EFFECT OF NITROGEN SOURCES ON GROWTH, YIELD AND YIELD COMPONENTS OF COMMON BEAN (*Phaseolus vulgaris* L.) VARIETIES AT MESKAN, SOUTHERN ETHIOPIA

MSc THESIS

BY

MESERET SHIFA

HAWASSA UNIVERSITY
COLLEGE OF AGRICULTURE

HAWASSA, ETHIOPIA

NOVEMBER, 2019

EFFECT OF NITROGEN SOURCES ON GROWTH, YIELD AND YIELD COMPONENTS OF COMMON BEAN (*Phaseolus vulgaris* L.) VARIETIES AT MESKAN, SOUTHERN ETHIOPIA

BY

MESERET SHIFA

MAJOR ADVISOR: TAREKEGN YOSEPH (PhD)

CO-ADVISOR: BERHANU ABATE (PhD)

A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL SCIENCE HAWASSA UNIVERSIT COLLEGE OF AGRICULTURE

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

HAWASSA, ETHIOPIA

NOVEMBER, 2019

SCHOOL OF GRADUATE STUDIES

HAWASSA

ADVISORS' APPROVAL SHEET (Submission Sheet^{-1})

This is to certify that the thesis entitled **"Effect of nitrogen sources on growth, yield and yield components of common bean (*Phaseolus vulgaris* L.) varieties at Meskan, southern Ethiopia"** Submitted in partial fulfillment of the requirements for the degree of **Masters of Sciences** with specialization in **Agronomy,** the Graduate Program of the **School of Plant and Horticultural Sciences,** and has been carried out by **Meseret Shifa Id**. No SGS/Agro/013/2010 E.C, under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

______________________	______________________	______________________
Name of Major Advisor	Signature	Date
______________________	______________________	______________________
Name of Co-advisor	Signature	Date

DEDICATION

This Thesis is dedicated to the memory of my mother Elahush Degelo and my brother Sitotaw Lemma.

STATEMENT OF THE AUTHOR

I declare and affirm this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation. This thesis is submitted in partial fulfillment of the requirements for MSc. degree at Hawassa University. The Thesis put in the Hawassa University Library and is made available to users under the rules of the Library. I seriously declare this Thesis has not been submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate. Brief citations from this Thesis may be made without special permission provided that accurate and complete acknowledgement of the source is made.

Name: ----------------------------------- Signature**:** ----------------------

Place: College of Agriculture, Hawassa University, Hawassa.

Date of Submission: --

ACKNOWLEDGMENTS

First of all, I would like to thank Almighty God and the Holy Virgin Saint Mary for letting it all happen. I would like to thanks next to God, my major advisor Dr. Tarekegn Yoseph for his consistent and stimulating advice, valuable suggestions, critical reading of the thesis and continuous interest throughout the entire research work and write up of the thesis. I am also give heartfelt thanks to my co-advisor Dr. Brehanu Abate for his valuable comments, suggestions, and support on the progress of my work and always was available when I needed his advises.

I am very grateful to thank my wife, Mrs. Assefash Lema for her enormous amount of faith, endless love and shouldering lots of home responsibilities during the whole period of my study. I feel a deep sense of gratitude to my entire family, my brothers and sisters for their constant encouragement and love I have relied on.

I would like to thank the South Agricultural Research Institute (SARI), Holeta Agricultural Research Center (HARC) and South Agricultural Research Institute (SARI) for facilitating this research work. My special thanks also go to Hawassa University College of Agriculture for their generous assistance on the laboratory analysis.

Lastly, and most importantly, I would like to thank my friends Mr. Mohamed Chali, Mr. Mohamed Hamid, Mr. Fekede Jemal, Mr. Workneh Tilahun, Mr. Mohamed Sani, Mr. Shimels Mohamed and Mr. Samson Henta for their efforts, encouragements and advices during my study.

LIST OF ABBREVIATION AND ACRONYMS

ANOVA	Analysis Of Variance
ATP	Adenosine Tri-Phosphate
BNF	Biological Nitrogen Fixation
CIAT	Centro International De- Agricultural Tropical
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
CV	Coefficient Variation
DM	Dry Matter
FAO	Food And Agricultural Organization of the UN
GFB	Gross Field Benefit
GY	Grain Yield
HI	Harvest Index
HSW	Hundred Seed Weight
LAC	Latin America Caribbean
LAI	Leaf Area Index
LSD	List Significant Difference
MoA	Ministry of Agriculture
MRR	Marginal Rate of Return
NB	Number of Branch
NDW	Nodule Dry Weight
NNPP	Nodule Number Per Plant
NPP	Number of Pod Per Plant
PH	Plant Height
RCBD	Randomized Complete Block Design
RDW	Root Dry Weight
SDW	Shoot Dry Weight
SNNPRSMA	Southern Nation, Nationalities People Regional State Metrological Agency
SNPP	Seed Number Per Pod
SY	Straw Yield
TSP	Triple Super Phosphate

TABLE OF CONTENTS

Content **Page**

LIST OF TABLES

Table **page**

LIST OF FIGURES

Figure **Page**

LIST OF TABLES IN THE APPENDIX

Table **Page**

Effect of Nitrogen Sources on Growth, Yield and Yield Components of Common Bean (*Phaseolus vulgaris* L.) Varieties at Meskan, Southern Ethiopia

Meseret Shifa (B.Sc.), Haramaya University
Major Advisor: Tarekegn Yoseph (PhD), Hawassa University
Co-Advisor: Berhanu Abate (PhD), Hawassa University

ABSTRACT

*Common beans (*Phaseolus vulgaris *L.) are an important cash crop and protein source for farmers in many parts of Ethiopia. However, lacks of adequate information on the use of nitrogen source fertilizers are the major yield limiting factors for common bean production in the study area. Thus, the field experiment was conducted at Meskan District in 2018 cropping season to evaluate the effect of nitrogen sources on growth, yield and yield components of common bean varieties; and to identify economically appropriate combination of nitrogen sources that give optimum yield of major common bean varieties. Factors studied includes four common bean varieties (Hawassa Dume, Gegeba, Rori and Ibado) and four level of N sources (T1= Control; T2=Rhizobium inoculated; T3=46 kg N ha^{-1}, T4= 46 kg N ha^{-1} + Rhizobium inoculated). The treatments were arranged using randomized complete block design* in factorial arrangements *with three replications. Results revealed varietal differences on growth, yield and yield components. The highest pod number plant^{-1}(29.1), seed number pod^{-1}(5.6) and grain yield (2.7 t ha^{-1}) were recorded from variety Hawassa Dume. Similarly, nitrogen sources had significant effect on growth, yield and yield components. Significantly, higher number of pods plant^{-1}(27.5), seeds pod^{-1} (5.6), and grain yield (2.7 t ha^{-1}) were recorded from combined application of Rhizobium inoculation+46kg N ha^{-1}. There was significant interaction effect of N sources with varieties on nodule number, root dry weight and straw yield, where by the highest nodule number plant^{-1} (40), root dry weight (11.6) and straw yield (4.5 t ha^{-1}) were recorded from combined application of Rhizobium strain HB-429 and 46 kg N ha^{-1} with variety Hawassa Dume except number of nodule plant^{-1}. Grain yield was positively and significantly correlated with phenological, growth, nodulation, yield and yield components except maturity date. Partial budget analysis of the study revealed that the highest net return (32,748 ETB ha^{-1}) was obtained from Hawassa Dume variety with combined application of inoculation and 46 kg N ha^{-1}. Based on the results of this study, it can be concluded that combined application of Rhizobium inoculation with 46 kg N ha^{-1} found to be appropriate for common bean variety Hawassa Dume in the study area. However, the result of the present study need to be evaluated and reconfirmed on farmers field across season and areas in order to reach to a conclusive recommendation.*

Keywords: Common bean, grain yield, nitrogen, *Rhizobium* inoculation

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an annual crop which belongs to legume family fabaceae. The crop is originated from Latin America and it has two primary centers of origin, in the Mesoamerican and Andean regions and is easily distinguished by molecular means (Blair *et al*., 2010). The crop is the world's most important food legume which is used for direct human consumption. It can be consumed in various forms like green and dry cooked seeds; or green leaves can be picked cooked and eaten as a green leafy vegetable (Katungi *et al*., 2009). It is a major source of protein for the poor in Africa, including Ethiopia. It has 38% of protein and caloric content of 12–16% (CIAT, 2008). Apart from being source of protein, common beans like other legumes also supply carbohydrates, vitamins and minerals such as iron, phosphorus, magnesium, manganese, zinc, copper and calcium and complement cereals, roots and tubers that compose the bulk of diets in most developing countries (CIAT, 2011). At present, it is estimated to be one of the most important source of nutrients for more than 300 million people in parts of Eastern Africa and Latin America, representing 65% of total protein and 32% of energy consumed (Blair *et al*., 2010).

Common bean is adapted to a wider range of climatic conditions. It grows best in warm climate at temperature range of 18 – 24°C with an altitude of 1400 – 2000 m above sea level. However, it's good production occurs in areas where a temperature is 21^{o}C. The crop is not suited to the very wet tropics; it prefers medium texture, well-drained soils with pH ranging between 6.0–7.5 (Walelign, 2015).

Globally, common bean production is approximately 12 million metric tons, with 5.5 and 2.5 million metric tons alone in Latin America, Caribbean (LAC) and Africa, respectively

(CGIAR, 2012). In Ethiopia pulses accounts about 11% of the country's total grain production and they are the second most important crop in the national diet, being the principal protein source and important dietary supplement to cereal consumption (CSA, 2014). According to CSA (2017) report, common bean is grown on an estimated 216,803.91 hectares by nearly 2.6 million smallholder farmers. Its production also reaches 3,727,664.85 tons with an average yield of 1.72 t ha^{-1}. Similarly, in Southern Nation Nationalities Peoples Regional State (SNNPRS) from 97,694.18 ha of land 1,529,62.70 tons of common bean was produced and with average productivity of 1.57 t ha^{-1} in 2017/18 cropping season (CSA, 2017). Whereas, based on (CSA, 2012/2013) area and production report in Guraghe zone, where this study was conducted from 797.91 ha of land coverage 908.23 tons of common bean was produced and with the average productivity of 1.14 t ha^{-1} which is low when compared with both national and regional average. However, this yield is far less than its attainable yield (2.76 – 3.30 tha^{-1}) under good management conditions for most improved cultivars in Ethiopia condition (Frehiwot, 2010).

According to a study conducted by Frehiwot (2010) pulses play a vital role in the export sector generating foreign currency for the country and it is the third in country's foreign currency earning contributing about 6.3% of the total export earnings after coffee (26.0%) and oil seeds (24.6%). A market demand for the common beans both in the domestic and export market has become the main reason for the growing trends in production (Frehiwot, 2010).

The main causes of low productivity of the crop at farmer's fields are poor agronomic practices, biotic and abiotic stress during the growth of the plant and cropping in low soil fertility, especially low N content (Beebe *et al.,* 2013). In small holder farmers field the use of nitrogen (N) fertilizer is limited and average yields of crops are low, usually less than 1 t ha^{-1} (CSA, 2013). The percentage of biological nitrogen fixation (BNF) of the N assimilation in common bean is lower as compared to other legumes being 40–50% compared to 75% with faba beans (*Vicia faba*), 70% with peas (*Pisum sativum*) and up to 95% with lupines (Werner, 1999). Because of high levels of N requirement of the crop, and the low availability of this nutrient in the soil, coupled with the short cycle and shallow roots of the plant contribute to its low yield.

Decomposition of soil organic matter, originating either naturally or from previous cropping can be a source for N. However, organic matter storage in tropical soils is low and is not sufficient for crop requirements; thus, management practices are a more effective option. In legumes, biological N_2 fixation can be taken as a good solution for N-deficiency in plants (Ferreira *et al*., 2009). However, inoculation is not always satisfactory, and the addition of mineral N may be required (Pelegrin *et al*., 2009; Kaneko *et al*., 2010). There are a few studies related to combined application of mineral N fertilization and inoculation with N_2-fixing bacteria in common bean and most of them are in greenhouse conditions (Brito *et al*. 2011). However, technical and economic evaluations of research data are quite relevant in terms of maximization of fertilizer use efficiency, based on theoretical yield and cost (Freire *et al*., 2011). Considering the diversity of climate and soil conditions, we hypothesized that variations commonly found in field results regarding the effects of inoculation can be reduced by joint application of inoculation and mineral N fertilization.

Rhizobial inoculants are an effective means of enhancing N supply to legume crops, particularly in soils with low Rhizobia populations. Under optimum environmental conditions, genetically superior genotypes of common bean that are nodulated with efficient *Rhizobium* strains are able to fix enough N to support grain yield (Kellman, 2008). The use of BNF for sustainable grain crops production is, therefore, recommended (Safapour *et al*., 2011). For new establishments, seed of legumes are required to be inoculated with the proper Rhizobia species. That is, a seed is coated with a sticking agent and the bacteria applied directly to the seed. This process takes place when the bacteria are in close proximity to the seed at the time of germination. Infection of the plant by the bacteria takes place at the root hair, which indicates infection with a curling response. The plant's response to *Rhizobium* infection is referred to as nodulation. Nodules appear as small lumps on the roots of legume plants. It is inside these nodules that N_2-fixation occurs (Redmon and Smith, 2004).

However, farmers have a wrong notion that common bean, being a legume crop, does not need any nutrition and usually grow it on marginal land without applying any fertilizer. This seems to be an important reason for its low seed yield in Ethiopia. This constraint could be alleviated through seed and/or soil inoculation with the proper *Rhizobium* bacteria before or at planting to facilitate N-fixation (Ndakidemi *et al*., 2006). Thus, to increase the productivity of the farmers, it is crucial to increase the awareness of farmers towards the utilization of improved agronomic practices that increase production and accelerate food security through proper implementation. Even if the area is potential for common bean production, the yield is still low mainly due to poor soil fertility and moisture constraint.

This experimental area is deficient in basic plant nutrients such as N, phosphorus (P) and sulfur (S), which are crucial to enhance plant productivity and quality (ATA and MoA, 2016). As a result of these deficient plant nutrients, common bean yield in the study area is below national and regional average. In the study area, it will be find out that farmers do not adopt the complete package of practices recommended by the research finding. Essentially, the observed failure of farmers to recognize and fully put the recommended production package into practice could be attributed to various factors which appeared to have some bearing on the farmers' decision to use the improved common bean production package. However, there is no empirical information in the study area about the determinants of the N-sources on common bean varieties along with the recommended agronomic practices.

Therefore, the main aim of the current study was to evaluate the response of common bean varieties to N-sources and to select the best combination of varieties and N-sources for optimum growth and grain yield under silt clay loam soil, at Meskan District, southern Ethiopia.

Specific objectives

- To assess the effects of N-sources on growth, nodulation, yield and yield components of common bean varieties.
- To assess the response of common bean varieties to applied inoculate/N fertilizer at Meskan.
- To examine the interactive effect of N-sources and varieties on growth, nodulation, yield and yield components of common bean varieties at Meskan.
- To determine the economic feasibility of the *Rhizobium* inoculation and N fertilizer application for common bean production at Meskan.

2. LITERATURE REVIEW

2.1. Common Bean

Common bean (*Phaseolus vulgaris* L.) is an important grain legume throughout the world providing a source of protein, dietary fiber, starch and minerals such as potassium, thiamine, vitamin B6 and folic acid in diets affordable by the poor (Garden-Robinson and McNeal, 2013). The crop is originated from Latin America and has two primary centers of origin, in the Mesoamerican and Andean regions and is easily distinguished by molecular means (Blair *et al*., 2010). Where it has been cultivated since 6000 BC in Peru and 5000 BC in Mexico (Wortmann, 2006). Currently, common bean is the world's third most important food legume after soybean and groundnut (Fageria *et al*., 2011). It is currently cultivated on 31 million hectares worldwide, with an average yield of 0.8 to 1.3 t ha^{-1} (FAOSTAT, 2013). In Africa, the largest common bean producers are Kenya, Uganda, Tanzania, Rwanda and Angola (Katungi *et al.*, 2009), with Ethiopia ranking ninth according to FAO statistics (FAO, 2008). It is one of the most important nutritious food legumes in the sub-Saharan Africa (SSA) region (Hillocks, 2011). The crop plays a significant dietary function of supplying proteins, essential vitamins and carbohydrates to both urban and rural communities (Hamdani and Wani, 2017). According to Thornton *et al*. (2010), the crop is estimated to contribute more than 50% of the dietary protein to the households in the entire SSA with the annual highest consumption per capita being among the low-income people.

Common bean was introduced to Ethiopia in the 16th century. Since then, it has become the most important food and fodder crop (Gidago *et al*., 2012). The total land area devoted to common bean production in 2013 was estimated to be 366 876.9 ha, with a national production of 463 008.5 tons (CSA, 2013). Early maturity, adaptation to contrasting local environments, broad local genetic diversity, and the high nutritional value of the grains, green leaves and young pods together make common bean ideal for combating food insecurity in Africa including Ethiopia (Buruchara *et al.*, 2011).

In Ethiopia, common bean ranks third as an export commodity, contributing about 9.5% of total export value from agriculture, and with a market value of USD 1,329 Million (FAOSTAT, 2010). However, the grain yield of common bean among smallholder farmers in Ethiopia is very low, and ranges from 0.5– 0.8 t ha^{-1} (EEPA, 2004), which is comparable to values reported 0.6 – 0.8 t ha^{-1} in Uganda, (Kalyebara, 2008), but much lower than the 4 t ha^{-1} yield potential reported elsewhere (Beebe *et al.*, 2013). This implies that farm yield of common bean in Africa ranges far below its potential. This situation has been attributed to low soil fertility, poor agronomic practices, and biotic and abiotic stress during the growth of the plant (Polania *et al*., 2016). Like in most African countries, legumes in Ethiopia including common bean are cultivated without *Rhizobial* inoculation and N fertilization (Mmbaga *et al*., 2014). Therefore, there is a great need to identify common bean varieties with high N_2-fixing ability and agronomic parameters that produce high grain yields in order to alleviate food insecurity among smallholder farmers in Africa.

2.2. Agro-ecological Requirements of Common Bean

Common bean is grouped under the lowland pulses category. It is best adapted in areas with a warm temperature. Areas having mean air temperature between 18 and 24 ^{o}C are best suited for its production. The crop is not suited to the very wet tropics, prefers medium textured, well-drained soils with pH ranging between 6.0 and 7.5 (Walelign, 2015). An evenly distributed rainfall is required throughout the growing period and during flowering, the relative humidity should be preferably above 50% since it is a short season crop and can be grown in summer-rainfall regions in the tropics. It is very sensitive crop for moisture stress at the flowering period and can reduce yields as much as 20% (Teshale *et al*., 2006).

In Ethiopia, common bean grows well between 1400 and 2200 m.a.s.l. The minimum and maximum mean temperature requirements are 10 and 32 °C, respectively. Common beans do not grow well at low altitudes as high temperatures cause abscission of flower buds, flowers and young pods, and poor fertilization and failure or poor seed set. At high altitudes, the growth is slow and beans are sensitive to frost. Areas with medium rainfall ranging from 350 – 700 mm (70 to 100 days) are good with a well-defined rainy season so that harvesting is done in dry weather. Some rain is required for the critical flowering period. Very high rainfall causes flower drop and increase the incidence of diseases. Therefore, the maximum relative humidity should not exceed 75% (Mandefro *et al*., 2009).

2.3. Production and Economic Importance of Common Bean in Ethiopia

Almost all common beans are produced by smallholder farmers (CSA, 2015). The average farm size for smallholder farmers is between 0.25 – 0.5 hectares. There is a wide range of common bean types grown in Ethiopia including mottled, red, white and black varieties (Frehiwot, 2010). The most commercial varieties are pure red and pure white colored beans and these are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008). To support both the growth in domestic and export bean markets, Ethiopian Institute of Agricultural Research (EIAR, 2014) has developed a range of high yielding, multi-disease resistant bean varieties. The focus of this genetic improvement program has been on the pure red and white beans to support the commercial sector. Within the red bean types, the most favored and most commercially accepted varieties include Red Melka, a mottled medium sized red; Red Wolayita, a medium sized pure light red; and Nassir, a small pure dark red variety (Ferris and Kaganzi, 2008).

Among the country pulse crops common bean is the second both cultivated area and in volume of production accounting 21% and 19% respectively (Ferris and Kaganzi, 2008).

Common bean is an essential food and cash crop in Ethiopia (Katungi *et al*., 2010). In Ethiopia, common bean is one of the most important market crops and basis of protein for farmers in many lowlands and mid-altitude zones. The country's export income is estimated to be over 85% of export earnings from pulses, exceeding that of other pulses such as lentils, faba bean and chickpea (Negash, 2007). Generally, it ranks third as sell abroad commodity in Ethiopia, contributing about 9.5% of sum export value from agriculture (Katungi *et al*., 2010). According to the same author, total countrywide production was projected at 421,418 t in 2008, with a market value of USD 132,900,609 million. Common bean is as well highly preferred by Ethiopian farmers because of its quick maturing characteristic that enables households to get cash income required purchasing food and other household needs when other crops have not yet matured (Legesse *et al*., 2006). Two types of common bean are grown: the canning type mostly grown for export market dominates the Oromiya region (Northeast rift valley), and the cooking type primarily grown for food in the SNNPR, south of lake Ziway. Significant amounts of the cooking kind are exported to the bordering countries predominantly Kenya (Ferris and Kaganzi, 2008).

2.4. The Role of Nitrogen

Nitrogen is a primary macronutrient, which plays most important roles in legumes for the formation of amino acids, which are the building blocks of protein. It occupies a conspicuous place in plant metabolism system. All vital processes in plants are associated with protein, of which N is an essential constituent. Consequently to get more crop production, N application is indispensable and unavoidable. It plays a key role in agriculture by increasing of crop yield (Massignam *et al*., 2009). N not only enhances the yield but also improves the food quality (Ullah *et al*., 2010). Optimum rate of N increases photosynthetic processes, leaf area production, leaf area duration as well as net assimilation rate (Ahmad *et al*., 2009). The maximum leaf area (LA) and total leaf biomass of plants are a determinant of higher crop yield (Rafiq *et al*., 2010). It is also directly involved in photosynthesis and is a necessary component of vitamins and acids in production and use of carbohydrates and influence energy reactions in plants as well (Sara *et al*., 2013).

It is a major factor in many biological compounds that plays a major role in photosynthetic activity. Besides, it is part of the enzymes associated with chlorophyll synthesis, which reflect relative crop N status and yield level in plants (Hokmalipour and Darbandi, 2011). Most N is naturally present in the soil as organic matter (Dashora, 2012).

2.5. Response of Common Bean to Nitrogen Fertilizer

Nitrogen is the most important of all the essential nutrients in its effects on plant growth. Since it is a necessary component of all proteins, N is involved in all plant growth processes. Adequate amount of N in the plant cell are essential for the absorption of other nutrients (Brady and Weil, 2002).

A deficiency of N limits cell expansion, chloroplast development, chlorophyll concentration and enzyme activity. Its deficiency symptoms including general stunting and yellowing of the older parts of the plant when its availability in the soil is low. Plants absorb it in the form of nitrate (NO_3^-) and ammonium (NH_4^+). It is the only plant nutrient, which can be added to the soil by BNF, but for many cropping systems in the tropics, addition of N through BNF is insufficient to cover the loss of N with crop removal, leaching and denitrification (Boddey *et al*., 1997).

Bliss (1993) reported that common bean can fix a maximum of only 50 kg N ha^{-1} and 40–50% of the plant N from fixation in adapted cultivars. Peoples and Herridge (2000) also reported that nodulated roots could fix between 30–50% of the total N. The N fixed by nodules can be used by the host plant, becomes accessible to non-fixing plants growing in combination with legumes, or immobilized and incorporated in the soil organic matter (Brady and Weil, 2002).

2.6. Response of Common Bean to Bio-fertilizer

Inoculating common bean with *Rhizobium* bacteria, increase performance and reduce the consumption of too much N fertilizer (Hemmati and Asadirahmani, 2004). One of the most efficient symbiotic bacteria with legumes is *Rhizobium leguminosarum* (Giller, 2001). N-fixing is important for crop plants as they increase its uptake and play a crucial role as plant growth promoting rhizobacteria (PGPR) in bio-fertilization system (Zaidi and Mohammad, 2006). Common bean shows a good and positive reaction to inoculation by proper rhizobacteria. However, there is a lack of efficient bacteria in most of the agricultural soils (Rodriguez *et al*., 2000). Seed inoculation by proper *Rhizobium* strain caused 78% increase in yield compared to control in wax bean (Asadi *et al*., 2005).

In common bean, the most common method of inoculation is to apply the culture of *Rhizobium* spp. to seed prior to sowing (Hungria *et al*., 2003). Inoculation of legumes with *Rhizobium* isolates, which result in nodulation, have a positive effect on shoot and root growth (Kyei-Boahen *et al*., 2005). Bio-fertilizer is “the formulated product containing one or more microorganisms that enhance the nutrient status and increase the growth and yield of the plants by either replacing soil nutrients and/or by making nutrients more available to plants (Malusá and Vassilev, 2014). *Rhizobium* inoculation also showed significantly effect on nutrient uptake of P, K, Ca, Mg and S in roots, shoots, pods and whole plant during glasshouse and field experimentation of *Phaseolus vulgaris* (Makoi *et al*., 2013).

2.7. Biological Nitrogen fixation

BNF is one of the important soil microbial activities which are affected by all ongoing processes in soil as well as other soil microorganisms. BNF process depends on the occurrence and survival of *Rhizobium* in soils and also on its efficiency (Adamovich and Klasens, 2001). Many of these factors, including temperature, affect many aspects of N-fixation and assimilation, as well as factors such as respiratory activity, gaseous diffusion and solubility of dissolved gases, which ultimately affect plant growth (Coskan and Dogan, 2011).

Establishment of effective N_2-fixing symbiosis between legumes and their N_2-fixing bacteria is dependent upon many environmental factors, and can be greatly influenced by farm management practices (Peoples *et al*., 1995). There are several environmental factors affecting BNF. The severe environmental conditions such as salinity, unfavorable soil pH, nutrient deficiency, mineral toxicity, extreme temperature conditions, low or extremely high levels of soil moisture, inadequate photosynthesis, and disease conditions can affect the plant growth and development. As a result, even the persistent *Rhizobium* strains will not be able to perform root infection and N_2-fixation in their full capacity (Panchali, 2011).

2.8. Factors Affecting Biological Nitrogen Fixation

2.8.1. Soil nitrogen

Nitrogen (N) is essential for plant growth, participating in several metabolic pathways and in the synthesis of molecules such as proteins, nucleic acids, hormones, and chlorophyll (Saturno *et al*., 2017; Bruijn, 2016). Attempts to supplement N_2-fixation using inorganic fertilizer have not been successful because the addition of fertilizer-N tends to substitute for, rather than supplement, N_2-fixation. Nevertheless, it is generally accepted that symbiotically fixed N_2 is inadequate for realizing maximum seed yield, and that an application of small amounts of "starter" fertilizer N is needed to establish seedlings and promote early N_2-fixation (Sogut *et al*., 2013). However, application of high levels of inorganic N inhibits the growth of rhizobia, nodulation and N_2-fixation (Coskan and Dogan, 2011).

According to Herridge *et al*. (1984) and Goi *et al*. (1993) who stated that under soils low in mineral N, a moderate dose of starter-N has been demonstrated to stimulate seedling growth and subsequently N_2-fixation. Similarly, Hansen (1994) reported that inorganic N is required by legume plants during the "nitrogen hunger period" for their nodule development, shoot and root growth before the onset of N_2-fixation process.

On the other hand, presence of high N levels in the soil inhibits both nodule formation and nitrogenase activity (Saturno *et al*., 2017). Weisany *et al*. (2013) reported that mineral N in the soil inhibited symbiotic N_2-fixation but it was relative to start of nodulation and N_2-fixation at early vegetative growth at low concentration. It is a well-established fact that, when legumes are grown in soils high in available N, the N_2-fixation rate is reduced (Solomon *et al*., 2012; Saha *et al*., 2017). Inhibitory effect of nitrate causes the reduction of capillary roots development as well as preventing particular infection's strands, indicating a shift from symbiotic to inorganic N nutrition (Coskan and Dogan, 2011).

2.8.2. Soil phosphorus

Phosphorus is used in numerous molecular and biochemical plant processes, particularly in energy acquisition, storage and utilization. P plays an important role in N2-fixing process, as adenosine tri-phosphate (ATP) is required in large quantities for legumes to undergo N_2-fixation (Mmbaga *et al*., 2014). The deficiency of P supply and availability remains a severe limitation on N_2-fixation and symbiotic interactions.

Availability of P in the soil influences the efficiency of *Rhizobium* that fixes atmospheric N in association with nodulating legumes as it is directly involved in BNF via legume-*Rhizobium* symbiosis. This has attracted considerable research attention world-wide due to its economic viability for resource poor farmers and environmental friendliness (Mahamood *et al*., 2009; Mmbaga *et al*., 2014). P influences nodule development through its basic functions in plants as an energy source. Furthermore, P increases the number and sizes of nodules and the amount of N assimilated per unit weight of nodules. Its deficiency in legume plants results in reduced nodule mass, N_2-fixation, and low yield. Low soil P availability, due to soil acidity and its high fixation, is a limiting factor to crop production (Zerihun *et al*., 2015; Abebe, 2017).

2.8.3. Competitiveness of native rhizobia

The proportion of the nodules formed on a particular host is influenced by the competitive ability of an inoculated *Rhizobium* strain in comparison to indigenous strains, which may vary in their effectiveness. The introduction of effective strains of rhizobia depends on the competition for nodules' sites between the introduced strains and the native population of rhizobia. Thus, a key property of an inoculum strain must be the ability to outcompete the indigenous soil bacteria. According to Triplett (1990) high competitiveness of inoculum strains in comparison with native rhizobia strains is as important as the effectiveness of symbiotic N_2-fixation itself. Study conducted by Montañez (2000) inoculation attempts failed to improve legume productivity because the indigenous strains occupied the root nodules rather than the inoculum strains. Thus, nodulation competitiveness is the ability of a given strain to dominate nodulation in the presence of other strains of the same species.

2.8.4. Soil pH

Soil acidity has long been known to decrease symbiotic N_2-fixation in legumes, negatively affecting growth and yield, especially in plants depending exclusively on symbiosis to acquire N (Bekere *et al*. 2013; Mohammadi *et al*. 2012). Nearly 30% of earth's land surface present acidic soil (pH<5.5) including 40% of arable land, affecting nutrient availability and root growth, and additionally increasing Al^{3+} toxicity, which ultimately lead to losses in crop yield (Lin *et al*., 2012). Under acidic conditions, cell-membranes permeability are altered by the excess of H^+ inducing cation efflux, impairing plant nutritional status and growth. To solve negative influence of acidic soil on plant growth, liming is required to neutralize undesired effect of high H^+ in the soil (Guo *et al*. 2009). Hence, symbiotic plants are frequently exposed to a range of soil pH, acidic, neutral, and alkaline conditions. The association between plant and bacteria drives N_2-fixation and can be positively or negatively affected by soil conditions, including soil pH.

2.8.5. High soil temperatures

Temperature has a profound influence of N_2 metabolism. Little activity is observed at low temperature and warming promotes the microbial N_2-fixation and uptake of fixed gas

(Saha *et al*., 2017). The plant nitrogenase activity reduces dramatically as a result of formation of ineffective nodules at high temperature (40 °C) (Hungria and Franco, 1993; Hungria and Vargas, 2000). In addition, the relative activity of the rhizobia is altered by temperature, so that *Rhizobium* that is highly effective at specified range of temperature is less active at another range of temperatures. For these reasons, greater N gains probably can be achieved by improvements in the heat resistance of the symbiosis. The optimum temperatures for growth in culture vary among strains and species, values between 27–39°C have been noted. The maximum temperatures are generally 35–39 °C, but proliferation may take place up to 42°C (Al-Falih, 2002). Rhizobial survival in soil exposed to high temperature is greater in soil aggregates than in non-aggregated soil and is favored by dry rather than moist conditions (Zahran, 1999).

2.8.6. Soil moisture

The moisture stress can adversely affect the nodule functions. The drought conditions can reduce nodule weight and nitrogenase activity. After exposure to the moisture stress for 10 days, the nodule cell wall started to degrade resulting in senescence of bacteroids (Ramos *et al*., 2003). The occurrence of rhizobia populations in desert soils and the effective nodulation of legumes growing there in emphasize the fact that rhizobia can exist in soils with limiting moisture levels. Viable strains of *Rhizobium* usually cannot tolerate or function under high levels of osmotic stress caused by drought. N_2-fixing legumes are especially sensitive to water deficit and other environmental stresses, with drought being one of the major environmental factors affecting plant productivity (Niste *et al*., 2013; Zahran, 1999). Nodules and N_2-fixation response to water stress depends on the stage of plant development. Water stress during growth has a direct effect on the development of nodules than in other stages and the possibility of recovery is almost impossible.

3. MATERIALS AND METHODS

3.1. Description of the Study Site

The study was conducted at Meskan District, Guraghe Zone, Southern Nations Nationalities and Peoples Regional State (SNNPRS), during 2018 cropping season under rain-fed condition. The experimental site is located 154 km from the capital city of Addis Ababa and about 168 km west of Hawassa, the capital city of Hawassa SNNPR. It is situated at 08^{o}03'52" N latitude and 38^{o}23'28" E longitude with an altitude of 1832 m a.s.l. It receives a mean annual rainfall of 1100–1200 mm with minimum and maximum average temperatures of 10.34 and 25.6 ^{0}C, respectively (SNNPRSMA, 2018) (Appendix 6 and Figure 2). The soil of the area is dominated by silt clay loam in texture and maize (*Zea mays* L.) being the dominant crop followed by common bean (*Phaseolus vulgars* L.).

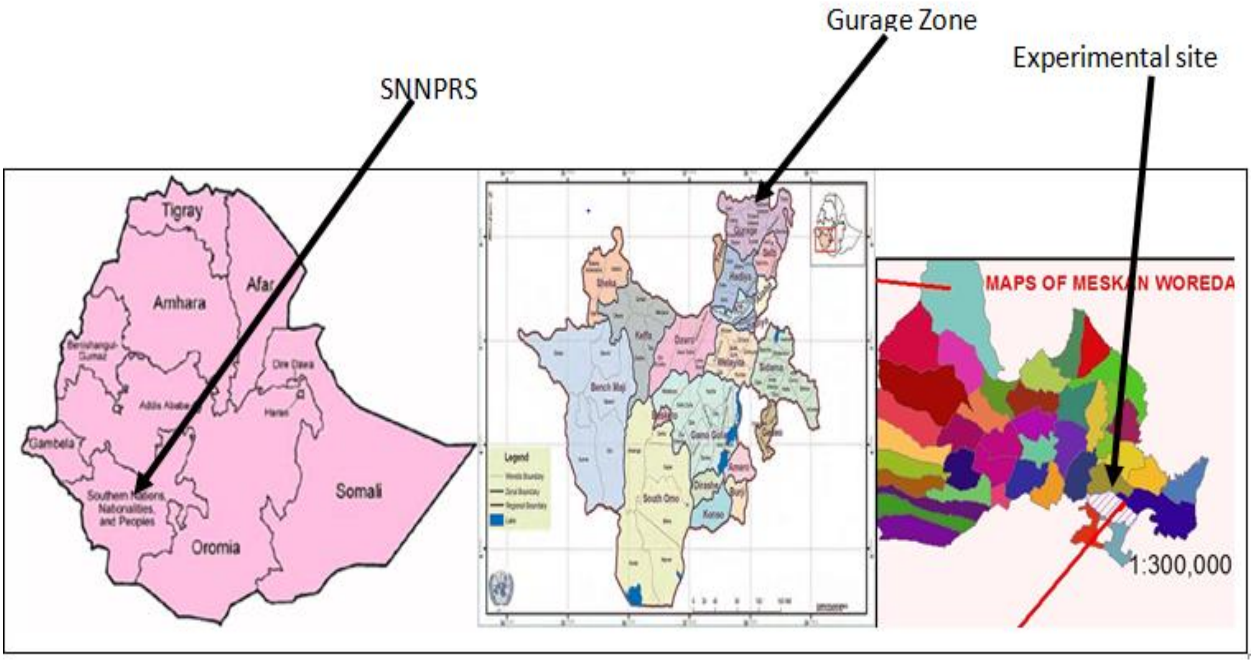

Figure 1. Administrative map of SNNPR where Gurage Zone, Meskan District and experimental site is located.

Source: https://www.researchgate.net/figure/.

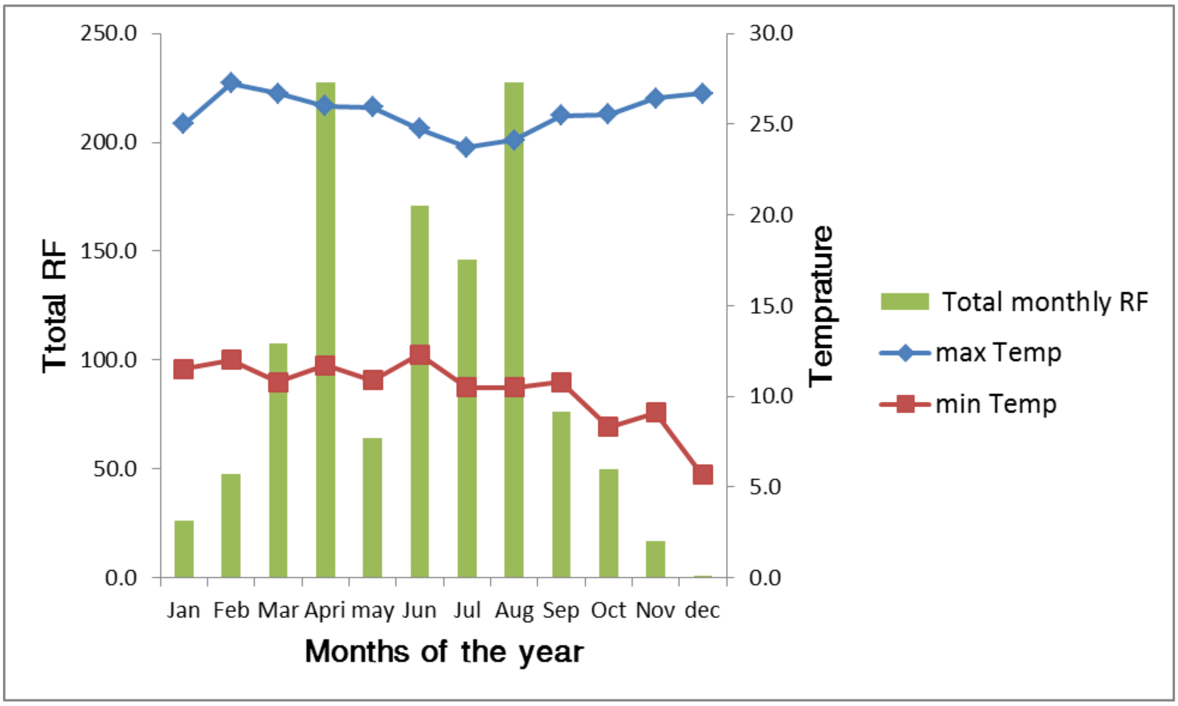

Figure 2. Metrological Data of Meskan District during 2018 cropping season.

Source: SNNPRS Meteorological Agency (2018).

3.2. *Rhizobium* Inoculation

Seed inoculation was done under shade in the field to reduce the bacterial cell death. Inoculated seeds were allowed to air-dry for a few minutes before planting. Two seeds were sown in each hole for both inoculated and uninoculated treatments. To avoid cross contamination, the uninoculated seeds were always planted first, followed by inoculated treatment. Soil ridges were made to separate inoculated and uninoculated treatments from each other in order to prevent cross contamination through rainwater movement. After sowing, the seeds were immediately covered with moist soil to avoid rhizobial cell death from desiccation.

3.3. Source of Plant Materials

Seeds of the three common bean varieties such as Hawassa Dume, Gegeba, and Rori were obtained from Hawassa Agriculture Research Center. While, a seed of Ibado variety was obtained from Areka Agricultural Research Centers. The varieties were purposefully chosen based on their adaptation, high grain yield, acceptability by farmers and seed availability (Appendix 1).

3.4. Experimental Treatments and Design

The treatments studied includes four improved common bean varieties (Hawassa Dume, Gegeba, Ibado and Rori) and four levels of N sources (T1= Control; T2 = *Rhizobium* inoculated; T3 = 46 kg N ha^{-1}, T4 = 46 kg N ha^{-1} + *Rhizobium* inoculated) which were laid out in randomized complete block design (RCBD) in factorial arrangements with three replications. Each treatment combination was assigned randomly to the experimental units within a block.

The size of each experimental plot was 2.4 m x 3.2m (7.68 m^2) with six rows. Planting was done using a spacing of 40 cm between rows and 10 cm between plants to give a final population density of 250,000 plants ha^{-1}. The pathways between blocks and plots are 1m and 0.5 m, respectively. From each plot the central three rows (2.88 m^2) were used for the final harvest. The triple super phosphate fertilizer (TSP) was applied at the rate of 100 kg ha^{-1} for all plots as a source of P at planting. The recommended urea fertilizer was applied by hand to designated plots at planting and 3 weeks after sowing.

3.5. Data Collected

3.5.1. Phenological data

Days to 50% flowering: it was recorded as number of days from emergence to the time when 50% of the plant population in each plot produce flowers.

Days to 90% maturity*:* days to maturity was taken as the number of days after seedling emergence to the period when 90% of the plants in a plot ready for harvest as revealed by change in the foliage and pod color and seed hardening in the pods.

3.5.2. Growth parameters

Plant height (cm): it was measured at 50% flowering and physiological maturity by measuring the main stem height from the ground up to the canopy height using a ruler from randomly selected five plants per plot.

Leaf area determination*:* five representative plants from each harvestable plot per treatment were randomly selected for leaf area determination at mid (50%) flowering stage. Then the leaf area of all the sampled plants were measured using portable automatic area meter (model LI 3000A Li-Cor, Lincoln, USA). Then, leaf area index (LAI) was calculated as,

$$\mathbf{LAI}=\frac{\text{Total green leaf area of the sampled plants}}{\text{Ground area occopied by the sampled plants}}$$

Number of primary branches: It was determined by counting the number of primary branches from the main stem of five randomly selected plants per plot.

3.5.3. Nodulation parameters

Nodule number and dry weight plant^{-1}***:*** The collected nodules were labeled and placed in perforated paper bags. Number of nodules was determined by counting the number of nodules from five randomly selected plants and the mean value of the five plants were recorded as number of nodules plant^{-1}. The nodule dry weight plant^{-1} was measured after drying the collected nodules in an oven with a temperature of 65 ^{o}C for 24 – 48 hrs until constant weight is attained. The average of five plants was taken as a nodule dry weight plant^{-1}.

3.5.4. Yield and yield components

Number of pods plant^{-1}: it was recorded from ten randomly selected plants from the net plot area at harvest.

Number of seeds pod^{-1}: it was determined from randomly selected ten pods from the plant used for pod number count.

Hundred seed weight: it was recorded by weighing 100 randomly selected dry seeds from the net plot harvest using a sensitive balance.

Grain yield (t ha^{-1}): It was recorded after threshing and adjusting the grain yield at the appropriate moisture level of 10%.

$$\textbf{Adj. yield t ha}^{-1} = \frac{(\text{Plot yield (kg)x }(100 - \text{actual moisture content})\text{x } 10000m^2)}{(2.88m^2(100 - standared\ moisture\ content)x1000\ kg)}$$

Above ground total dry biomass (t ha^{-1}): physiological mature ten plants was selected randomly and independently from each plot and the plants straw were sun dried in an open air until constant weight attained and measured to determine above ground total biomass yield and the average above ground total biomass yield was reported in t ha^{-1}.

Harvest index (HI %): were computed as ratio of dry grain yield to the above ground biomass yield.

$$\text{HI } = \frac{\text{Dry Seed yield } \text{ x } 100}{\text{total above ground biomass}}$$

3.6. Soil Sampling and Analysis

Before planting, soil samples were randomly taken from the experimental site at a depth of 0 to 30 cm using an auger and the samples was mixed thoroughly to produce one representative composite sample of 1 kg. The soil sample was air-dried and ground to pass 2 and 0.5 mm sieves and analyzed for physicochemical properties mainly textural analysis (sand, silt and clay), total N, available P, pH, organic carbon (OC) and cation exchange capacity(CEC) by using standard laboratory procedures.

Organic matter content was determined by the volumetric method (Walkley and Black, 1934). Total nitrogen was analyzed by Micro-Kjeldhal digestion method with sulphuric acid (Jackson, 1962). The cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH4OAc) and displacing it with 1N NaOAc (Chapman, 1965). Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen et al., 1954). Soil pH was measured in water at soil to water ratio of 1:2.5 (Van Reeuwijk, 1992). Soil textural analysis was performed by Bouyoucous hydrometer method (Day, 1965).

3.7. Economic Analysis

Partial Budget Analysis (PBA): Variable cost of common bean seed and fertilizer was largely used for partial budget analysis. It was calculated using marginal rate of return (MRR). This was calculated for each incremental in cost per a given increase in net benefit. It refers to net income obtained by incurring a unit cost of seed and fertilizer was calculated by dividing the net increase in yield of each treatment due to the application of each rate to the total cost of seed and fertilizer applied at each treatment. This enables us to identify the optimum fertilizer rate for common bean economic profitability (CIMMYT, 1988). The partial budget method measures profit or losses, which are the net profit or differences between gains and losses for the proposed change and include calculating net income. With the increase in total cost, there is increase in net income, but when the total cost exceeds the net income or with the increase in total cost, there is decrease in net income. MRR above 100% was profitable and acceptable (CIMMYT, 1988).

The MRR (%) is given by equations: $[\Delta NB/\Delta TVC] \times 100$

Where, ΔNB = Change in net benefit that was obtained on experiment.

ΔTVC=change in total variable cost that was invested on experiment.

MRR (%) = marginal rate of return expressed in percent.

3.8. Statistical Analysis

Data collected was subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the Statistical Analysis System software (SAS, 2002) version 9.0. Whenever the effects of the factors were found to be significant, the means were compared using the Least Significant Differences (LSD) test at 5% level of significance. Correlation analysis was done using Pearson’s simple correlation coefficients for the intended parameters.

4. RESULTS AND DISCUSSION

4.1. Soil Physico-chemical Properties

The results of pre-planting soil analysis revealed that the soil of the study area is silt clay loam in texture (22.4% sand, 46% silt and 31.6% clay). Soil texture is a fundamental soil property which in practice the farmer can do little to modify. It is also closely related to the nutrient and water-holding capacity of soils, since loams and clays hold more nutrient and water than do sandy soils (Brady, 2002). The soil was slightly acidic in reaction with the pH (H_2O 1:2.5) value of 6.2, which is within the range of optimum soil pH for legume production including common bean (Havlin *et al.*, 1999).

The total N, available P, OC and CEC of the soil before planting were 0.15%, 6 mg kg^{-1}, 1.56%, and 24 cmol (+) kg^{-1}, respectively (Table 1). The findings of Havlin *et al.* (1999) indicates that soils are classified depending on their total N content in percentage (%), as very low (<0.1), low (0.1 – 0.15), medium (0.15 – 0.25), and high (>0.25). Thus, the soil of the experimental site has low total N content. According to Olsen *et al.* (1954) classified available P content of the soil ranges < 5 as very low, 5 – 15 as low and 15 – 25 as medium and > 25 mg kg^{-1} as high. Thus, the soil of the experimental site has low available P content.

The soil OC content ranges of 1 – 2, 2 – 4, and 4 – 6% is rated as low, medium and high, respectively (Landon, 1991). Thus, the OC content of the soil is considered as low before planting. The CEC ranges of 5–15, 15– 25 and 25 – 40 cmol kg^{-1} are rated as low, medium and high, respectively. Based on, these ratings the CEC value of 24 cmol kg^{-1} before planting was in the medium range. Generally the pre-planting soil analysis result indicated that the area is nutrient deficient especially N and P to support the potential crop production. This may be attributed with poor farm management practices and continuous cropping with little or no fertilizers input which resulted in a decline in soil fertility of the area.

Table 1**.** Physico-chemical properties of the experimental soil before planting

pH (H_2O) (1:2.5)	Organic Carbon (%)	Total N (%)	Available P (ppm)	CEC cmol kg^{-1}	Silt (%)	Sand (%)	Clay (%)	Textural Class
6.2	1.56	0.15	6	24	46	22.4	31.6	Silt Clay loam

4.2.Effects of Nitrogen Sources on Phenological and Growth Parameters of Common Bean Varieties

4.2.1. Days to 50 % flowering

Number of days to 50 % flowering was significantly (P<0.01) affected by N sources and varieties. However, the interaction effect of variety and N sources did not showed any significant influence on days taken to 50 % flowering (Table 2 and Appendix 2).

The longest days to 50% flowering (45.50) was taken by variety Ibado followed by Gegeba. However, the shortest days to 50% flowering (43.4) were recorded from variety Hawassa Dume. Similar results were obtained by Nchimbi-Msolla and Tryphone (2010) also reported significant differences in the number of days required to reach 50% flowering among 20 common bean genotypes that ranged from 26.7 to 45.

Statistical analysis of data revealed significant effects of N sources on days to 50% flowering (Table 2). The longest days to 50% flowering (46.6) were taken with the combined application of 46 kg N ha^{-1} and inoculation with *Rhizobium* strain HB-429. The shortest days to 50% flowering (42.3) were observed in the control treatments. The findings indicated that the effects of supplied N sources on days to 50% flowering in common bean. The reasons for increase in days to 50% flowering under inoculation and N fertilizer could be due to the increased vegetative growth with applied N and nitrogen fixation. In line with this, Nebret and Nigussie (2017) obtained prolonged days to 50% flowering in common bean with increased N supply from 0 to 46 kg N ha^{-1}. Likewise, Habtamu *et al*. (2017) reported significantly longest days to flowering due to higher application of N. Additionally; the findings of Verma *et al*. (2013) revealed that delayed days to flowering with effective Mesorhizobium inoculation of chickpea.

4.2.2. Plant height (cm)

The analysis of variance showed highly significant (P< 0.01) differences in plant height due to the main effects of N sources and varieties. While the interaction effect of varieties with N-sources did not exert significant influence on plant height (Table 2 and Appendix 2).

Among the varieties, the tallest plant height was (102.7) recorded from variety Hawassa Dume. However, statistically significant differences were not detected between varieties Ibado, Rori and Gegeba. The observed differences in plant height among the varieties could be attributed to the genetic makeup of the varieties. This result is in line with the findings of Magani and kuchinde (2014) who reported a significant variation among varieties in plant height due to the genetic makeup of the varieties as well as environmental factors.

N sources had significant (P<0.01) effect on plant height (Table 2). The shortest plant height (77.6 cm) was recorded from the control treatments. While the longest plant height

(105.8) was recorded from the combined application of 46 kg N ha^{-1} and *Rhizobium* strain HB-429 inoculation. Statistically at par with *Rhizobium* inoculation and 46 kg N ha^{-1}.The reasons for increase in plant height under inoculation and N fertilizer could be due to the increased vegetative growth with applied N and N_2-fixation. In line with this, Yoseph and Shanko (2017) obtained increased growth of common bean fertilized with N in the presence of *Rhizobium* inoculants. Moreover, the increases in plant height with *Rhizobium* inoculation during the experimental period support the finding of Kubota *et al.* (2008) who stated that plant height of soybean was increase with N in the presence of *Rhizobium* inoculants. Other authors also reported Nyoki and Ndakidemi (2014) reported that *Rhizobium* inoculation in cowpea significantly improved the plant height measured at four, six and eight weeks after planting in both green house and field experiments relative to the control treatment.

Table 2. Effect of N sources on Phenological and growth parameters of common bean varieties at Meskan, during 2018 cropping season.

Treatment	**DF**	**PH(cm)**	**NPB**	**LAI**	**MD**
Varieties					
Hawassa Dume	43.4^{c}	102.7^{a}	2.9^{a}	5.3^{a}	81.0^{c}
Gegeba	44.8^{ba}	88.0^{b}	2.4^{c}	4.1^{c}	85.8^{ba}
Rori	44.2^{bc}	$88.4\ ^{b}$	2.6^{b}	4.6^{b}	83.3^{cb}
Ibado	45.5^{a}	$82.3\ ^{b}$	2.5^{cb}	4.1^{c}	87.8^{a}
LSD0.05	1.3	6.3	0.19	0.4	2.8
N sources					
Control	42.3^{d}	77.6^{c}	2.1^{d}	3.7^{c}	80.6^{c}
HB-429	45.2^{b}	91.8^{b}	2.7^{b}	4.6^{b}	85.0^{b}
46kgNha^{-1}	43.8^{C}	86.2^{b}	2.4^{c}	4.4^{b}	83.8^{cb}
46kgNha^{-1}+HB-429	46.6^{a}	105.8^{a}	3.2^{a}	5.4a	88.5^{a}
LSD0.05	**1.3**	**6.3**	**0.19**	**0.4**	**2.8**
CV (%)	**3.4**	**8.4**	**9.1**	**10.1**	**4.0**

Where, LSD=least significance deference, CV=cofietinet variation, DF=Days to 50% flowering, PH= Plant height, NPB=Number of primary branch, LAI=Leaf area index, days to reach 95% maturity, NNPP=Nodule number plant^{-1}, NDW=Nodule dry weight, SDW=Shoot dry weight, RDW= Root dry weight.

4.2.3. Number of primary branches plant $^{-1}$

The analysis of variance showed highly significant ($P<0.01$) differences in number of primary branches per plant due to the main effects of N sources and varieties. While the interaction effect of varieties with N-sources did not show significant effect on number of branches per plant (Table 2 and Appendix 2).

Maximum number of branches plant^{-1} (2.9) was recorded from the variety Hawassa Dume followed by Rori. The observed difference in number of branches plant^{-1} among common bean varieties might be attributed to the inherent ability of varieties responding to the availability of N sources.

The highest number of branches plant^{-1} was significantly ($P<0.01$) affected by N sources (Table 2). The highest (3.2) and lowest (2.1) number of branches plant^{-1} was recorded from the combined application of 46 kg N ha^{-1} and strain HB-429 inoculation and the control treatments respectively. Such increment on number of primary branches plant^{-1} with inoculation and N fertilizer might be attributed due to the increased vegetative growth with applied N and N_2- fixation. The present study in agreement with the findings of Umeh *et al.* (2011) who reported that increasing number of branches and leaves due to availability of N following inoculation. Similarly, this result confirmed by the work of Mfilinge *et al.* (2014) where they reported that inoculation of chickpea with *Rhizobium* in field and in the glass house significantly increased number of primary branches plant^{-1}. Moreover, this result agree with the finding of El-Awadi *et al.* (2011) Elkhatib (2009) and Moniruzzaman *et al.* (2008), also reported that number of branches per plant has shown a significant increment with successive application of N fertilizer.

4.2.4. Leaf area index

The analysis of variance indicated that the variety and N sources had very highly significant ($P<0.01$) effects on leaf area index. Whereas, the interaction effect of variety x N sources did not show significant effect on leaf area index (Table 2 and Appendix 2).

Among the varieties, maximum leaf area index (5.3) was recorded from variety Hawassa Dume followed by variety Rori. However, the lowest value of leaf area index (4.1) was recorded from Ibado and Gegeba variety. The observed differences in leaf area index among common bean varieties could be attributed to improved nutrients availability and enhanced growth of plant. The result is in agreement with the work of Mesfin *et al*. (2014) who reported that marked differences among the common bean varieties on leaf area index.

The maximum and statistically similar leaf area index of (5.4) was obtained from those plants which received combined application of 46 kg N ha^{-1} + strain HB-429. Statistically at par with *Rhizobium* inoculation and 46 kg N ha^{-1}. However, the control inoculated treatments had the minimum leaf area index (3.7). Increase in leaf area index due to application of N sources might be attributed due to improved nutrients availability and enhanced growth of plant. These results are in line with the findings of Lambon (2016) and Ahmed *et al*. (2013) who reported that promotive effect of supplied N on leaf area index of legume.

4.2.5. Days to 90% physiological maturity

The analysis of variance indicated that the main effects of variety and N sources had highly significant ($P<0.01$) effect on the number of days required to reach physiological maturity. However, the interaction effect of variety x N sources did not exert significant influence on days to 90% physiological maturity (Table 2 and Appendix 2).

The longest days to 90% physiological maturity was recorded from the Ibado (86.7 days) variety followed by Gegeba. However, the shortest days of 90% physiological maturity was recorded from Hawassa Dume (81.0) variety. The observed difference in days to physiological maturity among the common bean varieties might be attributed to inherent genotypic difference. Hence, variability among the varieties revealed that the possibility of selecting genotypes that mature earlier and adapt well in moisture deficit environments. In line with this result Kilasi (2010) reported that, differences in maturity can be caused by the genetic makeup of the varieties or by the environmental conditions existing during their growth and grain filling period of the crop.

N sources revealed a significant ($P<0.01$) effect on days to 90% physiological maturity (Table 2). The combined application of 46 kg N ha^{-1} + strain HB-429 prolonged days to 90% physiological maturity by 5.1 days when compared with the control. The earlier maturity of plants in the control treatment might be attributed due to plant competition for limited resources. On the other hands, the prolonged maturity of the plants due to applied N sources may be attributed to the role that N plays in promoting vegetative growth. This result was also in line with the findings of Nebret and Nigussie (2017) who reported that increase in nitrogen application rate from 0 to 46 kg N ha^{-1} led to a significant increase in the number of days required to reach physiological maturity from 87.9 to 89.9 days.

4.2.6. Nodule number plant^{-1}

The result concerning nodule number plant^{-1} revealed that there were highly significant ($P<0.01$) differences in nodule number among common bean varieties and N sources. Interaction among varieties x N sources was also significant ($P<0.01$) (Table 3 and Appendix 2).

The highest number of nodule plant^{-1} was obtained from Hawassa Dume (29.7) variety. However, the lowest number of nodule plant^{-1} was recorded from Gegeba variety. Statistically significant variation in number of nodule plant^{-1} was not detected between the varieties Ibado and Rori. However, the recorded values for these varieties were significantly lower than that of Hawassa Dume variety. The observed differences in nodule number among the common bean varieties could be related to inherent symbiosis characteristics of the varieties (Taylor and Francis, 2005). In line with this result Tarekegn *et al*. (2017) found that performance of five different varieties of cowpea varied significantly for nodule number. Similarly, this variation agrees with the findings of Salvucci *et al*. (2012) who reported that the environment has a severe impact on crop and its nodulation. However, this result did not agree with the work of Solomon *et al*. (2012) who reported that none-significant differences among the soybean varieties on nodule number plant^{-1}.

However, the lowest nodule number (17.4) was recorded from control which was significantly lower than the effect of other treatments. The increased nodule number with *Rhizobium* inoculation could be associated with the efficiency of introduced *Rhizobium* to compete with indigenous bacteria dwelling in the soil. These results are supported by the findings of Yoseph and Shanko (2017) who reported that the *Rhizobium* inoculation significantly enhanced nodule number. Similarly, Tesfaye *et al*. (2018) who observed that

Bradyrhizobium inoculation with strain Mar-1495 significantly increase nodule number of soybean varieties. However, application of N fertilizer at a rate of 46 kg N ha^{-1} decreased nodule number $plant^{-1}$ when compared to the *Rhizobium* inoculation alone and combined application of *Rhizobium* inoculation with strain HB-429 and 46 kg N ha^{-1}. This result indicated that application of N had suppressing effect on nodulation which might be attributed to the inhibitory effect of nitrate (NO3-). These finding confirm the work of Zahra (1999) who noted that higher concentration of nitrate depresses nodulation of legumes. similarly, this results agree with the findings of Kessel and Hartley (2000) who observed a significant decrease in nodulation of several varieties of common beans following the application of 40 kg N/ha.

There was highly significant ($P \leq 0.01$) interaction effect on the nodule number per plant (Figure. 3). Maximum nodule number was (41.00) recorded from variety Hawassa Dume with seed treated by strain HB-429. Statistically significant variation in number of nodule $plant^{-1}$ was not detected between the varieties Hawassa Dume and Rori. However, the lower nodule number was (15.00) observed under variety Gegeba x control. This observation suggests that *Rhizobium* inoculation resulted in increased number of nodules per plant compared to un-inoculated treatment which could be due to the fact that inoculated bacteria strain had good nodulation inducing capacity over the native soil *Rhizobium* population, low native *Rhizobium* population in the soil, less competitive native *Rhizobium* against the inoculated.

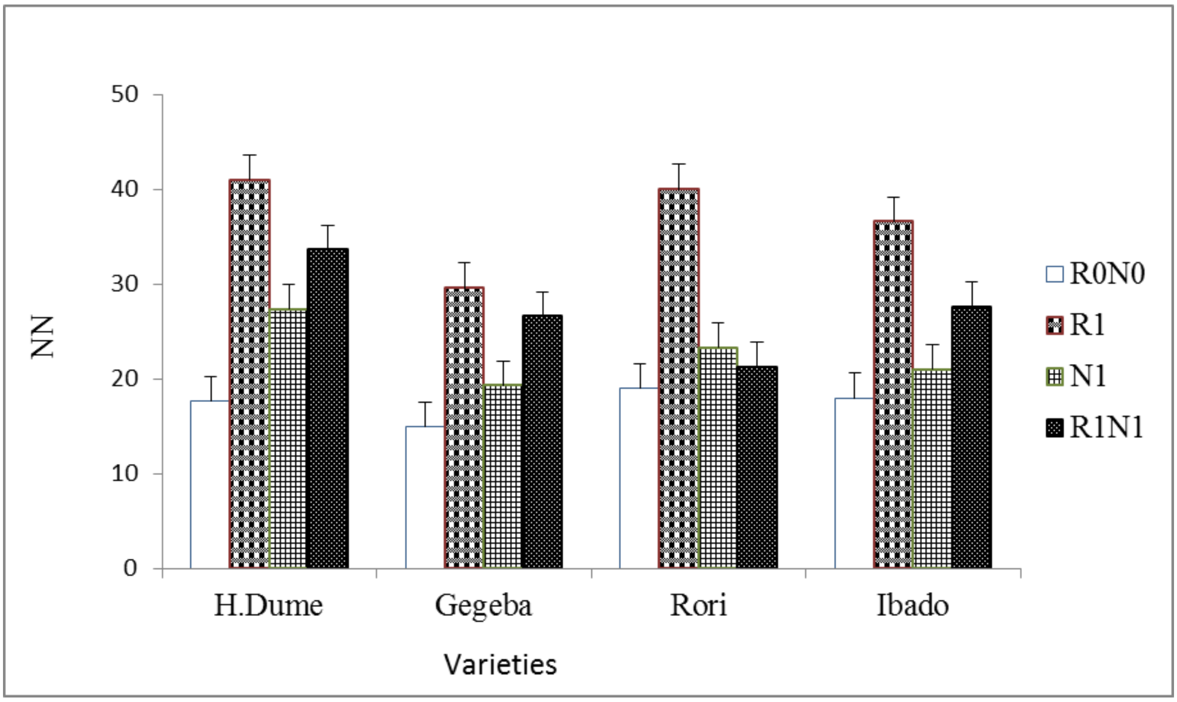

Figure. 3. Interaction Effects of N-sources x variety on Nodule Number plant^{-1}.Vertical lines on bars indicate standard error of the statistical means.

4.2.7. Nodule dry weight plant^{-1}

The analysis of variance revealed highly significant ($P<0.01$) differences among the varieties and N-sources on the nodule dry weight plant^{-1}. However, the interaction effect of variety x N sources did not show significant effect on Nodule dry weight plant^{-1} (Table 3 and Appendix 2).

Among the tested varieties the heaver nodule dry weight was produced from the variety Hawassa Dume (0.32g plant^{-1}). Statistically significant variation in Nodule dry weight plant^{-1} was not detected between the varieties Gegeba, Ibado and Rori (Table 3). The observed difference indicated that the inherent ability of varieties to responding N sources. Similar effects of seed inoculation on nodule dry weight have also been reported by Tarekegn *et al*. (2017) who observed that marked differences among the cowpea varieties on nodule dry weight plant^{-1}.

Highest nodule dry weight (0.4 g plant^{-1}) was recorded from plants inoculated with *Rhizobium* strain HB-429 while the lowest nodule dry weight (0.2) was recorded from the control treatments, but, the differences in nodule dry weight among 46 kg N ha^{-1} and the combined application of 46 kg N ha^{-1} + *Rhizobium* strain HB-429 were observed to be statistically at par. The difference between the nodule dry weight obtained from inoculated plants and uninoculated plants may be attributed to the size of the nodules. Inoculated plants produced bigger nodules than uninoculated plants due to the effectiveness of the introduced *Rhizobia* strain to initiate nodulation with common bean roots which agrees with the report of Ephraim *et al*. (2016). A similar promoting effect of seed inoculation on dry weight of nodules per plant has also been reported by Yoseph and Shanko (2017) and Habtamu *et al*. (2017).

4.2.8. Shoot dry weight plant^{-1}

Shoot dry weight plant^{-1} was significantly ($P<0.001$) affected by variety and N sources. However, the interaction effect of variety x N sources did not show significant effect on Shoot dry weight plant^{-1} (Table 3 and Appendix 2). The highest shoot dry weight (80.0 g plant^{-1}) was recorded from variety Hawassa Dume which was superior to the other varieties. However, the lowest shoot dry weight plant^{-1} was recorded from Ibado (64.5) (Table 3).The observed differences could be genetic or simply due to sensitivity to inherent environmental and climatic factors. Similar results have been reported by Singh *et al*. (2011) where the effects of cultivars were statistically significant on the shoot dry weight.

N-sources had significant effect ($P< 0.01$) on shoot dry matter accumulation of common bean. The highest shoot dry weight was (86.4 g plant^{-1}) recorded from the combined application of 46kg N ha^{-1} and inoculation with strain HB-429.The lower shoot dry matter accumulation of common bean was (51.8 g plant^{-1}) recorded from the control treatments.

However, statistically significant variation on shoot dry weight was also detected between the other N-sources (Table 3). The improved shoot dry weight of test bean varieties from combine application of N and *Rhizobium*, are a clear manifestation of the need of N sources for better plant growth. This result agree with the findings of Tarekegn and Serawit (2017) who noted that N application and seed inoculation had significant effect on shoot dry matter accumulation of common bean compared to the control treatments. Similarly, Togay *et al.* (2008) reported that the observed benefits on common bean by *Rhizobium* inoculation seem to be due to the supply of N to the crop through symbiotic N-fixation.

4.2.9. Root dry weight plant^{-1}

The analysis of variance revealed that root dry weight plant^{-1} was significantly ($P<0.01$) affected by N-sources and common bean varieties. The interaction effect of varieties x N-sources had also shown significance ($P<0.01$) effects on root dry weight (Table 3 and Appendix 2).

Regarding the main effect, variety Ibado produced highest root dry weight (9.9 g plant^{-1}) while the lowest root dry weight (7.9 g plant^{-1}) was recorded in variety Hawassa Dume. This result indicated that variation among varieties either genetic makeup or environmental factors. This result agrees with the findings of Addo-Quaye *et al*. (2011) who reported significant differences among varieties due to genetic variability.

Different N sources highly significant ($P<0.01$) effect on root dry weight plant^{-1}. The highest root dry weight (11.0 g plant^{-1}) was obtained from the combined application of 46 kg N ha^{-1}and *Rhizobium* inoculation with strain HB-429. However, the lower values was (6.1) observed from the control treatments. This may be due to the fact that through increased photosynthetic activity, there was accumulation of carbohydrates in leaves, thus increasing root dry weight (Shormin and Kibria, 2018). Our results are in agreement with the work of (Gai *et al.*, 2017), who pointed out that soybean root dry weight increased significantly with the application of intermediate 50 kg N ha^{-1}.

The variety x nitrogen sources interaction was significant (P<0.01) effect on root dry weight (Figure.4). The higher root dry weight was (11.6 g plant^{-1}) observed in variety Ibado x application of 46 kg N ha^{-1} and *Rhizobium* inoculation with strain HB-429. However, the lower root dry weight was (4.7 g plant^{-1}) recorded in variety Rori x control treatments. This observation suggests that combined application of N-sources with variety Ibado gave higher root dry weight compared to variety Rori x control.

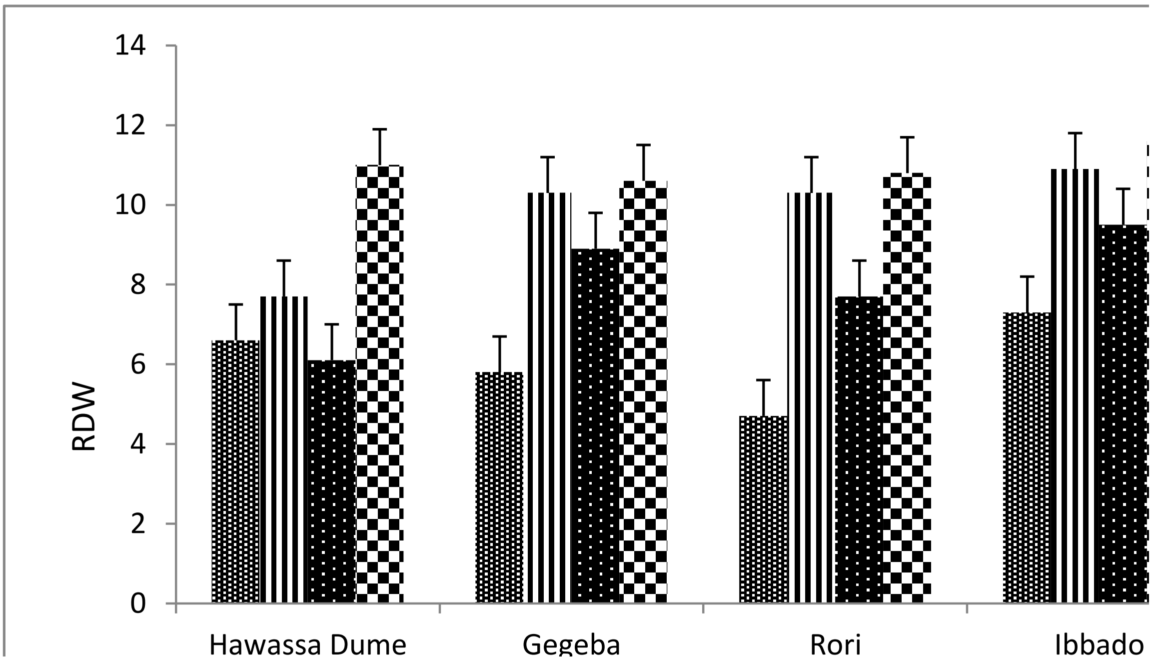

Figure. 4. Interaction effects of N-sources x variety on root dry weight plant^{-1}. Vertical lines on bars indicate standard error of the statistical means.

Table 3. Effect of N sources on nodulation parameters of common bean varieties at Meskan, during 2018 cropping season.

Treatment	**NNPP**	**NDW(g)**	**SDW(g)**	**RDW(g)**
Varieties				
Hawassa Dume	29.7^a	0.32^a	80.0^a	7.9^c
Gegeba	22.7^c	0.28^b	57.3^d	8.9^b
Rori	26.2^b	0.26^b	71.9^b	8.4^{cb}
Ibado	25.8^b	0.27^b	64.5^c	9.9^a
LSD0.05	**2.9**	**0.02**	**5.08**	**0.8**
N sources				
Control	17.4^d	0.2^c	51.8^d	6.1^d
HB-429	36.8^a	0.4^a	72.36^b	9.8^b
46kgNha^{-1}	22.8^c	0.3^b	63.07^c	8.1^c
46kgNha^{-1}+HB-429	27.3^b	0.3^b	86.4^a	11.0^a
LSD0.05	**2.9**	**0.02**	**5.08**	**0.8**
CV (%)	**13.4**	**12.1**	**8.9**	**11.6**

Where, LSD= List significance difference, CV= Coefficient variation, NNPP=Nodule number plant^{-1}, NDW=Nodule dry weight, RDW=Root dry weight, SDW=Shoot dry weight, RDW=Root dry weight.

4.3. Effect of Nitrogen Sources on Yield and Yield Components of Common Bean Varieties

4.3.1. Number of pod plant^{-1}

Pod number plant^{-1} was the yield component easily affected by change in environmental and cultural conditions. The results of the current research showed that the main effect of variety and N sources had significant ($P<0.01$) effects on number of pod plant $^{-1}$. However, the interaction effect of variety and N sources did not show significant effect on the number of pod plant^{-1} (Table 4 and Appendix 2). Maximum number of pod plant^{-1} (29.1) was obtained from Hawassa Dume which was significantly superior to other varieties. However, the lowest number of pod plant^{-1} (22.4) was recorded from Gegeba variety.

Statistically significant variation in number of pod plant^{-1} was not detected between the varieties Rori and Ibado. Such variation among the varieties was most likely due to variable genetic potential of the varieties for pod filling and adaptability to the environment in which varieties were grown. In line with the results of the present study, different authors reported significant variations in the number of pods per plant for common bean varieties (Fageria *et al.,* 2010; Gebre-Egziabher *et al.* 2014; Mourice and Tryphone, 2012; Tarekegn *et al*. 2017).

The applications of N sources on pod number of common bean were found to be statistically significant. The highest number of pods plant^{-1} (27.5) was recorded from the combined application of 46 kg N ha^{-1} and inoculation with strain HB-429 followed by Rhizobium strain HB-429 inoculation. While the lowest number of pods plant^{-1} (21.6) was recorded from the control. The increase in number of pods plant^{-1} with the supplied N sources might possibly be due to adequate availability of N which might have facilitated the production of primary branches and plant height which might in turn have contributed for the production of higher number of total pods (Deresa, 2018). In conformity with this result, Çiğdem Kucuk (2011) indicated that inoculation had given significantly higher number of pods plant^{-1} for common bean over the control. Similarly, Yoseph (2011) explained that the increased supply of N through N_2-fixation due to efficient *Rhizobium* inoculation play important roles in enhanced growth and assimilate accumulation, thereby improving the reproductive performance of the plants.

4.3.2. Number of seeds pod^{-1}

The analysis of variance revealed that number of seeds pod^{-1} was significantly ($P<0.01$) affected by varieties and N-sources. However, the interaction effect of varieties and N-sources had no significance difference on number of seeds pod^{-1} (Table 4 and Appendix 2).

The highest number of seeds pod^{-1} was recorded from Hawassa Dume variety (5.6); whereas the lowest was recorded from Ibado (4.3) and Gegeba (4.5) varieties, respectively. This variation might be due to inherent genetic difference among the common bean varieties for seed production pod^{-1}. This result was in agreement with Mourice and Tryphonne (2012) who reported that the number of seeds per pod of different common bean genotypes varied due to the genetic variation of cultivars.

Number of seed pod^{-1} was also highly significantly ($P<0.01$) affected by application of N sources (Appendix Table 2). The highest number of seeds pods^{-1} (5.6) was recorded from the combined application of 46 kg N ha^{-1} and *Rhizobium* strain HB-429 inoculation whereas, the lowest was (3.8) recorded from the control treatments. statistically there were no significant ($P<0.01$) differences among application of 46 kg N ha^{-1} and *Rhizobium* strain HB-429 inoculation (Table 4). This variation might be, due to the effect of N sources on physiological processes such as increased leaf area and improved root growth and development and the conversion of dry matter produced into fruit and seeds (Deresa, 2018). This result was in agreement with Yoseph and Shanko, 2017 who reported that number of seeds pod^{-1} on common bean differed significantly due to N fertilization and *Rhizobium* inoculation.

Table 4. Effect of N-sources on yield and yield components of common bean varieties at Meskan, during 2018 cropping season.

Treatment	**PNPP**	**SNPP**	**HSW(g)**	**GY(tha^{1})**	**SY(tha^{-1})**	**BY(t/ha)**	**HI (%)**
Varieties							
Hawassa Dume	29.1^{a}	5.6^{a}	23.9^{b}	2.7^{a}	3.3^{a}	5.02^{a}	0.52^{a}
Gegeba	22.4^{c}	4.5^{c}	30.2^{a}	2.0^{b}	3.1^{ba}	4.23^{b}	0.39^{c}
Rori	24.9^{b}	4.9^{b}	25.3^{b}	2.2^{b}	2.4^{c}	4.29^{b}	0.49^{ba}
Ibbado	23.6^{cb}	4.3^{c}	26.8^{b}	1.9^{b}	2.8^{bc}	4.09^{b}	0.47^{b}
LSD 0.05	**2.4**	**0.4**	**3.2**	**0.2**	**0.4**	**0.5**	**0.04**
N-sources							
Control	21.6^{c}	3.8^{c}	17.1^{d}	1.5^{d}	2.4^{c}	3.32^{c}	0.37^{c}
Strain HB-429	26.1^{a}	5.0^{b}	30.3^{b}	2.5^{b}	2.9^{b}	5.02^{a}	0.49^{ba}
46kg N ha^{-1}	24.8^{b}	4.9^{b}	25.3^{c}	2.2^{c}	2.8^{b}	4.12^{b}	0.49^{ba}
46kgNha^{-1}and HB-429	27.5^{a}	5.6^{a}	33.5^{a}	2.7^{a}	3.5^{a}	5.19^{a}	0.52^{a}
LSD 0.05	**2.4**	**0.4**	**3.2**	**0.2**	**0.4**	**0.5**	**0.04**
CV (%)	**11.3**	**9.7**	**14.44**	**12.1**	**14.6**	**13.25**	9.67

Where; LSD=Least significance deference; CV=Cofietinet Variation; PNPP= Pod number plant^{-1}, SNPP=Seed number plant^{-1}, HSW=100 seed weight, GY=Grain yield, SY=Straw yield, DM=Dry matter, HI=Harvest index.

4.3.3. Hundred Seed Weight (g plant^{-1})

Analysis of variance revealed that the main effect of variety and N sources had highly significant ($P< 0.01$) effect on hundred seed weight. However, it was not significantly affected by the interaction effects of varieties x N sources (Table 4 and Appendix 2).
Among the tested varieties the highest hundred seed weight was recorded from the variety Gegeba (30.2 g plant^{-1}). While, statistically there were no significant differences among varieties on hundred seed weight. The out performance of Gegeba and Ibado varieties in hundred seed weight is associated with the size of the seed is in accordance with Amare *et al*. (2014) who explained that the larger the seed, the higher its seed weight. The current observation is in line with El Naim and Jabereldar (2010) who reported that a significant variation in 100 seed weight of soybean crop. This result also supported by Yoseph *et al*. (2017) who reported that the significant difference in hundred seed weight among the cowpea varieties due to the difference in translocation and partitioning efficiency of assimilates from source to sink.

Regarding the N sources, combined application of 46 kg N ha^{-1} + *Rhizobium* strain HB-429 resulted in higher hundred seed weight (33.5 g plant^{-1}) and the lower seed weight (17.1 g plant^{-1}) was recorded from the control (Table 4). Increased hundred seed weight as a result of different N sources could be attributed due to high N nutrition of common bean for flower and seed formation through N_2-fixation and supplied N. These results are in line with Yoseph and Shanko (2017), who reported that inoculant/ N fertilizer enhanced yield components of common bean. The effects of seed inoculation on increasing seed weight were also observed by Lamptey *et al.* (2014).

4.3.4. Grain yield (t ha^{-1})

Grain yield was highly significant ($P<0.01$) different among the tested varieties. However, it was not significantly affected by the interaction effects of varieties x N sources (Table 4 and Appendix 2). The highest grain yield (2.7 t ha^{-1}) was obtained from Hawassa Dume variety. Varieties Rori, Gegebo and Ibado had statistically similar grain yield. The greater grain yield recorded for the variety Hawassa Dume was due to its ability to produce more and longer pods, as well as higher seed number per pod, which increased its economic yield and profitability as a crop. The higher grain yield could also be attributed to the better plant growth of Hawassa Dume and perhaps, its increased symbiotic performance (nodule number and dry weight).

Similar to other yield components, application of N sources exerted highly significant ($P< 0.01$) effect on grain yield (Appendix Table 2). The highest grain yield of 2.7t ha^{-1} was obtained from the combined application of N fertilizer and inoculation. However, the lowest grain yield of 1.5 t ha^{-1} was obtained from the control. There were statistically significant differences in grain yield between the used N level and inoculation. In fact, the grain yield increase from inoculation with *Rhizobium* strain HB-429 was 166% higher than control treatments. The higher grain yield due to *Rhizobium* inoculation explains that the effectiveness of introduced inoculant in fixing N thereby meeting the nutrient requirement of the plant (Nyoki and Ndakidemi, 2013). Generally, the observed positive response of common bean to applied N sources might be attributed due to low N contents of the experimental site. This result coincides with the findings of Abera and Tadel (2016) who reported that both application of chemical fertilizer and inoculation of *Rhizobium* increased seed yield ha^{-1} for crops. Similarly, this result is in accordance with the research outcomes of Said *et al*. (2011), who concluded that the treatments with

Rhizobium inoculation gave higher grain yield than those without inoculation. It may also be due to more number of pods and seeds due to *Rhizobium* inoculation and applied N. A similar increasing effect of *Rhizobium* inoculation on grain yield of soybean has also been reported by Abbasi *et al*. (2008). On the other hand, the increases in grain yield with N application support the finding of Nebret and Nigussie (2012) who reported that common bean crop supplied with 23 kg N ha^{-1} resulted in significantly more grain yield than the control.

4.3.5. Straw yield (t ha^{-1})

Straw yield was significantly ($P<0.01$) affected by variety, N sources and their interaction (Table 4 and Appendix 2). Regarding main effect, the highest straw yield (3.3 t ha^{-1}) was recorded for variety Hawassa Dume followed by variety Gegeba, which was not statistically lower than Hawassa Dume. While, the lowest straw yield (2.4 t ha^{-1}) was obtained from variety Rori. The significant variation in straw yield among the varieties is largely due to differences in inherent yielding potential of the varieties. Furthermore, the greater straw yield of Hawassa Dume variety might be attributed due to the tallest plant height and more number of primary branches than other varieties. This result in line with the findings of Herridge and Redden (1999) in which shoot biomass of two haricot bean varieties was reported to be significantly different (producing 20% more) among large number of genotypes that they have tested.

The highest straw yield of 3.5 t ha^{-1} was obtained from the combined application of N fertilizer and *Rhizobium* inoculation. The minimum straw yield of 2.4 t ha^{-1} was obtained from the control. Application of 46 kg N ha^{-1}and *Rhizobium* inoculation with strain HB-429 statistically similar straw yield that was lower than combined application of N fertilizer and *Rhizobium* inoculation. The higher straw yield obtained with combine application of N fertilizer and inoculation could be due to the presence of resident rhizobia may not always be sufficient in itself, to ensure supply of N for optimum growth in the host legume. In line with this result Pirbalouti *et al*. (2006) who reported that there were a significant differences among four rhizobial strains nodulating haricot bean on straw yield production at maturity.

The variety x N-sources interaction was significant ($P< 0.05$) effect on straw yield of common bean varieties (Figure. 5). The highest straw yield was (4.5 t ha^{-1}) recorded at Hawassa Dume variety x combined application of *Rhizobium* inoculation with strain HB-429 and 46kg N ha^{-1}followed by variety Gegeba x *Rhizobium* inoculation with strain HB-429. However, the least straw yield was (2.14 t ha^{-1}) recorded under variety Rori x control treatments. This observation suggests that Hawassa Dume variety x combined application of *Rhizobium* inoculation with strain HB-429 and 46kg N ha^{-1}gave higher straw yield compared to variety Rori x control treatments.

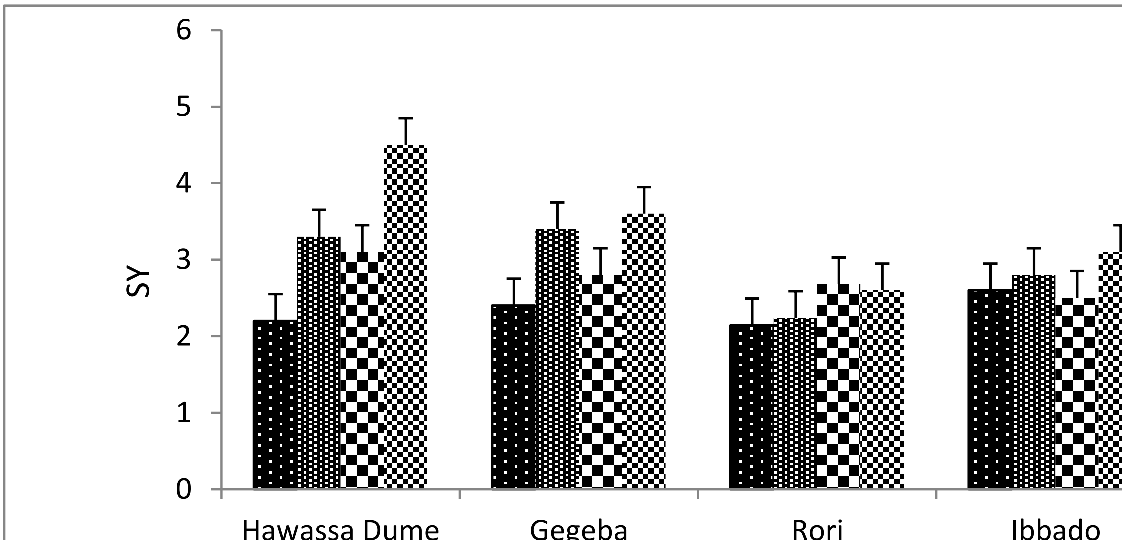

Figure. 5**.** Interaction Effects of N-sources x variety on straw yield. Vertical lines on bars indicate standard error of the statistical means.

4.3.5. Above ground biological yield

Above ground total biomass yield was significantly ($P<0.01$) affected by variety and N sources. However, it was not significantly affected by the interaction effects of varieties x N sources (Table 4 and Appendix Table 2). Regarding main effect, the highest above ground total biomass yield was recorded (5.02 t ha^{-1}) from Hawassa Dume variety, but statistically there is no significant difference between variety Gegeba, Ibado and Rori. The higher above ground total biomass yield could be associated to the better plant growth and grain formation ability of Hawassa Dume variety. The result of this study is in agreement with the finding of (Tesfaye *et al*. (2018)) on soybean.

The highest above ground total biomass yield (5.19 t ha^{-1}) was obtained from the combined application of N fertilizer and inoculation. While the lowest above ground total biomass yield (3.32t ha^{-1}) was recorded from the control. But, significant differences were not detected between the Rhizobium inoculation with strain HB-429 alone and combined application of N fertilizer and inoculation (Table 4). The increase in biomass yield in response to the different N sources may be ascribed to the predominant role that N plays in enhancing the physiological function of plants through promoting leaf expansion and photosynthesis. Nitrogen increases shoot dry matter, which is positively associated with grain yield in cereals and legumes (Fageria, 2008).This result is also consistent with that of Abbasi *et al*. (2010) who reported the highest total biomass yield of legumes due to the application of different N sources.

4.3.6. Harvest index

Analysis of variance indicated that varieties and nitrogen sources had significant ($P<0.01$) effect on harvest index. However, it was not significantly affected by the interaction effects of varieties x N sources (Table 4 and Appendix 2). The highest Harvest index was recorded (0.52) from Hawassa Dume variety, while the lowest Harvest index was recorded (0.39) from Gegeba variety, but statistically there is no difference between variety Ibado and Rori. This result indicate that the higher Harvest index was observed it might be the better plant shoot growth and grain formation ability of Hawassa Dume variety or inherent genetic potential of the varieties. This result is in accordance with the research outcomes of Hayat *et al.*(2004) who reported that harvest index signify physiological ability of a crop to convert proportion of dry matter in to economic yield, thus the higher harvest index the more productive efficiency of a crop. Likewise, this result in line with the findings of Daniel *et al.* (2012) reported that the varieties Beshbesh (0.50) and Nasir (0.48) recorded highest harvest indices.

Seed inoculation with strain HB-429 and application of 46kg N ha^{-1} resulted in significantly increased Harvest index compared to the non inoculated and fertilized (control) treatment. The highest Harvest index (0.52) was recorded from plants inoculated with strain HB-429 and application of 46kg N/ha while the lowest was (0.37) recorded from the control treatments. Among other N-sources there is no statistical different. The results indicated that adequate supply of N through biological N_2-fixation enhanced dry matter partitioning in favor of grain shown a greater harvest index. This result in line with the findings of Fageria NK (2009) who reported significant improvement in harvest index due to nitrogen application up to 50 kg ha^{-1}. Similarly, Pirbalouti *et al.*

(2006) reported that highly significant difference in harvest index among inoculants/N fertilizer (inoculation with four strains and 100 kg N ha^{-1}) and the control.

4.4. Correlation

According to the Pearson correlation analysis all parameters were positively and significantly (P<0.01) and (P<0.05) correlated with Days to 50% flowering (0.38*) Plant height (r = 0.71**), primary branches (r = 0.79**), leaf area index (0.65**) Nodule number per plant (r =0.63**), Nodule dry weight (r=0.63**), Shoot dry weight (r = 0.83**), Root dry weight (0.50**) pod number plant^{-1} (r=0.60**), Seed number pod^{-1}(r=0.72**), 100 seed weight (0.48**), straw yield (0.55**), above ground biomass yield (r=0.93**) and Harvest Index (0.66**)(Table 5). This implies that improve listed parameter in the above affect yield positively simultaneously increase grain yield. This finding is similar with the finding of Asmeret, (2015) who reported that in soya bean, yield was positively and significantly correlated with number of pods per plant, plant height, leaf area, number of seeds per pod and thousand grain weights.

Table 5. Pearson Correlation Coefficients between parameters of common bean.

	DF	PH	PB	LAI	NN	NDW	SDW	RDW	HSW	PNPP	SNPP	MD	GY	SY	BY	HI
DFF	1	0.30*	0.47**	0.22	0.31*	0.35*	0.44*	0.68**	0.63**	0.29*	0.39**	0.61**	0.38*	0.39**	0.39**	0.17
PH		1	0.77**	0.67**	0.41**	0.50**	0.69**	0.43**	0.44**	0.61**	0.76**	0.19	0.71**	0.59**	0.66**	0.43**
PB			1	0.73**	0.61**	0.51**	0.78**	0.66**	0.55**	0.55**	0.69**	0.35**	0.79**	0.58**	0.74**	0.48**
LAI				1	0.40**	0.34**	0.66**	0.39**	0.37**	0.52**	0.68**	0.13	0.65**	0.48**	0.64**	0.32*
NN					1	0.73**	0.53**	0.45**	0.48**	0.47**	0.54**	0.16	0.63**	0.37**	0.61**	0.36**
NDW						1	0.52**	0.43**	0.45**	0.52**	0.59**	0.1	0.63**	0.49**	0.65**	0.31*
SDW							1	0.50**	0.47**	0.70**	0.73**	0.24	0.83**	0.43**	0.74**	0.62**
RDW								1	0.67**	0.23	0.37**	0.67**	0.50**	0.39**	0.52**	0.22
HSW									1	0.27	0.43**	0.53**	0.48**	0.49**	0.51**	0.22
PNPP										1	0.75**	0.05	0.60**	0.42**	0.57**	0.36**
SNPP											1	0.13	0.72**	0.59**	0.67**	0.45**
MD												1	0.25	0.25	0.28*	0.09
GY													1	0.55**	0.93**	0.66**
SY														1	0.51**	0.32**
BY															1	0.34**
HI																1

Where, * and ** significant at 5% and 1% levels respectively; DF=Days to 50% flowering; PH=Plant height; PB=Primary branch; LAI= Leaf area index; NN=Nodule number; NDW=Nodule dry weight; SDW=Shoot dry weight; RDW=Root dry weight; HSW=Hundred seed weight; PN=Pod number; SN=Seed number; MD= Days to 90% maturity.

4.5. Economic Analysis

The agronomic data upon which the recommendations are based must be relevant to the farmers own agro-ecological conditions and the evaluation of these data must be consistent with the farmers goal and socio economics circumstance (CIMMMYT, 1988). Based on partial budget procedure described by CIMMYT (1988), the variable costs included the Nitrogen fertilizer cost (13.08 ETB kg^{-1}) , *Rhizobium* strain HB-429 160 ETB kg^{-1} and labor cost at time of planting and their application while the price of the current common bean was considered as gross benefit. The average grain yield of common bean was adjusted downward by 10% to reflect the farmer's field yield as described by CIMMYT (1988). Adjusted yield was multiplied by market price (12 ETB kg^{-1}) to obtain gross field benefit. Data presented in (Table 6) indicated that economic analysis of common bean as affected by the effects of *Rhizobium* inoculation and Nitrogen fertilizer application. However, Hawassa Dume variety with *Rhizobium* inoculation has the highest marginal rate of return than other varieties. The fact that the net benefits are lower than Hawassa dume variety with *Rhizobium* inoculation and 46 kg N ha^{-1}application. It is clear from the budget summary of economic analysis, the highest net returns (32748 ETB ha^{-1}) with acceptable marginal rate of return (11970%) was obtained from Hawassa Dume variety with *Rhizobium* inoculation and 46 kg N ha^{-1} application. This partial budget analysis indicates that the growers in the study area can obtain extra benefits 119.7 ETB for every 1 ETB expense by this treatment, followed by Hawassa Dume variety with *Rhizobium* HB-429 inoculation lone having calculated net return (32025) ETB ha^{-1} . In contrast, the lowest net benefit of (10709 ETB ha^{-1}) was obtained from variety Gegeba without nitrogen application and inoculation. In order to use the marginal rate of return (MRR) as a basis for fertilizer recommendation, the minimum acceptable marginal rate of return has to be 100% (CIMMYT, 1988).

Therefore, use of Hawassa dume variety with *Rhizobium* inoculation and 46 kg N ha^{-1} application found to be economically feasible at Meskan, Southern Ethiopia.

Table 6. Partial budget analysis

Treatment	GY (t ha^{-1})	AY (t ha^{-1})	GB (birr)	CU (ETB ha^{-1}	CS (ETB ha^{-1}	LC ETB ha^{-1}	TVC ETB ha^{-1}	NB (ETB ha^{-1}	Dominance	MRR (%)
V2N0R0	1.03	0.927	11124	0	0	280	415	10709	-	-
V4N0R0	1.4	1.26	15120	0	0	280	425	14695	ND	39860
V3N0R0	1.52	1.368	16416	0	0	280	431	15985	ND	21500
V1N0R0	1.7	1.53	18360	0	0	280	442	17918	ND	17572.72
V2R1	2.15	1.935	25800	0	160	280	636	25164	ND	3735.05
V4R1	2.27	2.043	24516	0	160	280	644	23872	D	-
V3R1	2.46	2.214	26568	0	160	280	650	25918	ND	34100
V1R1	3.03	2.727	32724	0	160	280	699	32025	ND	12463.26
V3N1	1.93	1.737	20844	1308.4	0	280	1743	19101	D	-
V4N1	1.8	1.62	19440	1308.4	0	280	1758	17682	D	-
V2N1	2.23	2.007	24084	1308.4	0	280	1789	22295	ND	30753.33
V1N1	2.95	2.655	31860	1308.4	0	280	1839	30021	ND	15452
V2N1R1	2.43	2.187	26244	1308.4	160	280	1968	24276	D	-
V4N1R1	2.45	2.205	26460	1308.4	160	280	1968	24492	D	-
V3N1R1	2.84	2.556	30672	1308.4	160	280	1994	28678	ND	16100
V1N1R1	3.22	2.898	34776	1308.4	160	280	2028	32748	ND	11970.58

Where, v1= variety Hawassa Dume, V2= variety Gegeba, V3= variety Rori, V4= variety Ibado, GB= Gross Benefit, TVC= total variable cost, MRR= marginal rate of return, ETB=Ethiopia birr, Ha= hectares, R1=strain HB-429, N1=nitrogen fertilizer, R0N0=control, GY=grain yield, CU=cost of urea, LC= labor cost, NB= net benefit AY= adjusted yield, CS=cost of strain.

5. SUMMARYAND CONCLUSION

A field study was conducted during 2018 main cropping season on field condition (at Meskan) to investigate effect of N sources on growth, yield and yield components of common bean varieties. The experiment consisted of four common bean varieties (Hawassa Dume, Gegeba, Rori and Ibado) and four levels of N sources (control, Strain HB-429, 46 kg N ha^{-1}, Strain HB-429 + 46 kg N ha^{-1}) and in randomized complete block design with factorial arrangement using three replications.

The result revealed that highly significant ($p<0.01$) varietal effect for most of studied parameters. Among varieties, Hawassa Dume variety seem to be superior over other varieties for most characters such as days to 50% flowering, plant height, number of primary branch, leaf area index, days to 90% maturity, nodule number, nodule dry weight, shoot dry weight, pod number, seed number, grain yield, straw yield, above ground total biomass and harvest index. While, root dry weight and 100 seed weight was performed better by variety Ibado and Gegeba, respectively (Table 2, 3 and 4).

On the other hands, the experiment indicated that most of the parameters tested responded significantly ($p<0.01$) to the treatments used. For nodulation and growth parameters, N sources showed significant differences in nodule number, nodule dry weight, plant height, number of primary branches, shoot dry weight, root dry weight and leaf area index. In the study, inoculation of common bean varieties with strain HB-429 increased nodule number plant^{-1} and nodule dry weight(g plant^{-1}) by 157 and 200 % , respectively as compared to the control (uninoculated and non-fertilized) treatments. In the case of yield and yield components, N sources showed significant effects on all parameters of yield and yield components and strain HB-429 and 46 kg N ha^{-1} appeared to be more effective than all other N source treatments. Combined application of strain HB-429 and 46 kg N ha^{-1} increased number of pods plant^{-1}, number of seeds plant^{-1}, hundred seed weight, straw yield, biological yield and Harvest index by 127.3, 147.4, 196, 146, 156,3 and 140.5%, respectively, over the control. The significant differences in these parameters had contributed to the superior grain yield performance of strain HB-429 and 46 kg N ha^{-1}(2.7 t ha^{-1}) compared to the control (1.5 t ha^{-1}), which was 180% increase (Table 4).

The interaction effect of N sources x variety was highly significant ($P \leq 0.01$) on nodule number, root dry weight and straw yield. Significantly highest nodule number (41) was obtained from *Rhizobium* inoculation. However, highest root dry weight (11.6 g plant^{-1}) and straw yield (4.5t ha^{-1}) were obtained from the combined application of *Rhizobium* inoculation of strain HB-429 and 46 kg N ha^{-1} as compared to the lowest values obtained from the control (non *Rhizobium* inoculation and non-Nitrogen fertilization).

The economic analysis also showed the highest net returns (32748ETB ha^{-1}) with acceptable marginal rate of return of (11970%) were obtained from Hawassa Dume variety with *Rhizobium* inoculation with strain HB-429 and 46 kg N ha^{-1} (Table 6). Based on the present findings, we can conclude that Hawassa Dume variety with *Rhizobium* inoculation and Nitrogen fertilizer application at a level of 46 Kg ha^{-1} improve grain yield of common bean. Therefore, the use of Hawassa Dume variety with *Rhizobium* inoculation and Nitrogen fertilizer application at a level of 46 Kg ha^{-1} could be recommended to common bean producers in the study area to achieve superior yield and better economic return. However, it is pre-mature to provide a conclusive recommendation as this result is generated from experiment conducted at single location for one season. For this reason, repeating the experiment for more seasons and similar location would help us draw sound conclusion and recommendations.

6. REFERENCES

Abbasi K.M., Manzoor M. & Tahir M. 2010. Efficiency of *Rhizobium* inoculation and P fertilization in enhancing nodulation, seed yield, and phosphorus use efficiency by field grown soybean under hilly region of Rawalakot Azad Jammu and Kashmir, Pakistan. *Journal of Plant Nutrition*, 33:1080-1102.

Abbasi M.K., Majeed A., Sadiq A. & Khan SR. 2008. Application of *Bradyrhizobium* japonicum and phosphorus fertilization on growth, yield and nodulation of soybean in the sub-humid hilly region of Azad Jammu and Kashmir. Plant Prod. Sci. 58:368-376.

Abebe Z. 2017. On-farm Yield variability and Responses of Common bean (*Phaseolus vulgaris* L.) Varieties to *Rhizobium* Inoculation with Inorganic Fertilizer Rates. *Journal of Animal and Plant Sciences*, 32(2):5120–5133.

Abera Habte & Tadel Buraka. 2016. Effect of *Rhizobium* Inoculation and Nitrogen Fertilization on Nodulation and Response of Common Bean (*Phaseolus vulgaries* L.) journal of biology, agriculture and healthcare *www*.iiste.org ISSN2224-3208 (Paper) ISSN2225-093X (online) 6(13) 72–75.

Adamovich A., Klasens V. 2001. Symbiotically fixed nitrogen in forage legume–grass mixture. *Grassland Science in Europe*, 6:12.

Addo-Quaye A.A., Saah M.K., Tachie-Menson C.K.B., Adam I., Tetteh J.P., Rockson-Akorly V.K. & Kitson J.E. 2011. General Agriculture for QSenior Secondary Schools, MOE 191-194.

Ahmad S., Ahmad R., Ashraf M.Y., Ashraf M. & Waraich E.A. 2009. Sunflower (*Helianthus annuus* L.) response to drought stress at germination and seedling growth stages. *Pakistan Journal* of *Botany*, 41(2): 647–654

Ahmed S., Gendy A., Hussein A.H., Said-Al Ahi., Abear A. & Hanna F.Y. 2013. Effect of nitrogen sources, bio-fertilizers and their interaction on the growth, seed yield and chemical composition of guar plants. Life Sci. J 10 (3): 389–399.

Al-Falih A.M.K. 2002. Factors affecting the efficiency of symbiotic nitrogen fixation by *Rhizobium*. *Pakistan Journal of Biological Sciences,* 5(11):1277–1293.

Asadi R.H., Afshar M., Khavazi K., Nourgholipour F. & Otadi A. 2005. Effect of common bean nodulating rhizobia native to Iranian soils on the yield and quality of bean. *Journal of Water and Soil,* 19(2): 215–223.

Asmeret K. 2015. Effect of Tillage Frequency and intercropping on Yield and Yield Components of Maize (Zea mays) in Adigudem Southeast Tigray, Ethiopia, M.Sc. thesis. College of Dryland Agriculture, Mekelle University, Mekelle, Ethiopia.

ATA and MOA. 2016. Ethiopian Agricultural Transformation Agency, Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia.

Beebe S.E., Rao I.M., Blair M.W. & Acosta Gallegos J.A. 2013. Phenotyping common beans for adaptation to drought. *Frontiers in Plant Physiology,* 4:1–20.

Bekere W., Kebede T. & Dawud J. 2013. Growth and nodulation response of soybean (*Glycine max* L.) to lime, *Bradyrhizobium japonicum* and nitrogen fertilizer in acid soil at Melko, South Western Ethiopia. *International Journal of Soil Science,* 8:25–31.

Blair M., Gonzales L.F., Kimani P.M. & Butare L. 2010. Genetic diversity, inter-gene pool introgression and nutritional quality of common beans from central Africa. *Theoretical* and *Applied Genetics*, 121: 237-248.

Bliss F.A. 1993. Breeding common bean for improved biological nitrogen fixation. *Plant and Soil,* 152: 71–79.

Boddey R.M., Alves B.J.R. & Urquiaga S. 1997. The contribution of biological nitrogen fixation for sustainable agricultural systems in the tropics. *Soil Biology and Biochemistry,* 29:787–799.

Brady N.C. & Weil R.R. 2002. The Nature and Properties of Soils, 13th Edition. Printice Hall, New Jersey, 960 p.

Brady N.C. 2002. Phosphorus and potassium. In Brady, N.C. and Weil, R.R. (eds.) The nature and properties of soils. Dehli, India: Prentice-Hall. 261 – 272.

Brito M.M.P., Muraoka T. & Silva E. 2011. Contribution of nitrogen from biological nitrogen fixation, nitrogen fertilizer and soil nitrogen on the growth of the common bean and cowpea. *Journal of Bragantia*, 70:206–15.doi:10.1590/S0006-87052011000100027

Bruijn F.J. 2016. Biological Nitrogen Fixation Book Summary. Advances in Microbiology 6:407 – 411.

Buruchara R. 2011. Background information on Common beans in Biotechnology, Breeding & Seed systems for African Crops. Nairobi, Kenya: The Rockefeller Foundation.

CGIAR (Consultative Group on International Agricultural Research). Common Bean, 2012. Available online: http://www.cgiar.org/our-research/crop-factsheets/beans/ (accessed on January, 2019).

Chapman H.D. 1965. Cation exchange capacity by ammonium saturation. Pp. 891-901. In: C. A. Black, L. E. Ensminger and F. E. Clark (Eds.). *Method of Soil Analysis. American Society of Agronomy*. Madison Wisconsin, USA.

CIAT (2009-2011). Improved Bean for the Developing World. 75 – 88.

CIAT (International Center for Tropical Agriculture). 2008. Highlights CIAT in Africa. New bean varieties for Ethiopian farmers. Africa coordination Kawanda agricultural research institute Kampala, Uganda.

Cigdem Kucuk. 2011. Inoculation with *Rhizobium* spp. in kidney bean (*Phaseolus vulgaris* L.) varieties. Agriculture, 98:49–56.

CIMMYT (Centro International De Mesoramiento De Maiz Y Trigo). 1988. from Agronomic Data to Farmer Recommendations. An Economics Training Manual. Completely revised edition. D. F, Mexico 79pp.

Coskan A. & Dogan K. 2011. *Symbiotic Nitrogen Fixation in Soybean*. 168-182

CSA (Central Statistical Agency). 2013. Report on area and production for major crops in 2012/2013.Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2014. Agricultural sample survey 2013/14. Volume I, Report on area production of major crops (private peasant holdings, Meher Season). Addis Ababa, May 2014. Statistical bulletin 532.

CSA (Central Statistical Agency). 2015. Agricultural sample survey 2014/15. Volume I, Report on area production of major crops (private peasant holdings, Meher Season).Addis Ababa, May 2015. Statistical bulletin 578.

CSA (Central Statistical Agency). 2017. Area and production of major crops private peasant holdings, Meher season. Addis Ababa, Ethiopia.

Daniel Tadesse, Teferi Alem, Tesfaye Wossen & Assefa Sintayehu. 2012. Evaluation of improved varieties of haricot bean in West Belessa, Northwest Ethiopia.

Dashora K. 2012. Nitrogen yielding plants: The pioneers of agriculture with a multipurpose. *American-Eurasian Journal of Agronomy,* 4(2): 34 – 37.

Day P.R., 1965. Hydrometer method of particle size analysis. *In*: Back, C.A. (Ed.), *Methods of soil analysis.* Amer. Soc. Argon. Madison Winscowin.Agron, 9 (2):562-563.

Deresa Shumi. 2018. Response of common bean (Phaseolus vulgaris L.) varieties to rates of blended NPS fertilizer in Adola district, Southern Ethiopia. *African Journal of Plant Science,* 12(8):164-179.

EEPA (Ethiopian Export Promotion Agency). 2004. Ethiopian pulses. Product Development and Research Directorate. Addis Ababa, Ethiopia.

EIAR (Ethiopian Institute of Agriculture Research). 2014. Rhizobia-based Bio-fertilizer Guide lines for smallholder farmers. pp. 1-19

El Naim M. & Jabereldar A.A. 2010. Effect of plant density and cultivar on growth and yield of cowpea (Vigna unguiculata L.Walp). *Australian Journal Basic and Applied Science,* 4(8):3148-3153.

El-Awadi M.E., El-Bassiony A.M., Fawzy Z.F., El-Nemr M.A. 2011. Response of snap bean (Phaseolus vulgaris L.) plants to nitrogen fertilizer and foliar application with methionine and tryptophan. *Nature and Science 9:87-94.*

Elkhatib H.A.2009. Growth and Yield of Common Bean (Phaseolus Vulgaris L.) in Response to *Rhizobium* Inoculation, N and Molybdenum Fertilization. Alex Sci Exch J 30: 319-332.

Ephraim Motaroki Menge. 2016. Improving biological nitrogen fixation in common bean (Phaseolus vulgaris L.) varieties grown within eastern kenya. Department of Microbiology, Kenyatta University, Kenya. I56/CE/25333/2014.

Fageria N.K & Santos A.B. 2008. Yield physiology of dry bean. *Journal Plant Nutrition,*31:983–1004.

Fageria N.K. 2009. The use of nutrients in crop plants. CRC press, Taylor & Francis group, New York, USA, pp. 1 – 127.

Fageria N.K., Moreira A. & Coelho A.M. 2011. Yield and yield components of upland rice as influenced by nitrogen sources. *Journal of Plant Nutrition,* 34: 361 - 370.

FAO (Food and Agricultural Organization of the United Nations). 2008. Guidelines on nitrogen management in agricultural systems. IAEA, Vienna. pp. 1018 - 5518.

FAOSTAT. 2010. "Food and agriculture organization." Available: www.fao.org

FAOSTAT.2013. "Food and agriculture organization." Available: www.fao.org

Ferreira P.A.A., Silva M.A.P., Cassetari A., Rufni M., Moreira F.M.S. & Andrade M.J.B. 2009. Inoculation with *Rhizobium* strains in beans crop. *Journal of Ciencia Rural*, 39:2210-2. doi:10.1590/S0103-84782009000700041

Ferris S. & Kaganzi E. 2008. Evaluating marketing opportunities for haricot beans in Ethiopia. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 7. ILRI (International Livestock Research Institute), Nairobi, Kenya, p: 68.

Frehiwot Mulugeta. 2010. Profile of Haricot bean production, supply, demand and marketing issues in Ethiopia, Ethiopia Commodity Exchange Authority, Addis Ababa, Ethiopia.

Freire A.H., Reis R.P., Fontes R.E. & Veiga R.D. 2011. Economic efficiency of coffee in the south of Minas Gerais: one application of production frontier. *Coffee Science,* 6:172-83.

Gai Z., Zhang J. & Li C. 2017. Effects of starter nitrogen fertilizer on soybean root activity, leaf photosynthesis and grain yield.

Garden-Robinson J. & McNeal K. 2013. Nutrition, Health Benefits, Preparation and Use in Menus. North Dakota State University Extension Service, North Dakota, USA.

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

Gidago, Sheleme Beyene & Walelign Worku. 2012. The response of haricot bean to phosphorus application on Ultisols at Areka, southern Ethiopia. *Journal of Biology, Agriculture and Healthcare,* 1(3): 38–49.

Giller K. E. 2001. Nitrogen Fixation in Cropping Systems. 2nd Edition. CABI, publishing. UK. 448pp.

Goi S.R., Sprent J.I., James E.K. & Jacob-Neto J. 1993. Influence of nitrogen form and concentration on the nitrogen fixation of *Acacia auriculiformis*. *Symbiosis,*14:115–122.

Guo Y., Yu Y., Yuan L. & Huang J. 2009. Effects of liming and Sinorhizobium inoculation on growth, nodulation and nutrient concentrations of Lucerne in acid soils. *Trop Grasslands*, 43:112–117

Habtamu Assefa, Berhanu Amsalu & Tamado Tana. 2017. Response of common bean (Pharsalus vulgaris L.) cultivars to combined application of *Rhizobium* and NP fertilizer at Melkassa, Central Ethiopia. *International Journal of Plant & Soil Science*, 14(1): 1-S10.

Hamdani A.M. & Wani I.A. 2017. Guar and Locust bean gum: composition, total phenolic content, antioxidant and antinutritional characterisation. *Bioactive Carbohydrates and Dietary Fiber*, 11: 53–59.

Hansen A.P. 1994. Symbiotic N fixation of crop legumes: Achievements and perspectives. Centre for Agriculture in the Tropics and Subtropics, University of Hohenheim, Germany.MargrafVerlag,Weikersheim,Germany.https://www.cabdirect.org/cabdirect/abstract/19940708595.

Havlin J.E., Beaton J.D., Nelson W.L. & Tisdal S.L. 1999. Soil Fertility and Fertilizers. An Introduction to Soil Management, 6th ed. Prentice Hall, Inc. 634p.

Hayat R., S. Ali. & F. S. Khan. 2004. Effect of Nitrogen and *Rhizobium* Inoculation on Yield, N-uptake and Economics of Mungbean, *Int. J. Agri.Biol.*, 6(3):236–242.

Hemmati A. & Asadirahmani H. 2004. Application of nitrogen and BNF in yield of beans 8th Congress of Crop Sciences, Iran. Proceedings, pp: 465.

Heritage J., Evans E.G.V. & Killington R.A. 2000. Microbiology in action. Cambridge University Press, London (pp.15-72).

Herridge D.F. and Redden R.J.1999. Evaluations of genotypes of navy and culinary bean (*Phaseolus. vulgaris* L.) selected for superior growth and nitrogen fixation. *Australian journal of experimental Agriculture,* 39(8)975-980.

Herridge D.F., Roughley R.J., Brockwell J. 1984. Effects of *Rhizobium* and soil nitrate on establishment and functioning of the soybean symbiosis in the field. *Australian Journal of Agricultural Research*, 35:146–161.

Hillocks R.J. 2011. Farming for balanced nutrition: an agricultural approach to addressing micronutrient deficiency among the vulnerable poor in Africa. *African Journal of Food, Agriculture, Nutrition and Development*, 11(2): 1–14.

Hokmalipour S. & Darbandi M.H. 2011. Effects of nitrogen fertilizer on chlorophyll content and other leaf indicate in three cultivars of Maize (*Zea mays* L.). *World Applied Sciences Journal,* 15(12): 1780–1785.

Hungria M. & Franco A.A. 1993. Effects of high temperature on nodulation and nitrogen fixation by *Phaseolus vulgaris* L. *Plant and Soil,* 149(1):95–102.

Hungria M. & Vargas M.A. 2000. Environmental factors affecting N_2-fixation in grain legumes in the tropics, with an emphasis on Brazil. *Field Crops Research,* 65(2):151–164.

Hungria M., Campo R.J. & Mendes I.C. 2003. Benefits of inoculation of the common bean (*Phaseolus vulgaris*) crop with efficient and competitive *Rhizobium* tropici strains. *Biology and Fertility of Soils,* 39(2): 88–93.

Jackson M.L. 1962. *Soil chemical analysis*. New Delhi, practice Hall of India.

Kaganzi E. 2008. Evaluating Marketing Opportunities for common beans in Ethiopia. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 7. ILRI (International Livestock Research Institute), Nairobi, Kenya.

Kalyebara R. 2008. The impact of improved bush bean genotypes in Uganda. *Network on Bean Research in Africa*, Occasional Publication Series, (43). Kampala, Uganda: CIAT.

Kaneko F.H., Arf O., Gitti D.C., Arf M.V., Ferreira J.P. & Buzetti S. 2010. Furrow opening mechanisms, inoculation of seeds and nitrogen fertilization in no tillage common bean crop. Bragantia.69:125-33.doi:10.1590/S0006-87052010000100017

Katungi E., Farrow A., Chianu J., Sperling L. & Beebe S. 2009. Common bean in eastern and southern Africa: A Situation and Outlook Analysis. International Centre for Tropical Agriculture, 61 p.

Katungi E., Farrow A., Mutuoki T., Gebeyehu S., Karanja D., Alemayehu F., Sperling L., Beebe S., Rubyogo J.C. & Buruchara R. 2010. Improving haricot bean productivity: An Analysis of socioeconomic factors in Ethiopia and Eastern Kenya.

Baseline Report Tropical legumes II. Centro Internacional de Agricultura Tropical -CIAT. Cali, Colombia.

Kellman A. 2008. *Rhizobium* inoculation, cultivar and management effects on the growth, development and yield of common bean (*Phaseolus vulgaris* L.), Doctoral dissertation, Lincoln University (pp. 39–87).

Kessel C.V. & Hartley C. 2000. Agricultural management of grain legumes: has it led to an increase in nitrogen fixation. Field Crops Res. 65:165–181.

Kilasi N.L. 2010. Comparison of selection indices for tolerance to water stress in common bean (Phaseolus vulgaris L.) for the dry environment of Tanzania. MSc thesis. University of Zambia.

Kubota A., Hoshiba K. & Bordon J. 2008. Effect of fertilizer-N application and seed coating with rhizobial inoculants on soybean yield in eastern Paraguay. Rev. Bras. Ciênc. Solo 32:1627–1633.

Kyei-Boahen S., Nleya T.M., Hynes R.K. & Walley F.L. 2005. Single and multi-strain rhizobial inocula for pinto and black bean cultivars. *Journal of Plant Nutrition,* 28: 1679–1692.

Lambon B.J. 2016. Inoculation and N fertilizers effects on the growth, grain yield and N remobilization in soybean (Gylcine max (l)) Merrill) in the Guinea savanna.

Lamptey S., Ahiabor B.D. K., Yeboah S. & D. Osei. 2014. Effect of *Rhizobium* inoculants and reproductive growth stages on shoot biomass and yield of soybean (Glycine max (L.) Merril). *Journal of Agricultural Science*, 6:44–54.

Landon J.R. 1991. Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub Tropics. Longman Scientific and Technical, Longman Group, UK Ltd.

Legesse Dadi, Gure Kumssa, Teshale Assefa, M., Taha, J., Gobena, T., Alemaw, A., Abebe, Y., Mohhamed and Terefe, H. 2006. Production and marketing of white pea beans in the Rift valley, Ethiopia. A Sub-Sector Analysis. *National Bean Research Program of the Ethiopian Institute of Agricultural Research*.

Lin M., Gresshoff P.M. & Ferguson B.J. 2012. Systematic Regulation of Soybean Nodulation by Acidic Growth Conditions. *Plant physiology,* 160:2028-2039. dio:10.1104/pp.112.204149

Magani I.E. & Kuchinda C. 2009. Effect of Phosphorus fertilizer on growth, yield and crude protein content of cowpea (Vigna unguiculata [L.]Walp) in Nigeria. *Jornal of Applied Bioscience,* 23:1387–1393.

Mahamood J., Abayomi Y.A. & Aduloju M.O. 2009. Comparative growth and grain yield responses of soybean genotypes to phosphorous fertilizer application. *African Journal of Biotechnology,* 8(6):1030–1036.

Makoi J., Sylvia Bambara H.J.R., & Ndakidemi P.A. 2013. *Rhizobium* inoculation and the supply of molybdenum and lime effect on the uptake of macro elements in common bean (*Phaseolus vulgaris*) plants. *Australian Journal of Crop Science,* 7: 784–793

Malusá E. & Vassilev N. 2014. A contribution to set a legal framework for bio-fertilizers. *Applied microbiology and biotechnology,* 98: 6599–6607

Mandefro Nigussie, Anteneh Girma, Chimdo Anchala & Abebe Kirub (Eds.). 2009. Improved technologies and resource management for Ethiopian Agriculture. A Training Manual. RCBP-MoARD, Addis Ababa, Ethiopia.

Massignam A.M., Chapman S.C., Hammer G.L. & Fukai S. 2009. Physiological determinants of maize and sunflower achene yield as affected by nitrogen supply. *Field Crops Research,* 113: 256–267.

Mesfin Kassa, Belay Yebo & Abera Habte. 2014.The Response of haricot Bean (Phaseolus Vulgaris L.) Varieties to Phosphorus Levels on Nitosols at Wolaita Zone, Southern Ethiopia. *Am. J. Plant Nutr.Fertiliz.Technol*.44:27–32.

Meskan District Annual Repot (2017). (Unpublished)

Mfilinge A., Kevin Mtei. & Patrick A. Ndakidemi. 2014. Effects of *Rhizobium* inoculation and supplementation with P and K, on growth, leaf chlorophyll content and nitrogen fixation of bush bean varieties. American Journal of Research

Communication, 2(10): 49-87 Miller, R.W. and Donahue, R.L. 1995. Soil in our Environment 7th Edition. Prentice hall, New Jersey, 649p.

Mmbaga G.W., Mtei K.M. & Ndakidemi P.A. 2014. Extrapolations on the use of *Rhizobium* inoculants supplemented with phosphorus (P) and potassium (K) on growth and nutrition of legumes. *Agricultural Sciences,* 5(12): 1207–1226.

Mohammadi K., Sohrabi Y., Heidar G., Khalesro S. & Majidi M. 2012. Effective factors on biological nitrogen fixation. *African Journal of Agricultural Research,* 7(12): 1782–1788.

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

Montañez A. 2000. Overview and case studies on biological nitrogen fixation: Perspectives and limitations. FAO, Case Study 2:1–11.

Nchimbi-Msolla S. & Tryphone G.M. 2010. The effect of the environment on iron and zinc concentrations and performance of common bean genotypes. *Asian Journal of Plant Science, 9:455–462.*

Ndakidemi P., Dakora F.D., Nkonya E., Ringo D., & Mansoor H. 2006. Yield and economic benefits of common bean (*Phaseolus vulgaris*) and soybean (*Glycine max*) inoculation in northern Tanzania. *Animal Production Science,* 46(4):571–577.

Nebret Tadesse & Nigussie dachassa. 2017. Effect of Nitrogen and Sulphur Application on Yield Components and Yield of Common Bean (Phaseolus Vulgaris L.) in Eastern Ethiopia. *Acad. Res. J. Agri. Sci. Res*. 5(2): 77–89.

Nebret Tadesse & Nigussie Dechassa. 2012. Effect of nitrogen and sulphur application on yield components and yield of common bean (*Phaseolus vulgaris* L.) In Eastern Ethiopia. MSc. Thesis, Haramaya University, Ethiopia. NMA-National Meteorological Agency (2015). Hawassa branch.

Negash R. 2007. Determinants of adoption of improved haricot bean production package in alaba special woreda, southern Ethiopia. *MSc. Thesis*, College of Agriculture, Haramaya University of earth's nitrogen cycle. Science, 330(1): 192–196.

Niste M., Vidican R., Pop R. & Rotar I. 2013. Stress factors affecting symbiosis activity and nitrogen fixation by *Rhizobium* cultured *in vitro*. *ProEnvironment,* 6: 42–45.

Nyoki D. & Ndakidemi P.A. 2014. Effects of Brady *Rhizobium* japonicum inoculation and supplementation with phosphorus on macronutrients uptake in cowpea (Vigna unguiculata L.) Walp. American Journal of Plant Sciences, 5: 442–451.

Olsen S.R., Cole V., Walanbe C.V. & Dean L.A. 1954. Estimation of Available phosphorus in soils by extraction with Sodium Bicarbonate. USA Circular NO 939.

Panchali K. 2011. Symbiotic nitrogen fixation and seed development of genetically modified soybean in relation to *Bradyrhizobium* inoculation and nitrogen use under acidic and saline dykeland and soil conditions. MSc thesis, Dalhousie University, Halifax, Nova Scotia.

Pelegrin R., Mercante F.M., Otsubo I.M.N. & Otsubo A.A. 2009. Response of common bean crop to nitrogen fertilization and *Rhizobium* inoculation. Rev Bras Cienc Solo.33:219-26.doi:10. Phaseolus; study guide to be used as a supplement to the audio tutorial unit on the same topic. Production: Fernando Fernandez O., Cali, Colombia.

Peoples M.B. & Herridge, D.F. 2000. Quantification of biological nitrogen fixation in agricultural systems. Pp.519-524. *In*: F.O. Pedrosa (Ed.). Nitrogen fixation: From molecules to crop productivity. Kluwer Academic Publishers, the Netherlands.

Peoples M.B., Ladha J.K. & Herridge D.F. 1995. Enhancing legume N_2-fixation through plant and soil management. In Management of Biological Nitrogen Fixation for the Development of More Productive and Sustainable Agricultural Systems. Springer Netherlands. pp. 83–101.

Pirbalouti A.G., Allahdadi I., Akbari G.A., Golparvar A.R. and Rostampoor S.A. 2006. Effect of different strains of *Rhizobium legominosarum* biovar phaseoli on Yield and N_2-Fixation Rate of Common bean (*Phaseolus vulgaris* L.) Iranian Cultivars. *Pakistan Journal of Biotechnology Science*, 9 (9): 1738-1743.

Polania J., Poschenrieder C., Rao I. & Beebe S. 2016. Estimation of phenotypic variability in symbiotic nitrogen fixation ability of common bean under drought stress using ^{15}N natural abundance in grain. *European Journal of Agronomy*, 79: 66–73.

Rafiq M.A., Ali A., Malik M.A. & Hussain M. 2010. Effect of fertilizer levels and plant densities on yield and protein contents of autumn planted maize. *Pakistan Journal of Agricultural Sciences*, 47: 201–208.

Ramos M.L.G., Parsns R., Sprent J.I., James E.K. 2003. Effect of water stress on nitrogen fixation and nodule structure of common bean. *Pesquisa Agropecuiria Brasileira*, 38(3):339–347.

Redmon J.W. & Smith K. 2004. N_2 fixation of legumes under high nitrate. *Plant and Soil*, 58:135–160.

Rodriguez D.N., Buendia A.M, Camacho M. & Lucas M.M. 2000. Characterization of *Rhizobium* spp. bean isolates from southwest Spain. *Soil Biology and Biochemistry*, 32: 1601–1613.

Safapour M.A., Rdakani M., Khaghani S., Rejali F., Zargari K., Changizi M. & Teimuri M. 2011. Response of yield and yield components of three red bean (*Phaseolus vulgaris* L.) genotypes to co-inoculation with *Glomus intraradices* and *Rhizobium phaseoli*. *American-Eurasian Journal of Sustainable Agriculture*, 11: 398–405.

Saha B., Saha S., Das A., Bhattacharyya P.K., Basak N., Sinha A.K. & Poddar P. 2017. Biological nitrogen fixation for sustainable agriculture. *In Agriculturally Important Microbes for Sustainable Agriculture*, 81-128.

Sajid M., Rab A., Wahid F., Shah SNM., Jan I., Khan MA., Hussain SA., Khan MA. & Iqbal Z. 2011. Influence of *Rhizobium* inoculation on growth and yield of groundnut cultivars. *Sarhad J. Agric*. 27(4):574–576.

Salvucci R.D., Aulicino M., Hungaria M. & Balatti A.P. 2012. Nodulation capacity of Argentinean soybean cultivars inoculated with commercial strains of Bradyrhizobia japonicum. *American Journal of plant Sciences* 3: 130–140.

Sara S., Morad M. & Reza C.M. 2013. Effects of seed inoculation by *Rhizobium* strains chlorophyll content and protein percentage in common bean cultivars (*Phaseolus vulgaris* L.). *International Journal of Biosciences,* 3(3): 1–8.

SAS, Institute Inc. 2002. SAS User's Guide, Statistics Version 9.0 ed. SAS Institute, Cary, NC, USA.

Saturno D.F., Cerezini P., Silva P.M., Oliveira A.B., Hungria M. & Nogueira M.A. 2017. Mineral nitrogen impairs the biological nitrogen fixation in soybean of determinate and indeterminate growth types. *Journal of Plant Nutrition*, 40(12):1690–1701.

Singh A., Baoule A.L., Ahmed H.G., Aliyu U. & Sokoto M.B. 2011. Influence of phosphorus on the performance of cowpea (Vigna unguiculata L.) Varieties in the Sudan savannah of Nigeria. *Agricultural Science*, 2:313–317.

SNNPRSMA (southern nation,nationalities people regional state).2018.(unpublished)

Sogut T., Ozturk F., Temiz M.G., Toncer O. & Onat B.Z. 2013. The effects of rhizobial inoculation and nitrogen fertilizer application nodulation, yield and yield components of groundnut *(Arachis hypogaea* L.). *Global Journal on Advances in Pure and Applied Sciences,* 01:158–167.

Solomon T., Pant L.M., Angaw T. 2012. Effects of Inoculation by *Bradyrhizobium japonicum* Strains on Nodulation, Nitrogen Fixation and Yield of Soybean (*Glycine max* L. Merill) Varieties on *Nitisols* of Bako, Western Ethiopia. *International Scholarly Research Notices,* 12:1–8.

Tarekegn Yoseph & Serawit Shanko. 2017. Growth, symbiotic and yield response of N-fertilized and *Rhizobium* inoculated common bean (Phaseolus vulgaris L.). African Journal of Plant Science, 11(6), 197–202.

Tarekegn Yoseph. 2011. Effects of *Rhizobium* inoculants and P fertilization on growth, yield and yield components of haricot bean at Umbullo Wacho watershed, Southern Ethiopia, School of plant and Horticultural Sciences, Hawassa University, Hawassa, Ethiopia.

Taylor & Francis. 2005. Root Growth, Nodulation, Grain Yield, and Phosphorus Use Efficiency of Lentil as Influenced by Phosphorus, Irrigation, and Inoculation. *Saskatchewan Journal of Food and Agriculture Number* 13–14.

Tesfaye Tekola, Tarekegn Yoseph & Walelign Worku. 2018. Biological and inorganic fertilizer applications improved growth, nodulation and yield of soybean (Glycine max L.) varieties. *International jornal of current research*, 10, (05), 68855–68862.

Teshale Assefa, Habtu Assefa & Kimani P. 2006. Development of improved haricot bean germplasm for the mid, low altitude and sub-humid agro ecologies of Ethiopia. 87–94.

Thornton P.K., Jones P.G., Alagarswamy G., Andresen J. & Herrero M. 2010. Adapting to climate change: agricultural system and household impacts in East Africa. *Agricultural Systems*, 103(2): 73–82.

Togay N., Togay Y., Cimrin K.M. & Turan M. 2008. Effect of *Rhizobium* inoculation, Sulfur and phosphorus application on yield, yield components and nutrient uptake in Chick Pea (Cicer arientinum L.). *Africa Journal of Biotechnology*, 7 (6):776–782.

Triplett E.W. 1990. Construction of a symbiotically effective strain of *Rhizobium leguminosarum bv. trifolii* with increased nodulation competitiveness. *Applied and Environmental Microbiology*, 56(1): 98–103.

Ullah M.A., Anwar M. & Rana A.S. 2010. Effect of nitrogen fertilization and harvesting intervals on the yield and forage quality of elephant grass (*Pennisetum purpureum*

L.) under mesic climate of Pothowar plateau. *Pakistan Journal of Agricultural Sciences*, 47: 231–234

Umeh M.O., Edeoga H.O. & Omosun G. 2011. Nitrogen fertilizer types and rates effects on growth and yield response of soybean varieties. *Continental J. Agronomy* 5 (2): 1–8.

Van Reewijk L.P. 1992. *Procedures for Soil Analysis (3rd Edition).* International Soil Reference Center, Wageningen, Netherlands, 371p.

Verma J.P., Yadav J., Tiwari K.N. & Kumar A. 2013. Effect of indigenous Mesorhizobium spp. and plant growth promoting rhizobacteria on yields and nutrients uptake of chickpea (Cicer arietinum L.) under sustainable agriculture. Eco. Engin. 51:282–286.

Walelign Worku. 2015. Haricot Bean Production Guide, Scaling-Up Pulses Innovation For Food And Nutrition Security In Southern Ethiopia.1–23.

Walkley A. and Black C.A. 1934. An examination of different methods for determining soil organic matter and the proposed modification by the chromic acid titration method. *Soil Sciences*, 37: 29-38.

Weisany W., Raei Y. & Allahverdipoor K.H. 2013. Role of some of mineralnutrients in biological nitrogen fixation. *Bulletin of Environment, Pharmacology and Life Sciences*, 2(4):77–84.

Werner D. 1999. II Körnerleguminosen: Biologische Stickstoff-Fixierung. In: Handbuch desPflanzenbaues,Band 3. Knollen- und Wurzelfrüchte, Körner- und Futter leguminosen. E.R Keller, H. Hanus und K.-U. Heyland, Hrgs. Verlag Eugen Ulmer, Stuttgart, S.554-562.

Wortmann C. 2006. *Phaseolus vulgaris* L. (common bean). In: Brink, M. and Belay, G. (Ed). Plant resources of Tropical Africa1.Cereals and Pulses. PROTA foundation, Wageningen, Netherlands blackhuy Publishers, Leiden, Netherlands CTA, Wageningen, Nether and s. 146–151 pp.

Yoseph T., Baraso B. & Ayalew T. 2017. Influence of Bradyrhizobia inoculation on growth, nodulation and yield performance of cowpea varieties. African Journal of Agricultural Research, 12(22):1906–1913.

Zahran H.H. 1999. Rhizobium-Legume Symbiosis and Nitrogen Fixation under Severe Conditions and in an Arid Climate. *Microbiology and molecular biology Reviews*, 63(4): 968–989.

Zaidi A. & Mohammad S. 2006. Co-inoculation effects of phosphate solubilizing microorganisms and *Glomus fasciculatum* on green gram *Bradyrhizobium* symbiosis. *Agriculture Science*, 30, 223–230.

Zerihun A., Alemayo D. & Wolde-Meskel E. 2015. On farm yield responses of soybean [*Glycine max* L. (Merrill)] to fertilizer sources under different soil acidity status in Gobu Sayo District, Western Ethiopia. *Journal of Agronomy,* 14(1):30–36.

7. APPENDIXS

Appendix 1. **Experimental Varieties**

No	Variety	Seed color	Year of release	Released by
1	Hawassa Dume	Small Red	2008	SARI-HARC
2	Ibado	Red Mottled	2003	SARI-ARARC
3	Gegeba	Red mottled	2017	SARI-HARC
4	Rori	Small Red	2017	SARI-HARC

SARI= South Agricultural Research Institute, ARARC= Areka Agricultural Research Center, Hawassa Agricultural Research Center.

Appendix 2. Mean squares of ANOVA for growth, yield and yield components of common bean varieties as affected by Nitrogen Sources**.**

	Treatment					
	Rep	N-sources	Var	V*N	Error	CV
Df	2	3	3	9	30	(%)
Days to 50% flowering	0.02	40.13**	9.36**	0.89	2.30	3.4
Plant height(cm)	0.43	1683.6**	903.24**	90.8^{ns}	57.5	8.39
Number of branch plant^{-1}	0.09	2.54**	0.53**	0.034^{ns}	0.05	9.12
Leaf Area index	1.80**	5.32**	3.71**	0.19^{ns}	0.24	10.96
90 % Maturity date	4.78	142.36**	74.6**	12.46	11.57	4.0
Nodule number plant^{-1}	23.08	813.38**	98.33**	33.98**	12.15	13.36
Nodule dry weight g plant^{-1}	0.00	0.059**	0.01**	0.00^{ns}	0.00	12.14
Shoot dry weight g plant^{-1}	107.19	2509.01**	660.76**	63.82^{ns}	27.23	7.43
Root dry weight g plant^{-1}	2.10	55.05**	8.71**	2.83**	1.02	11.56
Pod number plant^{-1}	13.40	75.99**	102.76**	4.25^{ns}	7.98	11.29
Seed number plant^{-1}	0.26	7.44**	4.28**	0.13^{ns}	0.21	9.65
Hundred seed weight g plant^{-1}	2.53	615.34**	88.80**	31.04^{ns}	14.47	14.32
Grain yield t ha^{-1}	0.12	3.36**	1.39**	0.11^{ns}	0.073	12.12
Straw yield t ha^{-1}	0.16	2.76**	1.74**	0.44*	0.17	14.56
Dry matter t ha^{-1}	0.29	8.98**	2.09**	0.15^{ns}	0.34	13.25
Harvest index	0.00	0.01**	0.00**	0.00	0.00	9.67

Where: *, Significance level at 0.05%, **, Significance level at 0.01%, Rep = Replication, Var = Variety, CV= Cofiecinent Variation, Df = degree freedom

Appendix 3. Means of interaction of N sources x Varieties on nodule number plant^{-1} and nodule dry weight (NNPP&RDW)

NNPP				
	Variety			
N-sources	Hawassa Dume	Gegeba	Rori	Ibado
Control	17.6^{hi}	15.0^{i}	19.0^{ghi}	18.0^{ghi}
HB-429	41.0^{a}	29.6^{cd}	40.0^{a}	36.6^{ab}
46kgNha^{-1}	27.333^{de}	19.3^{ghi}	23.3^{efg}	21.0^{gh}
HB-429 +46kgNha^{-1}	33.6^{bc}	26.6^{def}	21.3^{fgh}	27.6^{de}
LSD(0.05) = 2.9				
RDW				
Control	6.6^{fg}	5.8^{gh}	4.7^{h}	7.3^{efg}
HB-429	7.7^{def}	10.3^{abc}	10.3^{abc}	10.9^{ab}
46kgNha^{-1}	6.06^{fgh}	8.9^{cde}	7.7^{def}	9.5^{bcd}
HB-429 +46kgNha^{-1}	11.03^{ab}	10.6^{abc}	10.8^{ab}	11.6^{a}
LSD(0.05) = 0.8				

Appendix 4**.** Means of interaction of N sources x Varieties on straw yield(SY)

	SY			
	Varieties			
N-sources	HawassaDume	Gegeba	Rori	Ibado
Control	2.2^{e}	2.4^{de}	2.14^{e}	2.6^{de}
HB-429	3.3^{bc}	3.4^{bc}	2.24^{e}	2.8^{cde}
46kgNha^{-1}	3.1^{bcd}	2.8^{cde}	2.68^{cde}	2.5^{de}
HB-429 +46kgNha^{-1}	4.5^{a}	3.6^{b}	2.6^{cde}	3.1^{bcd}
LSD(0.05) =0.4				

Appendix 5. Monthly average temperature and total rainfall of Meskan Woreda for the year 2018

Month	**Monthly average temperature ^{0}C**		**Monthly total rain fall (mm)**
	Maximum	Minimum	
January	25.0	11.5	26.3
February	27.2	12.0	47.5
March	26.7	10.8	107.5
April	26.0	11.7	227.6
May	25.9	10.9	64.4
June	24.8	12.3	170.9
July	23.7	10.5	146.2
August	24.1	10.5	227.6
September	25.5	10.8	76.4
October	25.5	8.3	49.7
November	26.4	9.1	16.7
December	26.7	5.7	0.7
Mean	**25.6**	**10.34**	96.79

Source: SNNPRS Meteorological Agency (SNNPRSMA, 2018)

BIOGRAPHICAL SKETCH

The author; **Meseret Shifa**, was born on September 29,1985 in Gurage, Southern Nation Nationalities and Peoples Regional State, Southern Ethiopia from his father Mr. Shifa Beshir and his mother Mrs. Elahush Degelo. He attended primary school at different school of vicinity and junior secondary education at Mekicho Elementary School and secondary education at Butajira High School. He completed secondary education in 2006. He joined Mizan ATVET College in 2002 and graduated with Diploma in 2004 in plant science. Upon graduation, he was employed by Meskan District Agriculture and Rural Development Office on June, 2007. Then he got a chance to join the Haramaya University in-service program because of good achievement of the tasks and graduated with Dgree of Bachelor of science (BSc) in plant science in 2012. After graduate he was joined to work as a senior expert in Meskan District on October 03, 2013 where he is working until now. In October 2018, he joined Hawassa University to pursue a postgraduate study leading to the Degree of **Master of Science** in plant science with specialization in **Agronomy**.