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EFFECTS OF BLENDED NPSB, BIOFERTILIZER RATES AND INTRA ROW SPACING ON YIELD AND YIELD COMPONENTS OF MUNGBEAN (Vigna radiata (L) Wilczek) IN ANKOBER DISTRICT, NORTH EAST ETHIOPIA

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BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM IN AGRONOMY

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M. Sc Thesis

By

Hailu Kidanie Woldesemayate

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCES (MSc.) IN AGRONOMY

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THESIS APPROVAL SHEET

As members of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mr. Hailu Kidanie Woldesemayate** entitled "**Effects of Blended NPSB, Biofertilizer Rates and Intra Row Spacing on Yield and Yield Components of Mungbean (***Vigna radiata* **(L) Wilczek) in Ankober District, Northeast Ethiopia**". We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Agronomy.

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DECLARATION

This is to certify that this thesis entitled "**Effects of Blended NPSB, Biofertilizer Rates and Intra Row Spacing on Yield and Yield Components of Mungbean (***Vigna radiata* **(L) Wilczek) in Ankober District, Northeast Ethiopia**" submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in **"Agronomy"** to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. Hailu Kidanie Woldesemayate** (ID. No. BDU1207283PR) is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for the award of any degree or diploma to the best of our knowledge and belief.

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DEDICATION

This thesis is dedicated to all my family members and friends especially my wife Abebech Atlaw, my children Tsegazeab Hailu and Natanhem Hailu who did all my required to make success on my work sacrificed a lot.

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LIST OF ACRONOMY /ABBERIVATION

ADAO,	Ankober District Administrative Office; Development Plan Monitoring
DPMET	EvaluationTeam
ANRS	Amhara National Regional State
BIF	Biofertilizer
BLF	Blended NPSB Fertilizer
BNF	Biological Nitrogen Fixation
BoA	Bureau of Agriculture
CSA	Central Statistical Agency
DA	Dominance Analysis
ECX	Ethiopian Commodity Exchange
EIAR	Ethiopian Institute of Agricultural Research
EPP	Ethiopian pulse profile
ETB	Ethiopian Birr
FAO	Food and Agricultural organization of United Nations
FDRE,	Federal Democratic Republic of Ethiopia Ministry of Agriculture and
MoAAR	Animal Resource
ICAR	Indian Council of Agriculture Research
IR	Intra Row spacing
LSD	Least Significance Difference
MARC	Melkassa Agriculture Research Center
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
MRR	Marginal Rate of Return
NPSB	Nitrogen, Phosphorous, Sulfur and Boron
TVC	Total Variable Cost

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By Hailu Kidanie Woldesemayate

Advisors: Dr. Dereje Ayalew and Dr. Tilahun Tadesse

ABSTRACT

Mungbean (Vigna radiata (L) Wilczek), is a recently introduced grain legume crop with multiple uses for food, fix nitrogen from the atmosphere, source of animal feed and income for small holder farmers in Ethiopia particularly in Ankober District. Despite its high potential uses and export demand, current national productivity is 1.2 ton ha^{-1} *which is much lower than its' attainable yield 1.5-2.0 ton ha*$^{-1}$ *due to poor crop management such as poor site selection, imbalance fertilization, improper planting density, diseases and insect pests. Field experiment was conducted to in Ankober district North East Ethiopia in 2020 cropping season to evaluate the effects of blended NPSB biofertilizer rates, and intra row spacing on yield and yield components of mungbean. The Treatment consisted of factorial combinations of three blended NPSB rates (75, 100, and 125 kg NPSB ha*$^{-1}$*), two biofertilizer rates (0 and 500 gm ha*$^{-1}$*), and three intra row spacing of planting (5, 10, and 15 cm) laid out in randomized complete block design with three replications. Data on plant height, number of total and effective branches, number of pods per plant, number of seed per pod, above-ground biomass and grain yield of mungbean were collected and subjected to ANOVA and LSD at 0.001, 0.01% and 0.05% SAS version 9.4. The results indicated that the two-way interaction effect of blended NPSB with biofertilizer rates; blended NPSB with intra row spacing; and biofertilizer rates with intra row spacing had significantly affected grain yield. Accordingly, the highest above-ground dry biomass yield (3871.70 kg ha*$^{-1}$*) and grain yield (1639.82 kg ha*$^{-1}$*) was recorded by the interaction blended 100 kg NPSB ha*$^{-1}$ *with 10 cm intra row spacing. Similarly, the partial budget analysis revealed that the highest net benefit 38,525.38 ETB ha*$^{-1}$ *with acceptable MRR 2587.36 % was obtained from 100 kg blended NPSB + 10 cm intra row spacing. Therefore, it can be concluded that producing mungbean at the rate of 100 kg NPSB ha*$^{-1}$ *+ 10 cm intra row spacing was found to be a promising treatment combination for better production and productivity and higher net benefit in the study area for mungbean. However, repeating similar experiments over season and across locations is important to give reliable recommendations.*

Keywords: *attainable yield, biofertilizer, grain yield, intra row spacing, mungbean, NPSB.*

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CHAPTER 1 - INTRODUCTION

1.1 Background and Justification

Mungbean (*Vigna radiata* L.) is a major pulse crop farmed in tropical and subtropical regions all over the world (Kumar *et al*., 1997). It is a widely distributed, herbaceous, and annual legume crop used primarily by traditional farmers (Ali *et al*., 2010). Mungbean cultivation is now widespread in Africa, South America, Australia, and a number of Asian nations (Gebre Wedajo, 2015). Mungbean yearly production area is estimated to be around 5.5 million hectares, with a growth rate of 2.5 percent per year (Tomooka *et al*., 2005). Mungbean is cultivated all over the world due to its demand for growing in locations where the rainy season is short, as well as its vast adaptability and digestion. Mungbean is consumed in a variety of forms, including seeds, sprouts, and immature pods, all of which are high in amino acids, vitamins, and minerals (Somata *et al*., 2007). The grain has a protein content of 24.2 percent, a fat content of 1.3 percent, and a carbohydrate content of 60.4 percent (Hussien *et al*., 2012). It is a low-calorie, high-fiber, easily digestible crop that does not cause gas like many other legumes (Minh *et al*., 2014). Fast growth in hot weather, low water requirements, and great soil fertility enhancement via nitrogen fixation are all characteristics of this crop (Yagoob and Yagoob, 2014).

Mungbean is being grown in several locations of Ethiopia. Currently, the crop has been cultivated and familiarized in different regions of Ethiopia like Oromia, South People Nations and Nationalities, Tigray, and Amhara; (Degefa Itefa, 2016). It is mainly cultivated in North Shewa, Harerge, Illubabor, Gamo Gofa, South Wollo, Tigray, Gondar, and in some districts of Benshangul Gumuz Reginal State (CSA, 2018). The crop is also produced in moisture stress areas of the country such as Gofa, Konso, South Omo Zone, and Konta special district (Asfaw Asrate *et al*., 2012; Gebre Wedajo, 2015). Farmers in Ethiopia's moisture-stressed areas use and produce it well to augment their protein demands (Asfaw Asrate *et al*., 2012). Ethiopian green mungbean exports increased marginally from 822 tons in 2001 to 26,743 tons in 2014 to meet demand from India, Indonesia, Belgium, and the

United Arab Emirates (MoARD, 2008 and 2015). Mung bean covers roughly 27,086 hectares of land in Ethiopia and produces 241,589.90 tons per year in the main cropping season, with an average productivity of 0.9 ton ha^{-1} (CSA, 2016).

Mungbean is primarily originated and cultivated from India and diversified to East, South, Southeast Asia (China) and including some countries of Africa which is recently introduced in Ethiopian pulse production (ECX, 2014); being grown in few areas of North Shewa in order to reclaim less fertile land, act as crop rotation mechanisms and plant the crop in marginal lands. It is an important pulse crop for smallholders that has recently gained attention and was announced as the sixth export commodity by the Ethiopian Commodity Exchange Authority (ECX, 2014). Farmer in some moisture stress areas of Ethiopia effectively uses and produces it to supplement their protein needs, to replenish low fertile soil, and range and drier marginal environments which cause low productivity of the crop (Asfaw Asrate *et al*., 2012). The demand for Ethiopian mungbean export has grown slightly from 822 tons in (2001) to 26,743 tons in 2014 to fulfill the demand of India, Indonesia, Belgium, and the UAE (MoARD, 2015). Studies and reports showed that the yield of mungbeans is very low in Ethiopia as compared to other countries of the world especially in relation to soil fertility apparently due to limited amendment through the application of fertilizers (EEPA, 2004; Asfaw Asrate *et al*., 2012). Mungbean covers roughly 27,086 ha of land in Ethiopia, according to the CSA (2016) report, and produces 24,158.990 tons in the main cropping season per year, with an average productivity of 892 kg ha^{-1}. In Ethiopia, the area planted with mungbean climbed to 41,630.20 ha in the 2017/18 cropping season, with a productivity of 1,235 kg ha^{-1} (CSA, 2018). In the 2019/20 cropping season, 76,644.968 tons of yield was obtained from 63,638.36 ha of land with a productivity of 1,204 kg ha-1 (CSA, 2019/2020). This is significantly lower than the research center's average production of 1,650 kg ha^{-1} (Asfaw Asrate *et al*., 2012).

Despite the fact that mungbean has the advantage of supplying a balanced human diet and soil-improving ability in relation to fertility rehabilitation by giving BNF, global output and productivity, especially in Ethiopia, are poor. This is due to marginal land cultivation, a lack of high-yielding varieties, and a lack of attention to improved agronomic procedures. The adoption of improved varieties and enhanced agronomic practices are two methods for increasing agricultural production and productivity. Optimal plant population is one of the agronomic procedures that must be followed in order to achieve increased yield (Rafiei, 2009). Low fertilization levels and imbalanced N, P, and K fertilization have harmed mungbean growth and development, and yield and quality have declined as a result of low fertilization levels and imbalanced N, P, and K fertilization (Hayat *et al*., 2008; Singh *et al*., 2011); however, mungbean yield and quality have declined as a result of low fertilization levels and imbalanced N, P, and K fertilization (Singh *et al*., 2012). Mungbean output and quality can thus be increased by the use of balanced fertilizers and efficient manure management (Yadev *et al*., 2014).

Fertilizer is the single most significant input for increasing crop productivity and production in modern agriculture. Though the nitrogen demand of legumes is lower than that of phosphorus, both are equally vital in maximizing the crop's genetic potential. Nitrogen and phosphorus, either alone or in combination, have a significant impact on mungbean yield and quality (Malik *et al*., 2003). Nitrogen, which is found in many different chemicals and is a vital component of protein and chlorophyll, aids plant metabolism. Phosphorus is a component of nucleic acids that promotes root growth and increases nodule activity in plants. Pulses seeds are inoculated with Rhizobium in order to enhance their quantity in the rhizosphere, resulting in a significant increase in microbiologically fixed nitrogen for plant growth. Seeds inoculated with appropriate Rhizobium yielded more green pods than seeds that were not inoculated (Meena *et al*., 2014). It has been calculated that inoculation with an efficient Rhizobium strain increased mungbean production by 13-33%. More pulse production could be accomplished through seed inoculation with Bradyrhizobium strains, which are known to promote biological nitrogen fixation, to minimize production costs and meet demand. Mungbean seed production rose from 4.3 percent to 16.2 percent after Bradyrhizobium inoculation. Bradyrhizobium inoculation enhanced dry matter production by 25%, grain output by 28%, and hay yield by 21% above non-inoculated controls (Bhuiyan *et al*., 2007).

Several studies throughout the world have found that keeping adequate spacing between plants and rows increases mungbean yield. According to Ihsanullah *et al.*, (2002) determined that planting mung bean with intra-row of 10 cm and inter-row of 30 cm is best spacing under commercial agriculture to obtained 320,000 plants per ha^{-1}. Planting the crop at varying inter-row spacing (20, 30 and 40 cm), on the other hand, resulted in distinct yield responses (921, 818.8, and 727 kg ha^{-1}, respectively. Furthermore, Kabir and Sarkar (2008) discovered that planting the crop in 30 cm x 10 cm spacing produced good yields and was better favorable for mung bean farming. Seeding density or plant population are two crop management strategies that have a big impact on crop development and production (Jan *et al*., 2000).

The impact of several agronomic methods, such as NPSB fertilizer rates, intra-row spacing, and biofertilizer, is poorly known and investigated. With this in mind, the current study aims to evaluate the optimal NPSB fertilizer rate, intra row spacing, and biofertilizer for increasing mungbean seed yield under the study area's current climatic and edaphic conditions.

1.2 Statement of the Problem

Mungbean has the advantage of providing a balanced human diet as well as soil-improving ability in relation to fertility rehabilitation by providing BNF. Farmers in Ethiopia's moisture-stressed areas use and cultivate it well to satisfy their protein demands (Asfaw Asrate *et al*., 2012). However, global output and productivity, particularly in Ethiopia, are low. Despite its great potential uses and export demand, mungbean productivity in Ethiopia is low (1.2 ton ha^{-1}) compared to the research average of 1.5 to 2.0 ton ha^{-1}, which is attributable to a variety of causes. This illustrates the low crop productivity in the farmer's fields when compared to the research center. The lack of experience of farmers, as it is a newly introduced crop that is unknown in the area, less attention of farmers to produce, limited use of modern inputs, and inappropriate agronomic practices such as inadequate or imbalanced fertilizer application, planting spaces, and other management practices are the main reasons for the crop's low productivity (Asfaw Asrate *et al*., 2012). Furthermore, concerns such as a lack of improved varieties, poor crop yield potential, limited research and extension emphasis, a small national market, and crop performance divergence exist in the country (Itefa Degefa, 2016).

The most important agronomic practices include lack of quality and improved variety, disease, insect, optimum inter and intra row spacing and plant population per unit area, improper site selection, improper seed rate, planting in rangelands, and improper and recommended fertilizer treatment (CSA, 2020; ANRS BoA, 2020). The right planting method is an important biotic component that defines the proper plant population in the given region, which increases plant performance, production, and productivity. Plant density is an important factor because it is one of the most important contributors to yield (Rafiei, 2009).

Mungbean agronomy research has yet to be conducted in the district. Farmers in the study area prefers broadcasting than row planting, plant without inoculating biofertilizer, and do not apply the recommended dose or amount of fertilizer at the right time, instead growing on marginal and less productive soil. It is currently necessary to undertake research in order to analyze mungbean production and productivity. Because the crop is traded on the Ethiopian Commodity Exchange (EXC) for foreign exchange, it offers farmers with a source of income during the short growing season. As a result of the crop's short growing period, low moisture requirements, and rising market demand as an export legume crop, as well as the crop's poor agronomic treatment, it's critical to do research to enhance mungbean production and productivity. As a result, the goal of this study was to see how the main and interaction effects of different blended NPSB, biofertilizer rates, and intra row spacing affected mung bean output and productivity in the study area.

1.3 Objective of the Study

1.3.1 General objective

- The overall objective of the study was to assess the impact of organic and inorganic fertilizer rates with various intra rows spacing as means of sustainable intensification of mung bean in the North East Ethiopia.

1.3.2 . Specific objectives

- To study the effect of blended NPSB fertilizer rate on the productivity mungbean.
- To evaluate the effect of intra row spacing on mungbean production.
- To examine the effect of biofertilizer inoculation on mungbean production.
- To determine the optimum fertilizer rates blended NPSB with biofertilizer with appropriate intra row spacing for maximum productivity and profitability of mungbean.

CHAPTER 2 - LETRIETURE REVIEW

2.1 Origin, Distribution and Botany of Mungbean

The center of origin, genetic diversity including wild relatives, domesticated and cultivated mungbean *Vigna radiata* (L) Wilczek with the family Fabaceae; is Asia specifically India-Burma region in Neolithic sites of southern India (Sangsiri *et al.*, 2007) and Sangsiri 2009). The findings also point to both south-eastern and western Himalayan foothills as likely places where domestication could have been taken place (Tensay Ayalew, 2015). The primary genetic diversity and center of origin for mungbean was the central Asian region with India having the widest diversity of domesticated varieties, and wild relatives (Altaf 2009). It is currently grown widely in Southeast Asia, Africa, South America, and Australia, and is regarded as a high-yielding pulse crop (SADAFF, 2010). Mungbean agriculture has grown all over the world due to the short time it takes to grow and its extensive adaptability, as well as the ease with which it may be digested (Chadha, 2010).

Mungbean is an annual crop 65-120 days to harvest; that grows to be 0.3 to 1.5 meters tall, erect or sub-erect, and often twines at the tips. It has a deep root system and is heavily branched, with long petioles. The leaflets are oval and range in size from 5 to 12 cm wide and 2 to 10 cm long. The leaves are alternating, trifoliate, and dark or light green. An axillary raceme with a peduncle 2 to 13 cm long, the inflorescence is an axillary raceme. The keel petal is spirally coiled with a horn-like appendage, and the bloom is yellow (Sehrawat *et al*., 2013). Pods range in length from 6 to 10 cm and are slender, short, and hairy. Seeds are globose, 15 to 85 mg in weight, typically green but occasionally yellow, tawny brown, black, or mottled, and epigeal germination (Bailey, 1970). It is a very early maturing crop with unique characteristics such as high yield, good nutritional value, earliness and drought resistance, low production costs, and the ability to induce Striga without being parasitized (Malik, 1994). The germination of mungbean is epigeal with the cotyledons and stem emerging from the seedbed (Arain, 2012).

2.2 Agro-climatic Requirements of Mungbean

Mungbean is widely distributed in the tropics and subtropics. It's what's known as a'short-day' plant. The sensitivity of cultivars varies greatly, although most genotypes exhibit quantifiable short-day responses, with flower initiation being delayed as the photoperiod lengthens. While qualitative responses (no flower initiation if photoperiod exceeds a crucial value) have been seen, absolute day neutrality has yet to be established (Siemonsma and Arwooth, 2016). It is a warm-season annual grain legume with an ideal temperature range of 27-30 °C for good production (Imrie, 1998), hence it is typically grown in the summer. When the minimum temperature is above 15 °C, seed can be planted. Until ensure a decent harvest, enough rainfall is required from flowering to late pod fullness. It thrives in fertile, sandy loam soils with excellent internal drainage and a pH of 6.3 to 7.2. On more alkaline soils, it can show severe iron chlorosis signs and certain micronutrient deficits because it does not tolerate saline soils (SADAFF, 2010)

2.3 Production and Importance of Mungbean

Mungbean is an important cash crops serving as a source of income and foreign currency in the world (Somta and Srinives, 2007; Pandey *et al*., 2011). In developing countries, mungbean is consumed as dry seeds, fresh green pods, or leaves and seeds as vegetables due to its high protein, vitamin, and mineral content (Tang *et al*., 2014; Das *et al*., 2014). The main objective of producing mungbean is for its protein-rich edible seeds and fresh sprout; mainly used for making soups, bread, and biscuits (Sehrawat *et al*., 2013). In addition to food, it has the capacity to fix atmospheric nitrogen which rehabilitates the soil fertility status, use of land and water resources (Nawale, 2001). Mungbean is one of the most important grain legumes for generating money (Chadha, 2010; SADAFF, 2010). Mungbean demand is expanding rapidly in the global import-export industry (Zhichao *et al*., 2018). It was just added to ECX's list of exported commodities in Ethiopia (ECX, 2014). Mungbean is produced for its edible seed consumed in Asia (India, South East-Asia and East Asia), Southern Europe and Southern USA (AVRDC, 2012). Mungbean can be prepared as cooked fresh or dry. They can be eaten whole or made into flour, soups, porridge, snacks, bread, noodles and ice-cream. Split seeds can be transformed into dhal in the same way as black gram or lentils.

Mungbean production is mainly (90 %) situated and produced in Asia in which India is the largest producer with more than 50 % of world production and consumes almost its entire production. China produces large amounts of mungbeans next to India, which represents 19 % of its legume production. Thailand is the main exporter and its production increased by 22 % per year between 1980 and 2000 (Lambrides *et al*., 2006). Even though it is produced in many African countries, the mungbean is not a major crop there and the production and productivity are not yet progressed (Mogotsi, 2006). Mungbean is best known in the United States, where it is used to make bean sprouts. It is one of the Asian Vegetable Research and Development Centre's (AVRDC) required crops in Shantua Tainan, Taiwan (AVRDC, 1990). It is also grown in Australia, from the Northern Territory to southern New South Wales (NSW), with the majority of production taking place in central and southern Queensland, as well as northern NSW. The majority of a crop is exported, with Taiwan, the Philippines, the United States, and the United Kingdom being the top destinations. It is primarily used in Southeast Asian cuisine, particularly in China, Thailand, Japan, Korea, Vietnam, and India (Oplinger *et al*., 1990; SADAFF, 2010; and Zhichao *et al*., 2018).

Mungbean is grown in Ethiopia's lower, dryer, and warmer regions (Itefa Degefa, 2016). It was made in Shewa, Hararge, Ilubabor, Gamogofa, Tigray, and Gondar, among other places (Keatinge *et al*., 2011). Its production is gaining popularity among farmers, and Ethiopia's mungbean exports have increased marginally year after year. Mungbean is a grain legume grown by small holder farmers in drier marginal environments, and it has been an essential grain legume for resource poor farmers in these areas, despite its low productivity in Ethiopia when compared to other pulse crops (MOARD, 2008; Itefa Degefa, 2016).

2.4 Historical Perspective and Overview of Mungbean Production in Ethiopia

Mungbean is originated from India and diversified to East, South, Southeast Asia (China) and some countries of Africa which is recently introduced in Ethiopian pulse production (ECX, 2014); being grown in few areas of North Shewa in order to reclaim less fertile, act as crop rotation mechanisms and plant the crop in marginal lands. So, farmers regard mungbean as a traditional crop.

Currently, mung bean is mainly cultivated in North Shewa, Oromiya Special Zone, Southern Wollo, Harerge, Illubabor, Gamo Gofa, Tigray, and Gondar (Keatinge *et al*., 2011). In Southern Ethiopia, farmers were living in pocket areas that are vulnerable to moisture stress, scanty and erratic rainfall distribution (Gofa, Konso, South Omo Zone, and Konta) produce it to supplement their nutritional needs (Asfaw Asrate *et al*., 2012; ECX, 2014**).** Even though the international market demands for mung bean is increasing, there is a demand-supply gap in Ethiopia from the production side even if export has grown slightly from time to time (EPP, 2004).

2.5 Constraints of Mungbean Production

According to Waniale *et al*., (2012) and Das *et al*., (2014), the productivity of mungbean is decreased through biotic factors such as diseases and insect pests and abiotic factors which include drought stress, water stress, extremely high temperature, salinity stress as well as heavy metals. The proper method of planting in a given area of land is an important biotic factor that determines the proper plant population or density in space provided, which improves the performance and productivity of plants in the field. Plant population plays an important role as it is one of the most important yields affecting and contributing characters (Rafiei, 2009). There are also many challenges in mungbean production: unpredictable rainfall, prevalence of pests and diseases, lack of input supply and development, lack of proper storage and handling and low levels of local consumption (Mohamed Ahmed *et al*., 2015).

Ashrar *et al*., (2001) considered lower yield potential of mung bean is due to susceptibility to insect pests, diseases, undetermined excessive vegetative growth and small seed size. In Ethiopia, according to Tensay Ayalew (2015) abiotic factors limiting yields of mung bean in terms of both quality and quantity are extreme drought, cold weather, untimely rain (rain after pod filling) and type of soil used for cultivating it. Biotic factors limiting mung bean productivity includes weeds, leave diseases, flying insects on pod and leave at any growth stage (Tensay Ayalew, 2015). Chadha (2010) reported that all parts of crop plant including root, stem, branches, petiole, leaves, pods and seeds of the crops are vulnerable to disease and pest.

2.6 Effects of NPSB Fertilizer Rates, Biofertilizer and Inter Row Spacing on Mungbean Production

2.6.1 Effects of blended NPSB on yield and yield components of mungbean

According to Hussain *et al*., (2011), nitrogen (N), phosphorus (P), and potassium (K) are essential and present in high levels in mungbean seed and biomass, and play important roles in contents, production, and productivity. When soil N levels or total N content are low (<0.05%), the application of a small amount of N fertilizer at planting induces rhizobia formation and promotes the growth of strong mungbean seedlings. During the early growth stages, before the branches develop, mungbean cannot efficiently fix atmospheric N because it has little or no rhizobia. Increasing the application of N fertilizer during the early growth period promotes vegetative growth and creates conditions favoring high yield (Yani *et al*., 2001). P fertilizer promotes root growth, disease resistance, drought tolerance, and enhances nutrient and water absorption in the seedlings after they have depleted their endosperm reserves (Zafar *et al*., 2013; Jian *et al*., 2014). The application of P might have improved the nutritional environment in the rhizosphere as well as in the plant system leading to increased uptake and translocation of nutrients in reproductive structures which led to higher content and uptake. Adequate P availability improves the nodule number and N content in the tissues of mungbeans (Bashir *et al*., 2011). Such positive effects of a high P supply on nodule development are associated with the essential function of P in energy metabolism (Tang *et al*., 2001). Sulfur has been found to be an indispensable element for higher pulse production and it is an integral part of proteins, sulpholipids, enzymes, etc. (Das and Misra, 1991). It is involved in various metabolic and enzymatic processes including photosynthesis, respiration, and legume Rhizobium symbiotic N fixation (Rao *et al*., 2001) Micronutrients increase the nodulation and nitrogen fixation of a mungbean plants. Phosphorus and other micronutrients enhance biological activity especially nitrogen fixation in order to enhance plant height, number of nodules per plant, number of pods per plant, and straw quality (Kumar *et al*., 2012). As Bassil *et al*., (2004) reported, Boron ranks third among the micronutrients and has a chief role in the plant cell wall and membrane constancy. Boron application maximizes the light interception ratio, biomass production, leaf area index, net assimilation rate, crop growth rate, and seed yield in pulses (Renukadevi *et al*., 2002). It influences the pollen-producing capacity, pollen tube growth, anther viability of pollen grain, and pollen germination. The pollen tube grows well by the application of boron because pectin is internalized by cross-linking with boron which increases the number of seeds pod^{-1} in mungbean (Verma *et al*., 2004).

2.6.2 Effects of biofertilizer yield and yield components of mungbean

Despite the growing demand in the international market, there is a chronic supply gap in Ethiopia in terms of production. The major contributor to this increase in production is the remarkable improvement in productivity than the expansion in the area which indicates increasing productivity per unit area. Application of such beneficial microbes as rhizobium and others alone or along with fertilizers is an economically and environmentally promising strategy and can aid in replenishing and maintaining long-term soil fertility by providing good soil biological activity, by suppressing pathogenic soil organisms; by stimulating microbial activity in the rhizosphere and to improve plant health of the various plant nutrients (Ouehmane *et al*., 2007; Khan *et al*., 2010). So, the use and application of rhizobia inoculation seem to be the most effective and efficient way for the cultivation of summer mungbeans. There was a gap of information on the actual rates of biofertilizer specifically per unit area; hence blanket recommendation was still used (MoA, 2015).

The combined application of *rhizobium* inoculation and phosphorous fertilizer had a profound effect on the nodulation of mungbean varieties. The application of *Rhizobium* 500gm ha^{-1} and P_20_5 46 kg ha^{-1} increased plant height by 26.5 %, over the control. An increment of plant height with the highest level of *Rhizobium* was probably due to the availability of nitrogen due to nitrogen fixation. (Geletu Tufa and Fikru Mekonnen, 2018). The rhizobium inoculation alone and with the application of phosphorus fertilizer significantly increased all the parameters measured. Seed inoculation with *Rhizobium* alone (500g) and 500g plus P_2O_5 46 kg ha^{-1}significantly increased nodule number $plant^{-1}$ (218%) and (173%) compared to the uninoculated seeds of mungbean, respectively. Application of mungbean with Rhizobium 500 gm + P_2O_5 46 kg ha^{-1}, Rhizobium 500 gm + P 23 kg P_2O_5 ha^{-1} combinations, and Rhizobium 500 gm alone, increased yield and yield component trait compared with other treatment combinations. The study revealed that Rhizobium inoculation at 500 gm along with 23 kg P_2O_5 ha^{-1} application increased the growth and yield of mungbean. Seed yield of mungbean was significantly influenced by the different levels of phosphorus and *Rhizobium* inoculants. Treatment combination of 500 g *Rhizobium* plus P_20_5 46 kg ha^{-1} produced the highest seed yield (1846 kg ha-1), 58% yield advantage over the uninoculated control.

Inoculants strains and fertilizers are the key contributors to mungbean production. According to Muhammad *et al*., (2016), inoculation of mungbean with rhizobium increased the grain yield, photosynthetic activity, and dry matter production. Malik *et al*., (2002) reported seed inoculation with Rhizobium significantly increased the 100-seed weight of mung bean. Ashraf *et al*., (2003) reported, Rhizobium inoculation strains combined with NP fertilizers increased pod number $plant^{-1}$ of mung bean. The higher grain yield from the interaction of N, P, and Rhizobium strains is attributed to the higher number of pods $plant^{-1}$, number of grains pod^{-1} and 1000-seed weight (Muhammad *et al*., 2016). In glasshouse and field experiments, Makoi *et al*., (2013) found that Rhizobium inoculation in mungbean dramatically boosted the uptake of P, K, Ca, Mg, and S in roots, shoots, pods, and the entire plant. Rhizobium bacteria in symbiosis with legumes have the ability to fix nitrogen from the air (N_2). As a result of the symbiotic interaction, a large natural source of N from the air can be taken up, resulting in a decrease or lack of N mineral fertilizer application in the field (Abbas *et al*., 2011; Rahman *et al*., 2002). In terms of economic importance, mungbean high economic outputs, particularly in developing nations, were represented in a variety of ways. It may be grown in arid places, on marginal soils, and can enhance soil quality due to its ability to fix nitrogen symbiotically (Delic *et al*., 2011).

2.6.3 Effects of inter and intra row spacing yield and yield components of mungbean

Optimum plant population in a given area is a prerequisite for obtaining higher production and productivity (Rafiei, 2009). As Kabir and Sarkar (2008) reported the highest seed yield of mungbean was obtained maintaining 30 cm × 10 cm spacing between rows and plants, respectively. Plant density of 40 plants m^{-2} at 25 cm x10 cm planting was the optimum for achieving higher productivity (Singh *et al*., 2011). Grain yield of mung bean per unit area tended to increase up to 30 plants m^{-2} and a further increase in density did not result any further in yield per unit area (Jahan and Hamid 2004; Jenkins and Verrel, 2015; GRDC, 2017). Jahan and Hamid, (2004), also reported a decline in seed yield as the density of plants increased to 60 plants m^{-2}. According to GRDC, (2017) establish 20–30 plants/m^2 in dry, and 30–40 plants/m^2 in irrigated situations and resowing if <10 plants m^{-2} in order to get uniform plant density which is critical to achieving uniform plant maturity across the paddock. Nawale (2001) concluded the optimum plant population for mungbean was 666,667 plants per hectare obtained through the configuration of 30 cm and 10 cm between rows and plants within rows, respectively. In contrast, Gebremariam Gebrelibanos and Baraki Fiseha (2018) concluded inter-row of 30 cm and intra row spacing of 5 cm gave significantly better final seed yield.

2.6.4 Combined effects of blended NPSB, biofertilizer and intra row spacing on yield and yield components of mungbean

Different studies showed that seed yield plant^{-1} of mungbean showed positive correlation with number of nodule plant^{-1}, number of pod plant^{-1}, number of seed pod^{-1} and 100-seed weight of mungbean (Delic *et al*., 2011; Rahman *et al*., 2008). Among significant factors inoculants strains and fertilizers are the key contributors for mungbean production. Inoculation of mungbean with Rhizobium increased the grain yield, photosynthetic activity and dry matter production (Muhammad *et al*., 2016). Malik *et al*., (2002) reported that seed inoculation with Rhizobium significantly increased 100-seed weight of mungbean. Fertilizers also have key roles in pod filling and ultimately enhance the grain production (Xavier and Germida, 2002).

Ashraf *et al*., (2003) reported that Rhizobium inoculation strains combined with NP fertilizers increased pod number plant-1 of mungbean. Muhammad *et al*., (2016) also reported that the higher grain yield from interaction of N, P and Rhizobium strains is attributed to higher number of pods plant-1, number of grains pod-1 and 1000-seed weight. Sadeghipour *et al*., (2010) concluded that 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 mungbean. Hamza *et al*., (2016) indicated that mungbean responded significantly to P and B in respect to number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield, and biological yield and harvest index. It has been reported that legumes inoculated with Rhizobium species and supplemented with P and K, responded differently in growth, yield and N fixation (Yanni *et al*., 2001). Rhizobium inoculants along with P and Mo significantly influenced the number of pods plant^{-1}, seeds pod^{-1}, 100-seed weight and seed yield (Landge *et al*., 2002; Rahman *et al*., 2008).

Due to its short duration, mungbean can fit in as a cash crop between major cropping seasons (Hamza *et al*., 2016). The use of appropriate strains of inoculants in N deficient soils may offer an excellent opportunity for improving legume growth and development (Mfilinge *et al*., 2014). As Delic *et al*., (2011) reported that all investigated characteristics of grain and shoot dry matter (above ground biomass) yields of mungbean significantly increased due to seed inoculation with particular Rhizobial strains.

Mungbean growth parameters like height, leaf area plant-1, number of branches plant-1 and number of nodules plant-1 significantly increased due to NP fertilizers (Rathod and Gawande, 2014). Hamza *et al*., (2016) concluded that mungbean can respond significantly to P and B combination in growth parameters like plant height, number of branches plant^{-1}, pods plant^{-1} and pod length. Phosphate is needed, especially in early plant growth for root development (Muhammad *et al*., 2016).

CHAPTER 3 - MATERIALS AND METHODS

3.1 Descriptions of the Study Area

The field experiments was conducted in Aliyu Amba Zuria kebele FTC (Farmers Training Center) during the 2020 main cropping season which is located at $9^{o}33'46''$ North latitude) and $39^{o}47'11''$ East longitude (actual GPS reading of x-y coordinates) (Figure 3.1). The experimental site has an elevation of 1640 m a.s.l. It is located 172 km North East of Addis Ababa, 42 km East of Debre Birhan the capital city of North Shewa Zone and 735 km North East of Bahir Dar the capital city ANRS (ADAO, DPMET, 2020); bordered by Tarmaber district in North, Asagrit district in South, Basonawerana district in West and Afar region in East direction (ADAO, DPMET, 2020). Gorebella is the capital town of the district Ankober is characterized by bi-modal rainfall pattern with two growing season. Annual rainfall, and mean minimum and maximum temperatures of the site is 979 mm, 12.4°C and 26.7°C respectively. The topography of the district is mostly undulating; stone bund terrace has been an indigenous cultural practice. Agro-ecologically the district has four climatic zones: frost 3% (Wurch), lowland 32% (Kolla), mid-land 47% (Woina Dega), and highland 18 % (Dega) (ANRSBoFED, 2009). The dominant soil types based on color are red 10%, black 23%, brown 29%, grey 35%, and other 3%. Agriculture is the dominant activity in the rural areas of the district with typical mixed farming system: crop production and livestock rearing. Major crops grown in the district are teff (*Eragrostis tef*), sorghum *(Sorghun bicolor* L), wheat *(Triticum aestivum* L), and barley *(Hordeum vulgare).* (CSA, 2020).

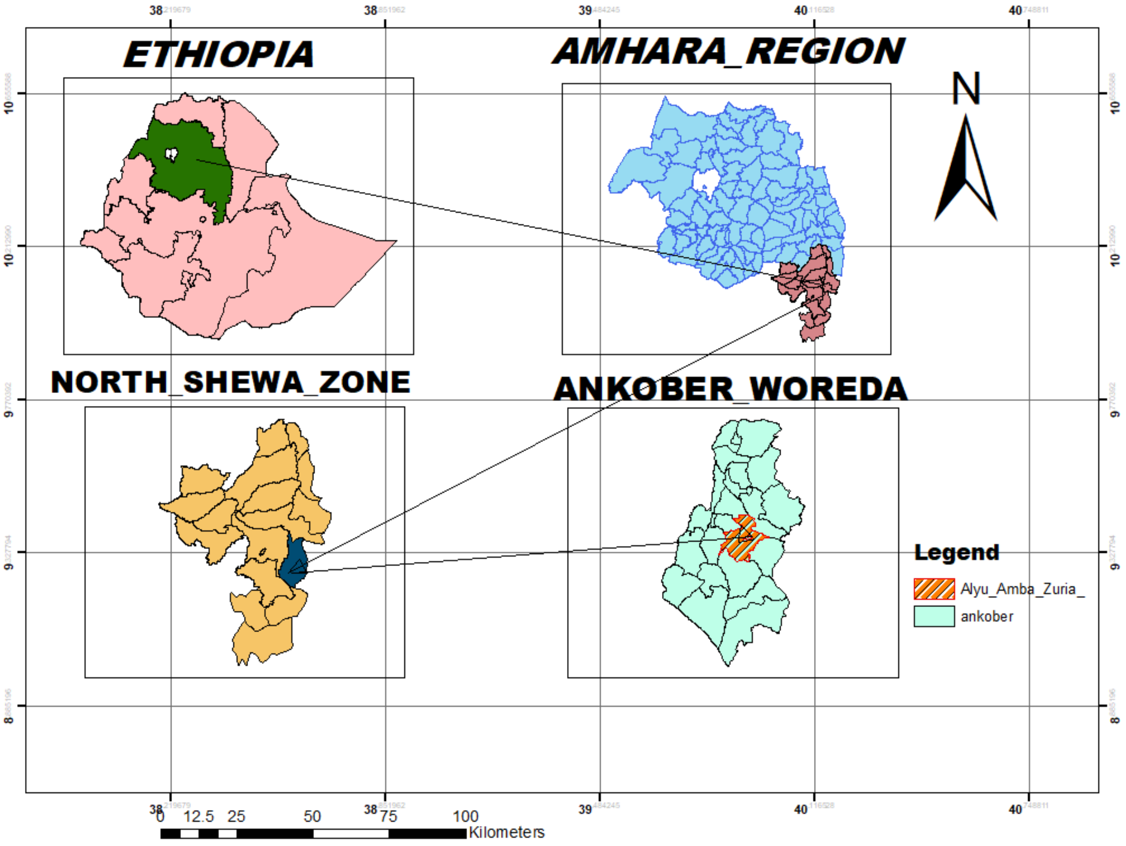

Figure 3.1. Map of study area

3.2 Experimental Planting Material

A mungbean variety, Rasa (N-26), which was released by Melkassa Agricultural Research Centre (MARC/EIAR) in 2011 was used for this experiment. Rasa (N-26) can grow in the altitude ranges from 900-1670 m above sea level with rainfall amount 350-550mm per annum and reaches to harvesting within 65-80 days (FDRE MoAAR, 2019). The variety was selected as an experimental material due to its high adaptation to the experimental site. In addition, blended NPSB (18.9% of N, 37.7% of P_2O_5, 6.95% of S and 0.1% of B) and biofertilizer were used as experimental materials. The biofertilizer was purchased from Menagesha Biotechnology Industry P.L.C.

3.3 Experimental Treatments, Design and Procedures

The treatment consisted of: three levels of blended NPSB (75, 100 and 125 kg ha^{-1}), two levels of biofertilizer rates (0 and 500 gm ha^{-1}) and three levels of intra row spacing (5 cm, 10 cm and 15 cm); with a total of 18 (eighteen) treatments which was arranged by factorial treatment combination (Table 3.1). The experiment was laid out in a randomized complete block design (RCBD) with three replications. In accordance with the specifications of the design, a field layout was prepared and each treatment was assigned randomly to experimental plots within a block. A plot size was 2 m x 3 m width and length; each plot and block was separated by 0.5 m and 1.0 m path along the width and along the length, respectively. There were 8 rows per plot under 30 cm rows spacing in the net plot area. The net plot size was 2.40 m length x 1.90 m width =4.56 m^2, 2.40 m length x 1.80 m width =4.32 m^2 and 2.40 m length x 1.70 m length = 4.08 m^2 for intra row spacing of 5 cm, 10 cm and 15 cm; respectively, excluding two outer rows and two outer plants from intra rows to avoid possible border effects.

The experimental field was ploughed two times by oxen plough and prepared according to the design. The variety was sown based on recommended seed rate as two seeds per hole. Planting was done with inter row 30 cm and intra row spacing 5 cm, 10 cm and 15 cm through drilling manually. Blended NPSB fertilizer was applied with side dressing and placement (band application) at the time of planting as per their treatment. Before planting, seeds were soaked in sun-hot water for few minute to help the inoculants carrier material to stick on the seed coat easily. The seed inoculation was done just before planting under shade to maintain the viability of cells in the biofertilizer inoculation at the rate of 15 g/kg of seed. Finally, the seed was incorporated with the soil and all necessary agronomic practices were carried out based on the recommendation of the crop. The experimental plots were hand hoed once and weeded by hand two times when weeding became necessary.

Crop was harvested at maturity manually for each plot by excluding two outer rows and two outer plants from intra rows and threshing was done manually and separately for each plot.

Table 3.1. Treatment number, treatment combination and treatment description

Treatment number	Treatment combination	Treatment description
1	F1B0R1	NPSB 75kgha^{-1}, without bio fertilizer and intra row (5)cm
2	F1B0R2	NPSB 75kgha^{-1}, without bio fertilizer and intra row (10)cm
3	F1B0R3	NPSB 75kgha^{-1}, without bio fertilizer and intra row (15)cm
4	F2B0R1	NPSB 100kgha^{-1}, without bio fertilizer and intra row (5)cm
5	F2B0R2	NPSB 100kgha^{-1}, without bio fertilizer and intra row (10)cm
6	F2B0R3	NPSB 100kgha^{-1}, without bio fertilizer and intra row (15)cm
7	F3B0R1	NPSB 125kgha^{-1}, without bio fertilizer and intra row (5)cm
8	F3B0R2	NPSB 125kgha^{-1}, without bio fertilizer and intra row (10)cm
9	F3B0R3	NPSB 125kgha^{-1}, without bio fertilizer and intra row (15)cm
10	F1B1R1	NPSB 75kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (5)cm
11	F1B1R2	NPSB 75kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (10)cm
12	F1B1R3	NPSB 75kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (15)cm
13	F2B1R1	NPSB 100kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (5)cm
14	F2B1R2	NPSB 100kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (10)cm
15	F2B1R3	NPSB 100kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (15)cm
16	F3B1R1	NPSB 125kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (5)cm
17	F3B1R2	NPSB 125kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (10)cm
18	F3B1R3	NPSB 125kgha^{-1}, 500gmha^{-1} bio fertilizer and intra row (15)cm

3.4 Method of Data Collection

Both phenological, vegetative and yield related parameters of mung bean were collected in the study. Data on plant height, number of branches, pod length, number of pod per plant and number of seed per pod were collected from randomly selected ten plants from net plot area.

3.4.1 Phenological parameters

- Days 50 percent flowering: was recorded by counting the number of days elapsed from the time of planting up to 50% of the plants in the plot produced flowers and recorded as days to 50 per cent flowering from the date of sowing by visual observation.
- Days 50 percent pod filling or setting was recorded when 50% of the pods fully capture seeds by visual observation.
- Days of 90 percent physiological maturity: was recorded when 90% of the plants in each plot to reach physiological maturity.

3.4.2 Vegetative growth parameters

- Plant height: The average height of ten plants which are selected randomly measured in centimeters from the base to tip of a plant from the net plot area of each plot at harvest. Average plant height for each plot was calculated.
- Number of total and effective branches: Number of total branches was determined by counting all branches arise on the main stem from randomly selected 10 plants from the net plot area. Number of effective branches was determined by counting branches bearing pods from randomly selected 10 plants of the net plot area.
- Pod length (cm) was measured by calculating the average pod length of ten randomly selected plant samples in the harvestable rows, following the measurement from its base to the tip.

3.4.3 Yield related parameters

- Number of pods per plant: was recorded based on ten randomly pre tagged plants in each net plot area and the average was taken as number of pods per plant.
- Number of seeds per pod: total number of seeds in ten randomly taken pods from the net plot was counted and divided by total number of pods to find the number of seeds per pod.
- Thousand-kernel weight (gm) was determined by weighing 1,000 randomly selected dry seeds from the harvested net plot using a sensitive balance and the weight adjusted to 10 % seed moisture content.
- Above-ground dry biomass yield (kg ha^{-1}) was recorded by harvesting from each net plot. It was sun-dried up to constant weight, weighed and then converted into kg ha^{-1}. It was taken and measured from the net plot harvestable area before threshing after sun drying for two weeks till it attains constant weight.
- Grain yield (kg ha^{-1}) was determined by taking the weight of the grains threshed from the net plot and will be converted to kilograms per hectare after adjusting the grain moisture content at 10%.
- Harvest index (HI %) was calculated by dividing the grain yield to the total above ground air dry biomass yield (straw +grain) multiplied by 100.

3.5 Methods of Data Analysis

3.5.1 Statistical data analysis

The data collected from the experimental plots were subjected to analysis of variance (ANOVA) using the procedures as described by Gomez and Gomez (1984) with the help of Statistical Analysis Software (SAS, 2008) version 9.4. Least significant difference (LSD) test at 5% or 1% probability was used for mean separation when the analysis of variance indicated the presence of significant differences. The correlation analysis also carried out using SAS software.

3.5.2 Partial Budget Analysis

Economic analysis was made following CIMMYT methodology (CIMMYT, 1988). The costs of fertilizers, seed and labor were considered as variable cost.

The prices of mungbean grain and straw in local market were 30 Birr kg^{-1} and 0.25 Birr kg^{1}, meanwhile the costs blended NPSB, biofertilizer and seed were 15.40 Birr kg^{-1}, 0.32 Birr gm^{-1} and 50 Birr kg^{-1}, respectively. Moreover, the costs of labor for harvesting, trashing and transporting were estimated. The treatments were arranged in increasing order of variable cost for recommend economically profitable treatments (CIMMYIT, 1988). The non-dominated treatments marginal rate of return (MRR) equated then the greater or equal to 50% with the highest net benefit is said to be economically profitable (CIMMYT, 1988). The net benefit (NB) was calculated as the difference between the gross field benefit and the total variable costs (TVC).

$$\mathbf{NB = GFB - TVC}$$

Where GFB = Gross Field Benefit, TVC = Total Variable Cost.

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield of farmers could expect from the same management.

The dominance analysis procedure as described by CIMMYT was used to select potentially profitable treatments from the range that was tested. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as “D”). The dominance analysis illustrates that to improve farmers’ income, it is important to pay attention to net benefits rather than yields, because higher yields do not necessarily mean high net benefits. The discarded and selected treatments using this technique were referred to as dominated and non-dominated treatments. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula

$$\text{MRR\%} \quad = \frac{\text{NBb} - \text{NBa}}{\text{TVCb} - \text{TVCa}} \times 100$$

Where NBa = NB with the immediate lower

NBb = NB with the next higher

TCV= TVCa the immediate lower and

TVC= TVCa the next highest TCV.

The % MRR between any pair of non-dominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input is set as the minimum acceptable MRR Rate (CIMMYT, 1988). A treatment having acceptable MRR and highest NB was claimed to be the most profitable.

CHAPTER 4 - RESULT AND DISUSSION

4.1 Phenological Parameters

4.1.1 Days to 50 % flowering

Analysis of variance revealed that the combined main effect blended NPSB had shown highly significant ($P < 0.01$) effect and biofertilizer was having very highly significant ($P<0.001$) effect and intra row spacing had no significant effect on days to 50% flowering. The two-way interaction of NPSB fertilizer rates and intra row spacing had highly significant ($P < 0.01$) effect on days to 50% flowering. The two-way interaction between biofertilizer with blended NPSB fertilizer rates and biofertilizer with intra row spacing, and the three-way interaction had no significant effect on days to 50% flowering (Appendix 1).

The longest days to 50% flowering (36.98 days) were recorded at 500 g ha^{-1} biofertilizer application, while the shortest (33.69 days) were recorded with no biofertilizer inoculants (Table 4.1). The use of biofertilizer inoculation delayed the flowering day of mungbean; the inoculation of rhizobium enhances nitrogen availability through biological nitrogen fixation (Geletu Tufa and Fikru Mekonnen 2018).

The longest days to 50% flowering (38.14 days) were recorded at 125 kg ha^{-1} NPSB fertilizer rate with 10 cm intra row spacing, while the shortest (33.27 days) were recorded at 75 kg ha^{-1} NPSB fertilizer rate with 5 intra row spacing (Table 4.2). Days to flowering linearly increased with increasing NPSB fertilizer rate and wider intra row spacing. This might be due to the competition among plants for available resources in low NPSB fertilizer rates and narrow intra row spacing that might have lead the plants to stress conditions and ultimately the plants flowered early instead of prolonged vegetative growth.

Table 4.1. Main effects of blended (NPSB) fertilizer rates and biofertilizer on days to flowering, days of pod setting and days to maturity of mungbean at Ankober district, 2020 cropping season.

Treatments	DF	DPS	DM
Blended (NPSB) fertilizer rates (Kg ha-1)			
75	34.21c	49.10b	64.61b
100	35.27b	49.80b	65.31b
125	36.54a	51.46a	66.76a
LSD (0.05)	0.99**	1.06**	1.10**
SE±	0.72	0.82	0.88
Biofertilizer rates (gm ha-1)			
0	33.69b	48.44b	64.26b
500	36.98a	51.80a	66.86a
LSD (0.05)	0.81***	0.87***	0.89***
SE±	1.04	1.11	0.94
CV (%)	4.15	3.13	2.48
Mean	35.34	50.11	65.56

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; ***: very highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; DF; days to flowering; DPS: days of pod setting; DM: days to physiological maturity.*

4.1.2 Days to 50% pod filling

Analysis of variance revealed that the main effect NPSB fertilizer rate and biofertilizer was highly significantly (P<0.01) affecting, and intra row spacing had no significant effect on days to 50% pod setting. The two-way interaction effect between NPSB fertilizer rates and intra row spacing had shown significant ($P < 0.05$) effect on days to 50% pod setting. The other two-way and three-way interaction effects of blende NPSB, biofertilizer and intra row spacing had not shown significant effect on days to pod filling (Appendix 1).

The longest days to 50% pod setting (51.80 days) were recorded at treatment 500 g ha^{-1}, while the shortest days to 50% pod setting (48.44 days) were recorded at treatment with no biofertilizer inoculation (Table 4.1). Using biofertilizer inoculation delayed the pod setting days of mungbean due to the availability of nitrogen through biological nitrogen fixation.

The longest days to 50% pod setting (52.74 days) were recorded at 125 kg ha^{-1} NPSB fertilizer rate with 10 cm intra row spacing, while the shortest (48.17 days) were recorded at 75 kg ha^{-1} NPSB fertilizer rate with 10 intra row spacing (Table 4.2). Days to pod setting increased with increasing NPSB fertilizer rate and intra row spacing. This might be due to less competition among plants for available resources in wider intra row spacing and high level of NPSB fertilizer rate. This might have leaded the plants to growth and branching instead of early pod setting.

Table 4.2. Interaction effects of intra row spacing with blended (NPSB) fertilizer rates on days to 50% flowering, days to 50% pod setting and days to 90% physiological maturity of mungbean at Ankober district, 2020 cropping season.

Treatments combination	Parameters		
NPSB rates (kg ha^{-1}) * intra row spacing (cm)	DF	DPS	DM
75 kg ha^{-1} with 5 cm	33.27^{c}	48.67^{bc}	64.54^{bc}
75 kg ha^{-1} with 10 cm	34.12^{bc}	48.17^{c}	63.07^{c}
75 kg ha^{-1} with 15 cm	35.09^{bc}	50.46^{abc}	66.24^{ab}
100 kg ha^{-1} with 5 cm	35.04^{bc}	49.03^{bc}	65.03^{bc}
100 kg ha^{-1} with 10 cm	34.25^{bc}	50.02^{abc}	66.56^{ab}
100 kg ha^{-1} with 15 cm	36.64^{ab}	50.34^{abc}	64.35^{bc}
125 kg ha^{-1} with 5 cm	35.24^{bc}	50.27^{ab}	66.10^{ab}
125 kg ha^{-1} with 10 cm	38.14^{a}	52.74^{a}	68.17^{a}
125 kg ha^{-1} with 15 cm	36.23^{ab}	51.37^{ab}	66.00^{ab}
Mean	35.34	50.12	65.56
LSD (0.05)	2.78**	2.91^{*}	2.80**
CV (%)	4.15	3.13	2.48
SE±	0.89	0.83	0.80

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; DF; days to flowering; DPS: days to pod setting; DM: days to physiological maturity*

4.1.1 Days to 90% physiological maturity

Days of 90 percent physiological maturity showed significant response to the main effects of blende NPSB fertilizer and biofertilizer rate. Both NPSB fertilizer rate and biofertilizer had highly significant at (P<0.01) and very highly significant (P<0.001) effect on physiological maturity of mungbean, respectively. On the contrary, intra row spacing did not shown significant effect on physiological maturity of mungbean. The two-way interaction effect NPSB fertilizer rate-biofertilizer ($P<0.05$), and NPSB fertilizer rate-intra row spacing ($P<0.01$) had shown significant effect on days to 90% physiological maturity. While the three-way interaction effect had not shown significant effect on days of 90% physiological maturity (Appendix 1).

The two-way interaction effect between NPSB fertilizer rates and biofertilizer revealed that days of physiological maturity increased from 64.10 days (treatments receiving 75 kg NPSB ha-1, 0 gm biofertilizer ha-1) to 68.99 days (treatments receiving 125 kg NPSB ha-1, 500 gm biofertilizer ha-1) (Table 4.3). This could be due to increased nitrogen in higher fertilizer rates, as well as the ability to fix atmospheric nitrogen due to rhizobium inoculation. Abdula (2013) found that the maximal fertilizer dose mixed with rhizobium inoculation caused a delay in maturity. Similarly, the interaction effect between NPSB fertilizer rates and intra row spacing revealed that the longest days of physiological maturity (68.17 days) were recorded at treatments receiving 125 kg NPSB ha-1 with 10 cm intra row spacing; while the shortest day to physiological maturity (63.07 days) at treatments receiving 75 kg NPSB ha-1 with 10 cm intra row spacing (Table 4.3). The minimum fertilizer and intra row spacing associated with early maturity might be due to plant competition for available resources. As blended NPSB fertilizer rate increases with the addition of biofertilizer and wider intra row spacing generally delays day’s maturity. Treatments having biofertilizer inoculation generally delays days to flowering, pod setting and maturity. Because using biofertilizer inoculation increases the availability of nitrogen through biological nitrogen fixation.

Table 4.3. Interaction effects of blended (NPSB) fertilizer rates with biofertilizer days to 90% physiological maturity of mungbean at Ankober district, 2020 cropping season.

Treatments combination	Parameter
NPSB rates (kg ha^{-1}) * biofertilizer (gm ha^{-1})	DM
75 kg ha^{-1} with no or zero gm ha^{-1}	64.10^{c}
75 kg ha^{-1} with 500 gm ha^{-1}	65.13^{bc}
100 kg ha^{-1} with no or zero gm ha^{-1}	64.17^{c}
100 kg ha^{-1} with 500 gm ha^{-1}	66.46^{b}
125 kg ha^{-1} with no or zero gm ha^{-1}	64.53^{bc}
125 kg ha^{-1} with 500 gm ha^{-1}	68.99^{a}
Mean	65.56
LSD (0.05)	1.95*
CV (%)	2.48
SE±	0.84

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; DF; days to flowering; DPS: days to pod setting; DM: days to physiological maturity.*

4.2 Vegetative Growth Parameters

4.2.1 Plant height

The result of the analysis of variance had shown the main effects of blended NPSB fertilizer rates and intra-row spacing; and the two-way interaction between biofertilizer and intra row spacing had shown significant ($P<0.05$) effect on plant height of mungbean. On the other hand, the main effect of biofertilizer and the other two-way interaction of biofertilizer with blended NPSB and intra row spacing and three-way interaction of NPSB fertilizer rate, biofertilizer and intra row spacing had not showed significant difference on plant height; except the interaction effect of biofertilizer with intra row spacing which is significant at ($P<0.05$) (Appendix Table 2).

As intra row spacing becomes wider, plant height decreased significantly. The longest mungbean plant (49.56 cm) was recorded with the narrowed (5 cm) intra row spacing, while the shortest plant (47.09 cm) was measured with the wider (15 cm) intra row spacing (Table 4.5). Mungbeans planted with 10 cm and 15 cm intra row spacing did not show statistically significant difference in plant height (Table 4.5). Decreasing the distance between plants (higher plant densities) increased the plant height significantly. Increase in plant height with decreasing intra row spacing might be due to intra-specific competition for the sunlight resulting in taller plants. This trend explains that as the number of plants increased in a given area, the competition among the plants for nutrients uptake and sunlight interception also increased. Taj *et al.* (2002) found competition for light in narrow spacing that resulted in taller plants of mungbean while at wider spacing light distribution is normal. Similarly, Shamsi and Kobraee (2009) on soybean observed that increasing the density of plants of soybean led to significant increases in plant height. This may be attributed to the highest intra specific competition for light at denser plant populations. This result agreed with Singh *et al.* (2012), plant height increased with increasing plant density.

The highest plant height (49.96 cm) was recorded in blended (NPSB) fertilizer rate at 100 kg ha^{-1} while the shortest plant height (45.63 cm) (Table 4.5); similar result was recorded by Geletu Tufa and Fikru Mekonnen (2018). The fact that nitrogen, phosphorus, and sulfur nutrients are involved in critical plant activities and lead to increased crop height growth could explain the increase in plant height with increasing NPS fertilizer rates. Furthermore, increased plant height with increased NPS application rate indicates maximum vegetative growth of the plants under higher N and S availability, and P also plays a key role in early root proliferation, which could increase the plant's nutrient uptake, resulting in increased vegetative growth. This result is in conformity with the finding of Taj, (1996) who reported an increase in plant height of mungbean in response to nitrogen and phosphorus application (20 kg N ha-1 and 69 kg P_2O_5 ha^{-1})

The two-way interaction effect between biofertilizer and intra row spacing showed that significant ($P<0.05$) effect on plant height of mungbean (Appendix Table 2). The longest plants (50.63 cm) were recorded at treatment receiving 5 cm intra row spacing with 500g ha^{-1} biofertilizer application, while the shortest plants (43.63 cm) were recorded at treatment receiving 15 cm intra row spacing with no biofertilizer application (Table 4.4). This may be due to the role of biofertilizer for fixing BNF which contributes a lot for plant height.

Table 4.4. Interaction effects of intra row spacing with biofertilizer on plant height of mungbean at Ankober district, 2020 cropping season.

Treatments combination Biofertilizer (gm ha^{-1})* Intra row spacing (cm)	Parameter PH
No or zero gm ha^{-1} with 5 cm	48.64^{ab}
No or zero gm ha^{-1} with 10 cm	44.85^{bc}
No or zero gm ha^{-1} with 15 cm	43.65^{c}
500 gm ha^{-1} with 5 cm	50.63^{a}
500 gm ha^{-1} with 10 cm	50.48^{a}
500 gm ha^{-1} with 15 cm	46.53^{abc}
Mean	47.46
LSD (0.05)	4.91*
CV (%)	10.43
SE±	3.01

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; PH; plant height.*

4.2.2 Number of total and effective branches

The analysis of variance showed that the main effect blended (NPSB) fertilizer rate and intra row spacing had shown highly significant ($P < 0.01$) effect on the number of total branches per plant whereas the main effect of biofertilizer was very highly significantly ($P < 0.001$) affected on number of total branches. Similarly, the main effect biofertilizer and intra row spacing had shown very highly significant ($P < 0.001$) and highly significant ($P<0.01$) effect on the number of effective branches per plant, respectively; while blended

NPSB fertilizer rate had no significant effect number of effective branches. The two-way and three-way interaction had no significant ($P>0.05$) effect on the number of branches per plant (Appendix 2).

The maximum number of total branches (10.42 and 11.35) was recorded at the treatments receiving 125 kg NPSB ha^{-1} and 500 gm ha^{-1} biofertilizer inoculation, respectively. The minimum number of total branches (8.76 and 7.97) was recorded at the treatments receiving 75 kg NPSB ha^{-1} and with no biofertilizer inoculation, respectively (Table 4.5). This indicates use of blended NPSB fertilizer and biofertilizer decrease the competition for plant nutrients and increases total branching, since branching is an important factor for mungbean productivity. Muhammad *et al*., (2004) found the number of branches per plant is significantly influenced with both inoculum and P application. Furthermore, the increased number of total and effective branches per plant in response to increased NPS application rate indicates maximum vegetative growth of the plants under higher N and S availability, and P plays a key role in early root proliferation, which may increase the plant's nutrient uptake, resulting in increased vegetative growth. In line with this finding, (Taj, 1996) found that the number of total and effective branches rose when the N rate (20 kg ha^{-1}) increased in chickpea and soybean, respectively. Similarly, on soybean, (Gebre Wedajo, 2015) found that 50 kg P_2O_5ha^{-1} resulted in a considerably higher number of effective branches (9.15) than the control.

On the other hand, the maximum number of total and effective branches (10.64 and 8.33) was recorded at the treatments receiving 15 cm intra row spacing; while the minimum number of total and effective branches (8.61 and 6.34) was recorded at the treatments receiving 5 cm intra row spacing (Table 4.5). This indicates wider spacing decreases plant population and competition for resource and space, and increases branching capacity. The increased number of branches with increasing spacing could be attributed to less competition for soil nutrients and moisture between plants in the wider plant spacing. Furthermore, when intra-row spacing increased, the number of branches increased, indicating that wider plant spacing supported lateral growth (branching) but not apical growth, and vice versa. According to Mtaita and Mutetwa (2014), lesser plant populations of 125,000 plants ha-1 had the maximum number of branches plant^{-1} compared to higher plant populations of 320,000 plants ha^{-1}. This finding is consistent with Pawar *et al*., (2007) and Mureithi *et al*., (2012), who found that greater spacing increased the number of branches per plant in haricot bean and French bean, respectively.

The highest number of effective branches per plant (8.72 and 8.33) was obtained from 500 gm ha^{-1} biofertilizer inoculants and 15 cm intra row spacing, respectively. While the lowest number of effective branches per plant (5.64 and 6.34) was found from non biofertilizer inoculants and 5 cm intra row spacing, respectively (Table 4.5). Singh *et al* (2011) found number of primary and secondary branches were higher when chickpea was inoculated with biofertilizer. Muhammad *et al*. (2004) reported on mungbean, the number of branches plant^{-1} was significantly influenced by higher level of *rhizobium* inoculums. From this study concluded those biofertilizer inoculations have the capacity to increase both total and effective branches of mungbean which is important to enhance production and productivity.

On the other hand, the highest number of total and effective branches per plant (10.64 and 8.33) was obtained from 15 cm intra row spacing respectively (Table 4.5). This result was in line with El Naim *et al*., (2010) and Asaye Birhanu *et al*., (2018) reported, the number of branches per plant was reduced with the increase in plant density. Regarding the effect of population density on number of branches per plant, Daniel and Kumar (2015) reported maximum number of branches per plant obtained in wider spacing whereas minimum number of branches per plant was obtained in narrow spacing. Mehmet (2008) who reported spacing gets wider; there will be more interception of sunlight for photosynthesis, which results in the production of more nutrients for partitioning toward the development of more branches. In addition to the effects of biofertilizer and intra row spacing, the highest total (10.42) branches was obtained in 125 kg ha^{-1} NPSB rates; which indicates the fertilizer rate increases number branches in general (Table 4.5).

Table 4.5. The combined main effects of NPSB fertilizer rate, biofertilizer and intra row spacing, on plant height (cm), number of total branches, number of effective branches and pod length of mungbean at Ankober district, 2020 cropping season.

Treatments	PH	NTB	NEB	PL
Blended (NPSB) fertilizer rates (Kg ha^{-1})				
75	45.63^{b}	8.76^{b}	6.76^{a}	8.35^{b}
100	49.96^{a}	9.81^{a}	7.21^{a}	8.79^{a}
125	46.81^{ab}	10.42^{a}	7.56^{a}	9.00^{a}
LSD (0.05)	3.35*	0.74**	0.91^{ns}	0.41**
SE±	2.86	0.63	0.78	0.35
Biofertilizer rates (gm ha^{-1})				
0	48.25^{a}	7.97^{b}	5.64^{b}	7.97^{b}
500	46.68^{a}	11.35^{a}	8.72^{a}	9.46^{a}
LSD (0.05)	2.74^{ns}	1.18***	1.81***	0.33***
SE±	3.50	0.77	0.95	0.42
Intra row spacing				
5	49.56^{a}	8.61^{c}	6.34^{b}	8.41^{b}
10	47.74^{ab}	9.74^{b}	6.83^{b}	8.66^{b}
15	47.09^{b}	10.64^{a}	8.33^{a}	9.08^{a}
LSD (0.05)	3.35*	0.74**	0.91**	0.41**
SE±	2.86	0.63	0.78	0.35
CV (%)	10.43	11.26	18.71	6.92
Mean	47.46	9.66	7.18	8.72

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; *** very highly significant NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; PH; plant height; NTB: number of total branches; NEB: number of effective branches; PL: pod length.*

4.2.3 Pod length

In the current study, the combined analysis showed that both effect of blended (NPSB) fertilizer rate and intra row spacing were highly significant a ($P < 0.01$) effect and biofertilizer inoculation had shown very highly significant ($P < 0.001$) effect on pod length. The two-way and three-way interaction effect of blended (NPSB) fertilizer rate, biofertilizer and intra-row spacing had not shown significant ($P > 0.05$) effect on the pod length (Appendix table 2).

The longest pod length (9.00 cm and 9.08 cm) was recorded at the treatment receiving 125 kg ha^{-1} NPSB and 15 cm intra row spacing, respectively. Similarly, the shortest pod length (8.35 cm and 8.41 cm) was recorded at the treatment receiving 75 kg ha^{-1} NPSB and 5 cm intra row spacing, respectively (Table 4.5). The result was not in line with Ihsanullah *et al*. (2002) who reported no significant effect of different row spacing or plant densities on pod length of mungbean.

On the other hand, biofertilizer had shown very highly significant ($P < 0.01$) effect on the pod length of mungbean. The longest pod length (9.46 cm) was recorded at the treatment receiving 500 gm ha^{-1} biofertilizer inoculation (Table 4.5). Using biofertilizer inoculation increases pod length of mungbean which have similar result with Dhiya *et al*. (2015).

4.3 Yield Related Parameters

4.3.1 Number of pods per plant

The production and productivity capacity of mungbean plant is ultimately considered and directly correlated by the number of pods per plant which provides an indicator of mung bean to be productive. The statistical analysis results revealed that pod number of mung bean was very highly significantly ($P < 0.001$) affected by main effects of blended (NPSB) fertilizer rate, biofertilizer and intra row spacing. The two-way interaction between blended

(NPSB) fertilizer rate, biofertilizer and intra row spacing had significant ($P < 0.05$) effect on number of pod per plant. On the other hand, the three-way interaction between blended (NPSB) fertilizer rate, biofertilizer and intra row spacing had not shown significant ($P > 0.05$) effect on pod number (Appendix Table 3).

The maximum pod number (28.30) was recorded from 100 kg ha^{-1} blended (NPSB) fertilizer rate with 500 gm ha^{-1} biofertilizer inoculants, while the minimum pod number (18.86) was recorded from 75 kg ha^{-1} blended (NPSB) fertilizer rate with no biofertilizer inoculants (Table 4.6). In line with this Kiros Wolday & Atsede Teklu, (2020) reported significantly highest number of pods per plant was counted from the combine effect of rhizobium inoculation and 125 kg NPSB ha^{-1} compared to the control over the two years. Their result revealed that the combined application rhizobium and NPSB could be the optimum levels to obtain the higher number of pods per plant on chickpea. Similarly, in case of uninoculated plants maximum number of pod per plant was observed where higher dose of fertilizer applied; which further increase to 23.5% with combined application of fertilizer with rhizobium inoculation and 42.11% high over its control (Arif *et al*., 201).

Similarly, the maximum pod number (27.66) was recorded from 500 gm ha^{-1} biofertilizer inoculants with 10 cm intra row spacing. While the minimum pod number (19.12) was obtained from no biofertilizer inoculants and 15 cm intra row spacing (Table 4.6). On the other hand, the maximum pod number (25.45) was recorded from 100 kg ha^{-1} blended NPSB fertilizer with 10 cm intra row spacing; while the minimum pod number (20.35) was obtained from 75 kg ha-1 blended NPSB fertilizer and 5 cm intra row spacing (Table 4.6). As increasing NPSB rates and intra row spacing with the addition of biofertilizer increases pod number positively. This might be due to more free space between plants at the higher intra row spacing and less intra-plant competition for available resources that resulted in higher pod number. The current result is in agreement with the finding of Kabir and Sarkar (2008) who reported that pod number was significantly affected by both blended fertilizer with intra and inter-row spacing. The highest number of pods at the highest rates of NPS might be attributed to the fact that improved availability of N, P and S enhances the canopy developments which in turn improve better solar radiation use through photosynthesis, thereby improving dry matter accumulation which later re-translocate to yield forming traits such as number of pods per plant.

Table 4.6 Combined two-way interaction effect of blended NPSB fertilizer rates, biofertilizer and intra row spacing on number of pods per plant on mungbean at Ankober district in 2020 cropping season.

NPSB rates (kg ha^{-1}) * biofertilizer (gm ha^{-1})	
Treatments combination	NPP
75 kg ha^{-1} X no or zero gm ha^{-1}	18.86^{d}
100 kg ha^{-1}X no or zero gm ha^{-1}	20.06^{cd}
125 kg ha^{-1} X no or zero gm ha^{-1}	21.29^{c}
75kg ha^{-1} X 500 gm ha^{-1}	24.27^{b}
100 kg ha^{-1} X 500 gm ha^{-1}	28.30^{a}
125 kg ha^{-1} X 500 gm ha^{-1}	27.26^{a}
LSD (0.05)	1.97*
SE±	0.85
NPSB rates (kg ha^{-1}) * Intra row spacing (cm)	
Treatments combination	NPP
75 kg ha^{-1} with 5 cm	20.35^{b}
100 kg ha^{-1} with 5 cm	25.15^{a}
125 kg ha^{-1} with 5 cm	24.97^{ab}
75 kg ha^{-1} with 10 cm	23.05^{ab}
100 kg ha^{-1} with 10 cm	25.45^{a}
125 kg ha^{-1} with 10cm	25.17^{a}
75 kg ha^{-1} with 15 cm	21.28^{ab}
100 kg ha^{-1} with 15 cm	21.93^{b}
125 kg ha^{-1} with 15 cm	22.68^{ab}
LSD (0.05)	4.72*
SE±	1.35
Biofertilizer (gm ha^{-1})* Intra row spacing (cm)	
Treatments combination	NPP
No or zero gm ha^{-1} X 5 cm	19.32^{d}
No or zero gm ha^{-1} X 10 cm	21.76^{c}
No or zero gm ha^{-1} X 15 cm	19.12^{d}
500 gm ha^{-1} X 5 cm	27.36^{a}
500 gm ha^{-1} X 10 cm	27.66^{a}

500 gm ha^{-1} X 15 cm	24.81^{b}
LSD (0.05)	2.08*
SE±	0.85
Mean	23.34
CV (%)	6.53

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; NPP: Number of Pods per Plant.*

4.3.2 Number of seeds per pod

Data recorded on number of seed per pod indicated that it was high significantly (P<0.01) influenced by the main effects of biofertilizer and intra row spacing; and had significant (P<0.05) effect by blended (NPSB) fertilizer rate. The two-way and three-way interaction effects of blended (NPSB) fertilizer rate, biofertilizer and intra row spacing had not shown significant (P<0.05) effect on number of seed per pod (Appendix Table 3).

Maximum number of seed per pod (10.17) was obtained from 15 cm intra-row spacing and minimum number of seed per pod (9.44) recorded from 5cm intra-row spacing (Table 4.7). This result was in line with the finding of Ihsanullah *et al.* (2002) recorded highest number of seeds per pod was recorded from wide spacing while the lowest number of seeds per pod was recorded from narrow intra and inter row spacing. Idris *et al*., 2008 showed that the quantity of seeds per pod increased when plant density of faba bean decreased, which is consistent with the current finding.

Similarly, highest number of seeds per pod (10.03) was obtained from the 125 kg ha^{-1} while the lowest (9.58) was recorded from 75 kg ha^{-1} (Table 4.7). It's possible that the increased quantity of seeds per pod with increased NPS fertilizer application rates is related to the fact that P is an important component in seed development. Phosphorus is required for protein synthesis, phospholipid synthesis, and phytin production, all of which are essential for plant growth (Rhahman *et al*., 2008). The findings of this study were consistent with those of (Shubhashree, 2007) and (Meseret Turuko and Amin Mohammed. 2014), who found that increasing P levels increased the number of seeds per pod of common bean substantially (92 kg P_2O_5).

On the other hand, maximum number of seed per pod (10.76) was obtained from biofertilizer treated, whereas the lowest number of seed per pod (8.92) was obtained from nil biofertilizer treatment. The result was not in line Geletu Tufa and Fikru Mekonnen (2018) and Ayalew Addis *et al*. (2020) reported various rhizobium inoculation rates did not significantly affect number of seeds per pod in mungbean.

Table 4.7 The main effect of blended NPSB fertilizer rate, intra row spacing and biofertilizer on number of seed per pod, of mungbean at Ankober district in 2020 cropping season.

Treatments VS Parameters	NSP
NPSB fertilizer rates (kg ha^{-1})	
75	9.58^{b}
100	9.90^{ab}
125	10.03^{a}
LSD (0.05)	0.36*
SE±	0.31
Intra row spacing (cm)	
5	9.44^{b}
10	9.91^{a}
15	10.17^{a}
LSD (0.05)	0.36**
SE±	0.31
Biofertilizer (gm ha^{-1})	
0	8.92^{b}
500	10.76^{a}
LSD (0.05)	0.29**
SE±	0.37
Mean	9.84
CV (%)	5.40

Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where: significant; **: highly significant; NS: Non significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; NSP: Number of Seed per Pod.*

4.3.3 Biomass yield

Biomass yield represents overall growth performance of the crop which considered as the essential yield parameter to get useful information about growth and performance of the crop. Biomass yield is highly inclined by crop nutrition and planting distance. The production and productivity of a crop is largely determined by the above ground biomass or biological yield. A field having large amount of biomass or biological yield is one of the attributes of seed yield or production. The results of this study showed that the main effect NPSB fertilizer rate significant ($P < 0.05$) effect, while the biofertilizer and intra row spacing had shown very highly significant ($P < 0.001$) effect on the mungbean biomass yield. The two-way interaction effect of blended NPSB fertilizer rate and intra row spacing had shown highly significant ($P < 0.01$) effect on aboveground biomass of mungbean. The other two-way and three-way combined interaction had not shown significant ($P >0.05$) effect on aboveground dry biomass yield (Appendix Table 3).

The highest above-ground dry biomass yield (3871.70 kg ha^{-1}) was recorded at the treatment plots receiving 100 kg ha^{-1} NPSB rates with 5 cm intra row spacing which was significantly decreased by wider spacing of 10 and 15 cm spacing, while the lowest value for above-ground dry biomass yield (2856.80 kg ha^{-1}) was obtained at 15 cm intra row spacing with 125 kg ha^{-1} NPSB rates (Table 4.8). The highest total dry biomass at the lowest intra-row spacing might be due to more plants per unit area. Dry matter production per unit area increases with increases in plant density up to a limit in biological yield. When plants are, widely spaced vegetative dry matter yields will at first tend to increase with inversing plant density. This indicates that no appreciable competition is occurring between neighboring plants. Plant numbers compensate almost exactly for a reduction in the production of individual plant.

Table 4.8 Interaction effect of blended NPSB fertilizer rate and intra row spacing on biomass yield and grain yield of mungbean at Ankober district in 2020 cropping season.

Treatments combination	Parameters	
NPSB rates (kg ha^{-1}) * Intra row spacing (cm)	BY	GY
75 kg ha^{-1} with 5 cm	3556.10^{a}	1246.20^{b}
100 kg ha^{-1} with 5 cm	3871.70^{a}	1605.40^{a}
125 kg ha^{-1} with 5 cm	3821.40^{a}	1436.60^{ab}
75 kg ha^{-1} with 10 cm	3120.80^{b}	1260.00^{b}
100 kg ha^{-1} with 10 cm	3617.00^{a}	1639.80^{a}
125 kg ha^{-1} with 10cm	3781.90^{a}	1408.90^{ab}
75 kg ha^{-1} with 15 cm	3026.70^{b}	1225.10^{b}
100 kg ha^{-1} with 15 cm	2891.30^{b}	1168.70^{b}
125 kg ha^{-1} with 15 cm	2856.80^{b}	1163.60^{b}
Mean	3393.73	1350.48
LSD (0.05)	412.34**	303.14**
CV (%)	8.02	7.26
SE±	118.05	86.78

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; BY: Biomass Yield; GY: Grain Yield:*

4.3.4 Grain yield

The analysis result showed the main effect and their two-way interaction effect of blende NPSB fertilizer rate, biofertilizer and intra-row spacing were highly significantly ($P < 0.01$)

affected on grain yield of mungbean except in the three-way interaction which revealed no significant ($P < 0.05$) effect (Appendix Table 3).

The highest grain yield (1634.90 kg ha^{-1}) was obtained at the 100 kg ha^{-1} NPSB rates with 500 gm ha^{-1} biofertilizer inoculation, while the lowest grain yield (1090.44 kg ha^{-1}) was recorded at the 75 kg ha^{-1} NPSB rates with no biofertilizer application (Table 4.9). The use of 125 kg ha^{-1} NPSB combined with rhizobium inoculation resulted in a 134 percent increase in yield over the untreated control (control). Messele Birhanu and Pant (2012) observed a synergetic and good response of rhizobium inoculation and di-amonium phsphate in chickpea grain yield at shoa robit area. The result of the present study also showed that biofertilizer inoculation had yielded 26.11% (1553.22 kg ha^{-1}) increase in grain yield of mungbean over non-inoculated one (1147.73 kg ha^{-1}). Similarly, Ayalew Addis *et al*. (2020) and Htwe *et al*. (2019) reported that rhizobium inoculation increased by 23.75% increment in grain yield of mungbean over non- inoculated.

The maximum grain yield (1639.80 kg ha^{-1}) was recorded at the 100 kg ha^{-1} NPSB rates with 10 cm intra-row spacing and the lowest grain yield (1163.60 kg ha^{-1}) was obtained at 15 cm intra row spacing with 125 kg ha^{-1} NPSB rates (Table 4.8). Intra-row spacing of 10 cm resulted in increasing yield by 0.25 ton (17.44%) over the highest intra row spacing of 15 cm. The grain yield obtained from the use of narrow intra row spacing might be high due to high density of plant population in rows and increased number of branches per rows as a result increased pod number in rows and then number of grains per pod. Based on this result average number of plants were reduced in the wider intra rows than narrow intra row spacing.

On the other hand, maximum grain yield (1632.16 kg ha^{-1}) was obtained at the treatment receiving 500 gm ha^{-1} biofertilizer inoculation with 10cm intra row spacing, while the lowest grain yield (1183.33 kg ha^{-1}) was recorded at a treatment receiving no biofertilizer with 5 cm intra row spacing (Table 4.10). The two-way interaction of biofertilizer inoculation with three level of intra row spacing had grain yield advantage than non-inoculated one which 27.20 %, 27.07 % and 17.85 % in 5, 10 and 15 cm intra row spacing, respectively (Table 4.10).

4.3.5 Thousand kernel weight

The analysis of variance revealed that the main effects of blended (NPSB) fertilizer rate, biofertilizer and intra row spacing had highly significant ($P<0.01$) effect on thousand kernel weight. The two-way interaction effect of blended (NPSB) fertilizer rate and biofertilizer, and biofertilizer an intra-row spacing did influence significantly ($P <0.05$) thousand seed weight of mungbean. Similarly, the interaction effect of blended (NPSB) fertilizer rate and intra row spacing had shown highly significant ($P<0.01$) effect thousand kernel weight of mungbean. The three-way interaction effect revealed significant ($P <0.05$) effect on thousand kernel weight of mungbean (Appendix Table 3).

The highest (56.95 gm) thousand seed weights were recorded at the treatment receiving 100 kg ha-1 NPSB rates, 500 gm ha-1 biofertilizer inoculation and 10 cm intra row spacing; while the lowest (37.90 gm) thousand seed weights were recorded at the treatment receiving 75 kg ha-1 NPSB rates, with no biofertilizer inoculation and 5 cm intra row spacing (Table 4.11). Generally, in the increasing NPSB fertilizer rates and wider intra row spacing with biofertilizer inoculation increases thousand kernel weights mungbean due the availability of space for light interception and plant nutrients for dry matter accumulation. This indicates that biofertilizer inoculation has an important role in dry matter accumulation of mungbean grain; Malik MA et al (2002) reported, seed inoculation with rhizobium significantly increased 1000 seed weight of mungbean. Kabir and Sarkar (2008) reported, there is a significant difference in thousand kernel weight of mungbean by the effect of row spacing.

4.3.6 Harvest index

The ability of a given crop to convert the dry matter (biomass) into economic yield (grain yield) is indicated by its harvest index. The higher the harvest index value, the greater the potential of the crop physiologically for the converting efficiency of dry matter to grain yield. Analysis of variance indicated that the main effects of blended NPSB fertilizer rate, biofertilizer and intra-row spacing had highly significant ($P < 0.01$) effect on harvest index. However, the two-way and three-way interaction of blended NPSB fertilizer rate, biofertilizer and intra-row spacing had shown significant ($P<0.05$) effect on harvest index except the interaction between blended NPSB fertilizer rate and intra row spacing which had highly significant ($P<0.01$) effect on harvest index (Appendix Table 3).

Higher harvest index implies higher partitioning of dry matter into grain. The highest harvest index (48.47 %) was recorded at 100 kg ha^{-1} NPSB + 500 gm ha^{-1} biofertilizer inoculation + 10 cm intra row spacing; while the lowest harvest index (32.25 %) was recorded at 75 kg ha^{-1} NPSB + 0 gm ha^{-1} biofertilizer inoculation + 5 cm intra row spacing (Table 4.11). Harvest index had interrelationship with grain yield and above ground-biomass yield that the highest harvest index was the result of greater grain yield. Lowest harvest index was mainly due to increased biomass yield rather than grain yield which lead to decrease of harvest index. The highest harvest index at the lower plant density and higher fertilizer rate might be due to less intra plant competition for resources such as nutrients, water and solar radiation as compared to higher plant density with low fertilizer rate that resulted in more competition and reduced assimilate production and partitioning to the grain. This might be also due to the influence of increased rate of NPSB rate on translocation of dry matter from vegetative part to economic yield.

Table 4.9. Interaction effect of blended NPSB fertilizer rate and biofertilizer on thousand seed weight and grain yield of mungbean at Ankober district in 2020 cropping season.

Treatments combination	Parameters
NPSB rates (kg ha^{-1}) * biofertilizer (gm ha^{-1})	GY
75 kg ha^{-1} with no or zero gm ha^{-1}	1090.44^{c}
100 kg ha^{-1} with no or zero gm ha^{-1}	1207.73^{c}
125 kg ha^{-1} with no or zero gm ha^{-1}	1145.03^{c}
75kg ha^{-1} with 500 gm ha^{-1}	1397.12^{b}
100 kg ha^{-1} with 500 gm ha^{-1}	1634.90^{a}
125 kg ha^{-1} with 500 gm ha^{-1}	1527.64^{a}
Mean	1350.46
LSD (0.05)	181.57**
CV (%)	7.26
SE±	78.12

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; TSW: Thousand Seed Weight; GY: Grain Yield.*

Table 4.10. Interaction effect of intra row spacing and biofertilizer on grain yield of mung bean at Ankober district in 2020 cropping season.

Treatments combination	Parameters
Biofertilizer (gm ha^{-1})* Intra row spacing (cm)	GY
No or zero gm ha^{-1} with 5 cm	1183.32^{bc}
No or zero gm ha^{-1} with 10 cm	1190.28^{bc}
No or zero gm ha^{-1} with 15 cm	1069.60^{c}
500 gm ha^{-1} with 5 cm	1625.49^{a}
500 gm ha^{-1} with 10 cm	1632.16^{a}
500 gm ha^{-1} with 15 cm	1302.02^{b}
Mean	1350.46
LSD (0.05)	161.57**
CV (%)	7.26
SE±	65.52

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error;; BY: Biomass Yield; GY: Grain Yield*

Table 4.11 The combined interaction effect of blended NPSB fertilizer rate, biofertilizer and intra row spacing on thousand seed weight and harvest index of mungbean at Ankober district in 2020 cropping season.

Treatments (blended fertilizer rate kg ha^{-1}; biofertilizer gm ha^{-1}; intra row spacing cm)	**TSW**	**HI**
75:00:05	37.90^{h}	32.25^{h}
75:00:10	39.26^{gh}	34.05^{gh}
75:00:15	40.16^{fgh}	33.42^{gh}
100:00:05 (control)	40.01^{gh}	37.67^{def}
100:00:10	48.72^{bc}	41.46^{bc}
100:00:15	45.26^{cde}	38.30^{cde}
125:00:05	43.24^{efg}	34.17^{fgh}
125:00:10	45.01^{cde}	36.80^{efg}
125:00:15	45.67^{cde}	38.86^{cde}
75:500:05	42.89^{efg}	36.50^{efg}
75:500:10	47.74^{bcd}	40.63^{bcd}
75:500:15	49.03^{bc}	41.73^{bc}
100:500:05	56.69^{a}	48.25^{a}
100:500:10	56.95^{a}	48.47^{a}
100:500:15	50.62^{b}	43.08^{b}
125:500:05	51.48^{b}	43.21^{b}
125:500:10	50.78^{b}	43.81^{b}
125:500:15	49.91^{b}	42.47^{b}
Mean	46.68	39.73
SE±	1.19	1.02
LSD (0.05)	**4.20***	**3.57***
CV%	5.42	5.42

*Means with the same column followed by the same letter (s) are not significantly different at 5% significant level. Where *: significant; **: highly significant; LSD: Least Significant Difference; CV: Coefficient of Variation in Percent; SE±: Standard error; TSW: Thousand Seed Weight; HI: Harvest Index.*

4.4 Correlation Analysis

Grain yield had strong significant positive correlations with biomass yield (r=0.79**), pod number (r=0.85**), moderate significant positive correlations with total branches (r=0.42**) effective branches (r=0.41**), pod length (r=0.47**), number of seed per pod (r=0.57**), harvest index (r=0.68**) and thousands kernel weight (r= 0.68**) and had non-significant negative correlation with plant height (r= -0.02**) (Table 4.12). The study showed that most of the traits were positively correlated with each other while some others are in a negative correlation especially plant height had shown mostly negative correlation with the traits correlated. These indicated that the yield increase is mainly attributed to an increase in biomass yield and pod number and moderately attributed to branches, pod length, number of seed per pod, harvest index and thousands kernel weight. In consistence with this finding, Canci and Toker (2014) was reported that grain yield was significantly and moderate positively correlated with the biological yield (r = 0.688), pods per plant (r =0.682), plant height (r =0.602), branches per plant (r=0.585), straw yield (r =581), grains per pod (r = 0.574), and pod number (r = 0.510) of mung bean.

It is well established and understood the fact that grain yield of mungbean is function of yield related attributes such as number of pods per plant, seeds per pod, thousand seed weight and above-ground biomass yield. Increase in this yield related attributes due to fertilization both blended NPSB fertilizer and biofertilizer and appropriate planting geometry might have increased grain yield of mungbean. Generally, grain yield had a positive relationship with number of pods per plant, seeds per pod, thousand seed weight, and above-ground biomass yield and harvest index (Table 4.12).

Table 4.12. Pearson Correlation coefficient

Traits	**PH**	**NTB**	**NEB**	**PL**	**NPP**	**NSP**	**TKW**	**BY**	**GY**	**HI**
PH	1.00									
NTB	-0.2^{ns}	1.00								
NEB	-0.21^{ns}	0.86**	1.00							
PL	-0.22^{ns}	0.71**	0.60**	1.00						
NPP	-0.01^{ns}	0.59**	0.51**	0.66**	1.00					
NSP	-0.25^{ns}	0.76**	0.69**	0.89**	0.73**	1.00				
TKW	-0.15^{ns}	0.57**	0.57**	0.54**	0.69**	0.66**	1.00			
BY	0.12^{ns}	0.12^{ns}	0.10^{ns}	0.21^{ns}	0.59**	0.25^{ns}	0.09^{ns}	1.00		
GY	-0.02^{ns}	0.42**	0.41**	0.47**	0.85**	0.57**	0.68**	0.79**	1.00	
HI	-0.15^{ns}	0.57**	0.57**	0.54**	0.69**	0.66**	1.00**	0.09^{ns}	0.68**	1.00

*NS: non-significant; *: significant; **: highly significant; NTB: number of total branches; NEB: number of effective branches; PH: plant height; PL: pod length; NPP: number of pods per plant; NSP; number of seed per pod; TKW: thousand kernel weights; BY: biomass yield; GY: grain yield; HI: harvest index.*

4.5 Partial Budget Analysis

According to the economic analysis, many of the treatments were dominated and excluded from the MRR analysis (Table 4.13). Among the non-dominated treatments, the results revealed that the maximum net benefit with acceptable level of MRR was obtained from two-way interaction of 500 gm ha^{-1} biofertilizer inoculation with 10 cm intra row spacing (37,796.02 ETB) (Table 4.13); 100 kg blended NPSB ha^{-1} + 10 cm intra row spacing (38,525.38 ETB) (Table 4.14) and 100 kg blended NPSB ha^{-1} + 500 gm ha^{-1} biofertilizer rates (38,259.41 ETB) (Table 4.15). The results showed a general increase in cost benefit ratio with an increase in the level of blended NPSB, biofertilizer inoculation and intra row spacing in combination. Thus, on the basis of the yield to be sold at market, net income or return and cost-benefit ratio or cost benefit analysis, it can be concluded and recommended that among the blended NPSB fertilizer rates, biofertilizer and intra row spacing tested, 100 ha^{-1} + 500 gm ha^{-1} + 10 cm was the most recommended and economically feasible for mung bean production in the study area.

Table 4.13 The partial budget analysis of two-way interaction biofertilizer and intra row spacing.

Treatment combination (g ha^{-1}: cm)	AGY (kg ha^{-1})	AdGY (kg ha^{-1})	ASY (kg ha^{-1})	AdSY (kg ha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	DA	MRR%
0 g ha^{-1} with 15 cm	1090.60	962.64	1734.30	1560.87	29269.42	5250.05	24019.37	ND	
500 g ha^{-1} with 15 cm	1302.02	1171.82	1743.90	1569.51	35546.92	5410.08	30367.87	D	
0 g ha^{-1} with 10 cm	1190.28	1071.25	2057.30	1851.57	32600.42	5625.03	26975.42	D	
500 g ha^{-1} with 10 cm	1632.16	1469.09	2033.40	1830.06	42581.05	5785.03	37796.02	ND	2762.09
0 g ha^{-1} with 5 cm	1182.32	1064.09	2312.40	2081.16	32442.93	6000.05	26442.43	D	
500 g ha^{-1} with 5 cm	1525.49	1462.94	2128.20	1915.38	41667.08	6160.02	35507.06	D	

AGY: average grain yield; AdGY: adjusted grain yield; ASY: average straw yield; AdST: adjusted straw yield; GB: gross benefit; TVC: total variable cost; NB: net benefit; DA: dominance analysis; ND: non-dominated; D: dominated; MRR: marginal rate of return.

Table 4.14 The partial budget analysis of two-way interaction blended NPSB and intra row spacing.

Treatment combination(kg ha^{-1}: cm)	AGY (kg ha^{-1})	AdGY (kg ha^{-1})	ASY (kg ha^{-1})	AdSY (kg ha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	DA	MRR%
75 kg ha^{-1} with 15 cm	1225.10	1102.59	1801.60	1621.44	33401.99	5405.02	27996.99	ND	
75 kg ha^{-1} with 10 cm	1260.00	1134.00	1860.70	1674.63	34354.93	5780.03	28574.93	ND	154.11
100 kg ha^{-1} with 15 cm	1168.10	1051.29	1722.50	1550.25	31848.75	5790.01	26058.75	D	
75 kg ha^{-1} with 5 cm	1246.20	1121.58	1977.30	1779.57	34003.31	6155.05	27848.31	D	
100 kg ha^{-1} with 10 cm	1639.80	1475.82	2309.90	2078.91	44690.38	6165.01	38525.38	ND	2587.36
125 kg ha^{-1} with 15 cm	1163.60	1047.24	1693.20	1523.88	31721.98	6175.03	25546.98	D	
100 kg ha^{-1} with 5 cm	1605.40	1444.86	2266.20	2039.58	43753.72	6540.02	37213.72	D	
125 kg ha^{-1} with 10cm	1408.90	1268.01	2373.10	2135.79	38467.46	6550.02	31917.46	D	
125 kg ha^{-1} with 5 cm	1436.60	1292.94	2384.80	2146.32	39217.46	6925.05	32292.46	D	

AGY: average grain yield; AdGY: adjusted grain yield; ASY: average straw yield; AdST: adjusted straw yield; GB: gross benefit; TVC: total variable cost; NB: net benefit; DA: dominance analysis; ND: non-dominated; D: dominated; MRR: marginal rate of return.

Table 4.15 The partial budget analysis of two-way interaction biofertilizer rates and intra row spacing.

Treatment combination(kg ha^{-1}:gm ha-1)	AGY (kg ha^{-1})	AdGY (kg ha^{-1})	ASY (kg ha^{-1})	AdSY (kg ha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	DA	MRR%
75 kg ha^{-1} with 0	1090.44	981.40	1941.00	1746.90	29878.61	5780.03	24098.59	ND	
75 kg ha^{-1} with 500	1207.37	1086.96	2012.20	1810.98	33061.46	5940.05	27121.41	ND	1889.26
100 kg ha^{-1} with 0	1397.12	1257.41	2040.40	1836.36	38181.35	6165.03	32016.32	ND	3059.32
100 kg ha^{-1} with 500	1634.90	1471.41	1965.00	1768.50	44584.43	6325.02	38259.41	ND	3901.93
125 kg ha^{-1} with 0	1445.03	1300.53	2150.70	1935.63	39499.72	6550.03	32946.69	D	
125 kg ha^{-1} with 500	1527.64	1374.88	2150.00	1935.00	41730.03	6710.05	35019.98	D	

AGY: average grain yield; AdGY: adjusted grain yield; ASY: average straw yield; AdST: adjusted straw yield; GB: gross benefit; TVC: total variable cost; NB: net benefit; DA: dominance analysis; ND: non-dominated; D: dominated; MRR: marginal rate of return.

CHAPTER 5 - CONCLUION AND RECOMMENDATION

5.1 CONCLUSION

The present investigation was conducted to evaluate the growth and yield performance of mungbean by blended NPSB fertilizer rate, biofertilizer and intra row spacing. The yield advantage of biofertilizer inoculation had 26.11% over non-inoculated plot and biofertilizer inoculation had shown significant effects overall phenological, vegetative and yield related attributes. Biofertilizer inoculation of mungbean had a significant effect on the interaction of NPSB fertilizer rate and intra row spacing in all traits of parameters. According to the findings of this study, significant values of number pod plant^{-1}, 1000-seed weight, grain yield and harvest index were recorded from interaction of blended NPSB fertilizer with biofertilizer inoculation, and biofertilizer and intra row spacing. Similarly, significant values of plant height, number pod plant^{-1}, 1000-seed weight, grain yield, straw yield and harvest index were recorded from interaction of NPSB blended fertilizer with intra raw spacing. Thus, for better production of mungbean in the study area, farmers shall better to use blended NPSB fertilizer in combination with biofertilizer and appropriate planting geometry.

The possible two-way interaction of blended NPSB with biofertilizer, blended NPSB with intra row spacing and biofertilizer with intra row spacing had shown significant effect with maximum grain yield of 1634.90 kg ha^{-1}, 1639.80 kg ha^{-1} and 1632.16 kg ha^{-1}, respectively; which provides an alternative opportunity for farmers and growers. From economic point of view, the highest net benefit 38259.41 Birr ha^{-1}, 38525.38 Birr ha^{-1}and 37796.02 Birr ha^{-1} with acceptable level of MRR was obtained from the treatment combination of 100 kg NPSB ha^{-1} + 500 gm biofertilizer ha^{-1}, and 100 kg NPSB ha^{-1} + 10 cm intra row spacing and 500 gm biofertilizer ha^{-1} +10 cm intra row spacing, respectively. Thus, based on the present findings, it can be concluded that growing mungbean by applying 100 kg NPSB ha^{-1} integrated with 500 gm biofertilizer ha^{-1}and at 10 cm intra row spacing with 30 cm inter row spacing can ensure better yield with the highest economic return for the farmers in the study area.

5.2 RECOMMENDATION

Mungbean producers in the study area do not implement the recommended agronomic practices such as fertilizer rates, plant spacing and biofertilizer in integrated manner which are necessary to increase the productivity and production. Therefore, continuous training and extension services should be given by the respective stakeholders such as Agricultural office professionals, extension workers, lead farmers, development groups, research institutions and concerned Non-Governmental Organizations to build capacity and performance efficiency of farmers. Moreover, the supply of inputs such as seeds of with high yielding mungbean varieties, biofertilizer with training and recommended type and pesticides should be accessed to boost up its production. Agricultural Office along with the practitioner should provide the necessary capacity building program for all stakeholders in the market chain with respect to providing and using selected seed types, fertilizers, pesticides, etc. since mungbean is currently cash crop as export commodity.

According to the finding of current experiment, the yield of mung bean at Ankober district can be increased by application of 100 kg Blended NPSB fertilizer rate ha^{-1}+ 500 gm biofertilizer ha^{-1}, and 10 cm intra and 30 cm inter row spacing in which the highest economic return was obtained. To develop forceful recommendations, however it is advised to repeat the experiment on other kebeles of the district using different varieties of mungbean with different levels of inter and intra row spacing and different fertilizer types and rates with different rates biofertilizer inoculation.

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APPENDICES

Appendix Tables

Appendix Table 1. Mean squares of analysis of variance (ANOVA) for phenology traits

SV	DF	MS phenology traits		
		DF	DPS	DM
Rep	2	12.31**	11.52*	19.71**
BLF	2	24.56**	26.52**	21.55**
BIF	1	147.02***	153.04***	90.79***
IR	2	0.53^{ns}	1.71^{ns}	2.28ns
BLF*BIF	2	5.98^{ns}	5.12^{ns}	13.55*
BLF*IR	4	13.60**	9.49*	14.78**
BIF*IR	2	3.63^{ns}	5.35^{ns}	8.56^{ns}
BLF*BIF*IR	4	1.51^{ns}	2.58^{ns}	6.07^{ns}
Error	34	2.15	2.45	2.64

*SV: source of variation; DF: degree of freedom; DF: days of flowering; DPS: days of pod setting; DM: days of physiological maturity; Rep: replication; BLF: blended NPSB; BIF: biofertilizer; IR: intra row spacing; NS: non significance; *: significance; **: highly significance; ***: very highly significance.*

Appendix Table 2 Mean squares of analysis of variance (ANOVA) for vegetative traits

SV	DF	MS vegetative traits			
		PH	NTB	NEB	PL
Rep	2	89.50*	6.03*	1.41^{ns}	1.63*
BLF	2	90.10*	12.78**	2.89^{ns}	1.97**
BIF	1	33.62^{ns}	154.57***	128.41***	30.12***
BLF*BIF	2	90.86^{ns}	0.18^{ns}	2.66^{ns}	0.11^{ns}
IR	2	18.10*	18.54**	18.90**	2.05**
BLF*IR	4	20.66^{ns}	0.53^{ns}	0.58^{ns}	0.13^{ns}
BIF*IR	2	84.66*	0.39^{ns}	0.40^{ns}	0.02^{ns}
BLF*BIF*IR	4	25.02^{ns}	1.15^{ns}	1.07^{ns}	0.06^{ns}
Error	34	24.49	1.18	1.81	0.36

*SV: source of variation; DF: degree of freedom; PH: plant height; NTB: number of total branches; NEB: number of effective branches; PL: pod length; Rep: replication; BLF: blended NPSB; BIF: biofertilizer; IR: intra row spacing; NS: non significance; *: significance; **: highly significance; ***: very highly significance.*

Appendix Table 3. Mean squares of analysis of variance (ANOVA) for grain traits

SV	DF	Mean Square grain traits					
		NPP	NSP	TKW	BY	GY	HI
Rep	2	6.230^{ns}	1.64*	4.18^{ns}	256573.68*	21811.09^{ns}	3.03^{ns}
BLF	2	42.62***	0.99*	110.87**	345448.78*	235662.81**	80.36**
BIF	1	577.55***	46.02**	860.72**	2411524.67***	2219702.95***	623.22**
BLF*BIF	2	10.14*	0.14^{ns}	23.68*	11718.00^{ns}	56458.64**	17.14*
IR	2	30.47***	2.46**	67.06**	3233052.67***	366270.34**	48.50**
BLF*IR	4	7.52*	0.35^{ns}	51.49**	293063.17**	92410.06***	37.24**
BIF*IR	2	10.85*	0.26^{ns}	21.60*	110228.86^{ns}	101093.97***	15.67*
BLF*BIF*IR	4	1.875^{ns}	0.23^{ns}	24.80*	55388.98^{ns}	13155.03^{ns}	17.96*
Error	34	2.32	0.28	6.41	74000.57	9624.03	4.64

*SV: source of variation; DF: degree of freedom; NPP: number of pod per plant; NSP: number of seed per pod; TKW: thousand kernel weight; BY: biomass yield; GY: grain yield; HI: harvest index; Rep: replication; BLF: blended NPSB; BIF: biofertilizer; IR: intra row spacing; NS: non significance; *: significance; **: highly significance; ***: very highly significance.*

Appendix Figures

Appendix figure 1. Land preparation and germination of mungbean

Appendix figure 2. Field performance of mungbean

Appendix figure 3. Field performance and farmers visiting of mungbean experimental site.

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The author, Hailu Kidanie, was born in Ankober district, North Shewa Zone of Amhara National Regional state, North-Eastern Ethiopia in October 25, 1985 from his father Kidanie Woldesemayate and mother Asdebeb Kebede. He attended his elementary and junior secondary school Dibi Gorgo. He also attended his high-school education at Hailemariam Mamo comprehensive senior secondary in Debre Birhan. After passing the Ethiopian School Leaving Certificate Examination (ESLCE) in 2001, he joined Bure Agriculture Vocational and Educational Training College graduated with Diploma in Plant Science and B Sc from Bahir Dar University summer program in Plant Science in 2005 and 2012, respectively.

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