square values for yield parameters

| | | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| Source of variation | D.F | NPPP | NSPP | HSW | AGDB | GY | HI |
| Replication | 2 | $18.81^{ns}$ | $5.85^{*}$ | $39.77^{ns}$ | $45151.5^{ns}$ | $2980.68^{ns}$ | $1.70^{ns}$ |
| NPSB rate | 7 | $93.35^{**}$ | $42.22^{**}$ | $143.27^{*}$ | $1891159.1^{**}$ | $410507.6^{**}$ | $87.29^{**}$ |
| Variety | 1 | $152.08^{**}$ | $8.09^{*}$ | $65.1^{ns}$ | $318502.1^{ns}$ | $410515^{**}$ | $127.1^{**}$ |
| NPSB*Variety | 7 | $16.81^{*}$ | $3.52^{*}$ | $95.8^{ns}$ | $372047.2^{ns}$ | $14505.1^{**}$ | $8.31^{**}$ |
| Error | 30 | 7.27 | 1.52 | 47.94 | 198643 | 3650.55 | 2.43 |

Where, D.F= degree of freedom, NPPP= number of pod per plant, NSPP= number of seed per pod, HSW=hundred seed weight, AGDB= above ground dry biomass, GY= grain yield, HI= harvest index

Appendix Table 4. Monthly and yearly total rainfall in the study area (2012-2022)

| Year | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2012 | 0.0 | 0.0 | 77.5 | 57.2 | 238.3 | 312.9 | 257.6 | 221.1 | 115.4 | 8.9 | 41.3 | 0.0 |
| 2013 | 0.0 | 0.0 | 6.9 | 45.7 | 47.9 | 224.8 | 257.5 | 219.1 | 168.0 | 17.3 | 8.2 | 2.2 |
| 2014 | 3.8 | 7.0 | 28.9 | 75.3 | 140.1 | 201.1 | 241.5 | 255.5 | 218.0 | 72.3 | 14.6 | 0.0 |
| 2015 | 3.6 | 72.0 | 45.1 | 93.9 | 206.2 | 122.7 | 210.8 | 216.7 | 197.5 | 119.1 | 11.0 | 0.0 |
| 2016 | 0.0 | 0.0 | 25.6 | 10.9 | 178.2 | 277.1 | 209.9 | 214.2 | 158.4 | 22.3 | 16.8 | 28.8 |
| 2017 | 32.0 | 12.3 | 25.7 | 177.8 | 172.3 | 106.3 | 230.4 | 241.3 | 160.0 | 96.1 | 10.1 | 0.0 |
| 2018 | 0.0 | 57.9 | 25.8 | 69.6 | 245.1 | 213.5 | 229.3 | 256.7 | 159.7 | 48.2 | 12.7 | 0.0 |
| 2019 | 3.7 | 60.7 | 49.5 | 110.2 | 94.8 | 339.8 | 254.7 | 232.6 | 225.2 | 42.3 | 66.1 | 1.2 |
| 2020 | 0.0 | 31.3 | 54.0 | 228.4 | 104.0 | 219.9 | 235.4 | 270.3 | 237.0 | 51.7 | 81.0 | 2.3 |
| 2022 | 23.1 | 16.1 | 119.4 | 200.2 | 134.2 | 191.0 | 372.4 | 260.9 | 163.2 | 64.9 | 24.9 | 25.2 |
| Total | 66.2 | 257.3 | 458.4 | 1069.2 | 1561.1 | 2209.1 | 2499.5 | 2388.4 | 1802.4 | 543.1 | 286.7 | 59.7 |

Source: Southern Nation Nationality and Peoples' Regional State Meteorological Services Agency (2022)

Appendix Table 5. Mean monthly and annual maximum temperature in the study area (2012-2022)

| Year | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2012 | 24.3 | 24.9 | 24.7 | 27.5 | 27.1 | 24.3 | 23.1 | 21.7 | 21.7 | 25.1 | 25.3 | 25.5 |
| 2013 | 25.6 | 28.0 | 28.0 | 27.0 | 27.5 | 23.0 | 21.0 | 21.4 | 22.2 | 25.2 | 25.2 | 25.3 |
| 2014 | 26.2 | 27.5 | 27.2 | 27.0 | 24.9 | 23.7 | 21.9 | 21.9 | 22.4 | 23.7 | 24.6 | 25.0 |
| 2015 | 26.5 | 26.1 | 26.6 | 26.5 | 24.8 | 25.0 | 22.7 | 21.3 | 22.0 | 24.0 | 24.6 | 24.9 |
| 2016 | 25.9 | 27.5 | 28.3 | 28.1 | 25.3 | 23.0 | 22.8 | 22.4 | 23.0 | 25.5 | 25.5 | 25.0 |
| 2017 | 26.0 | 26.5 | 26.4 | 25.5 | 27.3 | 23.3 | 22.2 | 22.0 | 22.9 | 25.4 | 25.4 | 25.3 |
| 2018 | 25.3 | 27.2 | 26.7 | 27.3 | 25.3 | 22.7 | 21.5 | 21.4 | 24.1 | 24.7 | 24.7 | 24.8 |
| 2019 | 25.7 | 26.6 | 27.3 | 25.1 | 25.8 | 22.4 | 21.4 | 21.7 | 23.5 | 25.1 | 24.4 | 25.1 |
| 2020 | 27.0 | 27.5 | 27.6 | 25.3 | 25.7 | 22.7 | 21.1 | 21.3 | 22.2 | 24.5 | 24.7 | 24.9 |
| 2022 | 26.0 | 27.0 | 26.2 | 26.0 | 24.7 | 23.0 | 21.0 | 21.3 | 22.3 | 24.4 | 25.3 | 25.5 |
| Total | 258.5 | 268.9 | 269.0 | 265.3 | 258.4 | 233.2 | 218.8 | 216.3 | 226.3 | 247.5 | 249.7 | 251.2 |

Source: Southern Nation Nationality and Peoples' Regional State Meteorological Services Agency (2022)

Appendix Table 6. Mean monthly and annual minimum temperature in the study area (2012-2022)

| | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2012 | 8.6 | 7.8 | 8.0 | 12.7 | 11.7 | 13.1 | 12.0 | 11.9 | 11.6 | 9.7 | 8.6 | 6.3 |
| 2013 | 8.4 | 6.8 | 9.6 | 12.9 | 11.8 | 12.3 | 12.5 | 12.5 | 11.9 | 9.0 | 8.8 | 6.9 |
| 2014 | 7.9 | 9.1 | 11.9 | 12.1 | 12.0 | 12.5 | 12.3 | 12.5 | 11.5 | 9.7 | 8.4 | 6.6 |
| 2015 | 7.1 | 10.3 | 10.2 | 10.8 | 11.5 | 11.3 | 12.1 | 11.7 | 11.9 | 10.7 | 9.0 | 7.7 |
| 2016 | 6.7 | 9.1 | 9.7 | 10.7 | 12.1 | 13.0 | 12.8 | 12.5 | 11.9 | 9.9 | 9.0 | 9.3 |
| 2017 | 6.5 | 9.7 | 10.2 | 10.6 | 11.9 | 12.3 | 12.5 | 12.7 | 12.0 | 9.1 | 9.2 | 7.7 |
| 2018 | 7.1 | 9.3 | 11.1 | 11.8 | 12.0 | 12.7 | 12.1 | 12.1 | 11.5 | 9.8 | 9.7 | 8.7 |
| 2019 | 7.8 | 9.8 | 10.9 | 12.6 | 12.4 | 22.4 | 12.3 | 12.3 | 11.3 | 9.4 | 8.9 | 7.0 |
| 2020 | 5.5 | 9.2 | 10.8 | 12.8 | 11.0 | 13.5 | 12.6 | 12.5 | 12.5 | 9.8 | 10.0 | 8.8 |
| 2022 | 8.5 | 10.4 | 12.6 | 12.3 | 12.7 | 12.9 | 13.1 | 13.2 | 12.0 | 9.0 | 7.7 | 6.2 |
| Total | 74.03 | 91.5 | 105.0 | 119.3 | 118.9 | 136.0 | 124.3 | 123.9 | 118.1 | 96.0 | 89.3 | 75.3 |

Source: Southern Nation Nationality and Peoples' Regional State Meteorological Services Agency (2022)