



**RESPONSE OF MUNGBEAN (*Vigna radiata* (L.) Wilczek) VARIETIES TO
DIFFIRENT RATES OF NPSB FERTILIZER RATESAT ZALA DISTRICT,
SOUTHERN ETHIOPIA**

M.Sc. THESIS

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HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

HAWASSA, ETHIOPIA

APRIL, 2021

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SOUTHERN ETHIOPIA**

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**COLLEGE OF AGRICULTURE SCHOOL OF PLANT AND
HORTICULTURAL SCIENCES**

ADVISORS' APPROVAL SHEET

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This is to certify that the thesis entitled “**Response of Mungbean (*Vigna radiata* (L.) Wilczek) Varies to NPSB Fertilizer Rate at Zala District, Southern Ethiopia**” submitted the thesis in partial fulfilment of the requirements for the Degree of Master of Science in plant science(Agronomy) to Graduate Program of the School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University. It is a record of original research carried out by Habtamu Haringo under our supervision, and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the course of this investigation have been duly acknowledged. We recommend that this thesis submitted as it fulfilling the requirements.

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We, undersigned, members of the Board of Examiners of the final open defense by Habtamu Haringo Ushacho have read and evaluated his thesis entitled “**Response of Mungbean (*Vigna radiata* (L.) Wilczek) Varieties to NPSB Fertilizer Rate at Zala District, Southern Ethiopia**” and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfilment for the requirements for the Degree of Master of Science in Plant Science with Specialization in Agronomy.

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DEDICATION

This thesis is dedicated to my beloved wife Tesfanesh Yimer for her love, strength and vision as well as for her dedicated help and partnership in the success of my life.

STATEMENT OF THE AUTHOR

First of all, I declared that this thesis is a result of my genuine work and that I have duly acknowledged all sources of materials used for writing. I submitted this thesis to Hawassa University in partial fulfilment for the Degree of Master of Science in Agronomy and it is deposited in the library of the University to be made available to borrowers for reference. I solemnly declared that I have not so far submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief quotations from this thesis are allowed without requiring special permission provided that an accurate acknowledgement of the source is made. Requests for extended quotations from reproduction of this manuscript in whole or part Zala wereda agricultural office and head Administration when, his or her judgment, the proposed use of the material is for a scholarship interest. In all other instances, however, permission must be obtained from the author.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGY	Adjusted grain yield
B	Boron
CEC	Cat ion exchange capacity
GFB	Gross field benefit
MRR	marginal rate of returns
N	Nitrogen
NB	Net benefit
OC	Organic carbon
P	Phosphorous
S	Sulphur
TVC	Total variable cost
UGY	Unadjusted grain yield
CSA	Central static agency
MOA	Ministry of Agriculture
MoAR	Ministry of Agriculture And Rural Development
ATA	Ethiopian Agricultural Transformation Agency
DMARC	Melkasa Agricultural Research Center
Ethio SIS	Ethiopian Soil Information System
CIMMYT	International Maize and Wheat Improvement center
AVRDC	Asian Vegetable Research and Development Center

CONTENTS	PAGE
DEDICATION	iv
STATEMENT OF THE AUTHOR.....	v
ACKNOWLEDGEMENTS	vi
LIST OF ACRONYMS AND ABBREVIATIONS.....	vii
LIST OF TABALE	x
LIST OF FIGURES.....	xi
LIST OF TABLES IN THE APPENDICES	xii
LIST OF FIGURES IN THE APPENDICES	xiii
ABSTRACT.....	xiv
1. INTRODUCTION.....	1
1.1 Background	1
1.2. Objectives.....	5
2. LITERATURE REVIEW	6
2.1 Origin, Distribution and Production of Mungbean	6
2.2 Mung Bean Production in Ethiopia.....	7
2.4. Importance of Mung bean	8
2.5. Performance of Mung bean Varieties.....	9
2.6. Soil Nutrients Status in Ethiopia	9
2.7. Role of NPSB Blended Fertilizer on Yield and Yield Components of Mung bean.....	10
2.7.1. Effect of nitrogen application on yield and yield components of mung bean.....	10
2.7.2. Effect of phosphorous application on yield and yield Components of the mung bean	13
2.7.3. Effect of sulfur application on yield and yield components of the mung bean.....	14
2.7.4. Effect of boron application on yield and yield Components of the mung bean	16
2.7.5. Effect of blended NPSB fertilizer application on crop yield and yield Components...18	18
3. MATERIALS AND METHODS	20
3.1. Description of the study area.....	20
3.2. Treatments and Experimental Design	21

3.3. Agronomic Practices	23
3.4. Data collection and measurements	24
3.4.1. Soil sampling and analysis	24
3.4.2. Crop Data	25
3.6. Economic Analysis.....	27
4. RESULTS AND DISCUSSION	29
4.1. Soil Physico-chemical properties of Experimental soil.	29
4.2. Effect of NPSB Blended Fertilizer rates on Yield and Yield Components of the Mung bean	31
4.2.1. Days to flowering	31
4.2.2. Days to physiological maturity.....	33
4.3. Growth Parameters	34
4.3.1. Plant height (cm)	34
4.3.2. Branch number	36
4.4. Nodulation parameters	37
4.4.1. Nodule number	37
4.5. Yield and Yield related Components	39
4.5.1. Pod number plant ⁻¹	39
4.5.2. Seed number pod ⁻¹	41
4.5.3. Seed weight	43
4.5.4. Grain yield.....	44
4.5.5. Straw yield.....	46
4.5.6. Above ground dry biomass.....	48
4.5.7. Harvest index (%).....	49
4.6. Partial Budget Analysis	51
5. SUMMARY AND CONCLUSION	54
6. REFERENCE.....	56
APPENDICES.....	75
Appendix A: Lists of Appendix in Tables.....	75
Appendix B: Lists of Appendix in Figures	76

LIST OF TABALE

Table 1: Description and recommendation domain of mung bean varieties used for the study...	22
Table 2: Description of treatment combinations.....	23
Table 3: Selected physicochemical properties of the soil of the experimental site before planting	31
Table 4: Main effect of NPSB fertilizer rates and varieties on plant height and brunch number of mung bean.....	37
Table 5: Main effect of varieties and NPSB fertilizer rates on total nodule number of mung bean	39
Table 6: Main effects of varieties and NPSB fertilizer rate on pod number plant-1 of mung bean.	41
Table 7: Interaction effects of varieties and NPSB fertilizer rate on 1000-seed weight of mung bean (g)	44
Table 8: Interaction effects of varieties and NPSB fertilizer rate on Straw yield of mung bean..	47
Table 9: Interaction effects of varieties and NPSB fertilizer rate on Above ground dry biomass of mung bean	49
Table 10: Effects of interaction of varieties and NPSB fertilizer rate on harvest index (HI) of mung bean.....	50
Table 11: Summary of partial budget analysis of the response of mung bean varieties to the application of NPSB fertilizer at Zala district.....	53

LIST OF FIGURES

Figure 1: Location map of study area	21
Figure 2 Effects of interaction of varieties and NPSB fertilizer rate on days to 50% flowering of Mungbean	32
Figure 3: Interaction effects of varieties and NPSB fertilizer rate on days to 90% physiological maturity of mung bean.....	34
Figure 4: Interaction effects of varieties and NPSB fertilizer rate on seed number of mung bean.....	42
Figure 5: Interaction effects of varieties and NPSB fertilizer rate on grain yield of mung bean.....	46

LIST OF TABLES IN THE APPENDICES

Table: 1 Mean squares of analysis of variance for phenological, growth and nodulation parameters of mung bean as affected by varieties and NPSB rates	75
Table: 2 Analysis of variance for yield and yield components of the mung bean as affected by varieties and NPSB rates	75

LIST OF FIGURES IN THE APPENDICES

Figure: 1 Layout preparation of the experimental field and eighteen day after germination ..	76
Figure: 2 Field performance of a trial at 31 days after planting.....	77
Figure: 3 Measuring seed weight	78

Response of Mungbean (*Vigna radiata* (L.) Wilczek) Varieties to NPSB Fertilizer Rate at Zala District, Southern Ethiopia

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ABSTRACT

Mungbean (Vigna radiata L.) is the sixth exportable pulse crop in Ethiopia and is a useful protein source for consumers in semi-arid and arid areas of the country. However, its current national productivity is 1.003ton ha⁻¹, which is much lower than its potential due to the unavailability of balanced nutrients in the soil. Therefore, this study was carried out to evaluate the response of Mungbean varieties to NPSB fertilizer rates. The experiment was conducted in Zala woreda, during the main cropping season of 2021. The experiment was laid out using RCBD in a factorial arrangement with three replications. There was a total of sixteen treatments from a factorial combination of four fertilizer rates (0, 50, 100 & 150 kg ha⁻¹) and four varieties of Mungbean (Borda, Rasa (N26), NVL-1 & Gofa local). The results revealed that fertilizer had a significant ($P < 0.05$) effect on days to flowering, days to physiological maturity, plant height, branch number, nodule number, pod number per plant, seed number per pod, thousand seed weight, grain yield, above ground dry biomass, and strow yield. Varieties also had a significant ($P < 0.05$) effect on days to physiological maturity, branch number, pod number per plant, seed number per pod, thousand seed weight, grain yield and harvest index. The interaction of NPSB fertilizer application with varieties also had a significant ($P < 0.05$) effect on days to flowering, days to physiological maturity, number of seeds per pod, thousand seed weight, grain yield, dry above ground biomass and harvest index. The highest yield (2.5tonha⁻¹) resulted from the interaction effect of the 150kg NPSB with the Boreda Variety application. The partial budget analysis also indicated that the best treatments were interaction of the 150kg ha⁻¹ NPSB with Borda and Rasa (N-26), which gave the first and second highest net benefits of 126126 and 96600 ETB ha⁻¹, respectively, with an acceptable marginal rate of returns. Therefore, mung bean producers can use the NPSB mixed fertilizer at the rate of 150kg ha⁻¹ and Boreda Variety in the Zala district of the Gofa Zone and other similar areas to increase their productivity.

Keywords: Grain yield, Mungbean, NPSB, variety,

1. INTRODUCTION

1.1 Background

Among pulses, mung bean (*Vigna radiata* L. Wilczek), which is commonly known as green gram (bean), is one of the most important crops grown in different tropical and subtropical parts of the world (Khan *et al.*, 2012; Kumari *et al.*, 2012). The crop belongs to the Fabaceae family. It has been domesticated in India and most of the world's mung bean production comes from Asia (AVRDC, 1990). India is the world's largest producer of the crop (Singh *et al.*, 2011). A total of 27,085.92 mung bean accessions are available worldwide in Gene Bank at different stations and more than 110 mung bean cultivars have been released by the Asian Vegetable Research and Development Center (AVRDC) in South Asia and around the world (Ali and Gupta, 2012).

The crop is rich in vitamin A and protein that is considered a substitute for animal protein and forms a balanced diet when taken in combination with cereals that contain a low level of protein (Consideine, 1992; Rahman *et al.*, 2008). The grain contains 24.2% protein, 1.3% fat, and 60.4% carbohydrate (Hussain *et al.*, 2011). It is also known to be very healthy and packed with a variety of nutrients such as vitamin B, vitamin C, protein, manganese, and many other essential nutrients required for effective functioning of human health. The mung bean seed is low in calories and rich in fibre and is easily digestible that does not cause flatulence as occurs with many other legumes (Minh, 2014). The seed of mung bean is mainly used for making soups, bread and biscuits (Sehrawat *et al.*, 2013). The main purposes of growing this crop are for its protein rich edible seeds and fresh sprouts. It is a vital crop in developing

countries where it is consumed as dry seeds, fresh green pods, or leaves due to its high protein, vitamin, and mineral content.

The mung bean crop is a recent introduction to Ethiopian pulse production and is grown in few areas of the country. The volume of production is also very small and is concentrated mainly in the Amhara region (north Shewa and south Wollo zones), and South Nation Nationalities of the people (SNNPR) (Gamo, Gofa, Konso, South Omo, Konta) and in the Oromia region (Harerghe) and in some wereda of the Benishangul Gumuz region (CSA, 2012). However, the crop is becoming increasingly important in other dry areas of Ethiopia due to its high market and nutritional value and early maturity (Ahmed, M., 2017). For example, its production has increased in Ethiopia from 14,562.00 ha with an average seed yield of 966 kg ha⁻¹ in 2014/15 cropping season (CSA, 2015) to 24,038.85 ha with an average productivity of 1003 kg ha⁻¹ in 2015/16 cropping season (CSA, 2012). According to Ethiopian Commodity Exchange (ECX), the crop has also been included as the sixth commodity to be traded on its floor as of January 2014 (Addis Fortune, 2014).

The national mung bean production in Ethiopia is estimated at 27,085.92 ha with a total production of 27,898.50 tons ha⁻¹ (CSA, 2017/18). Similarly, the average productivity at the national level is 1.003 ton ha⁻¹ (CSA, 2017), while the average productivity reported at the research center is 1.65 ton ha⁻¹ (Asrat, *et al.*, 2012). The productivity of mung bean in the Gofa Zone Zala district is 0.6 ton ha⁻¹ (Gofa zone Agricultural and natural resource office, 2020) and 0.7 ton ha⁻¹ (Zala District Agricultural and Natural Resources Office, 2020).

This is lower than the production achieved in the research center (i.e., 1.65 ton ha⁻¹) (Asrat, *et al.*, 2012). This low yield might be attributed to numerous factors, including biotic and

abiotic factors, growing of low-yielding varieties and inappropriate agronomic practices such as row spacing, fertilizer application, and plant population, which are prerequisites for obtaining higher productivity (Rafiei, 2009). Of all the environmental factors that limit bean production, low soil fertility plays a greater role in reducing yields in most of the agricultural areas of Ethiopia (Tana and Fininsa, 2006; Girma, 2009). The loss of soil fertility and the mismatch between fertilizer technology and environmental requirement in the last five decades were among the main production constraints of the country that contributed to the decline in yield (Mesfin, 2009). So far, the most commonly used fertilizers in Ethiopia are N and P, but they are not the only yield-constraining elements. Others such as S, Zn, B, Fe, Cu, and K have recently been identified to be deficient in most of the Ethiopian soils (ATA, 2015). According to ATA (2015) there were 53,000 soil samples collected from 18,000 kebel to identify deficient nutrients in Ethiopian soils.

The results in the country indicate that Ethiopian soils are deficient in 99% P, 92% S, 86% N, 65% B, 53% Zn, 7.5% K and 0.2% Cu. Following this, 35 types of blended fertilizers have been identified and a country-wide map of Ethiopian soil resources and fertility status has been prepared for each of Ethiopian regions up to wereda levels (ATA, 2015). The very recent soil survey in SNNPRS also revealed that nitrogen (N), phosphorous (P), potassium (K), sulfur (S), copper (Cu), zinc (Zn), boron (B) and iron (Fe) were reported as growth limiting nutrients ((Hordofa, Melkamu2020).. The result of the soil survey in the Zala district also demonstrated that all Kebels including the study area, were marked as N,P,S and B deficient (Hordofa, Melkamu2020).

The reports mentioned above indicated that the productivity of mung bean in the study area could be greatly influenced by the low status of soil nutrient availability. Eden *et al*,(2002),

and Kaganzi (2008), Girma (2009), also reported the influence of low soil nutrient status on bean productivity. Blends are mixes of fertilizers in appropriate proportions to supply multiple nutrients for a crop, whereas compound fertilizers are imported directly from the international market. The advantages of blended fertilizers are their flexibility to define formulas and can be developed by the local industry (AFAP, 2015). Like other legumes, it requires nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, boron, zinc, and sulfur for growth and development (Arain, 2012; IFPRI, 2010). Selection of varieties that perform well under local agro ecological conditions and soil fertility management could improve crop productivity.

In the production of mung bean, nutritional imbalance and the use of unimproved varieties are among the important problems. These can be solved by using improved varieties and agronomic practices, including use of balanced fertilizers. Nutrient management is one of the important factors that greatly influence mung bean growth and yield (Muhammad *et al.*, 2014). However, little has been done on the growth parameters of mung bean and on its production constraints in the Ethiopia (Fanuel and Walelign, 2013). Several research studies have been conducted on the application of chemical fertilizers in mung bean. However, the response of the Mungbean varieties to blended fertilizers and its optimal rate of recommendation and economic feasibility in the study area is lacking. Thus, this research was initiated to identify high yielding mung bean varieties and the optimal level of blended NPSB fertilizer at Zala in southern Ethiopia.

1.2. Objectives

1. To investigate the response of mung bean varieties to application of NPSB fertilizer.
2. To suggest the economically feasible NPSB application rate for production of mung beans in the study area.
3. To identify best performing mungbean variety for the study area.

2. LITERATURE REVIEW

2.1 Origin, Distribution and Production of Mungbean

The mung bean crop is believed to have originated from the Indian subcontinent, where it was domesticated as early as 1500 BC. Cultivated mung beans were introduced to southern and eastern Asia, Africa, Austronesia, the Americas and the West Indies. It is now widespread throughout the Tropics and is found from sea level up to an altitude of 1850 m in the Himalayas (Lambrides *et al.*, 2006; Mogotsi, 2006).

Mung bean is an annual crop, cultivated mainly in rotation with cereals. It is an erect plant which is highly branched and is about 60 to 76 cm tall (Oplinger *et al.*, 1990). The optimal temperature range for growth is between 27 ° C and 30 ° C. This means that the crop is generally grown during summer. Seeds can be planted when the minimum temperature is above 15 ° C. Mung beans respond to daylight length. Short days result in early flowering, while long days result in late flowering. However, the mung bean varieties differ in their response to photoperiods.

Mung bean is considered to be heat and drought tolerant. Adequate rainfall is required from flowering to late pod fill to ensure good yield. Late plantings that result in flowering during high-temperature-low-moisture periods will reduce yield. Mung beans do best on fertile, sandy loam soils with good internal drainage and a pH in the range of 6.3 and 7.2 (Arzani, Ahmad2008).The crop is characterized by fast growth under warm conditions, low water requirement, and excellent soil fertility enhancement through nitrogen fixation (Yagoob and Yagoob, 2014). It is well adapted to areas that receive an annual average rainfall ranging from 600 to 750mm, altitude between 1000 to 1450 meters above sea level.

Mung bean is considered to be heat and drought tolerant (Rashid *et al.*, 2013).

2.2 Mung Bean Production in Ethiopia

Mung bean is a recently introduced crop in Ethiopian pulse production and is grown in the eastern part of the north of the Amhara region (North Shewa, Oromia special zone and Southern Wollo), SNNPR (Gamo, Gofa, Konso, South Omo, Konta), pocket areas in the Oromia region (Hararge) and in some woreda of Benishangul Gumuz regional state (ECX, 2014). The average crop yield is limited to 0.6-0.8 ton ha⁻¹ due to different reasons (EPP, 2004). Although its production in Ethiopia is very negligible compared to other pulse crops, small farmers in drier marginal environments grow mung beans and it has been an important grain legume for resource-poor farmers in these areas (MOARD, 2008). Its cultivation is gaining popularity from time to time among farmers and Ethiopia's export of mung beans has grown slightly from year to year.

2.3 Agro ecological requirements of the mung bean

The widespread allocations of Mungbean are in the tropics and subtropics. It is a "short-day" plant. Qualitative responses (no flower initiation if photoperiod is longer than a certain critical value) occur, while absolute day neutrality has yet to be confirmed (Siemonsma and Arwooth, 2016). Seed can be planted when the minimum temperature is greater than 15 ° C. Adequate rainfall is required from flowering to late pod filling to ensure good yield. It performs best in fertile sandy loam soils with good internal drainage and a pH in the range of 6.3 and 7.2. It does not tolerate saline soils and can show severe iron chlorosis symptoms and certain micronutrient deficiencies in more alkaline soils (SADAFF, 2010).

Ethiopia's Commodity Exchange (ECX) announces the introduction of a new commodity, green mung bean, on its trading floor. Green mung bean is the sixth product that Ethiopian Commodity Exchange is trading. Coffee, sesame, white beans, maize and wheat have been traded in the Ethiopian Commodity Exchange so far. Despite its growing demand on the international market, there is a chronic supply gap in Ethiopia on the production side. However, Ethiopia's mung bean export has grown slightly from time to time (Ahmed, M., 2017).

2.4. Importance of Mung bean

The mung bean is produced for both human consumption and as feed (Lee et al., 1997). It is a vital crop in developing countries where it is consumed as dry feed, fresh green pods, or leaves due to its high protein, vitamin, and mineral content. It is also consumed as forage or green pods and seeds as vegetables (Tang *et al.*, 2014). Mostly it has the potential to fill the protein shortage gap, since its seeds are rich in protein and amino acids, thus serving as a protein source for human consumption. It can provide significant amounts of protein, carbohydrate, and a range of micronutrients in diets (Anwar *et al.*, 2007). Minh (2014) also reported that the mung bean contains many minerals, such as calcium and potassium, which are essential to improve the strength of bones and teeth.

Mungbean is also one of the most important grain legumes produced for income generation Pandey *et al.* (2011) also reported that the crop is the most important cash crop in the world. There is increasing demand for mung beans in the import export market of the world (Zhichao *et al.*, 2018). In Ethiopia, it is recently included among exported commodities by

(Ahmed, M., 2017). Adaptation to short growth duration, low water requirement, ability to increase soil fertility and usefulness in crop rotation practices are also another significances of mung bean. And it also has the ability to improve soil fertility by fixing atmospheric nitrogen in available form with the help of rhizobia species for the growth and development of the plant are characteristics of mung bean (Singh *et al.*, 2011). Capacity of forming important ecological relationships with most invisible soil microbes for the achievement of limiting macro and micronutrients especially in the nutrient poor ecosystems increase productivity of crop and land (Yasmeen *et al.*, 2013). The symbiotic relation also has a very good ability to enhance the physical, chemical, and biological properties of soil. Therefore, it is considered an important component of sustainable agricultural production.

2.5. Performance of Mung bean Varieties

Modern high-yielding varieties of mung bean give higher yields compared to local varieties. This is due to the high-yielding genetic makeup of the modern variety. Ahmed, M., (2017) reported that improved varieties of mung bean usually produce higher seed yields. The variation in 1000 seed weight among mung bean varieties might be due to their different genetic makeup of the varieties (Kabir and Sarkar, 2008). They also showed a significant variation in plant growth, number of branches, and yield components of four Mungbean varieties. Furthermore, higher productivity in any crop can be achieved through a combination of ideal varieties associated with a suitable environment and appropriate agronomic practices.

2.6. Soil Nutrients Status in Ethiopia

Ethiopia has potential rich land resources, but agricultural productivity has been below optimal yield mainly due to a range of factors including soil erosion, acidity and nutrient depletion, lack of soil fertility replenishment, nutrient mining and lack of balanced

fertilization (Tesfahunegn *et al.*, 2011) and Wondowosen Sheleme, (2011). Crop yield tends to decrease when soils are depleted of nutrients (Tilahun, 2007). The problems might be greater in the case of the Southern Nations, Nationalities, and people's regional state due to high population density and fragmented farm land as well as continuous farming. However, Ethiopian farmers used to apply only chemical fertilizers diammonium phosphate (DAP) and urea to increase crop yields for about decades, and this did not consider soil fertility status and crop requirement.

The very recent soil survey in SNNPRS revealed that nitrogen (N), phosphorus (P), potassium (K), sulfur (S), copper (Cu), zinc (Zn), and boron (B) were reported as growth limiting nutrients (Kassahun, Behailu 2015). A soil fertility survey conducted by Abiye *et al.* (2004) indicated the K deficiency in some Ethiopian soils. Furthermore Sori, Gedefa,etal(2019) reported that the sulfur content in the soils they studied was found to be very low in some Ethiopian soils. All of these findings suggest the need to apply balanced fertilizers containing N, P, K, S, B, Zn etc. in a blend form according to site-specific nutrient deficiencies.

2.7. Role of NPSB Blended Fertilizer on Yield and Yield Components of Mung bean

2.7.1. Effect of nitrogen application on yield and yield components of mung bean

Nitrogen (N) is the most limiting nutrient in plant growth and development, being found to be an essential component of metabolically active compounds such as proteins, enzymes, coenzymes, nucleic acids, phytochrome, and chlorophyll; it plays an important role in the biochemical processes of the plant. According to Thakuria and Ioikham (2012), nitrogen is also most useful for pulse crops because it is the component of protein. Without N, it is not possible to synthesize the necessary proteins, enzymes, DNA, and RNA required in virtually all plant cells for their initial development, sustained growth, and functioning to support other tissues of the plant.

Therefore, deficiencies in reduced N necessarily result in fewer biochemical machinery to catalyse plant metabolism and generate new cells. Consequently, nitrogen deficiencies result in decreased crop leaf area, photosynthetic assimilation, and seed growth. Nitrogen also plays an important role in the physiological process of the plant and its appropriate rate at the time of sowing leads to rapid leaf area development, prolongs leaves life, and improves leaf area duration (LAD), after flowering, causing an increase in the overall assimilation rate, thus contributing to increased seed yield. It is involved in all major plant development and yield formation processes. Furthermore, a good supply of nitrogen to the plant stimulates root growth and development, as well as uptake of other nutrients (FAO 2000).

It is now well established that despite nitrogen fixation, N assimilation in legumes is a limiting factor in terms of quantitative (seed) or qualitative (N) yields. In fact, young plants find their initial nitrogen requirements through the mineral nitrogen of the soil. During the early stages of growth before the branches develop, mung bean cannot efficiently fix atmospheric N because it has few or no rhizobia. When soil N levels are low (total N content <0.05%), the application of a small amount of N fertilizer induces the formation of rhizobia and promotes the growth of strong mung bean seedlings (Cheng XZ, Cao EC (1996).

Ardeshana *et al.* (1993) also observed that application of nitrogenous fertilizer as starter or initial dose becomes helpful in increasing the growth and yield of legume crops although pulses fix atmospheric N₂ by symbiotic means. Increasing the application of N fertilizer during the early growth period promotes vegetative growth and creates conditions that favor high yield (Yanni YG *et al.*, 2001). 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. Generally, after nodules have been established, N

fixation succeeds to assimilation, reaches peak at pod development stage, and declines thereafter. Later, most of the seed filling is achieved by redistribution of N from vegetative plant organs to the developing seeds.

An imbalance in the supply of nitrogen fertilizers affects not only nodulation but also crop yield and the pattern of use of nutrients in pulses. As most Ethiopian soils have a deficit in nitrogen and phosphorus nutrients, especially nitrogen and phosphorus fertilizer application has significantly increased crop yields (Tekalign *et al.*, 1991). However, there is a quantitative relationship between crop yield and accumulation of N by plants; i.e., when the soil cannot supply with adequate N, the crop yield will be constrained (Sinclair and Vadez, 2002). This indicates that yield can be considered as a good measure of the collective impact of environment on plant growth (i.e., the more favourable the environment, the more effective N applied, and hence the greater the yield). Adequate supply of nitrogen is essential for normal growth and yield (Mozumder *et al.*, 2003). Rajender *et al.* (2003) also observed that grain yield in mung bean increased with nitrogen at a rate of 0.02 ton ha⁻¹ over control and crop exhibited better cost benefit ratio however Patel *et al.* (2003) with careful investigations found that 0.01 ton N ha⁻¹ was enough better mung bean crop production. Similarly, Quash and Jafar (1994) noted that the 1000 seed weight of the mung bean increased significantly with the application of nitrogen at 0.05 ton ha⁻¹. Agbenin *et al.* (1991) also found that the applied N significantly increased the dry matter of the mung bean over the control. Leelavathi *et al.* (1991) also reported that different levels of nitrogen showed a significant difference in the dry matter of mung bean yield to 0.06 ton N ha⁻¹. The beneficial effect of applied nitrogen is to retain more leaf area, causing an accelerated photosynthetic rate, leading to a higher production of dry matter and consequently higher yield per plant (Dahatonde *et al.*, 1996).

2.7.2. Effect of phosphorous application on yield and yield Components of the mung bean

In addition to nitrogen, phosphorus (P) is the most important element for adequate grain production (Brady and Weil, 2008). P is one of the most important essential macro-elements for plants, which contributes in numerous vital functions in plants like photosynthesis, energy transfer, respiration, cell division, and seed formation (Mengel and Kirkby, 2001). (P) is also a major component of compounds whose functions relate to growth, root development, flowering, and ripening (Raboy, 2003). The P fertilizer promotes root growth, resistance to disease, tolerance to drought and improves nutrient and water absorption in seedlings after they have depleted their endosperm reserves (Zafar *et al.*, 2013; Jian *et al.*, 2014).

An adequate supply of P early in the life of a plant is important in the development of its reproductive parts. Large amounts of P are found in seeds and fruit and are considered essential for seed formation. P is also associated with early maturity of crops, particularly grain crops. The quality of certain fruit, forage, vegetable, and grain crops is improved and disease resistance increased when these crops have satisfactory P nutrition (Havlin, *et al.*, 1999). According to Chaudhary *et al.* (2003) also reported that P improves the quality of grains and serves the dual purpose of increasing the yield of the main crop and of the succeeding crop. According to Tahir *et al.* (2003), phosphorus helps in energy transfer reactions and is important for the growth of roots and branches of the plants, whereas its deficiency restricts both top and root growth.

Plants suffering from P deficiency are retarded in growth and the shoot/root dry matter ratio is usually low. With severe deficiency, the root system is poorly developed and the stems are thin and erect with few branches and small, narrow leaves. The formation and quality of fruits

and seeds are depressed in plants suffering from P deficiency. Poor nodulation and poor plant vigour are observed in beans grown in P-deficient soils (Giller Amijee and, 1998). Phosphatic fertilizer is of great importance for Mung bean. It not only increases the yield and yield components of the crop, but also improves the quality of the produce. It is also involved in metabolic and enzymatic reactions and is a constituent of ATP and ADP (Singh *et al*, 20014). According to Mitra *et al.* (2006), the application of phosphorus to Mung bean has been reported to increase dry matter at harvest, number of pods per plant, seed per pod, 1000 grain weight, seed yield and total biomass. The nonaddition of P to mung bean ultimately decreases the yield and quality of the crop. Therefore, phosphorus fertilization is very essential to exploit the maximum yield potentials of the mung bean crop.

2.7.3. Effect of sulfur application on yield and yield components of the mung bean

Sulphur(S) is an important macronutrient element, along with NPK, that has a profound effect on pulse crops. In a broad sense, the functions of nitrogen and sulfur are similar and synergistic. The application of sulfur increases the concentration as well as total uptake of N, P, K, Ca, S, Zn, and B at different stages of crop growth (Agrawal *et al.*, 2000). Pulses are particularly responsive to sulfur-containing fertilizer and that elementary sulfur or sulphate increases the percentage of nitrogen and yield on such deficient soils (Khan S., Ahmed I., Ansar M. and Shah H. 2006).

Sulfur plays a remarkable role in protein metabolism, and it is required for the synthesis of proteins, vitamins, and chlorophyll. Furthermore, S containing amino acids such as methionine, cysteine, and cysteine, which are essential components for proteins (Kumar *et al.*, 2012). The increased photosynthetic efficiency, which favored dry matter production and nutrient concentration in plants, appears to be the major factor responsible for higher nutrient

uptake under the influence of sulfur application. Ghanshyam and Pareek (2002) reported that green gram yield increased with increasing levels of P and S fertilizers. Mondal *et al.* (2003) also observed that application of sulfur significantly increased the dry matter accumulation, number of pods per plant, number of seeds per pod, and seed yield. Sulfur not only improved grain yield, but also improved crop quality. Mitra *et al.* (2006) reported that green gram yield increased with Phosphorus at 0.06 ton P₂O₅ and S at 0.04 ton ha⁻¹ gave the highest number of pods per plant, number of seeds per pod, thousand seed weight, seed yield, and net return on mung bean crop.

The main sources of sulfur addition to soil are chemical amendments or fertilizers, farm manures, or crop residues. Furthermore, gaseous forms of hydrogen sulfide (H₂S) and sulfur dioxide (SO₂) are released into the atmosphere by burning fossil fuels and deposited in the soil by rain. Sulfur dioxide when combined with water forms sulfuric acid (H₂SO₄), and when this acid finds its way to the soil, it is known as acid rain. Sulfur is also available to plants from some irrigation water sources.

The important sources of sulfur depletion from soil are intensive cultivation of high-yielding varieties of rice, nonjudicious chemical fertilization, higher cropping intensity without proper replenishment of nutrient elements, loss through erosion, surface runoff, leaching and immobilization by soil microbial activities, and adsorption by soil colloids, organic matter, and very limited use of organic matter are the most probable reasons for sulfur deficiency. Sulfur deficiency symptoms are similar to those of nitrogen. However, N deficiency symptoms first appear in older leaves; generally, sulfur deficiency symptoms first appear in younger leaves because S is not easily trans located in the plant (Flaten, 2004).

Sulfur-deficient plants lack vigour, are stunted, are pale green to yellow in color, and have thin elongated stems. S deficiency also induced chlorosis in young leaves and decreased seed yield by 45% (BARI, 2004). Sulfur deficiency can delay maturity in grain crops. Sulphur uptake by several crops revealed that the highest sulphur requirement (12 kg/ton of yield) has been attributed to oil seeds followed by pulses (8 kg/ton), millets (5-8 kg/ton) and cereals (3-4 kg/ton) (Tandon 1986).

2.7.4. Effect of boron application on yield and yield Components of the mung bean

Boron (B) is one of the eight essential micronutrients, also called trace elements, required for normal growth of most plants (Barker and David, 2007). Plants require boron nutrient in a lower amount than the requirements for all other nutrients except molybdenum and copper. It is the non-metal element among micronutrients and also the only micronutrient present in a wide pH range as a neutral molecule rather than an anion (Fageria, 2009). The essentiality of B for the growth and development of higher plants has been demonstrated earlier (Marschner, 1986).

Boron plays an important role in the movement and metabolism of carbohydrate in the plant, synthesis of plant hormones and nucleic acids, protein, pollen germination, flowering and fruiting, water use, nitrogen assimilation, and generative growth of plants. Kaisher *et al.* (2010) also studied the effect of boron on pulses and concluded that it is important for protein synthesis and improved protein content. The most important functions of boron in plants are believed to be its structural role in cell wall development and stimulation or inhibition of specific metabolism pathways (Ahmad *et al.*, 2009). It influences the major cellular functions and metabolic activities in plants and is required for cell differentiation at all growing tips of

plants (meristems) where cell division is active (El-Hamdaoui *et al.*, 2003). The influence of boron on various metabolic processes such as photosynthesis, respiration, and enzyme activity (Ganie *et al.*, 2013) increases the production of metabolites and their translocation to different plant parts to increase the concentration of nutrients in the seed and Stover.

Increases the yield and growth of legume crops by increasing the leaf area expansion, nodule formation, pods per plant, pod length, number of grains per pod, 1000-grain weight, seed yield, and Stover yield. Chowdhury *et al.* (2010) also proved that plant height, total dry matter; number of pods per plant, number of seeds per pod, 1000 seed weight, and seed yield were enhanced with exogenous application of boron. According to Renukadevi *et al.* (2002), the application of boron increases the light intercept ratio, biomass production, leaf area index, net assimilation rate, crop growth rate, and seed yield in pulses. Boron also increases nodulation activity (Yakubu *et al.*, 2010) even in soil deficient in boron, which may have increased nitrogen content and nutrient uptake and dry matter production (Debnath and Ghosh,2011; Debnath *et al.*,2011). According to Kumria *Ret al.* (2003) the combined effect of boron with different growth regulators is effective in improving the translocation of photo-assimilates which improve the grain yield and harvest index. Researchers also reported that the application of boron has a positive effect on mung bean yield (Verma and Mishra, 1999; Ashraf, 2007). Nabi *et al.* (2006) checked the effect of boron on the growth and production of mung beans. They examined a notable increase in height, leaf area, and biomass production of mung bean by the application of boron. It influences the pollen producing capacity, pollen tube growth, the inner viability of pollen grain, and pollen germination. The pollen tube grows well with the application of boron because pectin is internalized by crosslinking with boron, which increases the number of seeds per pod in mung bean. The enzyme activity of urease,

dehydrogenase, and phosphatase showed a significant and positive correlation with boron application. Bilen *et al.* (2011) also observed the effect of boron on the soil microbial population and enzymatic activity. Renukadevi and Savithr (2003) reported that the quality of mung bean increased with an increase in the level of boron. Two types of B deficiencies are encountered in agricultural soils. One is a natural deficiency, due to a lack of boron in soil-forming minerals, and the other is an induced deficiency, the result of over liming or other adverse environmental conditions (Fageria, 2009). The deficiency of boron inhibited growth, for which a reduction in the root-to-shoot ratio and limited the contents of P, K, and Fe in both the root and the shoot of the plant. When boron supply was limited, poorer calcium content was observed in the shoot, whereas boron supplied increased the calcium content in the plant. A low concentration of boron also limits nitrogen fixation in legumes by restricting nodule formation, and nitrogen fixation increases with higher boron concentration (Yakubu *et al.*, 2010).

2.7.5. Effect of blended NPSB fertilizer application on crop yield and yield Components.

The growth parameters of the mung bean, such as height, number of branches of plant⁻¹, and number of nodules of plant⁻¹, increased significantly due to NP fertilizers (Rathod and Gawande, 2014). Hamza *et al.*, (2016) concluded that mung bean can respond significantly to combination of P and B in growth parameters such as plant height, number of branches plant⁻¹, pods plant⁻¹, and Pod length. Phosphate is necessary, especially in early plant growth for root development. (Muhammad *et al.*, 2016). Berg (1985) also described that P is needed in relatively large amounts by legumes for growth and has been reported to promote leaf area, biomass, and Number of nodules and mass of nodules in different legumes.

Different studies showed that Mungbean seed yield plant^{-1} showed a positive correlation with the number of nodule plant^{-1} , the number of pod plant^{-1} , the number of seed pod^{-1} and the weight of 100 seeds of Mungbean (Delic *et al.*,2011; Rahman *et al.*, 2008).Fertilizers are the key contributors to Mungbean production and also have key roles in pod filling and ultimately enhance grain production (Xavier and Germida,2002). Sadeghipour *et al.* (2010) concluded that the application of N and P fertilizers, increased number of pods plant^{-1} , seeds pod^{-1} , 1000 seeds weight (g) and seed yield (g m^{-2}) of Mung bean. Hamza *et al.* (2016) indicated that Mungbean responded significantly to P and B with respect to the number of $\text{pod}^{-1}\text{plant}$, 1000 seed weight, seed yield, Stover yield, and biological yield and harvest index. Boron application maximizes biomass production, crop growth rate, and seed yield in pulses. It influences the pollen producing capacity, pollen tube growth, the inner viability of pollen grain, and pollen germination. The pollen tube grows well with the application of B because pectin is internalized by cross-linking with boron, which increases the number of seeds pod^{-1} in Mungbean (Verma *et al.*, 2004).

3. MATERIALS AND METHODS

3.1. Description of the study area

The experiment was carried out in Zala district, Gofa Zone, SNNPR state under rain-fed conditions during the main growing season of 2021 (February-March). The area is located at a distance of 550 km to south of Addis Ababa, 250 km from Hawassa (regional city) and 120 km southwest of Wolaita Sodo town. The geographical coordinates of the experimental site are 06°04 '00 to 06°30'00 N latitude, 36 ° 58'20 37 ° 13'30 E longitudes and the long-term mean annual rainfall is 900-1700 mm with erratic distribution having peaks in February to late March and its Altitude is 1194-1484 masl . The longterm (1998-2021) mean monthly maximum and minimum temperature is 18C⁰ and 32C⁰, respectively (National meteorological service Hawassa branch 2021). Rainfall is spread throughout the year into two main rainy seasons; in the 'meher' season, mung beans can be planted between early July and late September. However, in the 'belg' season, the crop can be planted from February to late March (Unpublished report from the Zala District Agricultural Office 2020). The soil is clay in texture and has a pH of around 6.43. The main crops growing in the district include maize (*Zea mays L.*), common beans (*Phaseolus vulgaris L.*), and mung beans (*Vigna radiata L.* Wilczek), teff (*Eragrostis tef* (Zucc.)), fruits and vegetables (Zala district Agricultural Office, 2020). The experimental site was cultivated for maize (*Zea mays L.*) in the previous year.

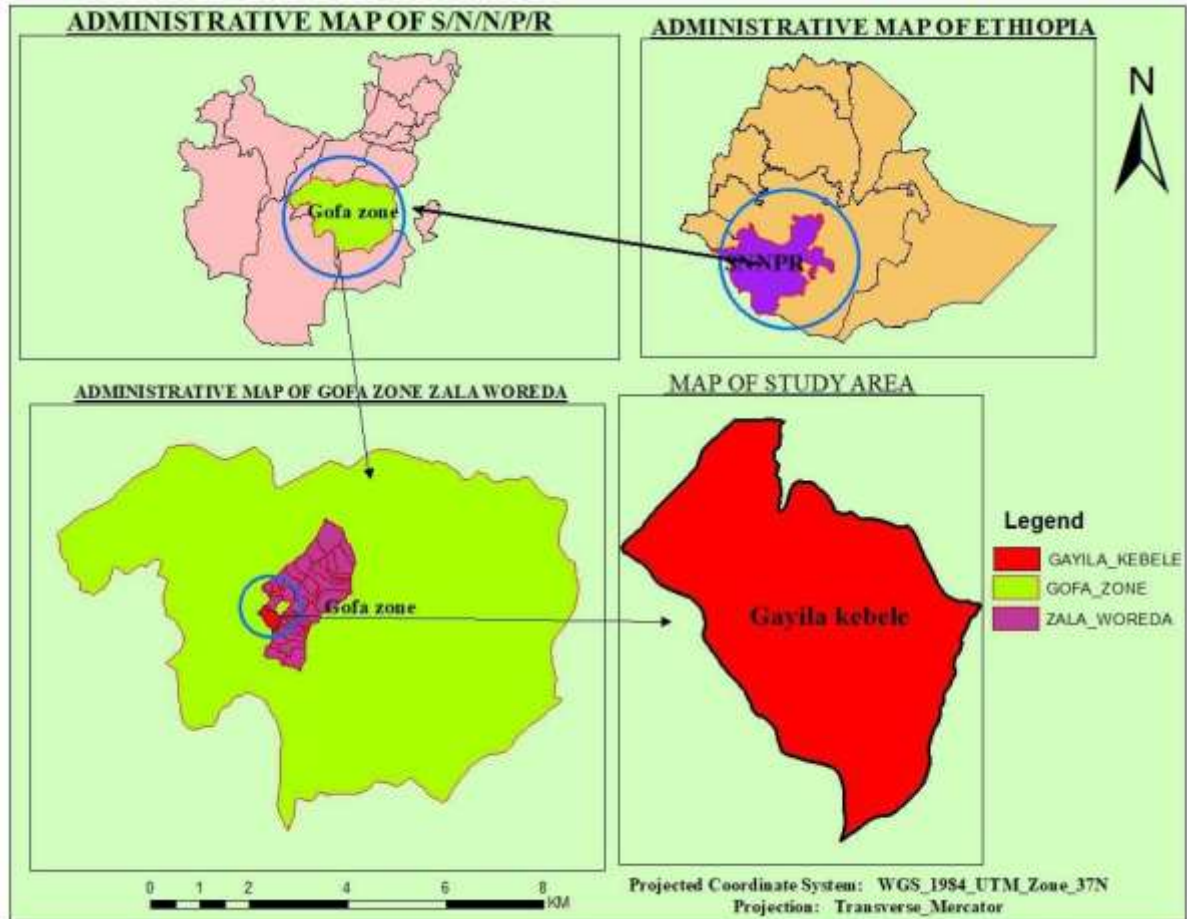


Figure 1: Location map of study area

3.2. Treatments and Experimental Design

The treatments consisted of four varieties of mung bean (Boreda (MH-97-6), Rasa (N-26), NVL-1 and local Gofa varieties and four levels of NPSB fertilizer rates (0, 50, 100, 150,kg ha⁻¹). These varieties were selected for the experiment due to short maturing and well-performing characteristics in the agro-ecological zone of the district. The characteristics of the varieties are stated in Table 1. The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement with three replications. The gross size of each plot were 2.4 m × 2.1 m (5.04m²) area having 7 rows. The spacing between rows and plants

were 30 cm and 10 cm, respectively. The distance between the adjacent plots and the blocks was separated by 0.5 and 1 m, respectively. Consequently, treatments and treatment combinations including control treatment were randomly assigned to the experimental unit within a block.

Table 1: Description and recommendation domain of mung bean varieties used for the study

Characteristics	Varieties			
	Boreda (MH-97-6)	Rasa (N-26)	NVL-1	Gofa local
Altitude (masl)	1100 – 1750	900-1670	1450-1670	1194-1484
Annual Rainfall (mm)	>500	350-550	350-750	900-1700
Length of growing Period(Days)	60	65-80	60-70	65-90
Growth habit	Bushy	Bushy	Bushy	Bushy
Seed colour	Green	Green	Green	Green
Yield in research site (t ha ⁻¹)	1.6-2	0.8-1.5	0.75-1.5	-
Year of release	2008 G.C	2011 G.C	2014 G.C	-

Source: MOA, Ministry of Agriculture (2015/16). Hawassa Agri-Research Center. Melkasa agricultural research center 2005.

Table 2:Description of treatment combinations

Variety	Fertilizer rate (kg ha ⁻¹)	N- P ₂ O ₅ -S-B (kg ha ⁻¹)
Borda (MH-97-6)	0(NPSB)	0 -0 - 0
	50(NPSB)	9.35-18.7-3.45-0.125
	100(NPSB)	18.7-37.4-6.9-0.25
	150(NPSB)	28.05-56.1-10.35-0.375
Rasa (N-26)	0(NPSB)	0 -0 - 0- 0
	50(NPSB)	9.35-18.7-3.45-0.125
	100(NPSB)	18.7-37.4-6.9-0.25
	150(NPSB)	28.05-56.1-10.35-0.375
NVL-1	0(NPSB)	0 -0 -0 0
	50(NPSB)	9.35-18.7-3.45-0.125
	100(NPSB)	18.7-37.4-6.9-0.25
	150(NPSB)	28.05-56.1-10.35-0.3
Gofa local Variety	0(NPSB)	0-0-0-0
	50(NPSB)	9.35-18.7-3.45-0.125
	100(NPSB)	18.7- 37.4- 6.9-0.25
	150(NPSB)	28.05-56.1- 10.35- 0.375

The NPSB blend fertilizer that contains 18.7% N, 37.4% P₂O₅, 6.9% S, and 0.25% B was used as a fertilizer source.

3.3. Agronomic Practices

Before sowing, the experimental field was well prepared by using a local plough (maresha) according to the farmers' conventional farming practices and the plots were levelled manually.

According to the design, a field layout was made, and each treatment was assigned randomly to the experimental units within a block. After the seed beds were levelled, and the mung bean varieties were sown according to the recommended rate, which is 25 kg of seed ha⁻¹. Two seeds per hill were planted at a spacing of 30 inter-row and 10 cm intra-row spacing. Thinning was done a week after emergence to allow one plant per hill. The fertilizer application was performed on the basis of the recommended treatment rates. All mixed formula fertilizer (NPSB) was applied at the time of sowing to all plots. Weeding, harvesting, and threshing were carried out manually according to the recommendation for the crop.

3.4. Data collection and measurements

3.4.1. Soil sampling and analysis

The pre-planting soil samples were taken randomly in a zigzag fashion from the experimental field at a depth of 0-20 cm before planting. Soil samples were taken with an auger from the entire experimental field and combined to form a composited sample in a bucket. The collected samples were then air dried at room temperature under shade and ground to pass through a 2mm sieve for laboratory analysis of soil pH and available phosphorus. A small quantity of this 2mm sieved soil material allowed passing through a 0.2mm sieve for soil organic carbon (OC) and total nitrogen. The composite soil samples were analysed for selected physicochemical properties mainly for textural analysis (sand, silt and clay), soil pH, total nitrogen (N), available sulfur (S), available boron (B), organic carbon (OC), available phosphorus (P), cation exchange capacity (CEC) (c mol kg⁻¹), using the appropriate laboratory procedures in the Southern agricultural research institute, Areka agricultural research center soil Laboratory.

The Bouyoucas hydrometer method (Day, 1965) was used to determine soil texture. The Walkley and Black (1934) method was used to determine the organic carbon content (OC) of the soil. Total nitrogen in the soil was determined by the Kjeldahal method (Dewis and Freitas, 1970). Soil pH was measured potentiometrically in 1:2.5 soil-water suspensions with a standard glass electrode pH meter (Van reeuwijk, 1992). Cation Exchangeable Capacity (CEC) was determined by leaching the soil with neutral 1N ammonium acetate (FAO, 2008). The available phosphorus was determined by the Olsen method using a spectrophotometer (Olsen *et al.*, 1954). The available sulfur (S) was measured using the turbid metric method (ATA and, 2014). (b) Available boron was measured using dilute HCL methods. Electro conductivity was determined by a standard glass electrode using an EC meter.

3.4.2. Crop Data

3.4.2.1. Phonological data

Days to flowering were recorded as the number of days from sowing to when 50% of plants in a net plot produced flower through visual observation.

3.4.2.2. growth parameters

Days to physiological maturity: Days to maturity were recorded by counting the number of days from the date of sowing until 95% of the pod in the plants changed green to yellowish.

Number of total nodules per plant: The count of root nodules was taken at 50% flowering from five randomly selected plants from four borderrows. The plants were carefully removed from the soil without damaging the roots and then a count of nodules was taken.

Number of branches per plant: The number of branches per plant was counted from five tagged plants, and their mean was recorded as the number of branches per plant at physiological maturity.

Plant height (cm): It was measured at physiological maturity from the base to the tip of a plant for randomly pre-tagged 5 plants in harvestable rows by use of meter tape and averaged on a plant basis.

3.4.2.3. Yield and Yield Component Samples

Number of pods per plant: It was recorded based on five plants sampled in each net plot area at harvest, and the average was taken as number of pods per plant.

Number of seeds per pod: the total number of seeds in the pods of five plants was counted and divided by the total number of pods to find the number of seeds per pod.

1000 seed weight (g): The weight of 1000 seeds was determined for each plot using a sensitive balance. The weight was adjusted to a moisture content of 10%.

Biological yield (t ha⁻¹): Dry above-ground biomass was measured from plants harvested manually from the three central rows of each plot. The harvested plants were sun-dried in open air for a days and the average total biological yield was reported in ton ha⁻¹.

Grain yield (ton ha⁻¹): The harvested plants from three central rows for determining biological yield were threshed and weighed, and the grain yield was converted to ton ha⁻¹. After measuring the seed yield with a seed moisture tester, it was adjusted to a moisture level of 10% and its formula is described as follows .

Adjusted plot yield to the standard moisture content (10%)

$$= \frac{\text{plot yield} \times (100 - \text{Actual moisture content})}{100 - 10}$$

Straw yield (ton ha⁻¹): It was calculated by subtracting the grain yield from the corresponding total above-ground biomass yield.

Harvest index (%): The harvest index was calculated as the ratio of economic yield (grain) to biological yield (grain + straw). Its value was expressed as a percentage, using the following formula (Kemanian et al 2007).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biomass yield}} \times 100$$

3.5. Statistical analyses

Data collected were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) procedure of SAS version 9.0 (SAS Institute, 2004) and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the treatments are found to be significant, the means were compared using the least significant difference (LSD) test at a 5% level of significance.

3.6. Economic Analysis

An economic analysis was performed using the partial budget procedure described by CIMMYT (1988). The cost of NPSB and the labor cost involved for the application of NPSB fertilizer were recorded and used for this analysis.

Unadjusted grain yield (UGY) (ton ha⁻¹): is an average yield of each treatment.

Adjusted grain yield (AGY) (ton ha⁻¹): is the average yield adjusted grain yield down ward by 10% to reflect the difference between the experimental yield and the yield of farmers.

Gross field benefit (GFB) (ETB ha⁻¹): it was calculated by multiplying the field / farm gate price that farmers receive for the crop when they sell it as adjusted yield. $GFB = AGY \times \text{field/farm gate price for the crop}$.

Total variable cost (TVC) (ETB ha⁻¹): it was calculated by summing the costs that vary, including the cost of NPSB fertilizers (14.00 ETB kg⁻¹) at the time of planting (April 29, 2021) and according to Zala, the daily farm payment of labor cost for the application of NPSB (3 persons ha⁻¹, each 100 ETB day⁻¹). The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, and chemical spraying, harvesting, and threshing are considered the same for all treatments or plots.

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

Marginal rate of return (MRR) (%): It was calculated by dividing the change in net benefit (ΔNB) by the change in total variable cost (ΔTVC) then multiplied by 100.

4. RESULTS AND DISCUSSION

4.1. Soil Physico-chemical properties of Experimental soil.

Soil texture is an important physical characteristic of the soil as it determines the water intake rate (infiltration), the water holding capacity of the soil, the ease of tilling, the amount of aeration and also influences soil fertility (Gupta, 2000). It is one of the inherent soil properties less affected by management and determines the nutrient status, organic matter content, air circulation, and water holding capacity of a given soil.

According to the soil textural class determination triangle, the soil of the experimental site was found to be clay (Table 3). A high clay content could indicate a better water and nutrient holding capacity of the soil of the experimental site. According to the soil analysis test, the soil pH of the experimental site was 6.43 (Table 3). FAO reported that the preferable pH ranges for most crops and productive soils are 5 and 8. Thus, the pH of the experimental soil was within the range of productive soil (FAO, 2008).

The analysis revealed that the available P of the soil was 12.34 mg kg^{-1} (Table 3). EthioSIS (2013) suggests the optimal P content for most Ethiopian soils at 15 mg kg^{-1} . On the basis of this, the available phosphorous of the study area is low and needs phosphorous fertilizer. Masresha (2014) also reported a low amount of P content in soils that are repeatedly cultivated due to P fixation and P mining. Similarly, Habtamu *et al.* (2015) reported that the low content of P is due to the fixation problem.

Tekalign *et al.* (1991) classified soil total N availability of $\leq 0.05\%$ as very low, $0.05-0.12\%$ as poor, $0.12 - 0.25\%$ as moderate and $> 0.25\%$ as high. According to this classification, the soil

samples were found to have a low level of total N (0.12%) (Table 3), indicating that the nutrient is a limiting factor for optimum crop growth. Thus, the level of N in the soil showed the need to apply N for the mung bean crop to obtain the optimal yield.

The soil of the study site had 2.94% of organic carbon (OC) (Table 3), which is medium according to the Walkley and Black rating (1934), they rated soils with an OC value in the range of 0.5-1.5% as low, 1.5-3 as medium, > 3 as high. Cation exchange capacity (CEC) is an important parameter of the soil, because it gives an indication of the type of clay mineral present in the soil and its ability to retain nutrients against leaching. According to Landon (1991), top soils having CEC greater than 40 cmol (+) kg⁻¹ are rated as very high and 25-40 cmol (+) kg⁻¹ as high, and 15-25, 5-15 and < 5 cmol (+) kg⁻¹ of soil are classified as medium, low and very low, respectively, in CEC. According to this classification, the soil of the experimental site had high CEC (39 cmol (+) kg⁻¹ soil), indicating that the soil of the study site has the capacity to retain nutrient actions and supply to the crop. Indicative ranges of available sulfur were established using the turbid metric method (Chesnin and Yien (1951).

The analysis revealed that the available sulfur in the soil was medium 33.7 mg kg⁻¹. According to the EthioSIS (2013) rating, the soil which has < 9 mg kg⁻¹ (very low), 10-20 mg kg⁻¹ (low), 20-80 mg kg⁻¹ (medium), and > 80 mg kg⁻¹ (high). Thus, the soil of the experimental site was considered to be medium with the available sulfur content, which is not satisfactory for optimal mung bean growth and yield. Therefore, it is important to apply sulfur sources fertilizer for good crop growth and yield (FAO, 2008). The result showed that the mean B value of the soil was 0.14 mg kg⁻¹. According to EthioSIS (2013) the critical B value for most Ethiopian soils is 0.8 mg kg⁻¹. This showed that the soil of the study site is deficient in B indicating the need to apply

fertilizers containing B. Intensive cultivation in the area might be responsible for the low B content of the soil.

Table 3: Selected physicochemical properties of the soil of the experimental site before planting

Soil characters	Values	Rating	Reference
Soil texture:			
Sand	24		
Clay	54		
Silt	22		
Textural Class	Clay		
pH (water)	6.43	Moderately acidic	ATA(2014)
Total N (%)	0.12	Poor	Tekalign et al. (1991)
Organic C (%)	2.94	Medium	Walkley&Black, (1934)
Avalable P (mg/Kg)	12.34	low	Olsen <i>et al.</i> , 1954(2013)
Available S (mg/Kg)	33.7	Medium	EthioSIS (2013)
Available B (mg/Kg)	0.14	poor	EthioSIS (2013)

4.2. Effect of NPSB Blended Fertilizer rates on Yield and Yield Components of the Mung bean

4.2.1. Days to flowering

Analysis of variance revealed that variety had a non-significant effect ($P \leq 0.001$) on days to 50% flowering of mung bean, whereas the NPSB fertilizer rate and interaction had brought a significant effect ($P \leq 0.005$) on days to 50% flowering of mung bean (Appendix 1).

The longest days to reach 50% flowering (47 days) of mung bean were recorded from interaction of Variety Gofa Local with 150 kg NPSB ha⁻¹, while the earliest days to reach 50% flowering

(36 days) were obtained from the Boreda variety with 0 kg NPSB ha⁻¹ (control) (Figure 2). The result agrees with reports by MoA, (2011) and MoARD, (2008) reported that the increase in the number of days to flowering in response to the increasing rates of NPSB fertilizer (Figure 2) also indicated the influence of NPSB nutrient source for vegetative growth. This result is in agreement with that of Deresa (2018) who reported that increasing the NPS fertilizer rate significantly prolonged the days to 50% flowering of common bean. The addition of nitrogen and phosphorus fertilizer could have contributed to the availability of soil nutrients to plant growth, causing nitrogen fertilization to delay days to flowering. Also, the finding of Haleh *et al.* (2010) indicated that the duration of the reproductive growth period was significantly influenced by the interaction effect of N and P on lentils.

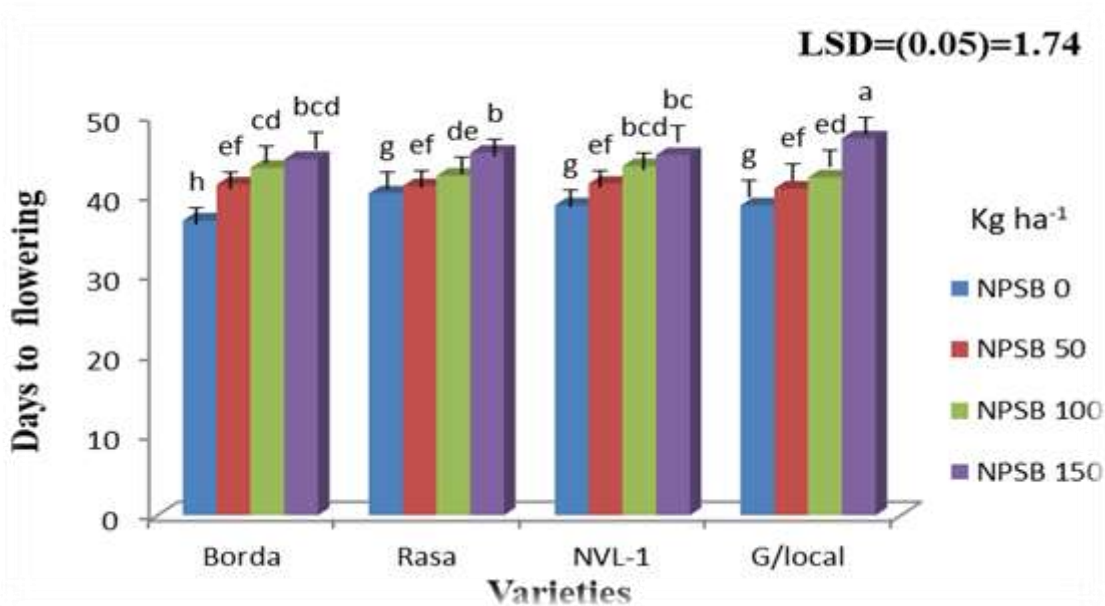


Figure 2 Effects of interaction of varieties and NPSB fertilizer rate on days to 50% flowering of Mungbean

LSD (0.05) = Least Significant Difference at the 5% level; The means in the figure above by the same letters are not significantly different at the 5% level of significance.

4.2.2. Days to physiological maturity

The main effects of the variety and NPSB fertilizer rates had a highly significant effect ($p \leq 0.001$) on days to physiological maturity of mung bean and the interaction of both factors had brought a significant effect ($p \leq 0.05$) on days to physiological maturity (Appendix Table 1).

The maximum number of days to physiological maturity was recorded from the highest rate of NPSB fertilizer ($150 \text{ kg NPSB ha}^{-1}$) compared to control (0) treatments.

The use of Variety Boreda with 150 kg ha^{-1} had resulted in the longest days to reach physiological maturity (82 days), while the Borda variety with $0 \text{ NPSB kg ha}^{-1}$ rate was the earliest to reach physiological maturity (67 days), which is statistically similar to Variety Gofa Local at rate of $0 \text{ NPSB kg ha}^{-1}$ (Fig. 3).

Phonological characteristics are genetically controlled and individual varieties have different growing habit, flowering, and maturity days. This variation might be attributed to genotypic differences of the respective varieties in responding to the various rates of NPSB application. The delay in days to maturity at the highest rate of NPSB could also be due to the fact that N fertilization increases the vegetative growth of plants. In line with this result, Khan *et al.* (2008) stated that mung bean maturity is delayed by application of N fertilizer (20 kg ha^{-1}). Gan *et al.* (2009) also reported that the appearance of the phonological stages and the growth period increased with increasing nitrogen fertilizer rates (20 kg ha^{-1}) in chickpea and soybean, respectively. Similarly Bekele, and Muluneh (2008) reported that greater N (23 kg ha^{-1}) can result in excessive vegetative growth and delayed maturity of legume crop.

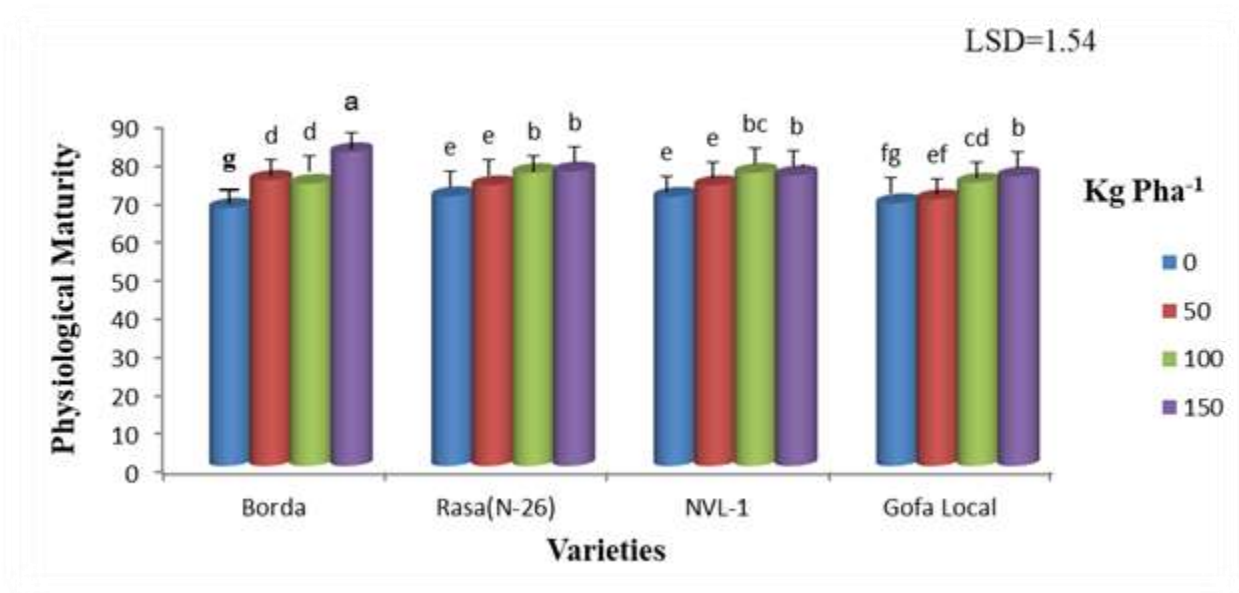


Figure 3: Interaction effects of varieties and NPSB fertilizer rate on days to 90% physiological maturity of mung bean.

LSD (0.05) = Least Significant Difference at the 5% level; The means in the figure above by the same letters are not significantly different at the 5% level of significance.

4.3. Growth Parameters

4.3.1. Plant height (cm)

Analysis of variance revealed that the Variety and interactions had a non-significant effect ($P \leq 0.001$) on Mung bean plant height, while fertilizer rate had a significant effect ($p \leq 0.05$) on Mung bean plant height (Appendix Table 1).

Among the fertilizer rates, the highest plant height (55 cm) of Mungbean was recorded from the high rate of NPSB fertilizer (150 kg NPSB ha⁻¹), which was statistically similar to the NPSB

fertilizer (100 kg NPSB ha⁻¹) (Table 4) The shortest plant height (47 cm) was recorded from the control plots, although statically it was similar to the plots received NPSB of 50 kg ha⁻¹ (Table 4).

In a broad sense, the functions of nitrogen and sulfur are similar and have a synergistic effect on the height of the plant. Additionally, the increase in plant height in response to the increasing S rates may be attributed to chlorophyll formation, which enhances vegetative growth. According to Islam *et al.* (2017), the height of the mung bean plant was significantly influenced by the application of sulfur. Phosphorus also plays a pivotal role in early root proliferation that could increase the nutrient uptake of the plant, consequently resulted in increased vegetative growth. This result is in agreement with the finding of Taj (1996) who reported an increase in the plant height of mung bean in response to nitrogen and phosphorus application (20 kg N ha⁻¹ and 69 kg P₂O₅ ha⁻¹). Boron also has a positive effect on growth and development, nitrogen assimilation, and root growth. Nabi *et al.* (2006) reported a notable increase in height, leaf area, and biomass production of mung bean by the application of boron.

4.3.2. Branch number

Analysis of variance revealed that fertilizer rate and Varieties had a significant effect ($P \leq 0.001$) on the number of branches per plant. The interaction effect of the fertilizer rate with Varieties had a no significant effect ($P \leq 0.05$) on the number of branches per plant of Mungbean (Appendix Table 1).

For fertilizer, the highest branch number (4.87) of mung bean was recorded from the NPSB fertilizer at 150 kg ha^{-1} and the lowest branch number (2.91) was obtained from the control, which is statistically similar to ($50 \text{ kg NPSB ha}^{-1}$) (Table 4). The highest rate effect might be especially due to the influence of S for cell division, enlargement, and elongation (Islam *et al.*, 2017). Muhammad *et al.* (2004) also found that the number of branches per plant is significantly influenced by application of P and application of B has also positive effect on branching of mung bean crop.

For variety, the highest branch number (4.36) of mungbean was recorded from Variety Borda, which is statically similar with Variety Rasa (N-26) and the lowest (3.29) was obtained from Variety Gofa Local (Table 4). Branching is basically a genetic character, but environmental conditions can also influence the number of branches per plant and play an important role in improving grain yield. The increase in branch number per plant in response to the increased NPSB application rate also indicates maximum vegetative growth of the plants under higher N and S availability (Jawahar, *et al.*, 2013). Also P plays a pivotal role in early root proliferation that might increase the nutrient up take of the plant, consequently resulted in increased vegetative growth. The increased number of branches plant^{-1} was formed because vigorous

growth by plants is a result of better photosynthetic activities with adequate availability of nutrients at vegetative growth stages(K. Kawte, S. Dereje *et al.*2000).

Table 4:Main effect of NPSB fertilizer rates and varieties on plant height and brunch number of mung bean

Treatment	plant height (cm)	Branch number
NPSB rate (kg ha-1)		
0	47 ^b	2.91 ^d
50	48 ^b	3.40 ^c
100	51. ^{ab}	4.07 ^b
150	54. ^a	4.87 ^a
LSD (0.05)	5.37	0.6
Varieties		
Borda (MH-97-6)	52 ^a	4.36 ^a
Rasa (N-26)	51 ^a	3.91 ^{ab}
Gofa Local	50 ^a	3.70 ^{bc}
NVL-1	48 ^a	3.29 ^c
LSD (0.05)	5.37	18.87
CV (%)	12.74	0.6

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

4.4. Nodulation parameters

4.4.1. Nodule number

The main effect of NPSB fertilizer rates was significant ($p \leq 0.001$) on the total number of nodules per plant while the main effects of the varieties and the interaction were not significant

(Appendix Table 1). The highest total number of nodules per plant was recorded from the application of 100 kg of NPSB ha⁻¹ while the lowest total number of nodules was recorded from the control (Table 5). The highest value could be due to the fact that P plays an important role in the utilization of S, resulting in an increase in the number of nodules that facilitate the fixation process of N. This is in line with the results of Singh *et al.* (2015) who reported that the application of S has a profound effect on the nodulation of the mung bean by influencing the number of nodules plant⁻¹. According to Habtamu (2015), the number of nodules plant⁻¹ is significantly affected by the combined application of fertilizer with N and P. In another study (Beza, 2017) found that S had a significant effect on the number of chickpea nodules.

The application of phosphorus has a significant effect on legume yield and agronomic parameters. P in the blended NPSB fertilizer improved root development and nitrogen fixation in mung beans. According to Farid and Navabi (2015), P availability could have been the main determinants of N fixation between genotypes by affecting the number of nodules. As Tang *et al.* (2001) observed nodule number and nitrogenous fixation activities increased with increase to phosphorus rates of 69 P₂O₅ kg ha⁻¹. The increased number of total nodules might also be due to increased application of S and B along with other major nutrients.

Table 5: Main effect of varieties and NPSB fertilizer rates on total nodule number of mung bean

Treatment	Nodule number
NPSB rate (kg ha ⁻¹)	
100	24.8 ^a
150	21.7 ^b
50	20.2 ^c
0	19.2 ^d
LSD (0.05)	0.7
Varieties	
NVL-1	21.7 ^a
Gofa Local	21.5 ^a
Rasa (N-26)	21.4 ^a
Borda (MH-97-6)	21.3 ^a
LSD (0.05)	0.7
CV (%)	3.93

LSD (0.05) = Least Significant Difference at the 5% level; CV (%) = Coefficient of variation;*= significant at $P < 0.05$. The mean values in the table followed by the same letter are not significantly different at the 5% level of significance.

4.5. Yield and Yield related Components

4.5.1. Pod number plant⁻¹

Analysis of variance revealed that variety and NPSB fertilizer rate had a significant ($P \leq 0.001$) effect on number of podsplant⁻¹, while the interaction effect of variety and NPSB fertilizer rate had a non-significant ($P \leq 0.05$) effect (Appendix-Table 2).

For variety, the highest pod number plant⁻¹ (17.6) of mung bean was obtained from Rasa (N-26) variety which is statistically similar to Variety Borda, while the lowest pod number plant⁻¹ (13.5) was recorded from Variety Gofa Local (Table 6). The number of pods plant⁻¹ is mainly associated with the number of branches plant⁻¹ and generally it is assumed that the higher the branch number plant⁻¹, the higher the pod number. The variation in pod number plant⁻¹ was found due to the variation of branch production and also the genetic makeup of the crop plants. Similarly, Wedajo (2015) reported that the Rasa variety (N-26) gave the highest number of pods per plant over Shewa robit and NVL-1 varieties.

For fertilizer rate, the highest (19.7) pod number plant⁻¹ of Mungbean was recorded from NPSB blend fertilizer at 150 kg ha⁻¹ and the lowest (13.3) was obtained from the control (Table 6). This highest number of pods at the highest rate of NPSB (150 kg ha⁻¹) could be attributed to the fact that NPSB enhances the establishment of beans, promotes the formation of nodes, canopy development, and pod setting. Also, the increase in pod number with these levels might be due to various enzymatic activities that controlled flowering and pod formation.

The increment of pod number plant⁻¹ due to the increased application of P could be due to the function of the fertilizer P that promotes the formation of nodes in legumes and various enzymatic activities that control flowering and pod formation. Consistent with this result, Veeresh (2003) observed significantly more pod number plant⁻¹ (28.08) at application rate of 75 kg P₂O₅ ha⁻¹ in mung bean. Sulfur exerted a positive influence on the pod number plant⁻¹.

Table 6: Main effects of varieties and NPSB fertilizer rate on pod number plant-1 of mung bean.

Treatment NPSB rate (kg ha-1)	Pod number plant-1
150	19.7 ^a
100	15.7 ^b
50	14.6 ^c
0	13.3 ^d
LSD (0.05)	1.01
Varieties	
Rasa (N-26)	17.7 ^a
Borda (MH-97-6)	16.9 ^a
NVL-1	15.1 ^b
Gofa Local	13.5 ^c
LSD (0.05)	1.01
CV (%)	7.63

LSD (0.05) = Least Significant Difference at the 5% level; CV (%) = Coefficient of variation. The mean values in the table followed by the same letter are not significantly different at the 5% level of significance.

4.5.2. Seed number pod-1

Analysis of variance suggested that the main effects of the varieties and the rate of NPSB fertilization had a highly significant effect ($p \leq 0.01$) on the seed number pod^{-1} . The interaction of both factors had also brought a significant effect ($p \leq 0.05$) on the seed number pod^{-1} of the mung bean (Appendix Table 2). The highest seed number (15.5) of Mungbean was recorded from the interaction of the NPSB blend fertilizer at 150kg ha^{-1} rate with Boreda Variety while the lowest pod number (5.3) was obtained from the interaction of the control NPSB blend fertilizer with Gofa Local Variety (Fig. 4).

The seed number per pod⁻¹ is an important character that had a direct effect on the seed yield plant⁻¹ and per unit area. Differences in seed number among varieties might be due to their genetic constituents. In this study, the highest seed number per pod⁻¹ could be due to the combination of the photosynthesis function of N (Sadeghipour *et al.*, 2010), the metabolic energy role of S (Islam *et al.*, 2017), the pollen producing capacity of B (Verma *et al.*, 2004) and the ability of P for the production of dry matter and the partitioning to pods that leads to better seed quality and quantity (Tariq *et al.*, 2001).

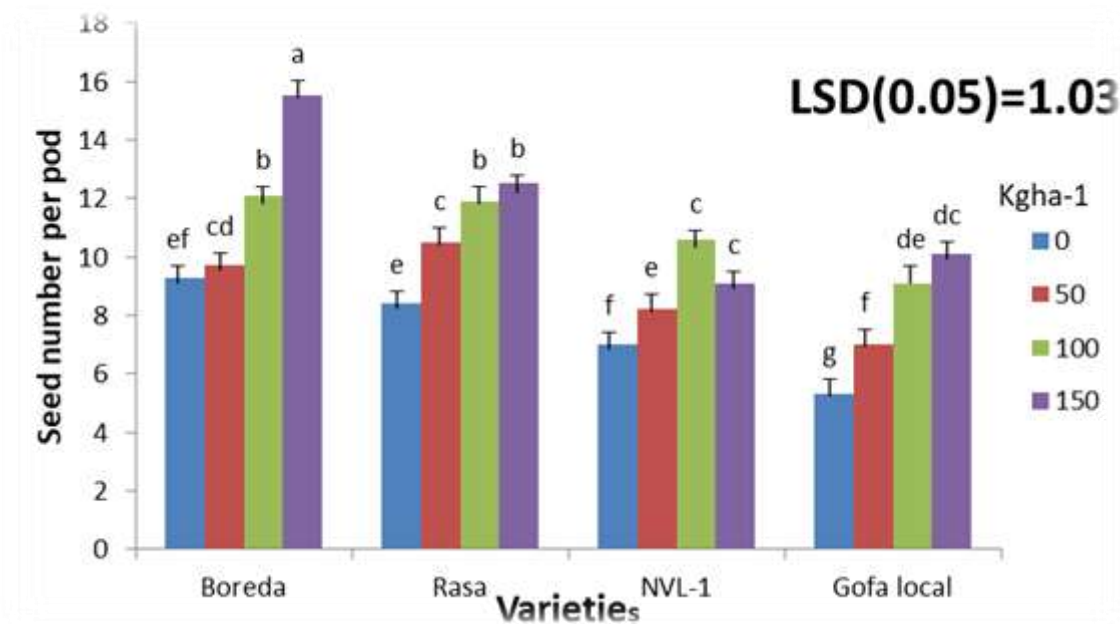


Figure 4: Interaction effects of varieties and NPSB fertilizer rate on seed number of mung bean

LSD (0.05) = Least Significant Difference at 5% level, Means in the figure followed by the same letters are not significantly different at the 5% level of significance.

4.5.3. Seed weight

The fertilizer rate and variety had a highly significant ($P \leq 0.001$) effect on seed weight, according to the analysis of variance. The interaction of fertilizer rate and variety had a significant effect ($P \leq 0.05$) on Mungbean seed weight (Appendix 2).

The data pertaining to grain weight given in the table revealed that the variable levels of NPSB (50 to 150kg/ha) led to the production of significantly heavier seed compared to the control.

The highest (61.5g) 1000 seed weight of Mungbean was recorded from the interaction of the 150kg ha^{-1} NPSB blend fertilizer with Borda even though this variety statistically similar 1000 seed weight at all the NPSB rates. The lowest (39.6 g) 1000 seed weight was obtained from the control unit, which is statically similar to 50kg ha^{-1} (Table 7).

The increased seed weight could be due to the enhanced efficiency of nutrient use by the optimal level of NPSB, generally. The 1000 seed weight of the grain indicates the amount of resources utilized during critical growth periods. This might be due to better growth and development and larger pod formation. The supply of phosphorus improves seed formation. Tariq *et al.* (2001) reported that the application of phosphorus significantly increased dry matter production and resulted in greater partitioning of dry matter to pods and leads to seed quality and quantity.

Table 7: Interaction effects of varieties and NPSB fertilizer rate on 1000-seed weight of mung bean (g)

Varieties	NPSB (kg ha ⁻¹)			
	0	50	100	150
Borda (MH-97-6)	55.6 ^{abcde}	57.2 ^{abc}	60.9 ^{ab}	61.5 ^a
Rasa (N-26)	52.7 ^{cde}	55.4 ^{bcde}	57.7 ^{ab}	57.78 ^{abc}
NVL-1	39.6 ^f	51.9 ^{cde}	56.4 ^{abcd}	56.77 ^{abc}
Gofa Local	40.9 ^f	41.9 ^f	50.3 ^e	50.6 ^{de}
LSD(0.05)	6.02			
CV (%)	5.8			

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

4.5.4. Grain yield

The ultimate goal in crop production is maximum economic yield, which is a complex function of individual yield components in response to the genetic potential of the varieties and inputs used.

Analysis of variance revealed that the fertilizer rate and variety had a highly significant effect ($P \leq 0.001$ and $P \leq 0.01$, respectively) in grain yield. The interaction of fertilizer rates and Variety had a significant effect ($P \leq 0.05$) on the grain yield of Mung bean (Appendix 2). It can be seen from the results presented in Figure 5 that the highest grain yield (2.5ton ha⁻¹) was obtained from interaction of variety Boreda with 150 kg of NPSB ha⁻¹. The lowest (0.86ton ha⁻¹) grain yield

was obtained from the Gofa Local variety with 0 NPSB (control) plots, although this was statistically similar to the variety NVL-1 with control fertilizer level (Fig.5).

This highest result might be due to the combined effect of high-yielding variety and the nutrients N, P, S and B.

Addition of nitrogen (N) and phosphorus (P) fertilizer enhances root development, which improves the supply of other nutrients and water to the growing parts of the plants, resulting in an increased photosynthetic area and thereby more dry matter accumulation. (Ardeshna *et al.*, 1993). Nitrogen in the early stages of growth promote vegetative growth and create conditions conducive to high yield and play a critical role in the formation of chlorophyll and protein (Sadeghipour *et al.*, 2010). P improved cellular respiration in starch, protein, and fat metabolism (Iqbal and Chauhan, 2003), play a fundamental role in metabolism and energy-producing reaction, building phospholipids and nucleic acids (Marschner, 1986) . Sadeghipour *et al.* (2010) observed that the interaction effects of N and P levels on seed yield of mung bean are highly significant. The grain yield of mung bean could have been also varied greatly due to different levels of sulfur and boron. According to Halwai *et al.* (2016) sulphur and boron are very important in the yield and yield components of mung bean. S enhances chlorophyll concentration, root nodules, and dry matter production, which contributed to yield increment (Erdal *et al.*, 2006). According to Islam *et al.* (2017) and Singh *et al.* (2014), statistically significant mung bean yield is obtained due to the effect of different levels of S nutrition. Mondal *et al.* (2003) also reported that the grain yield of mung bean increased significantly with the increase in the application of S fertilizer.

Boron increases the yield and growth of plants by increasing the leaf area expansion, seed weight, nodule formation, seed yield, and biological yield. According to Renukadevi *et al.* (2002) boron application maximizes the light interception ratio, biomass production, leaf area index, net assimilation rate, crop growth rate and seed yield in pulses. Ali *et al.* (2010), Bhuiyan *et al.* (2008) and Tesfaye *et al.* (2016) reported a highly significant effect of the application rate of P fertilizers on the seed yield of mungbean and common bean, respectively.

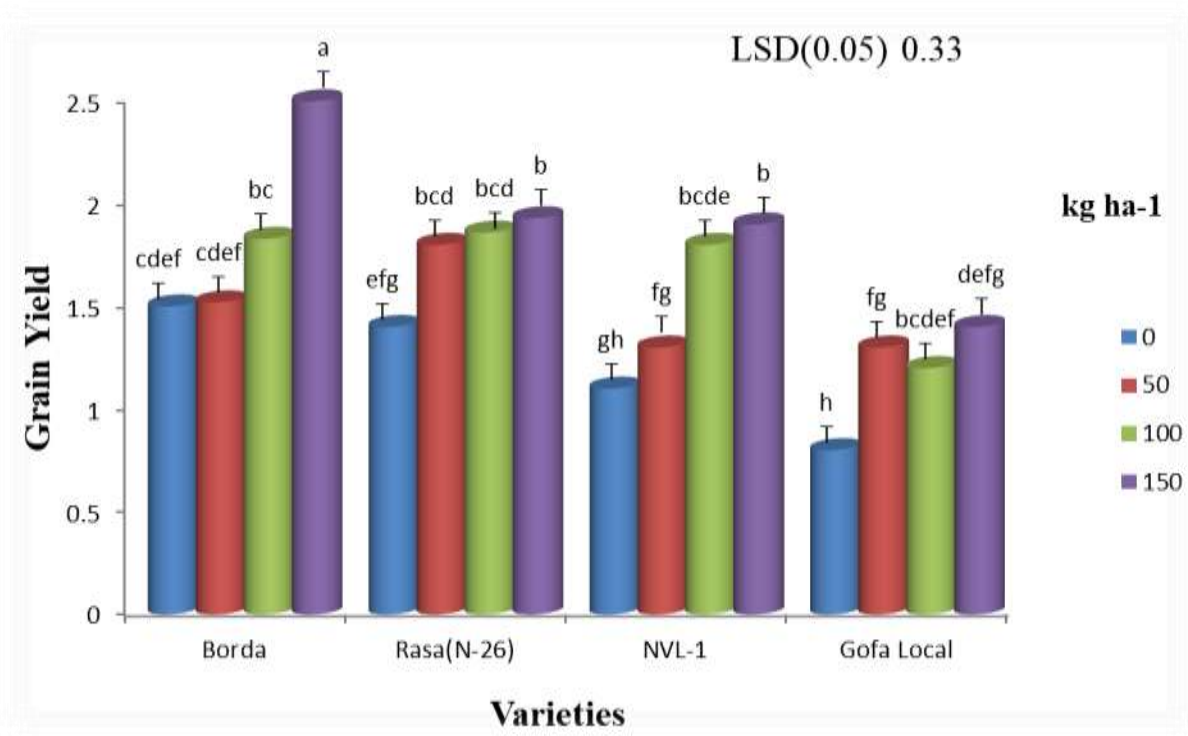


Figure 5: Interaction effects of varieties and NPSB fertilizer rate on grain yield of mung bean

LSD (0.05) = Least Significant Difference at 5% level, the mean values in the table followed by the same letters are not significantly different at the 5% level of significance.

4.5.5. Straw yield

The main effect of the NPSB rate and the interaction had a significant effect on the straw yield of the Mungbean (Table8). However, the main effect of the variety had a non-significant effect

($P < 0.05$) on the yield of mung bean. The highest Straw yield (4.4 ton ha^{-1}) was recorded from the Variety Boredain combination with 100 kg ha^{-1} , while the lowest Straw yield (2.0 ton ha^{-1}) was obtained from the control treatment (0) (Table 8). The interaction result generally showed an increase in the yield of the straw with increase in the rate of blended NPSB fertilizer rate. Consistent with this finding, Deresa *et al.* (2018) reported a significant effect of the interaction of variety with the rate of blended NPS fertilizer. The same authors recorded the highest Straw yield for an Angar variety at the application rate of $150 \text{ kg NPS ha}^{-1}$. On the other hand, Arega and Zenebe (2019) reported a non-significant effect of the interaction of NPKSB with the varieties on the Straw yield. The increase in straw yield with an increase in fertilizer NPSB rates is in agreement with the findings of Chiezey *et al.* (1992) in relation to the lower value of Straw yield at a low level of phosphorus application to poor plant development.

Table 8: Interaction effects of varieties and NPSB fertilizer rate on Straw yield of mung bean

Varieties	NPSB (kg ha^{-1})			
	0	50	100	150
Borda (MH-97-6)	2.0 ^f	3.4 ^{bcd}	4.4 ^a	4.3 ^a
Rasa (N-26)	2.7 ^{def}	2.7 ^{def}	4.1 ^{ab}	4.1 ^{abc}
NVL-1	2.5 ^{ef}	3.2 ^{cde}	3.8 ^{abc}	4.3 ^a
Gofa Local	2.8 ^{def}	2.8 ^{def}	3.8 ^{abc}	4.2 ^{ab}
LSD(0.05)	0.84			
CV (%)	14.8			

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.

4.5.6. Above ground dry biomass

The results showed that, while there was no significant difference between varieties for dry biomass, the effect of NPSB rate and the interaction of variety and NPSB had a significant ($p \leq 0.05$) and highly significant ($P \leq 0.01$) effect on dry biomass, respectively.

The highest dry biomass yield (6.2 tons) was produced at a rate of 150 kg NPSB ha⁻¹ with variety NVL-1, which is significantly similar to that obtained from 100 kg NPSB ha⁻¹, while the lowest dry biomass yield (3.6 tonnes ha⁻¹) was obtained at 0 kg NPSB ha⁻¹ (control) (Table 9).

The result generally showed that there was an increase in above-ground dry biomass production by all varieties with increasing NPSB application rates.

The increase in the biomass yield of the varieties in the blended rates of NPSB could be attributed to the fact that the increased availability of N significantly increased plant height, the number of pods per plant, and the overall vegetative growth of the plants that contributed to the higher yield of dry biomass above ground.

This result is in line with that of Veeresh (2003) who reported that total dry matter production per plant increased significantly from 12.0 to 16.03 g due to increased nitrogen application from 40 to 120 kg N ha⁻¹ in French beans (*Pharsalus vulgaris*). The increase in biomass yield could also be due to the adequate supply of P from the NPSB that could be attributed to an increase in the number of branches per plant, which increased the photosynthetic area and the number of pods per plant. This result was in agreement with the findings of Agegneu *et al.* (2006) who reported a significant linear response of above-ground dry biomass yield to phosphorus application in fababeans on acidic Nitisols. The interaction of nitrogen and phosphorus also increases the

above-ground dry biomass. This could be due to the cumulative effect of NP on root, vegetative, and reproductive growth and development of beans.

Table9: Interaction effects of varieties and NPSB fertilizer rate on Above ground dry biomass of mung bean

Varieties	NPSB (kg ha ⁻¹)			
	0	50	100	150
Borda (MH-97-6)	3.6 ^g	4.9 ^{bcd}	6.1 ^a	4.8 ^a
Rasa (N-26)	4.16 ^{fg}	4.7 ^{def}	5.9 ^a	5.9 ^a
NVL-1	3.7 ^g	4.5 ^{ef}	5.5 ^{abc}	6.2 ^a
Gofa Local	3.66 ^g	4.2 ^{efg}	5.4 ^{abcd}	5.7 ^{ab}
LSD(0.05)	0.78			
CV (%)	9.39			

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

4.5.7. Harvest index (%)

Analysis of variance showed a significant effect ($P < 0.001$) of Variety as well as interaction on harvest index (HI) while the fertilizer rate did not significantly influence the harvest index (HI) (Appendix Table 2).

The maximum harvest index (53.2%) was recorded from the interaction effect of the 150 kg ha⁻¹ blended NPSB fertilizer with Borda variety (Table 10). The minimum harvest index (23.7%) was obtained from Variety Gofa local without applying fertilizer (Table 10). HI is very useful in measuring nutrient partitioning in crop plants, providing an indication of how efficiently the plant utilized acquired nutrients for grain production. Therefore, the highest HI also implies higher partitioning of dry matter into grain. The increase in HI at these treatments could also be

due to the increased production of photo assimilates and its ultimate partitioning to grains compared to partitioning to straw under improved soil conditions in the study area.

The increase in the harvest index in response to the increased application rate of blended NPSB could be due to the synergistic functions of nutrients in blended fertilizers.

The study in Mulu (2019) also reported that the maximum harvest index was obtained from the N-26 variety at an NPS rate of 150 kg ha⁻¹, which was followed by the same variety N-26 (39.05%), with a rate of 100 kg NPS ha⁻¹. The study in Malik *et al.*, (2003) also reported an increase in the mung bean harvest index in response to the addition of N and P.

Table10: Effects of interaction of varieties and NPSB fertilizer rate on harvest index (HI) of mung bean

Varieties	NPSB (kg ha-1)			
	0	50	100	150
Borda(MH-97-6)	42.5 ^b	31.7 ^{cde}	53.2 ^a	29.8 ^{ced}
Rasa (N-26)	42.5 ^b	39.3 ^{bc}	30.5 ^{cde}	34.6 ^{bcd}
NVL-1	31.1 ^{cde}	30.2 ^{cde}	31.5 ^{cde}	31.1 ^{cde}
Gofa Local	23.7 ^e	32.5 ^{bcd}	30.0 ^{ced}	25.8 ^{ed}
LSD(0.05) 10.45				
CV (%) 17.98				

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

4.6. Partial Budget Analysis

Partial budgeting is a method of organizing experimental data and information on the costs and benefits of various alternative treatments. Partial budget analysis is used to understand efficiency and economics of inputs and outputs of crop production. From this study, the average yields of mung beans were estimated.

The average yields of mung bean were adjusted downward by 10% to reflect the difference between the experimental and field yields of farmers (CIMMYT, 1988). From the use of various interactions of different fertilizer rate with Variety, the total variable cost and net benefits were estimated. The total variable cost (TVC) was estimated during the field experimental period that included the cost of fertilizers and Variety, as well as the labor cost for the applications of fertilizers and Variety (Table 11).

The total variable cost (TVC) was subtracted from the gross field prices (GFP) to obtain net benefits (NB). After estimating net benefits, the treatments were arranged in ascending or increasing order of total variable costs to identify dominated and non-dominated treatments. In this study of 16 treatments, twelve were dominated and three were non-dominated (Table 11). Dominated treatments were omitted from subsequent steps in the marginal analysis, whereas for non-dominated treatments, marginal rates of returns were calculated. According to CIMMYT (1988) among three non-dominated treatments) [Rasa * 50, Rasa *150, and Boreda * 150] gave more than 100% marginal rate of return (Table 11). The marginal rate of return (MRR) is a characteristic of the change from one treatment to another and since dominated treatments are not included it will always be positive. So below 100% e MRR is considered as low and unacceptable to farmers, because such returns would not return capital and other related costs, and something would not be added to the cost of capital to repay the producers for the time and

effort spent. The recommendation is not necessarily the treatment with the highest marginal rate of return compared to that of the next lowest cost, nor the treatment with the highest net benefit, nor the treatment with the highest yield.

The identification of a recommendation requires a careful marginal analysis using an appropriate minimum rate of return (CIMMTY, 1988). In this study, the partial budget analysis indicated that the best treatment was the interaction of Boreda Variety with the application of the 150kg ha⁻¹ NPSB blended fertilizer rate, which gave high net benefits of 126126 ETB ha⁻¹ with above minimum MRR of 100%. The second alternative recommendation was the interaction of the NPSB blend fertilizer rate with the use of variety Rasa (N-26) Variety, which gave 96600 ETB ha⁻¹ net benefit with acceptable marginal rate of return (Table 11).

Table11: Summary of partial budget analysis of the response of mung bean varieties to the application of NPSB fertilizer at Zala district

Fertilizer	Variety	GAY (t ha-1)	AJAY (t ha-1)	GFP (ETB ha-1)	TVC (ETB ha-1)	NB (ETB ha-1)	MRR%
Control(0)	Borda	1.5	1.35	81,000	2750	78250	-
	NVL-1	1.1	0.99	59600	2781	56819	D
	Gofa Local	0.8	0.72	43200	2788	40412	D
	Rasa(N-26)	1.4	1.26	75600	3890	71710	D
50	Borda	1.53	1.37	82200	4440	77660	D
	Rasa(N-26)	1.8	1.6	96000	4480	92520	830
	NVL-1	1.3	1.2	72000	4510.5	67489.5	D
	Gofa Local	1.3	1.1	66000	4600	61400	D
100	NVL-1	1.7	1.53	91800	5700	86100	D
	Gofa Local	1.6	1.4	84000	5890	78110	D
	Borda	1.8	1.62	97200	7001	90199	D
	Rasa(N-26)	1.8	1.6	96000	7004	88996	D
150	Rasa(N-26)	1.93	1.73	103800	7200	96600	150
	NVL-1	1.9	1.71	102600	7900	94700	D
	Gofa Local	1.4	1.26	75600	7907	67693	D
	Borda	2.5	2.25	135000	8874	126126	1763

5. SUMMARY AND CONCLUSION

Mungbean is one of the most important pulses grown in different tropical and subtropical parts of the world, which is commonly known as green gram (bean). It is rich in vitamin A and protein that is considered as a substitute for animal protein. In Ethiopia, mung bean is an important pulse crop for small farmers that recently gained attention and was announced as the sixth export commodity by the Ethiopian Commodity Exchange. Studies and reports showed that the Mung bean yield is very low in Ethiopia, especially in relation to soil fertility. Both macro and micronutrients increase the nodulation and nitrogen fixation of mung bean plants. It requires nutrients such as N, P, K, Ca, Mg, B, Zn, and S for growth and development. It has the ability to fix atmospheric nitrogen for its own use and improves soil fertility.

The loss of soil fertility and the mismatch between fertilizer technology and the environment in the last five decades were among the main production constraints of the country that contributed to the decline in yields. Following these blended fertilizers, improved Varieties were being formulated to recover those problems in the country. But mungbean growth, yield, and yield component responses to the recently formulated blended fertilizers, to improved mungbean variability as well as to their interactions have not been studied extensively. Therefore, the experiment was conducted with the objective of evaluating the response of mung bean varieties to the application of mixed NPSB fertilizer rates and to identify and suggest the economically feasible rates of NPSB fertilizer for Mung bean production in the study area. four fertilizer rates (0,50,100,150) with four types of varieties (Borda, Rasa (N-26), NWL-1 and Gofa Local Variety) were used. The experiment plot was laid on the RCBD design in a factorial arrangement with three replications. Analysis of variance showed that the effect of fertilizer rate had a significant effect on days to 50% flowering, days to 90% physiological maturity, plant height, branch

number, nodule number, pod number per plant, seed number per pod ,thousand seed weight, grain yield, above-ground dry biomass yield, and straw yield. The other effect of Variety also had a significant effect on days to 90% physiological maturity, branch number, pod number per plant, seed number per pod, thousand seed weight, grain yield, and harvest index . On the other hand Analysis of variance showed that the interaction effect of different fertilizer rate with Varieties had brought a significant effect on days to 50% flowering, days to 90% physiological maturity, seed number per plant, thousand seed weight, grain yield, above ground dry biomass, harvest index and straw yield.

Partial budget analysis showed that the treatment involving the interaction rate of the 150kgha⁻¹ NPSB blend fertilizer with variety Borda and Rasa(N26) gave the first and second highest net benefits of 126126 ETB ha⁻¹ and 96600ETB ha⁻¹, respectively, with an acceptable marginal rate of return.

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APPENDICES

Appendix A: Lists of Appendix in Tables

Table: 1 Mean squares of analysis of variance for phonological, growth and nodulation parameters of mung bean as affected by varieties and NPSB rates

Sources of variation	DF	Days to 50% flowering	Days to 90% maturity	Plant height	Number of branches	Nodule number
Rep	2	3.3033333	0.7481250	31.7306250	0.73937500	2.2433333
Variety	3	1.5458333 ^{ns}	12.2697222**	29.9891667 ^{ns}	2.4069*	0.2986111ns
NPSB	3	101.2913889**	161.836389***	144.1280556*	8.654**	70.585**
NPSBx Variety	9	3.3452778*	11.0949074**	69.5134259ns	0.458ns	0.5763889ns
Error	30	0.9531111	0.8654583	41.443292	0.51937500	0.7144444
CV		2.315961	1.273294	12.74466	18.87206	3.932149

Table: 2 Analysis of variance for yield and yield components of the mung bean as affected by varieties and NPSB rates

Source variation	DF	Pod number	Seed number	Seed weight	Grain yield	Biomass yield	Harvest index	Straw yield
Rep	2	0.0043750	1.2152083	63.779158	0.08093958	0.27083333	96.973958	0.42937500
Variety	3	41.9705556**	34.3790972**	381.121631**	0.6284743**	0.38909722ns	282.450208**	0.48243056ns
NPSB	3	91.0605556**	52.3257639**	240.056297***	1.169968***	10.698**	65.420764ns	5.25020833**
NPSB* Variety	9	0.6081481ns	1.8744676**	25.428297*	0.1164502**	0.49483796*	125.29224*	1.03391204**
Error	30	1.4621528	0.3309861	9.716847	0.03757958	0.21772222	35.669292	0.24537500
Cv		7.628991	5.824735	5.883472	11.97403	9.398717	17.98796	14.86990

Appendix B: Lists of Appendix in Figures

Figure: 1 Layout preparation of the experimental field and eighteen day after germination



Figure: 2Field performance of a trial at 31 days after planting



Figure: 3 Measuring seed weight

