EFFECTS OF INOCULANT AND NPS FERTILIZER ON NODULATION, GROWTH AND YIELDS OF COMMON BEAN (*Phaseolus vulgaris* L.) VARIETIES AT BILATE ZURIA DISTRICT, SIDAMA REGIONAL STATE, ETHIOPIA

MSc THESIS

BY

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HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

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

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SCHOOL OF PLANT AND HORTICULTURAL SCIENCES

ADVISORS' APPROVAL SHEET -1

HAWASSA UNIVERSITY

(Submission sheet -1)

This is to certify that the thesis entitled **"Effects of inoculant and NPS fertilizer on growth, nodulation and yield of common bean (*Phaseolus vulgaris* L.) at Bilate Zuria district, Sidama regional state, Ethiopia"** Submitted in partial fulfillment of the requirements for the degree of **Masters of Science** with specialization in **Agronomy,** the Graduate Program of the **School of Plant and Horticultural Sciences,** is a record of original research carried out by **Enjamo Nagesso Sato** Id**.** No SGS/Agrok/131/08, under our supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this examination are accordingly acknowledged. Therefore, we recommend that it be accepted as fulfilling the thesis requirements.

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EXAMINERS' APPROVAL SHEET -1

(Submission sheet -2)

We, the under signed members of the Board of Examiners of the final open defense by Enjamo Nagesso , have read and evaluated his thesis entitled **"Effects of inoculant and NPS fertilizer on growth, nodulation and yield of common bean (*Phaseolus vulgaris* L.) at Bilate Zuria district, Sidama regional state, Ethiopia"**, and examined the candidate. This is therefore to certify that the thesis is accepted as partial fulfillment of the requirements for the degree Master of Science in Plant Sciences with specialization in Agronomy.

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Date

DEDICATION

I dedicate this thesis manuscript to my beloved father, Nagesso Sato and my beloved mother Kure Kuma who had always sought my success and have been supporting me towards it.

STATEMENT OF THE AUTHOR

I declare and affirm that 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 is put in the Hawassa University Library and is made available to users under the rules of the Library. I seriously declare that this Thesis has not been submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
ATA	Agricultural Transformation Agency
BNF	Biological Nitrogen Fixation
BoANR	Bureau of Agriculture and Natural Resources
CEC	Cation Exchange Capacity
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of United Nations
HARC	Hawassa Agricultural Research Center
LSD	Least Significant Difference
MoA	Ministry of Agriculture
RCBD	Randomized Complete Block Design
SARI	Southern Agricultural Research Institute
SAS	Statistical Analysis System
SNF	Symbiotic Nitrogen Fixation
SNNPR	Southern Nations Nationalities and Peoples Region
TSP	Triple Super Phosphate

TABLE OF CONTENT

Table of Contents Page

LIST OF TABLES

Table **page**

LIST OF FIGURES

Figure **Page**

LIST OF TABLES IN THE APPENDIX

Appendix **Page**

Effects of Inoculant and NPS Fertilizer on Growth, Nodulation and Yields of Common bean (*Phaseolus vulgaris* L.) Varieties at Bilate Zuria District, Sidama Regional State, Ethiopia

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ABSTRACT

Common bean (Phaseolus vulgaris L.) is a major grain legume grown and consumed in sub-Saharan Africa, including Ethiopia. It is the most important food legume, fodder and cover crop. However, its cultivation is globally constrained mainly by low soil fertility and lack of improved agronomic practices. Four common bean varieties (Ibaddo, Hawassa Dume, Omo-95 and Nasir were studied under three nutrient conditions (0kg ha^{-1},100 kg ha^{-1} NPS, Inoculation by strain HB-429) in three replication of randomized complete block design (RCBD) during the 2019 main cropping season (June to September). The objectives of the study were investigating the response these varieties to the three nutrient statuses in nodulation, growth, yield and yield components and investigating the variety X inoculant/fertilizer interaction in the same traits. There were significant differences between the four varieties in all traits (nodulation, growth, yield and yield components). Ibaddo had the highest grain yield (2.81 t ha^{-1}) while Hawassa Dume had the highest mean in yield (2.53 t ha^{-1}). The three fertilizer levels also differed significantly in all traits, 100 kg ha^{-1} NPS giving the highest means in all traits, while the control (no fertilizer application) had the lowest mean in all traits. Inoculation by rhizobium strain had intermediate mean of all traits. The variety X inoculant/fertilizer interaction was also significant for all traits except for nodule dry weight, leaf area index, shoot dry weight, grain yield, above biological yield and harvest index. Omo-95 variety had the lowest means in all traits except leaf area index, plant height, number of primary branches where ranks first, second and third. The highest net return (48325 ETB ha^{-1}) with acceptable marginal rate return (5993%) was obtained from Hawassa Dume variety with 100 kg NPS ha^{-1}followed by Hawassa Dume variety with strain HB-429 inoculation had net return of 41337 ETB ha^{-1} with 4895% marginal rate of return. This implies that the grower on the study area can gate additional benefit of 59.93 and 48.95 ETB for every 1 ETB expense by growing Hawassa Dume with the application of 100 kg NPS ha^{-1} and strain HB-429 inoculation, in that order. Moreover, the highest net benefits (37763.5) with MRR (%) of 3084 ETB and net benefits of 3935ETB with MRR (%) obtained from variety Ibaddo and Nasir grown with strain HB-429 and 100 kg NPS ha^{-1} fertilizer application. Therefore, use of both Hawassa Dume and Nasir varieties with 100 kg NPS ha^{-1} and Hawassa Dume and Ibaddo grown with strain HB-429 found to be economically feasible at the study area. However, verification of the result on farmers' fields across season and similar areas could be required before wide use of this study to put the recommendation in firm ground.

***Keywords**: Common bean, nodulation, NPS, Rhizobium, yield.*

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most important food legume, fodder and cover crop, and form nodules with a diversity of rhizobial genotypes (Sore and Habte, 2016). The crop originated in the highlands of Central and Southern America (Aguilar *et al.*, 2004). Nutritionally, its grains are rich in protein, carbohydrates, oil, fiber, and sucrose (Gebre-Egziabher *et al.*, 2014). Hence, the inclusion of common beans in the daily diet has several health benefits such as reduction of cholesterol, reduction of coronary heart diseases, favorable effects against, decrease diabetes and obesity, and high antioxidant capacity (Tarekegn Yoseph and Serawit Shanko, 2017).

Common bean grows in a wide range of agro-ecology and is adapted to temperate and cool tropical climatic conditions. It grows best in a warm climate at a temperature of 18 – 24^{o}C with an altitude of 1400 – 2000 m a.s.l. It requires about 300 to 400mm of water during its growth period. However, the lack of moisture, especially during flowering and seed filling, is detrimental to the final crop yield. Fageria & Baligar (1997), its good production occurs in areas where the temperature is around 21^{o}C. However, temperature extremes have significant effects on common bean growth and development. For instance, high temperatures (>30°C) can cause flower and pod abortion which reduces yield and it is intolerant of frost and short exposure to 0 °C or below kills its tissue (Fageria & Baligar, 1997). The crop is not suited to the very wet tropics; it prefers medium textured, well-drained soils with pH ranging between 6.0 and 7.5 (Walelign, 2015).

Common beans in Ethiopia are grown mainly by smallholder as an important food and cash crops. It is a legume that provides an essential part of most Ethiopians' daily diet and foreign income (Belessa, 2014). According to the CSA (2018) report, pulse covered 12.61 % (1,598,806.51 hectare of the grain land and contributed 9.7% (about 2,978,588.1 ton) grain. Among the pulse production, the common bean covered 216,803.91 hectares of the crop area and contributed to 372,766.49 tons of the pulse production in the country with 1.72 t ha^{-1} productivity (CSA, 2017/18). Under optimum growing conditions, the common bean can give grain yield up to 5 t ha^{-1}(Tarekegn *et al.,* 2017). However, in most African countries average yield of this crop is often less than 1.0 t ha^{-1}. This implies that the farm yield of common bean in Africa ranges far below its potential (Tarekegn and Shanko, 2017). Low crop yields are mainly due to low soil fertility, especially low soil N content, and lack of improved crop varieties (Tarekegn *et al.,* 2017).

There are several options that are available to manage soil fertility particularly soil nitrogen (N) in farmers' fields chemical fertilizers are often considered immediate solutions for current nutrient deficiency in the soil. Unfortunately, commercial inorganic fertilizers are very expensive and are inaccessible to most smallholder farmers in developing countries (Abaidoo *et al*., 2013). As a result, there is a need to find a cheaper source of N to improve crop productivity and increase food security. The expensive fertilizer cost can be cut down through the process of N_2-fixation by legume crops to meet their nutritional N needs. In addition N fixation they provide some nutrients leftover to succeeding crops through the decomposition of their nodules, shoots, and roots (Vanlauwe *et al*., 2014).

Soil nutrients play an important role in the growth and yield of legume crops, including common beans. In legume, N is more useful because it is the main component of amino acid as well as protein (Hussain *et al.,* 2011). Common bean growth and yield often benefited from the application of N fertilizer, and the added N often stimulates early bean growth, because the starter N applied to poor N soil is used to initiate nodule formation (Sore and Habte, 2016).

Phosphorus (P) is an important plant macronutrient, making up about 0.2 – 0.5% of a plant's dry weight and it is second only to N as the most limiting element for plant growth. It is a major growth-limiting nutrient, and unlike the case for N, there are no large atmospheric P sources that can be biologically available to the crops (Bashir *et al.*, 2011). It is known that inadequate P availability restricts root growth, the process of photosynthesis, translocation of sugars, and other such functions, which directly influence N_2-fixation, by legume plants (Abdul-Aziz, 2013). Symbiotic N_2-fixation has a high P demand because the process consumes large amounts of energy and energy-generating metabolism strongly depends upon its availability (Tang *et al*., 2001).

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of phosphorus (Ali *et al.*, 2008). Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. Sulphur nutrition of bean and other plants is important since its application not only increases growth rate but also improves the quality of the seed (Clarkson *et al.*, 1989). Total number of nodules and active nodules significantly increased with application of S up to 20 kg S ha^{-1} (Ganeshamurthy and Readly, 2000). Formation of nodules was increased due to Sulphur application in blackgram (*Phaseolus mungo*) and is involved in the formation of nitrogenase enzyme known to promote nitrogen fixation in legumes (Scherer *et al.*, 2006).

Inoculation with effective *Rhizobium* strains substantially increases the N_2-fixing potential and yields of legumes, including common bean. However, farmers have a wrong idea that the common bean, being a legume crop, does not need any nutrition and usually grows on marginal land without applying any fertilizer (Yoseph and Shanko, 2017). This constraint could be alleviated through seed and/or soil inoculation with the effective Rhizobium bacteria before or at planting time to facilitate N_2-fixation.

Bilate Zuria district is the area in Sidama Regional State where farmers grow common bean widely as a source of food, cash and also rotate and relay cropping with maize crops. In most parts of the area, the soil is poor in nutrient content and is deficient in essential plant nutrients for potential crop production including the common bean. To alleviate these constrain the inorganic fertilizers are considered as the immediate solution for the farmers. However, most farmers of the area cannot afford the cost of inorganic fertilizers. As a result, farmers apply these fertilizers below the national average, which reduces annual bean production year after year. Currently, there is limited information regarding the effect of NPS fertilizer and *Rhizobium* inoculation on common bean yield in the study area. Therefore, this study was conducted to evaluate the effect of inoculant and NPS fertilizer on growth, nodulation, and yields of common bean varieties in Bilate Zuria district, Sidama Regional State, Ethiopia.

Specific objectives

- To assess the effect of inoculant and NPS fertilizer on growth, nodulation and yield of common bean varieties in Bilate Zuria District.
- To investigate whether there is interaction between fertilizer treatments and varieties in growth, nodulation, yield and yield related traits of common bean.
- To determine the economic feasibility of the inoculant and NPS fertilizer application for common bean production in the study area.

2. LITERATURE REVIEW

2.1. Common bean Origin and Production status in Ethiopia

Common bean (*Phaseolus vulgaris* L.) is a member of the family Fabaceae, sub-family Papilionideae, tribe Phaseoleae, and genus *Phaseolus* (Debouck, 2002; McClean *et al.,* 2010). The crop originated from Central and South America, where it has been cultivated since 6000 BC in Peru and 5000 BC in Mexico. Currently, the common bean is the world's third most important food legume after soybean and peanut. It is currently cultivated on 31 million hectares worldwide, with an average yield of 0.8 to 1.3 t. ha^{-1} (FAO, 2015). 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, 2010).

Common beans were introduced to Ethiopia during the 16^{th} century. Since then, they have become the most important food and fodder crop (Gidago *et al.,* 2012). The total land area devoted to common bean production in the 2018/2019 cropping season estimated to be 288,637.23 ha, with a national production of 488,320.17 tons (CSA, 2018).

In Ethiopia, the common bean ranks third as an export commodity, contributing about 9.5% of the 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 to 0.8 t. ha^{-1}, which is much lower than the 4 t. ha^{-1} yield potential reported elsewhere (Beebe *et al.*, 2013). These low yields are attributed to the use of poor-quality seed, low soil N and P concentrations, drought, pest and disease incidences (Ndakidemi *et al.,* 2006).

Therefore, there is a need to identify common bean varieties with better agronomic practices that produce high grain yields in order to alleviate food insecurity among smallholder farmers in Africa.

2.2. Economic Importance and Utilization of Common Bean

In Ethiopia, common bean is mostly grown in small and medium-sized farms due to the small landholding of most of the farmers. Taking into account its nutritional value, the crop is rich in protein, carbohydrates, minerals, and vitamins. The common beans can have a protein content of up to 40%, but the meat is approximately 20%, which is not easily affordable for poor farmers. Common bean is suitable for crop rotation where it can be successfully grown with crops such as maize or cassava and is in high demand both in local and international markets. In addition to this, it is also important in providing fodder for feeding livestock and contributes to soil fertility improvement through atmospheric N_2-fixation during the cropping season (David, 2016).

When common bean economic importance is considered, it is used as a source of foreign currency, food crop, means of employment, source of cash, and plays a great role in diversifying the farming system (CSA, 2016). According to Gezahegn and Dawit (2006), common beans cover the bulk of Ethiopia's grain export, which contributes about $134 million to the country's economy. The export amount increased from 51 to 171 tons during the same period, which is about 41% among the other pulses (FAO, 2015). In addition, its early maturity, adaptation to different environments, wide geographical diversity, and high nutritional value of grains, green leaves, and young pods together make common beans an ideal crop to fight food insecurity in Africa, including Ethiopia (USAID, 2012). Furthermore, the inclusion of common bean in the daily diets has been shown to reduce blood cholesterol levels (Rosa *et al.*, 1998), coronary heart diseases, diabetes and obesity (Mitchell *et al.*, 2009), and the incidence of cancer in humans (Oomah *et al.*, 2005).

2.3. Agro-Ecological Requirement of Common Bean

Common beans are suitable for tropics, subtropical and warm temperate regions climates and can grow from 40°S to 40 °N latitude (ICTA, 2000). The length of the growing season varies from 85 – 115 days, but this depends on a cultivar type and night temperatures during the growing season. It grows optimally at temperatures of 18 – 24 °C. The maximum temperature during flowering should not exceed 30 °C. Day temperatures below 20 °C would delay maturity and cause the development of empty mature pods. Common beans grow in non-acidic and well-drained soil. The pH values should be within the range of 6.0 – 7.5 and not below 5.0 and above 8.0 (Walelign, 2015).

In Ethiopia, it grows at an altitude of 1400 and 2000 meter above sea level, in an area which receives an annual rainfall of 350 to 1100 mm. It requires about 300 to 400 mm of water during its growth period. Common bean is susceptible to both scarcity and excess moisture (EIAR, 2014). Moisture stress is very critical, especially during the flowering and pod filling stages, and can directly affect the final yield of the crop (Walelign, 2015).

2.4. Biological Nitrogen Fixation

Biological Nitrogen Fixation (BNF) is an efficient source of N and it is the process whereby atmospheric nitrogen (N=N) is reduced to ammonia in the presence of nitrogenase enzyme (Biomate, 2008; Ferris & Laganzi, 2008). Hence, the relationship between leguminous plants and rhizobia help to fix atmospheric N_2 symbiotically (Shridhar, 2012). In general, these interactions are based on the specific identification of signal molecules produced by bacterial and plant partners (Spaink, 2000). According to the study of Rascio and Rocca (2008), it is was estimated that 80 – 90% of the N available to plants in the natural ecosystem is derived from BNF. The total annual terrestrial inputs of N from BNF range from 139 – 175 million tons of N, with symbiotic associations growing in arable land accounting for 25 – 30% and permanent pasture accounting for another 30% (Sarioglu *et al.,* 1993). This underlines the significance of legume symbioses in cropping systems as a major contributor to BNF. However, a number of factors affect BNF's contribution to legumes production during the cropping season.

2.4.1 Factors Affecting Biological Nitrogen Fixation

Nitrogen fixation, along with photosynthesis as the energy supplier, is the basis of the soil environment under a constant state of change and, as such, can be relatively stressful for both macro-and micro-organisms. Fluctuations in pH, nutrient availability, temperature, and water status, among other factors greatly influence the growth, survival, and metabolic activity of N_2- fixation bacteria and plants, and their ability to enter into symbiotic interactions (Werner and Newton, 2005).

2.4.1.1 Soil pH

The influence of soil pH is one of the main environmental factors that interrupt the symbiotic association between *Phaseolus* and *Rhizobium* (Graham, 1982). Legume and rhizobial growth are affected by soil pH. Most leguminous plants require a neutral or only a slightly acid soil pH for growth with nodulation problems to be expected once the pH falls below 5.5 (Bordeleau and Prévost, 1994). The optimum pH range for rhizobial growth is between 6.0 and 7.0 (Graham *et al*., 2004). In soils with pH below 5.0 aluminum and manganese become an additional stress which could kill the rhizobia (Drew *et al*., 2012). According to Vassileva *et al*. (1997), low soil pH of 4.0 - 4.5 extremely reduced nodulation and nitrogenase activity of common bean. On the other hand, Sulieman *et al.* (2009) discovered that failure of nodulation in common bean due to high calcareous soil which prevailed at pH of 8.1 and 8.5 in the top soil and subsoil, respectively.

2.4.1.2 Soil nutrient

Soil nutrient conditions have a significant impact on symbiosis and independent growth and survival of both partners. Therefore, N_2-fixation tends to decrease with legume age, mainly because of the associated increase in soil N. A negative exponential relationship is observed between N fertilizer rate and N_2-fixation when N is applied to the soil surface. Thus, heavy soils with excessive N and poor aeration can affect the nodule formation. Legume plants need macronutrients such as N and P more than any other mineral element. However, these nutrients are deficient in most agricultural soils (Walelign, 2015). Thus, it is required to supply the plants with the application of additional fertilizers.

2.4.1.3 Soil temperature

Temperature has a marked influence on the survival and persistence of rhizobial strains in soils. Hence, the process of symbioses such as root hair infection, bacteroids differentiation, nodule structure, and functioning are affected directly by temperatures (Mohammadi *et al.*, 2012). For instance, high soil temperature is associated with delaying or restricting nodulation in the sub-surface region (Graham, 1992). The optimal temperature for nodule functioning in the common bean is between 25 – 30°C, but is disadvantaged by root temperatures between 30 – 33°C. Similarly, Michiels *et al.* (1994), reported that the acetylene reduction activity of common bean plants was strongly diminished at 35°C when plants were inoculated by heat-sensitive or heat tolerant strains. In another way, continually cool root zone temperature can significantly delay the onset of nitrogen fixation compared to an optimum soil temperature (Abendroth *et al.*, 2006). However, Surange *et al.* (1997) isolated highly temperature tolerant strains (50°C) of *Rhizobium* nodulating leguminous trees from tropical soils.

2.4.1.4 Soil water content

Soil water influences the growth of soil microorganisms and plants. Thus, symbiotic fixation of atmospheric nitrogen (N_2) is sensitive to even modest soil water deficits (Katerji *et al.,* 2011). Drought-related inhibition of N_2-fixation seriously limits legume yield in many arid and semi-arid regions of the world. Three major factors are proposed to be involved in drought effects on BNF: Oxygen limitation, carbon shortage, and regulation by N metabolism (Ladrera *et al.,* 2007). The decline of N_2-fixation with soil drying causes yield reduction of common bean due to inadequate N for protein production, which is the critical seed product (Sinclair *et al.,* 1987).

Generally, higher N_2-fixations at the pod filling stage found to have higher yield under water stress than those having low N_2-fixation (Pimratch *et al.,* 2008). This suggested that maintaining high N_2-fixation under drought stress could be a means for a legume genotype to achieve high yield under water-limited conditions.

2.4.1.5 Rhizobial competition

Crop responses to inoculation with selected strains of *Rhizobium* are often low, frequently due to the high competitive ability of native strains (V´asquez-Arroyo *et al*., 1998). Indigenous soil rhizobia might differ in population density and infectivity from place to place ranging from < 10 to 107 cells g^{-1} of soil (Abdula, 2013). Where naturalized rhizobia are fewer, absent, the introduction of new strains by seed, or soil inoculation is normally successful (Campo and Hungria, 2004). On the other hand, where large populations of naturally occurring *rhizobia* exist, inoculation is invariably fruitless. At intermediate levels of naturalized *rhizobia* (10–1000 g^{-1} of soil), competition between naturalized and introduced *rhizobia* for nodule formation is of practical concern. These include the ability to colonize the soil and tolerate environmental stresses, the ability to compete for nodule formation with indigenous population of rhizobia, and the capacity to form effective nodules that fix-N. Rhizobia strains differ widely in their ability to survive, nodulate and fix-N in the soil environment; thus, strain selection plays a major part in its survival and infective ability (Campo and Hungria, 2004).

2.5 Effect of NPS Fertilizer on Growth, Nodulation and Yield Components of common bean

Among the nutrients, nitrogen is the critical limiting element for growth of most plants including common beans due to its unavailability and poor fixation (Vance, 2001). Deficiency in N causes reduced growth, leaf yellowing, reduced branching and small trifoliate leaves in common beans (CIAT, 1998). According to Dakora and Keya (1997), grain legumes fix about 15 - 210 kg N ha^{-1} seasonally in Africa. However, common bean is said to be a poor fixer of N in comparison to other legumes with rates as low as 20 kg N/ha (Manrique *et al.,* 1993). Common bean N fertilizer requirement depends on soil fertility levels; for low soil nitrogen levels (below 34 kg N $ha^{-1)}$, N fertilizer is generally recommended in order for deficiency symptoms not to manifest and for full development up to production. Moreover, up to 60 kg N ha^{-1} also promotes increased nodule number, mass and size, giving highest yields (Dwivedi *et al.*, 1994). However, nitrogenase activity declines with applied nitrogen (Davis and Brick, 2009), decreasing the sink strength, and hence, reduce the quantity of photo-assimilate partitioned to nodules and grain. Early application may also result in excessive vegetative growth leading to delayed flowering, reduced pod set, lower seed yield and a greater risk of disease infestation (Setegne and Leggese, 2003).

The application of inorganic phosphorus fertilizer has positive effect on the yield and yield components of common bean. Rana and Singh (1998) discovered that grain weight per plant exhibited a pronounced response to phosphorus application, mean values of grain weight per plant records of 13.0, 17.4 and 20.7 g due to phosphorus fertilization of 0, 50 and 100 kg P_2O_5 ha^{-1}, respectively. Veeresh (2003) observed significant increase in grain weight per plant (8.65 g) due to P application up to 75 kg P_2O_5 ha^{-1}. Dwivedi *et al.* (1994) also reported linear increase in the number of grains pod^{-1} of common bean due to increase in phosphorus fertilization from 50 to 150 kg P_2O_5 ha^{-1}, but the differences were not significant beyond 100 kg P_2O_5 ha^{-1}. Saxena and Verma (1994) reported that the mean number of grains per pod linearly increased from 5.53 to 7.50 due to increased phosphorus fertilization from 0 to 120 kg P_2O_5 ha^{-1}.

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of phosphorus (Ali *et al.*, 2008). Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. Sulphur nutrition of bean and other plants is important since its application not only increases growth rate but also improves the quality of the seed (Clarkson *et al.*, 1989). Total number of nodules and active nodules significantly increased with application of S up to 20 kg S ha^{-1} (Ganeshamurthy and Readly, 2000). Formation of nodules was increased due to Sulphur application in blackgram (*Phaseolus mungo*) and is involved in the formation of nitrogenase enzyme known to promote nitrogen fixation in legumes (Scherer *et al.*, 2006).

2.6 Effect of *Rhizobium* Inoculation on Growth, Nodulation and Yield Components of common bean

According to Zerihun (2017), significantly higher active nodule number and plant tissue dry weights were recorded from application of ‘rhizobium inoculants’ and phosphorus fertilizer, which resulted in more than 69% nodulation and 62% dry matter accumulation compared to the untreated controls.

Farmers in many parts of the world have received dramatic increases in yields due to inoculating their legumes (Cigdem and Merih, 2008). Inoculation of seeds by *Rhizobium spp.* prior to planting has also been reported to be a key factor in enhancing nodulation, early emergence, crop vigor and high grain yield (Otieno *et al.,* 2009). The study conducted by Mbugua *et al.* (2009), on effects of commercial *Rhizobium* strain inoculants and triple superphosphate fertilizer on yield of new dry bean lines in central Kenya showed that bean seeds inoculated with *Rhizobium* strain had higher daily germination count, crop vigor, number of seeds per pod and grain yield as compared with those of un-inoculated crops.

Furthermore, Bambara and Ndakidemi, (2010) who reported high seed yield of 1679 kg ha^{-1} with inoculated common bean compared to 758 kg ha^{-1} from the unfertilized treatment. These authors further indicated that higher yields were obtained with inoculation confirm that the *Rhizobium* technology is efficient in supplying nitrogen to legumes and is a better option for resource-poor farmers who cannot afford to purchase expensive inputs.

However, the findings of these two studies were contrary to those of Musandu and Ogendo, (2001) who stated that there was no significant difference observed in yield and yield components of common bean between inoculated and uninoculated crops. According to Silva and Uchida, (2000) negative results were associated with inoculation failure due to loss of viability of Rhizobia in the inoculant caused by exposure to heat or prolonged storage, environmental and management factors. Inoculation effectiveness was also reduced when soil nitrogen sources are high enough to meet the crop nitrogen requirements or soils have many native Rhizobia that can infect the plant and fix nitrogen for the crop.

3. MATERIALS AND METHODS

3.1. Description of the Study Site

A field experiment was conducted at Bilate Zuria district Kitawo Danbe Kebele, Sidama regional state during 2019 cropping season. The district was located at latitude 06°56'00"N and longitude 36°16'00" E, with an elevation of 1915 meters above sea level. The soil of the site was clay soil in type and clay loam in texture and dark black in colour. The study site has a bi-modal rainfall pattern which means the rain comes twice a year in Belg and meher season with an average annual rainfall of 1,181 mm and a mean temperature 23.5°C. The Belg rain was starts from February to April while, Meher rain was starts from June to August. The field trial was conducted at meher season from June and November 2019. The field had no known history of '*Rhizobium* inoculation' in earlier cropping seasons and planted in maize.

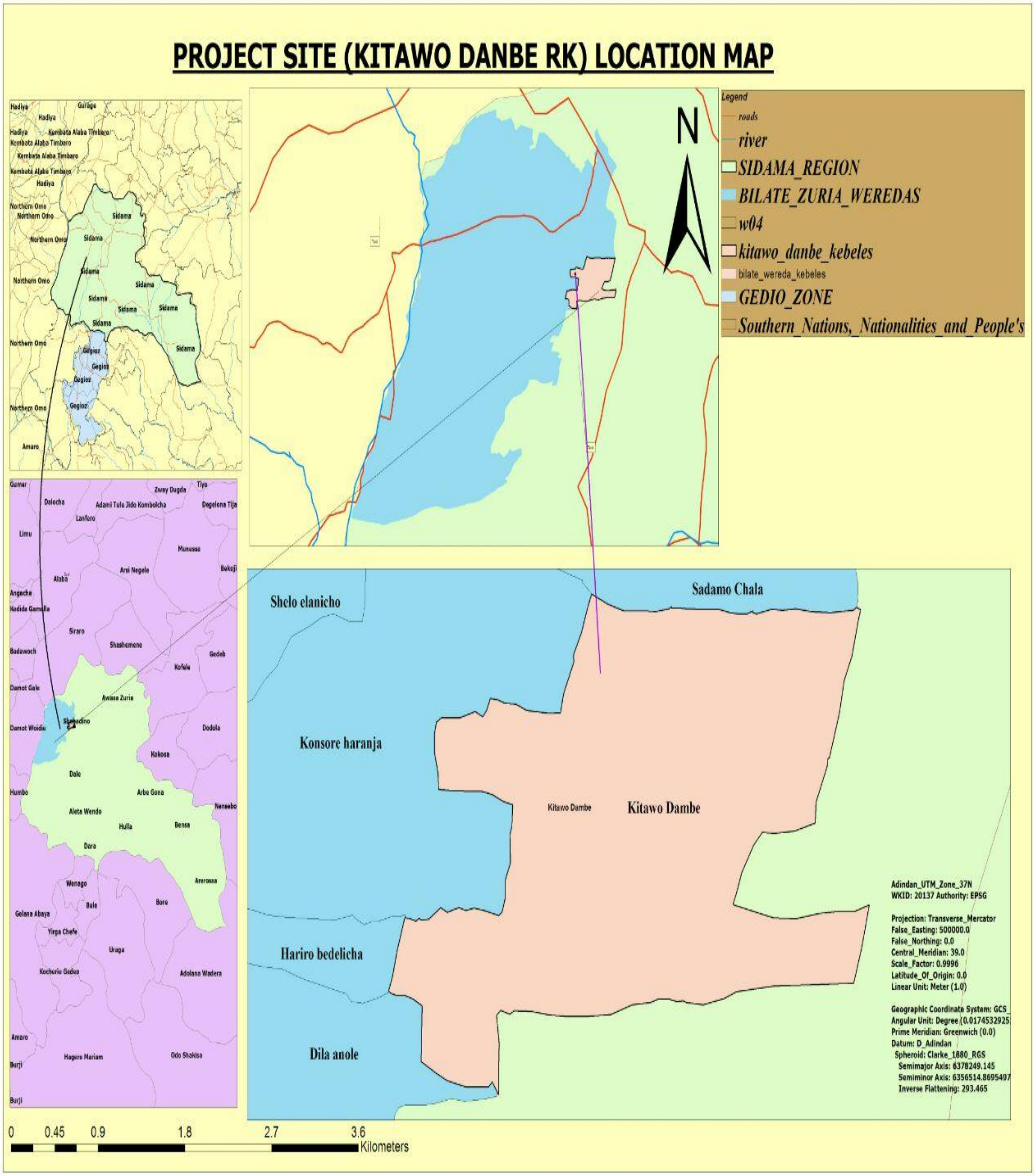

Figure 1: Administrative Map of the Study Area (Source BOA, 2019)

3.2 Source of Planting Material and Rhizobium Strain

The common bean varieties (namely Ibaddo, Hawassa Dume, Omo-95, and Nasir) were used in this experiment were obtained from the Hawassa Agriculture Research Centre. These four varieties were selected based on their high grain yield production capacity, farmers' acceptance, and seed availability. The commercial *Rhizobium strain* (HB-429) was obtained from Menagesha Agricultural Input Enterprise, PLC Addis Ababa. The NPS fertilizer was obtained from Bilate Zuria district cooperative.

3.3 Treatment used (Experimental Design and Procedure)

The experiment was laid down in a factorial arrangement using a randomized complete block design (RCBD) with three replications. The treatments included three fertilizers (0kgNPS, 100 kg NPS, Inoculant) and four varieties (Ibaddo, Hawassa Dume, Omo-95, Nasir). Thus, the experiment consisted 12 treatments that were repeated three times with 36 plots. The composition of NPS that used during experiment was $19N+38P_2O_5+7S$ = 19-38-0-7. These nutrients have their own role of energy Storage and transfer. For example: Nitrogen had - NO_3^-, NH_4^+ (nitrate, ammonium) amino acids, proteins, nucleic acids. Phosphorous had - $H_2 PO_4^-$ (orthophosphate); ATP, ADP, NADPH, DNA, RNA and Sulfur had - $SO_4^{- -}$ (sulfate); amino acids, proteins, enzyme activation roles. The area of each experimental plot was 2m x 2.8m (5.6 m^2) and spaces between plants, rows, plots and blocks were 0.1, 0.4, 1.0 and 1.5m, respectively.

3.4 Seed Inoculation

Seeds were inoculated with a peat based inoculants of *Rhizobium* strain HB-429 at the rate of 10 g kg^{-1} of seeds and were applied to the moistened seeds. The inoculation was done just before planting under shade to maintain the viability of the bacterial cells. Seeds were allowed to air dry for 5 minutes before planting to avoid fungal growth (EIAR, 2003).

3.5 Experimental field management

The experimental field was prepared using oxen, and the plots were leveled manually. Seeds were planted on June 16 during the 2019 cropping season. The NPS fertilizer treatments were applied fully at sowing time by using the basal application method. The experimental field was weeded three times during the growing season. The first weed started after 25 days from planting to avoid competition during the early stage of crop growth. The second weeding was undertaken one month later and finally, the third weeding was undertaken one month later. To reduce the risk of cross-contamination the control plots (without *Rhizobium* inoculation) were weeded first followed by those treatments that receive inoculant. Thinning after germination was done to maintain the population density of plants in each plot.

3.6 Soil Analysis

About 1 kg pre-sowing surface soil sample was collected from different spots of the experimental field at the depth of 0 – 20 cm using Augur and was bulked together to get a representative composite soil sample. Then, air-dried and crushed thoroughly and packed in a polythene bag, labeled and transported to soil laboratory for analysis of the selected parameters. The determined parameters were soil textural class (sand, silt and clay), soil pH, total N, organic carbon, available P, Cation exchange capacity (CEC) and exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{2+} and K^{2+}) were analyzed following the standard procedures.

Analysis of organic carbon content of the soil in a laboratory was determined by Walkley and wet oxidation method as described by Jackson (1958) and total N by Kjeldhal method as described by

Dewis and Freitas, (1975). The pH of the soil was measured in water at soil to water ratio of 1:2.5 (Page, 1982). Cation exchange capacity was determined using Kjeldhal procedure as described by Ranist *et al*. (1999). Available P was determined according to the methods of Olsen and Dean (1965). Soil texture analysis was performed by Bouyoucous hydrometer method (Day, 1965).

3.7 Data Analysis

3.7.1 Economic Analysis

Mean grain yield of the treatments was used in partial budget analysis (CIMMTY, 1988). The field price of 1 kg of common bean that farmers receive from sale for the crop was taken as the market price of the crop at Balela market near the experimental site. The gross benefit was calculated as 10% adjusted grain yield (kg ha^{-1}). The total variable cost includes the cost of NPS, strains, and labor as the sum of all costs that were variable or specific to treatment against the 0 kg NPS treatment. Dominance analysis and marginal rate of return (%) were used to evaluate the economic performance of treatments and net return was calculated by subtracting total variable cost from the gross benefit.

The MRR (%) is given by equations: MRR (%) = ($\triangle$NB/$\triangle$TVC) x100

Where : $\triangle$NB = Change in net benefit that was obtained on experiment

$\triangle$TVC = Change in total cost that was invested on experiment

MRR = Marginal Rate of Return expressed in percent

The minimum acceptable rate of return was set at 100 % CIMMYT (1988).

3.7.2 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using the Statistical Analysis System Software (SAS, 2002) version 9.1.3. Significant treatment means were compared using the least significant difference test (LSD) at a 5% probability level. Correlation analysis was done using Pearson's simple correlation coefficients for the intended parameters.

3.8 Data Collection

3.8.1 Nodulation and growth parameters

Nodulation assessment: five plants were randomly selected from next to the border rows of both sides at the mid flowering stage. The roots were uprooted carefully with the bulk of root mass and nodules. The nodules were separated from the soil by washing on a metal sieve and the total number of nodules was determined by counting and then the averages of the five plants were taken as the number of nodules plant^{-1}.

Nodule dry weight plant^{-1} (g): after determination of nodule number, nodules were dried in an oven at 70°C for 48 hours to determine nodule dry weight and the average of the five plants was taken as nodule dry weight plant^{-1}.

Plant height (cm)*:* five plants from the central rows of each plot were randomly selected for measuring plant height at the mid flowering stage. Then the average values of these plants were recorded as the plant height of the crop.

Leaf area index*:* the leaf area was measured from five randomly selected plants from the central rows of each plot at the mid flowering stage. The average of the five plants leaf area taken as the leaf area of the plant and the leaf area index calculated using the formula.

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

Shoot dry matter (g): It was determined at the mid flowering stage of the crop from the five plants that were sampled for nodule determination. The samples were placed in labeled perforated paper bags and oven-dried for 48 hours at 70^{o}C to constant weight as described by Jones (2001) to determine the shoot dry matter plant^{-1}. Their averages were recorded as shoot and root dry matter plant^{-1}.

3.8.2 Yield and yield components

Number of primary branches plant^{-1}: the number of primary branches was determined by counting the average number of primary branches from the main stem from the five randomly selected plants plot^{-1} at physiological maturity. The average of the five plants branch number was taken as the number of primary branches plant^{-1}.

Number of pods plant^{-1}: the total number of pods from the five randomly selected plants was counted at the time of harvest and recorded as the number of pods plant^{-1}.

Number of seeds pod^{-1}: from the above-counted pods plant^{-1}, the total number of seeds was threshed and counted to determine the average number of seeds pod^{-1}.

Hundred seed weight: hundred seeds weight was counted from the harvested bulk of seeds per net plot and their weight (g) were determined at the seed moisture content of 10% by using a sensitive balance.

Grain yield: the three central rows were harvested manually and threshed to determine grain yield plot^{-1} and the average yield was reported in ton ha^{-1}.

Above ground total biomass: at harvest, plants from three central rows were manually harvested. The harvested plant straw was sun-dried on open air until constant weight attained and weighed to determine above-ground total biomass yield and the average above-ground total biomass yield reported in ton ha^{-1}.

Harvest index: the harvest index was calculated as the ratio of grain yield to above ground total biomass yield.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Total above ground biological yield}} * 100$$

4. RESULTS AND DISCUSSION

4.1. Soil Physico-Chemical Properties of the Study Area

The results of pre-planting soil analysis revealed that the soil of the study area is clay loam in texture (24% sand, 40% silt and 36% clay). Although the soil texture is not under the control of farmers, it influences soil Physico-chemical properties. It is also closely related to the water-holding capacity of soils since loam and clay soils hold more water than do sandy soils (Brady, 2002). Therefore, the soil around the study site has good water retention capacity and creates a good growing media for beans.

The soil was slightly acidic with the pH (H_2O 1:2.5) value of 5.8, which is within the range of optimum for legume production including common bean (Walelign, 2015). The total N, available P, organic carbon (OC), CEC and the exchangeable cations (Ca, Mg, Na, and K) of the soil before planting were 0.15%, 3.2 mg kg^{-1}, 3.2%, 45.12, 1.64, 1.84, 0.87, and 0.15, cmol (+) kg^{-1}, respectively (Table 1). According to Landon (1991) soils are classified depending on their total N content in percentage (%), as very low (<0.1), low (0.1 – 0.15), medium (0.2 – 0.5), high (0.5 – 1) and >1 very high. Thus, the soil of the study site has low total N content. Olsen *et al*. (1954) classified available P content in the range < 5 as very low, 5 – 15 as low, 15 – 25 as medium and > 25 mg kg^{-1} as high, based on this the study site had very low available soil P. According to Landon (1991), the soil organic carbon content ranges of 1 – 2, 2 – 4, and 4 – 6% are rated as low, medium and high, respectively. Thus, the OC content of the soil is considered as medium 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 (45.12 cmol kg^{-1}) before planting was within the high range.

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

pH (H_2O) (1:2.5)	OC (%)	Total N (%)	Available P mg kg^{-1}	CEC cmol/kg^{-1}	Exchangeable cations cmol/kg^{-1}				Textural class
					Ca^{2+}	Mg^{2+}	Na^{2+}	K^{+}	
5.8	**3.2**	**0.15**	**3.2**	**45.12**	**1.64**	**1.84**	**0.87**	**0.15**	**Clay loam**

4.2. Effect of Inoculant/NPS fertilizer on Nodulation of Common bean Varieties

4.2.1. Number of nodules plant^{-1}

Analysis of variance indicated that the effect of varieties and fertilizer was highly significant ($P \leq$ 0.001) difference on number of nodules plant^{-1}.The Variety X NPS/Inoculant effect also highly significant difference on number of nodules plant^{-1}(Appendix Table 1).

Regarding the main effect of varieties, the highest nodule number plant^{-1} was recorded from the Hawassa Dume variety followed by Ibaddo and Nasir. However, the variety Omo-95 produced the lowest number of nodules plant^{-1} (Table 2). The observed differences in nodule number among the common bean varieties could be attributed due to genotypic differences. In line with these results, Habtamu *et al*., 2017 and Mamaru *et al*., 2018 also reported that there are differences among common bean cultivars grown at Melkassa and Alage. Similarly, Tarekegn *et al.* (2017) also reported marked differences among cowpea varieties on nodule number plant^{-1}.

Among inoculant/fertilizer effects, the highest numbers of nodules plant^{-1} were produced from plants inoculated by *Rhizobium* strain HB-429, which is at par with the application of 100kg NPS ha^{-1}. However, the lowest nodule number plant^{-1} was recorded from the control (Table 2). The increased nodules due to Rhizobium inoculation could be associated with the efficiency of introduced Rhizobia to compete with indigenous bacteria dwelling in the soil. These results are in line with the findings of Tesfaye *et al.* (2018); Tarekegn and Walelign (2014) who reported that *Rhizobium* inoculation with effective strains significantly enhanced the nodule number of soybean varieties. On the other hand, the increase in the number of nodules at the recommended rate of NPS fertilizer application might be due to the vital role of N, P and S in increasing the number and size of the nodule and the amount of N assimilated per unit of nodules (Scherer *et al.,* 2006; Shumi, 2018; Bashir *et al.,* 2011).

Regarding the interaction effects, the highest number of nodule plant^{-1} was recorded from Ibaddo variety when fertilized with 100kg NPS ha^{-1}. However, the highest nodule numbers were recorded for the varieties Hawassa Dume, Nasir and Omo-95 with *Rhizobium* strain HB-429 inoculation followed by the application of the recommended NPS fertilizer. In general, the lowest number of nodules plant^{-1} in all varieties was recorded from the control (Figure 2). The differences among the varieties due to inoculant/fertilizer treatments revealed that the varietal difference in making the symbiosis with the inoculated strain. In agreement with this result, Tesfaye *et al.* (2018) reported that the varietal differences in response to applied treatments.

Table 2: Effect of inoculant/ NPS fertilizer on nodulation of common bean varieties at Bilate Zuria district, Sidama Regional State, Ethiopia, during 2019 cropping season

Parameters	Nodule number plant^{-1}	Nodule dry weight (g)
Variety		
Ibaddo	28.7±1.17^{b}	0.32±0.02^{a}
Hawassa Dume	29.41±0.55^{a}	0.29±0.02^{a}
Omo-95	17.10±0.23^{d}	0.21±0.01^{b}
Nasir	19.73±0.61^{c}	0.22±0.01^{b}
LSD.05	0.33	0.05
Inoculant/NPS fertilizer		
0 kg NPS	19.11±0.72^{b}	0.20±0.01^{b}
100 kg NPS ha^{-1}	26.02±1.34^{a}	0.23±0.01^{b}
Strain HB-429	26.10±0.95^{a}	0.35±0.02^{a}
LSD.05	0.29	0.04
CV (%)	1.44	19.71

Mean Values followed by dissimilar letters in a column are significantly different at *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$

4.2.2. Nodule dry weight plant^{-1}

The effect of varieties and inoculant/NPS fertilizer was found to be highly significant ($P \leq 0.001$) on nodule dry weight plant^{-1}. However, their interaction was not significant ($P \geq 0.786$) the nodule dry weight plant^{-1} (Appendix Table 1).

The highest nodule dry weight was recorded from the varieties Ibaddo and was at par with the Hawassa Dume variety (Table 2). However, the lowest nodule dry weight plant^{-1} was recorded from the varieties Omo-95 and Nasir. The observed differences on nodule dry weight plant^{-1} among the four common bean varieties could be attributed to inherent genotypic differences. The result is in line with the findings of Tarekegn *et al.* (2017) who reported that there was a marked difference among the cowpea varieties on nodule dry weight plant^{-1}.

Inoculation with *Rhizobium* strain HB-429 significantly increased nodule dry weight over the application of NPS fertilizer and the control (Table 2). The observed difference in the nodule dry weight due to inoculation over other treatments may be attributed to the size of the nodules. Inoculated plants produced bigger nodules than the control due to the effectiveness of the introduced *Rhizobium* strain to initiate nodulation with common bean roots. In line with this result, Tarekegn *et al.* (2018) also reported a similar promoting effect of seed inoculation on dry weight of nodules plant^{-1}. Similarly, several other researchers also reported the promoting effect of seed inoculation with effective rhizobial strains (Bhuiyan *et al.*, 2008; Dereje, 2007; Tarekegn and Shanko, 2017). According to Fatima *et al.* (2006), high nodule dry weight can be generally a prerequisite for increasing N_2-fixation in legumes rather than a number of nodules.

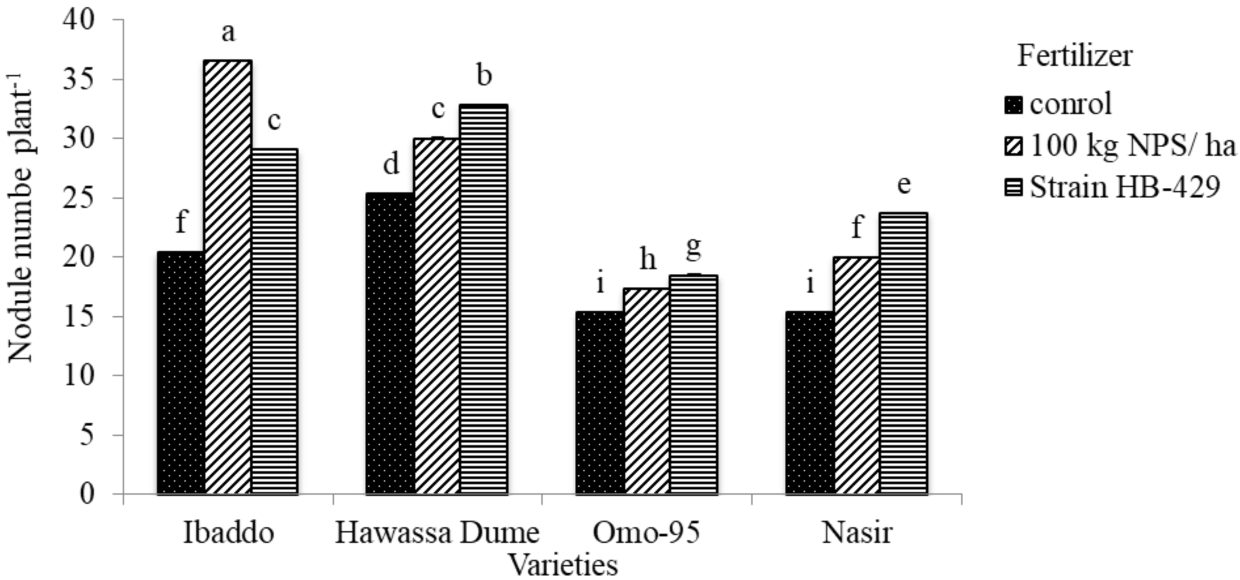

Figure 2: The interaction effect of variety x inoculant/NPS fertilizer on number of nodules plant^{-1}. Letters on the top of bars represent mean values.

4.3. Effect of Inoculant/NPS fertilizer on Growth parameters of Common bean Varieties

4.3.1. Plant height

The analysis of variance indicated that the main effects of variety and inoculant/NPS fertilizer had highly significant ($P \leq 0.001$) effects on plant height of common bean varieties. Likewise, the interaction effect of variety and inoculant/NPS fertilizer was also significant ($P \leq 0.001$) differences on plant height (Appendix Table 1) indicating different response of variety x Inoculant/NPS fertilizer.

Regarding the main effect of the variety, the tallest plant was recorded from the variety Ibaddo. However, the shortest plant height was recorded from the variety Hawassa Dume (Table 3). 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 Samago *et al*. (2017) who reported a marked variation between varieties in plant height due to the genetic makeup of the varieties as well as environmental factors.

Regarding the main effect of inoculant/NPS fertilizer, the tallest plant was recorded from the application of 100 kg NPS ha^{-1} followed by the *Rhizobium* inoculated plants. Whereas, the shortest plant was recorded from the control (Table 3). The increase in plant height in response to the blended NPS fertilizer application may be attributed due to the maximum vegetative growth of the plants under applied N, P, and S availability. Similarly, the increased plant height under inoculation could be due to the increased vegetative growth with N_2-fixation. This result is similar with the findings of Farkhand *et al.* (2019); Shumi (2018) who reported that the improved plant height due to applied NPS fertilizers.

Interestingly the inoculant/NPS fertilizer application revealed a marked effect on plant height of common bean varieties. The tallest plant height was recorded from the variety Omo-95 with the application 100 kg NPS ha^{-1}. However, the shortest was recorded from the Hawassa Dume variety followed by Nasir and Omo-95 varieties without inoculant/NPS fertilizer (Figure 3). In general, regardless of the variety inoculant/NPS fertilizer application resulted in relatively better plant growth over the control. The improved plant height due to the applied treatments might be attributed due to the availability of plant nutrients for growth. For instance, N helps in chlorophyll formation, P establishes strong root system and S enhanced the formation of chlorophyll and encouraged vegetative growth (Halvin *et al.,* 2003). This result is in line with the report of Halvin *et al.,* (2003), who stated that plant height of soybean was increase with blended NPS fertilization in the presence of *Rhizobium* inoculants.

4.3.2. Leaf area index

The analysis of variance indicated that the variety and inoculant/NPS fertilizer application had very highly significant ($P \leq 0.001$) effects on leaf area index. Whereas, the interaction effect of variety and inoculant/NPS fertilizer did not show significant effect on leaf area index (Appendix Table 1).

Among the varieties, the highest leaf area index was recorded from varieties Ibaddo followed by the variety Omo-95. However, the lowest leaf area index was recorded from the variety Nasir (Table 3). The higher leaf area index of Ibaddo and Omo-95, which is superior to other varieties, may be attributed due to the genetic makeup of these varieties. The increased leaf area index is also due to the size of the leaf, which is directly responsible for the increase in photosynthesis. Similarly, the studies conducted by Mesfin *et al*. (2014) indicated that an existence of the genetic differences among the common bean varieties on leaf area index.

Significantly higher mean leaf area index was obtained from application of 100 kg NPS ha^{-1} followed by the *Rhizobium* strain HB-429 inoculation. While the minimum leaf area index was recorded from the control (Table 3). The increase in LAI due to adequate NPS fertilization could be elaborated in terms of possible increase in nutrient mining capacity of plant as a result of better root development and increased translocation of carbohydrates from source to sink in adequate NPS fertilized treatments (Bashir *et al*., 2011; Makoi *et al*., 2013). This result is in line with that of Shahid *et al.* (2009) who reported that application of adequate amount of NPS resulted in markedly increase on leaf area index of soybean plants. On the other hand, the increment on LAI with *Rhizobium* inoculation could be explained in terms of the effectiveness of the introduced strain to fix atmospheric N which in turn enables the common bean to full fill its N requirement which is expressed in higher leaf area index compared to the un-inoculated treatment. Similar finding was reported by Tahir *et al*. (2009) who indicated that inoculation with effective *Rhizobium* brought a significant effect on leaf area index of legumes.

Table 3: Effect of inoculant/ NPS fertilizer on growth parameters of common bean varieties at Bilate Zuria district, Sidama Regional State Ethiopia, during 2019 cropping season

Parameters	Plant height (cm)	Leaf area index	Shoot dry weight (g)
Variety			
Ibaddo	45.71±0.28[a]	5.54±0.028[a]	9.95±0.015[a]
Hawassa Dume	42.08±0.65[c]	4.85±0.024[c]	9.83±0.014[b]
Omo-95	44.20±0.65[b]	5.49±0.019[b]	8.94±0.013[d]
Nasir	43.45±0.35[b]	4.68±0.018[d]	8.98±0.014[c]
LSD	1.3	0.04	0.04
Inoculant/NPS fertilizer			
0 kg NPS	41.05±0.36[c]	5.00±0.066[c]	9.35±0.079[c]
100 kg NPS ha^{-1}	46.74±0.30[a]	5.30±0.069[a]	9.53±0.081[a]
Strain HB-429	43.77±0.43[b]	5.13±0.066[b]	9.41±0.082[b]
LSD	1.12	0.03	0.03
CV	3.02	0.8	0.43

Mean Values followed by dissimilar letters in a column are significantly different at *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.001$.

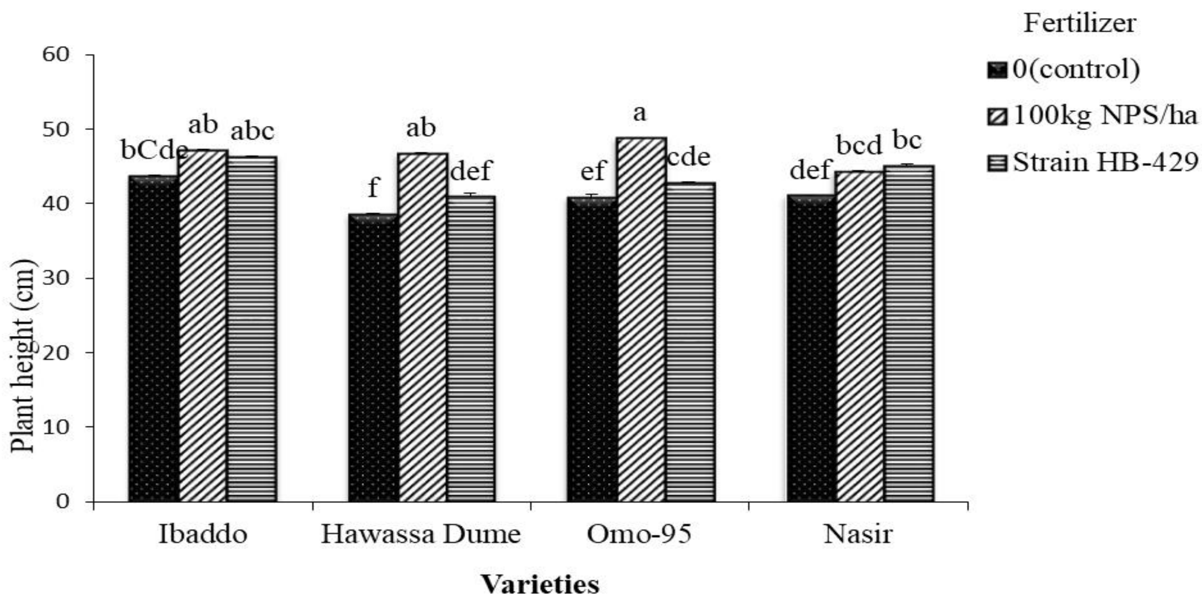

Figure 3: The interaction effect of variety x inoculant/NPS fertilizer on plant height. Letters on the top of bars represent mean values.

4.3.3. Shoot dry weight

Plant growth parameters measured as shoot dry weight was highly significantly ($P \leq 0.001$) affected by the main effect of variety and inoculant/NPS fertilizer. Whereas, their interaction effect did not bring significant effect on shoot dry weight (Appendix Table 1).

The highest shoot dry weight was recorded from Ibaddo variety followed by Hawassa Dume. However, the lowest shoot dry weight was recorded from Omo-95 variety (Table 3). The observed differences on shoot dry weight plant^{-1} among the four common bean varieties could be attributed to the difference in genotypic variations of the varieties. The result is in line with the findings of Tarekegn *et al.*, (2017) who reported that marked differences among the cowpea varieties on shoot dry weight plant^{-1}.

Concerning the effect of inoculant/NPS fertilizer on shoot dry weight, application of 100kg NPS ha^{-1} exhibited the highest shoot dry weight followed by *Rhizobium* strain HB-429 inoculation. Whereas, the lowest shoot dry weight was recorded from the control treatment (Table 3). The marked increased in shoot dry weight in response to NPS application might be attributed to the increased availability of NPS in the soil for uptake by plant roots, which may have sufficiently enhanced vegetative growth through increasing cell division and elongation (Sara *et al*., 2013). Similarly, the highest shoot dry weight on soybean reported due to supply of optimum NPS rates over the control (Tesfaye *et al.*, 2017). Similarly, *Rhizobium* inoculation with strain HB-429 gave higher shoot dry weight $plant^{-1}$ over the control. The observed benefits on common bean by *Rhizobium* inoculation seem to be due to the supply of N to the crop through symbiotic N_2-fixation (Togay *et al*., 2008). The study conducted by Mbugua *et al.* (2009) on effects of commercial *Rhizobium* strain inoculants and TSP fertilizer on yield of new dry bean lines in central Kenya showed that bean seeds inoculated with *Rhizobium* strain had higher daily germination count, crop vigour, number of seeds per pod and grain yield as compared with those of un-inoculated crops.

4.4. Effect of Inoculant/NPS fertilizer on Yield and Yield Components of Common bean Varieties

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

The analysis of variance indicated that the main effects of variety and inoculant/NPS fertilizer had significant ($P \leq 0.001$) effects on number of primary branches $plant^{-1}$. Likewise, the interaction effect of variety and inoculant/NPS fertilizer also revealed highly significant ($P \leq 0.01$) differences on the number of primary branches $plant^{-1}$ (Appendix Table 1).

The highest number of primary branches plant^{-1} was obtained at the combination of varieties Ibaddo and Hawassa Dume both with 100 kg NPS ha^{-1} fertilizer. However, the lowest number of primary branches plant^{-1} was obtained at combination of variety Nasir with the control (Figure 4). Regardless of the varieties, application of the treatments (inoculant/NPS fertilizer) resulted in improved number of primary branches plant^{-1} than the control. The increased number of primary branches observed under inoculation and NPS fertilizer application attributed to readily available form of N, P, and S that enhanced uptake of nutrients even at the initial stage of crop growth. In line with this result Asrat (2013) reported that a maximum branch plant^{-1} due to the application of optimum NPS fertilizer. The result was also in agreement with the finding of Jawahar *et al.* (2017) who reported that application of S containing fertilizer recorded highest number of branches plant^{-1} in blackgram. Moreover, *Rhizobium* inoculation and application of NPS fertilizer produced higher number of primary branches than the control treatment; which might be due to higher vegetative growth of the plants under higher N availability via NPS fertilizer and BNF. This result was in line with report by Mfilinge *et al*. (2014) who reported that inoculation of chickpea with *Rhizobium* in field significantly increased number of primary branches plant^{-1}. Similarly, Moniruzzaman *et al.* (2008) also reported that the number of branches plant^{-1} of common bean increased significantly due to application of N containing fertilizer. Furthermore, the observed differences on primary branches plant^{-1} among cultivars might be attributed due to inherent genetic variation. In line with this result Habtamu *et al.* (2017) also reported the marked differences among common bean varieties for number of branches plant^{-1} under the field experiment.

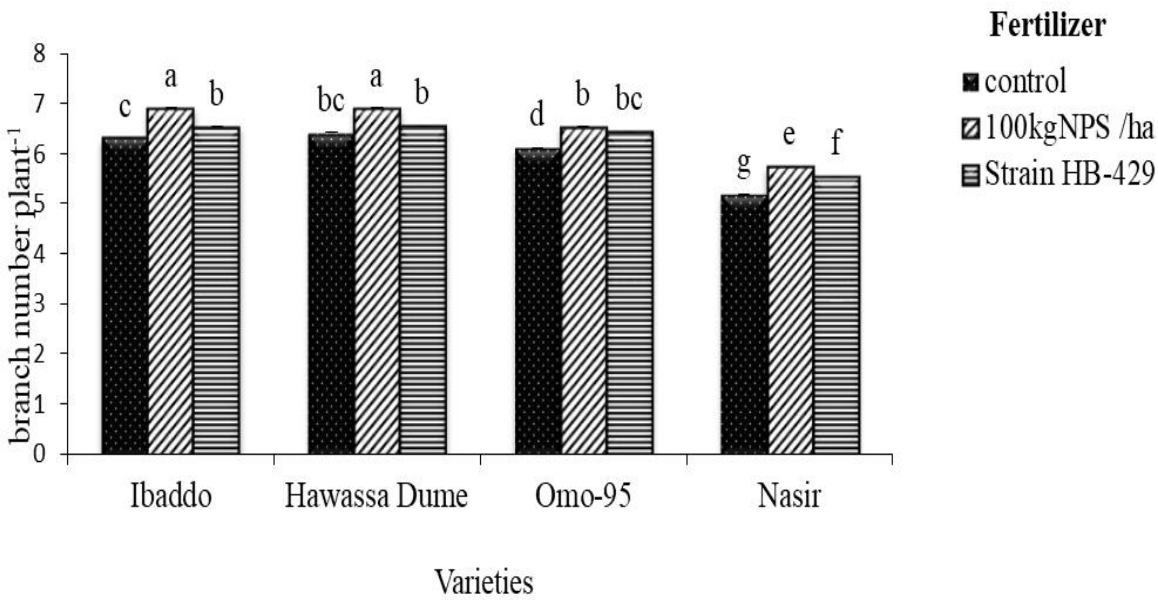

Figure 4: The interaction effect of variety x NPS fertilizer on branch number plant^{-1}. Letters on the top of bars represent mean values.

4.4.2. Number of pods plant^{-1}

The analysis of variance revealed that the main and interaction effects of variety and inoculant/NPS fertilizer had highly significant effect on the number of pods plant^{-1} (Appendix Table 1).

Regardless of the inoculant/NPS fertilizer, Hawassa Dume variety produced more number of pods plant^{-1}. Whereas, the variety Omo-95 produced the lower number of pods plant^{-1}. The varieties Ibaddo and Nasir produced almost similar number of pods plant^{-1} (Figure 5). The result is in agreement with the work of Tarekegn *et al.* (2017) who reported marked differences among the cowpea varieties on pod numbers plant^{-1}. In line with this result, different authors reported significant variations in the number of pods plant^{-1} for common bean varieties (Fageria *et al.*, 2010; Mourice and Tryphone, 2012). Similarly, among all the tested varieties the applied treatments resulted in higher number of pods plant^{-1}. This result indicates the need to use the right amount of

NPS fertilizer and effective rhizobia to get more pod plants^{-1}. The increment of the number of pods plant^{-1} due to the application of P containing fertilizer confirms the fact that P fertilizer promotes the formation of nodes and pods in legumes (Buttery, 1969). In agreement with this result, Dereje *et al.* (2015) also found that the number of pods plant^{-1} of common bean significantly increased in response to the increasing rate of P supplying fertilizers. On the other hand, Jawahar *et al.* (2017) reported that application of S containing fertilizers recorded the highest number of pod plant^{-1} of legume crops. This could be due to the increasing levels of S application enhanced its availability to the crop and increase photosynthetic activity of crop.

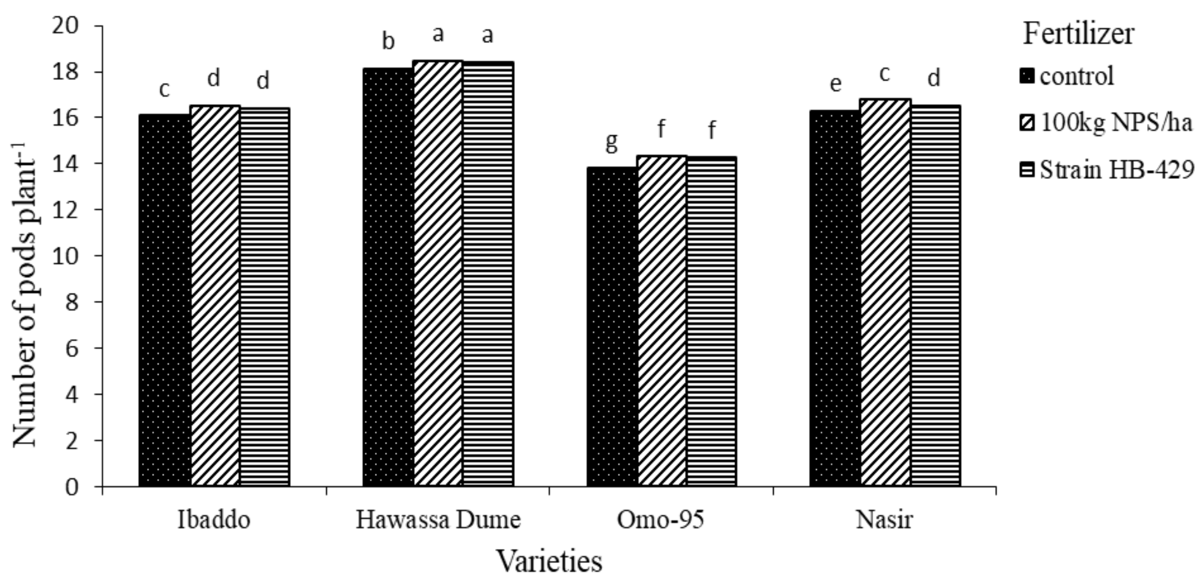

Figure 5: The interaction effect of variety x NPS fertilizer number of pods plant^{-1}. Letters on the top of bars represent mean values.

Table 4: Effect of inoculant/ NPS fertilizer on yield and yield components of common bean varieties at Bilate Zuria district, Sidama Regional state Ethiopia, during 2019 cropping season

Treatments	**Number of primary branches plant^{-1}**	**Number of pods plant^{-1}**	**Number of seeds pod^{-1}**	**Hundred seed weight (g)**	**Grain yield (t.ha^{-1})**	**Total biomass yield (t.ha^{-1})**	**Harvest index**
Variety							
Ibaddo	6.59±0.044[a]	16.33±0.033[c]	5.50±0.05[b]	34.65±0.06[a]	2.25±0.09[a]	4.11±0.04[a]	0.83±0.02[a]
Hawassa Dume	6.62±0.037[a]	18.34±0.027[a]	6.33±0.08[a]	28.85±0.36[b]	2.00±0.07[b]	3.89±0.03[b]	0.78±0.01[ba]
Omo-95	6.36±0.034[b]	14.14±0.039[d]	4.93±0.07[c]	20.65±0.04[d]	1.91±0.07[c]	3.58±0.04[c]	0.66±0.01[c]
Nasir	5.49±0.040[c]	16.54±0.037[b]	6.24±0.04[a]	25.13±0.04[c]	1.92±0.066[c]	3.63±0.03[c]	0.75±0.01[b]
LSD	0.05	0.08	0.33	0.8	0.13	0.1	0.07
Inoculant/NPS fertilizer							
0 kg NPS	6.01±0.085[c]	16.09±0.26[c]	5.58±0.12[b]	26.83±0.90[b]	1.50±0.015[c]	3.59±0.04[c]	0.71±0.01[b]
100 kg NPS ha^{-1}	6.53±0.084[a]	16.52±0.25[a]	6.01±0.11[a]	27.87±0.91[a]	2.52±0.033[a]	4.04±0.04[a]	0.78±0.02[a]
Strain HB-429	6.26±0.073[b]	16.40±0.25[b]	5.65±0.10[b]	27.27±0.91[ba]	2.03±0.045[b]	3.79±0.05[b]	0.76±0.02[a]
LSD	0.04	0.07	0.29	0.68	0.12	0.08	0.01
CV	0.74	0.52	5.91	2.97	6.77	2.59	9.42

Mean Values followed by dissimilar letters in a column are significantly different at *: $P \leq 0.05$; **: $P \leq 0.01$; ***: $P \leq 0.00$

4.4.3. Number of seeds pod^{-1}

The result concerning number of seeds pod^{-1} revealed that there were highly significant ($P \leq 0.001$) differences among common bean varieties and inoculant/NPS fertilizer. Interaction among varieties and inoculant/NPS fertilizer was also significant ($P \leq 0.05$) (Appendix Table 1).

Among the common bean varieties, the highest number of seeds pod^{-1} was recorded from Hawassa Dume variety which was at par with Nasir. However, the lowest was recorded from Omo-95 variety (Table 4). This result is consistent with Mamaru *et al.* (2018), who reported a significant difference in the number of seeds pod^{-1} due to varietal differences.

Regarding the main effect of inoculant/NPS fertilizer application, the highest number of seeds pod^{-1} was recorded from the application of recommended rate of NPS fertilizer. However, the lowest number of seeds pod^{-1} was recorded from the control, although it was statistically at par with the inoculation of strain HB-429 (Table 4). The increase in numbers of seed pod^{-1} due to the application of recommended NPS fertilization could be explainable in terms of possible increase in nutrient mining capacity of plant because of increased translocation of carbohydrates from source to growing points. This result is in line with that of Shahid *et al.* (2009) who reported that application of adequate amount of NPS and rhizobium inoculation resulted in markedly increase in the yield of soybean plants.

The variety x inoculant/NPS fertilizer interaction showed higher number of seeds pod^{-1} in Hawassa Dume variety with the application of 100 kg NPS ha^{-1} fertilizer. Similarly, application of recommended NPS fertilizer showed better performance for all varieties than the other treatments. Regardless of the inoculant/NPS fertilizer application, the variety Omo-

95 produced fewer seeds pod^{-1} than the other varieties (Figure 6). The improved seeds pod^{-1} due to applied treatments over the control revealed that the important roles of these essential nutrients to improve seed production, which in turn improve the final yield of the crop.

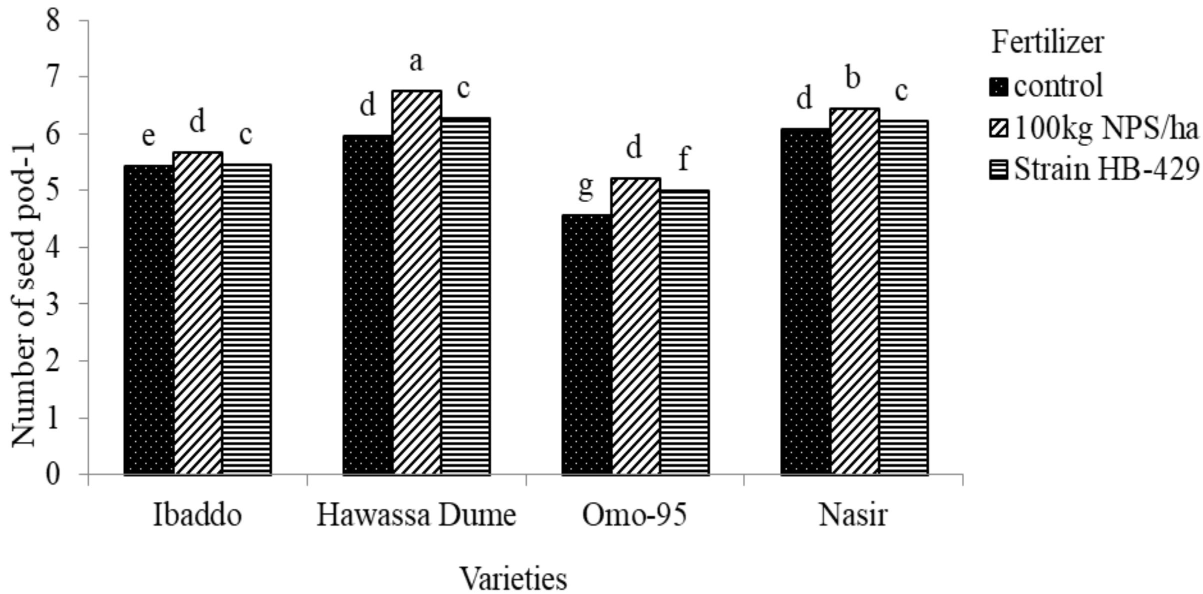

Figure 6: The interaction effect of variety x inoculant/NPS fertilizer on number of seed pod^{-1}. Letters on the top of bars represent mean values.

4.4.4. Hundred seed weight

The analysis of variance indicated that both variety and inoculant/NPS fertilizer had highly significant effect on hundred seed weight. Likewise, their interaction also revealed highly significant ($P \leq 0.001$) effects on hundred seed weight (Appendix Table 1).

Among the tested varieties the heaver hundred seed weight was produced from the variety Ibaddo followed by variety Hawassa Dume. While, the lowest hundred seed weight was produced by Omo-95 variety (Table 4). The heavier seed weight of Ibaddo and Hawassa Dume varieties over other varieties might be attributed due to the genetic makeup of these varieties which might lead to increased photosynthesis and accumulations of carbohydrates. Moreover, the observed variation in hundred seed weight among the varieties might be due to the presence of difference in seed size among the common bean varieties as hundred seed weight increases with increase in the seed size. In line with this result, Hawtin *et al*. (1980) reported the heaver seed weight from the larger seed size. Similarly, Tessema and Alemayehu (2015) also reported that the differences in hundred seed weight among common bean varieties.

Among the inoculant/NPS fertilizer, application of 100 kg NPS ha^{-1} produced the heaver seed weight followed by *Rhizobium* strain HB-429 inoculation. However, relatively the lowest hundred seed weight was recorded from the control (Table 4). Increased hundred seed weight as a result of *Rhizobium* inoculation and NPS fertilizer application could be attributed due to the availability of N,P and S for flowering and seed formation through N_2-fixation and applied NPS fertilizer. Similar to this result Habtamu *et al.* (2017); Fageria *et al.* (2010), reported that an increased seed weight of common beans due to *Rhizobium* inoculation and mineral fertilizer application.

The interaction results revealed that relatively higher hundred seed weight from Ibaddo supplied with 100kg NPS fertilizer followed by *Rhizobium* strain HB-429 inoculation. Of the varieties tested the lowest hundred seed weight was recorded from the variety Omo-95 with and without inoculant/NPS fertilizer application (Figure 7). This indicates that the existence of varietal differences on producing the heavier or lighter seeds even if the optimum plant nutrients applied. Similarly, the studies conducted by Glen *et al.* (2006) also indicated greater genetic effect on grain size over environmental effect even when experimental sites suffered terminal moisture stress.

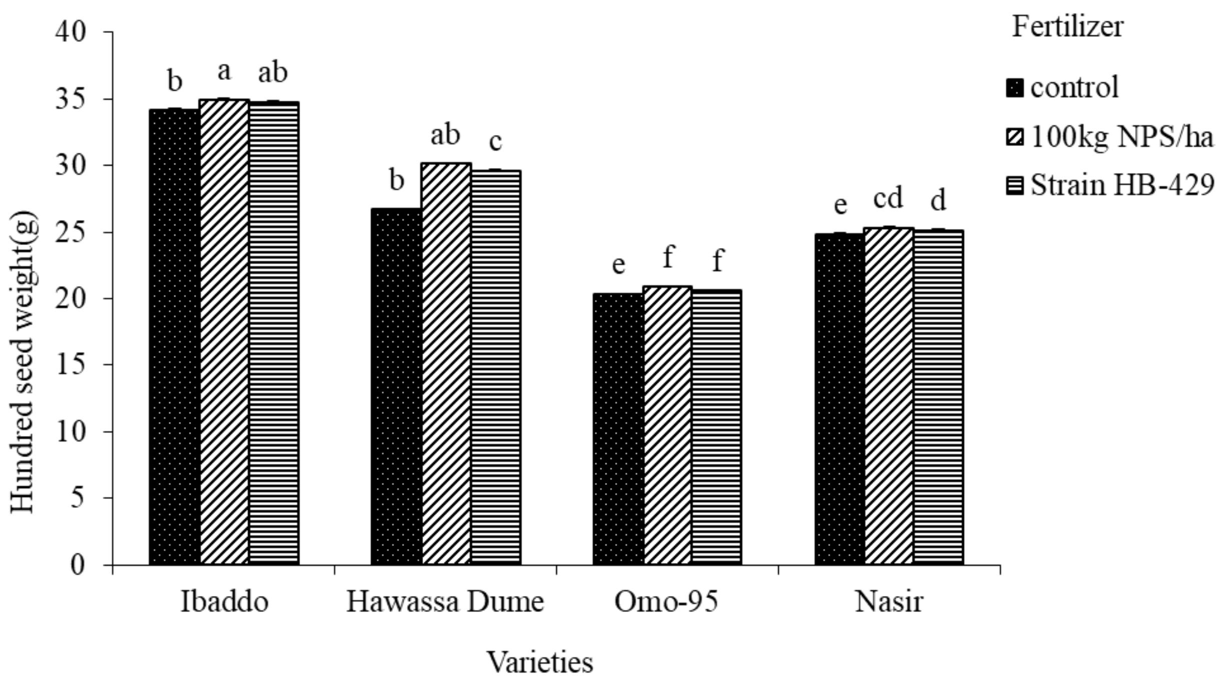

Figure 7: The interaction effect of variety x inoculant/NPS fertilizer on hundred seed weight (g). Letters on the top of bars represent mean values.

4.4.5. Grain yield

The grain yield was significantly ($P \leq 0.001$) affected due to the main effects of varieties and, inoculant/NPS fertilizer application. However, their interaction did not show a significantly ($P \geq 0.172$) effect on grain yield (Appendix Table 1).

Among the varieties, the highest grain yield was recorded from the Ibaddo variety followed by Hawassa Dume. However, the lowest grain yield was recorded from the varieties Omo-95 and Nasir (Table 4). The higher grain yield recorded for the variety Ibaddo was due to its ability to produce more pods, as well as higher hundred seed weight, which increased its economic yield. The higher grain yield could also be attributed to the better plant growth of Ibaddo variety. The result in line with finding several authors signifies that there was significant difference among common bean cultivars on grain yield (Gebre-Egziabher *et al*., 2014; Tarekegn and Serawit, 2017). Similar to this result Haruna and Usman (2013) observed a significant variation in grain yield of some improved varieties of cowpea at the same location and attributed to genetic makeup of the varieties examined (Mourice and Tryphone, 2012; Mulugeta, 2011). Negash and Rezene (2015) reported improved grain yield with a higher level of NPS.

Concerning the inoculant/NPS fertilizer, the application of 100kg NPS ha^{-1} fertilizers to common bean, resulted in higher grain yield followed by the *Rhizobium* strain HB - 429 Inoculation. However, the lowest grain yield was recorded from the control (Table 4). Increased grain yields due to 100kg NPS ha^{-1}, might be attributed due to the development of more extensive root system and thus enabling plants to extract water and nutrients from more depth. This could enhance the plants to produce more assimilates, which was reflected in higher biomass. In line with this result, adequately available of N, P and S to the legumes enhanced plant growth; promote nodulation, early maturity and grain formation (Shahid *et al*., 2009; Tarekegn *et al*., 2017). On the other hand, the increased grain yield due to *Rhizobium* inoculation might be attributed to the effectiveness of the inoculant in fixing N thereby meeting the nutrient requirement of the plant for better plant growth (Nyoki and Ndakidemi, 2014). Furthermore, comparable results were obtained by Bambara and Ndakidemi (2010) who reported high common bean seed yield of 1.68 ton ha^{-1} with inoculated crop compared to 0.76 ton ha^{-1} from the control. A similar promoting effect of *Rhizobium* inoculation on grain yield of common bean has also been reported by Tarekegn *et al*. (2017). Similar to this finding Shahid *et al*. (2009) reported that grain production of soybean crop can increase by 70-75% when the proper *Rhizobia* strains are used for inoculation. However, the findings of the present studies were contrary to those of Musandu and Ogendo (2001) who stated that there was no significant difference observed in yield and yield components of dry bean between inoculated and un-inoculated crops.

4.4.6 Total biomass

The analysis of variance indicated that the variety and inoculant/NPS fertilizer application had very highly significant ($P \leq 0.001$) effects on total biomass. Whereas the interaction effect of variety and inoculant/NPS fertilizer did not show significant effect on total biomass (Appendix Table 1).

Among the varieties tested, the highest and lowest biomass weight was recorded from Ibaddo and Omo-95 varieties, correspondingly. The observed difference in biomass weight among the common bean varieties may be due to the genetic difference in translocation and partitioning efficiency of assimilates from source to sink. Similarly, Tessema and Alemayehu, (2015) reported that the differences in above ground biomass among common bean varieties.

Application of inoculant/NPS fertilizer to common bean crop markedly increased the total biomass (Table 4). Application of 100kg NPS ha^{-1} provided the heaver total biomass when compared to *Rhizobium* and control treatments (Table 4). This result is in line with that of Fageria *et al*. (2010) who reported that application of adequate amount of NPS fertilizer resulted in marked increase in total biomass weight of common bean plants. This result was in conformity with the findings of Getachew and Angaw, (2006) who reported a significant linear response of total biomass to phosphorus application in faba bean on acidic Nitisols. This result was also similar with that of Agegrew and Fessehaie, (2006) and Tadesse, (2012) who reported a linear response of bio-mass to P and Sulphur in common bean plants.

4.4.7 Harvest index

The analysis of variance indicated that common bean varieties and inoculant/NPS fertilizer were significantly ($P \leq 0.001$) affected the Harvest Index. However, their interaction was not significantly ($P \geq 0.98$) affected Harvest Index (Appendix Table 1).

The physiological ability of a crop plant to convert proportion of dry matter into economic yield measured in terms of harvest index. Among the varieties, Ibaddo exhibited greatest harvest index. Hawassa Dume exhibited medium value of harvest index while Omo-95 variety showed the lowest value (Table 4). The observed difference related with genotypic difference and directly linked to productivity or partitioning capacity of the crop.

Significant difference also observed on harvest index among fertilizers. The application of 100kg NPS ha^{-1} and strain HB-429 gave highest mean value of harvest index, equally; while the lowest was from control plots (Table 4). The results indicated that adequate supply of N through biological N_2-fixation enhanced dry matter partitioning in favor of grain showing a greater harvest index. Similar to these Roy *et al.* (1995) reported that soybean seeds inoculation increased harvest index.

4.5 Correlation Analysis

The correlation analysis result of the present study (Appendix Table 2) showed that grain yield significantly and positively correlated with all of the parameters tested except seeds pod^{-1} and pods $plant^{-1}$. Moreover, the correlation of grain yield was strong and highly significant ($P \leq 0.001$) with total biomass (r = 0.83***), plant height (r = 0.75***), number of nodules $plant^{-1}$(r = 0.57***) and harvest index (r = 0.68***) .The result of these relations showed that the increased grain yield is the function of positively and significantly related parameters (Appendix Table 2). Similarly, total biomass was significantly associated and positively correlated with all parameters tested. However, the relations were strong with shoot dry weight(r = 0.77***), number of nodules plant^{-1} (r = 0.77***), and hundred seed weight (r = 0.75***). This implies that the increase in the shoot dry weight and seed weight resulted due to improved vegetative growth and better light use efficiency of the plant which might help it to increase the photo assimilate production and partitioning to different parts. Similarly, shoot dry weight and seed weight were correlated positively and strong (r = 0.88***).

Harvest index was positively correlated with nodule number (r = 0.61***), Nodule dry weight (r = 0.62***), Shoot dry weight(r = 0.63***), number of pods plant $^{-1}$ (r = 0.54***), number of seed pod^{-1}(r = 0.54***), hundred seed weight (r = 0.68***), grain yield(r = 0.51***) and total biomass(r = 0.76***). These relations reveals that, an increase in nodule number, nodule dry weight, and shoot dry weight, number of pods plant^{-1}, number of seeds pod^{-1}, seed weight, grain yield and total biomass increased the harvest index.

4.6 Partial Budget Analysis for Experimental Site

From the result of this study, the mean yield of all 12 treatments tested obtained. According to CIMMYT (1988), the average yield was adjusted down ward by 10%. This is the reason that, the researcher has assumed that using the same treatments, the yield from experimental plots and farmers field is vary, thus average yield obtained from the treatment tested should be adjusted down ward. Net benefit was calculated by current NPS fertilizer cost of 10.46 ETB kg^{-1}, *Rhizobium* strain HB-429 0.45 ETB g^{-1}, Labor cost to apply fertilizer ha^{-1} was 1000 ETB and that of applying rhizobia strain HB-429 was 250 ETB and adjusted as treatments^{-1}

receiving the fertilizers. Seed price of common bean varieties varied due to their color, palatability and cook ability and related preference. Accordingly, the seed prices of a kilo of Nasir, Hawassa Dume, Ibaddo, and Omo-95 grain were 22.50 ETB, 25.00 ETB, 27.25 ETB and 21.00 ETB, in that order. According to the economic analysis data (Table 5), all marginal rates were above 100% that is in a rage of acceptance (CIMMYT, 1988). According to the budget summary of economic analysis, the highest net return (48325ETB ha^{-1}) with acceptable marginal rate of return (5993%) was obtained from Hawassa Dume variety with 100 kg NPS ha^{-1} followed by Hawassa Dume variety with HB-429 strain inoculation. This had net return of 41,337ETB ha^{-1} with marginal rate of return 4895 %. This implies that the grower on the study area can get additional benefit of 59.93 and 48.95 ETB for every 1 ETB expense by growing Hawassa Dume with the application of 100 kg NPS ha^{-1} and inoculation of strain HB-429, in that order. On the other hand, growing Ibaddo and Nasir with HB-429 gave the highest marginal rate of return (3084%) that is 37763.5 ETB net benefits and (3493%) ETB with 31547 net benefits with inoculation of strain HB-429. This implies that grower on the study area can get additional benefits 30.84 and 34.93 ETB for every 1 ETB expense by growing Ibaddo and Nasir with strain HB -429 inoculation. Additionally, variety Nasir gave the high net benefits of 36339 with marginal rate of return (3935%) by application of 100kg NPS ha^{-1}. Common bean growing farmers in the study area and similar agro ecology can gate additional benefit of 39.35 ETB for every 1 ETB investments. Therefore, use of Hawassa Dume and Nasir varieties with 100 kg NPS fertilizer ha^{-1} application and varieties Ibaddo, Nasir and Hawassa Dume with strain HB-429 found to be economically feasible at the study area. This report supports the finding of Ewnetu Teshale and Afework Lagasse, 2020 the research that conducted at Hawassa Dume in the Meskan districts of South Ethiopia showed there was significant response observed in growth, yield and yield components on blended fertilizer application level of 100 kg/ha. Similarly, the economic analysis shows the highest net benefit obtained from 100 kg NPSZnB ha^{-1} with highest marginal rate of return by 12.78% (Lake and Jemaludin, 2018).

Table 5: Partial Budget Analysis for Experimental Site (Bilate Zuria district)

Trts	Trts comb.	Average grain yield (t ha^{-1})	Adjusted grain yield (t ha^{-1})	Total cost (Birr ha^{-1})	Gross benefit	Net benefit	Dominance & MRR (%)
1	V1*F1	1580	1422	2725	30004.2	27279.2	D
2	V1*F2	2810	2529	4771	53361.9	48590.9	D
3	V1*F3	2150	1935	3065	40828.5	37763.5	3084
4	V2*F1	1405	1264.5	2200	27819	25619	D
5	V2*F2	2530	2277	4046	52371	48325	5993
6	V2*F3	2110	1899	2340	43677	41337	4895
7	V3*F1	1400	1260	1680	21420	19740	D
8	V3*F2	2310	2079	3726	35343	31617	D
9	V3*F3	1920	1728	2020	29376	27356	D
10	V4*F1	1390	1251	1900	23769	21869	D
11	V4*F2	2350	2115	3846	40185	36339	3935
12	V4*F3	1970	1773	2140	33687	31547	3493

Hint: (**V1**= Ibaddo, V2=Hawassa Dume, V3= omo-95 and V4=Nasir common bean varieties, While, F1= 0 kg NPS, F2 = 100 kg NPS and F3 = strain HB-429 fertilizer Levels)

5. SUMMARY AND CONCLUSION

This research conducted during the 2019 main cropping season at Bilate Zuria district, Sidama regional state to investigate nodulation and yield performance of common bean varieties in response to *Rhizobium* inoculation and NPS fertilizer application. The experiment consisted of four common bean varieties (Ibaddo, Hawassa Dume, Omo-95 and Nasir), three levels of fertilizer (0 kg NPS, 100 kg ha^{-1} and strain HB-429) in randomized complete block design with factorial arrangement using three replications.

The results of present study revealed that highly significant ($P \leq$ 0.001) varietal effect on most of studied parameters. Among the varieties, Hawassa Dume performed better for parameters such as number of primary branches, number of pods plant^{-1} and number of seeds pod^{-1}. Whereas, variety Ibaddo provided superior hundred seed weight, total biomass, grain yield and Harvest index. The effect of variety x fertilizer interaction caused significant variation in number of nodules plant^{-1}, plant height, number of primary branches, pods plant^{-1}, seed pod^{-1}, and hundred seed weight. The highest grain yield was recorded from Ibaddo (2.81 t ha^{-1}) and Hawassa Dume (2.53 t ha^{-1}) varieties both with 100kg NPS ha^{-1} while the lowest was from Omo-95 (1.41t ha^{-1}) variety without fertilizer application.

Results obtained from this experiment indicated that almost all of the parameters tested responded significantly to common bean varieties regardless of fertilizer application and HB-429 strain inoculation. The application of NPS fertilizer at the rate of 100 kg ha^{-1}showed number of branches plant^{-1}(6.53), number of pods plant^{-1}(16.52), number of seeds pod^{-1} (6.01), hundred seed weight (27.87g) , total biomass (4.04t ha^{-1}), grain yield (2.53t ha^{-1}) and harvest index (0.78) respectively.

According to the partial budget summary, the highest net return (48325ETB ha^{-1}) with acceptable marginal rate return (5993%) was obtained from Hawassa Dume variety with 100 kg NPS ha^{-1} followed by Hawassa Dume variety with strain HB-429 inoculation, which had net benefits of 41337ETB ha^{-1} with acceptable marginal rate of return 4895%. This implies that the grower on the study area can get additional benefit of 59.93 and 48.95 ETB for every 1 ETB expense by growing Hawassa Dume with the application of 100 kg NPS $ha^{-1}$and strain HB-429 inoculation. Moreover, the highest MRR (3084%) with net benefit of 37763.5 ETB and MRR (3935%) with net benefit of 36339 obtained from variety Ibaddo and Nasir grown with strain HB-429 and 100 kg NPS ha^{-1} respectively. Therefore, use of Hawassa Dume, and Nasir varieties with 100 kg NPS ha^{-1} application and Hawassa Dume and Ibaddo grown with strain HB-429 were found to be economically feasible at the study area.

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Appendix Table 1: ANOVA of nodulation and growth parameters in response to Inoculant and NPS fertilizer

Source of variation	**DF**	**Nodule number plant^{-1}**	**Nodule dry weight(g)**	**Plant height(cm)**	**Leaf area index**	**Shoot dry weight (g plant^{-1})**
Variety (V)	3	352.434^{***}	0.025^{***}	20.566^{***}	1.754^{***}	2.600^{***}
Inoculant/NPS fertilizer (I/F)	2	191.433^{***}	0.076^{**}	97.215^{***}	0.273^{***}	0.102^{***}
V* I/F	6	36.33^{***}	0.001^{ns}	9.77^{***}	0.003^{ns}	0.01^{ns}
error	24	0.116	0.0026	1.75	0.002	0.002
Total	35					
CV		1.44	19.71	3.02	0.80	0.43

CV = coefficient of variance, DF = degree of freedom, ns = non significance *, ** and *** = Significant at p≤0.05, 0.01 and 0.001

Appendix Table 2 : ANOVA of yield parameters in response to Inoculant and NPS fertilizer

Source of variation	**DF**	**Branch number plant^{-1}**	**Pods plant^{-1}**	**Seeds pod^{-1}**	**Hundred seed weight (g)**	**Grain yield (t ha^{-1})**	**Total biomass (t ha^{-1})**	**Harvest index**
Variety (V)	3	2.530***	26.679***	3.948***	315.999***	0.227***	0.539***	0.046***
Inoculant/NPS fertilizer (I/F)	2	0.809***	0.595***	0.630**	3.250**	3.133***	0.599***	0.014**
V* I/F	6	0.015***	0.01**	0.105*	2.67***	0.03^{ns}	0.015^{ns}	0.0003^{ns}
error	24	0.002	0.007	0.12	0.66	0.02	0.01	0.005
Total	35							
CV		0.74	0.52	5.91	2.97	6.77	2.59	9.42

CV=coefficient of variance, DF = degree of freedom, ns = non significance *, ** and *** = Significant at $p \leq 0.05$, 0.01 and 0.001

Appendix Table 3: Correlation results among parameters

	NNP	NDW	PH	LAI	SDW	BN	PP	SP	HSW	GY	TBM	HI
NNP												
NDW	0.60***											
PH	0.23	0.22										
LAI	0.12	0.15	0.53***									
SDW	0.83***	0.48**	0.15	0.22								
BNP	0.63***	0.37*	0.35*	0.64***	0.70***							
PPP	0.67***	0.32	-0.15	-56**	0.65***	0.16						
SPP	0.34*	0.16	-0.03	-0.63**	0.26	-0.11	0.79***					
HSW	0.69***	0.44*	0.17	0.16	0.88***	0.40*	0.55***	0.32				
GY	0.57***	0.35*	0.75***	0.42*	0.38*	0.54***	0.17	0.30	0.35*			
TBY	0.77***	0.48**	0.53***	0.41**	0.77***	0.67***	0.43*	0.35*	0.75***	0.83***		
HI	0.61***	0.62***	0.27	0.06	0.63***	0.30	0.54***	0.54***	0.68***	0.51***	0.76***	

$^{*, **}$ and *** = Significant at p≤0.05, 0.01 and 0.001, NNP= number of nodules plant^{-1}, NDW = nodule dry weight, PH = plant height, LAI = leaf area index, SDW = shoot dry weight, BN= branch number plant^{-1}, PP = pods plant^{-1}, SP = seeds pod^{-1}, HSW = hundred seed weight, GY = grain yield, TBM = total biomass, HI= harvest index.

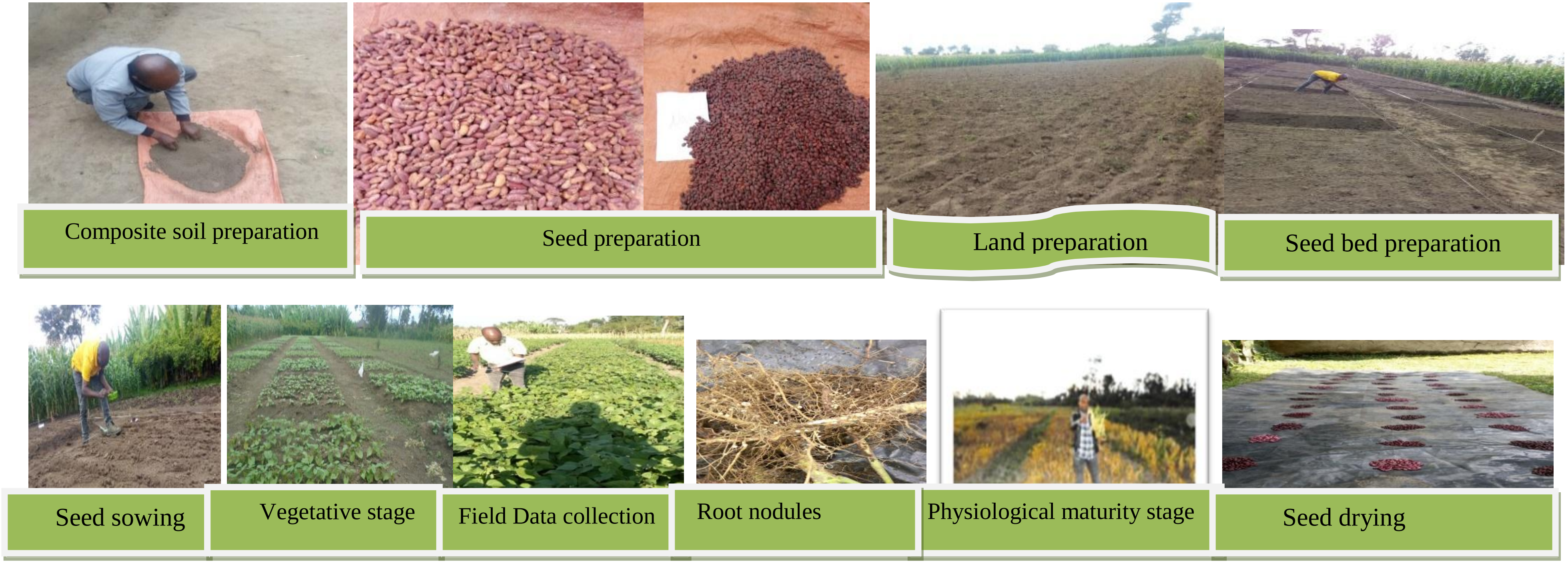

Figure 8: Some pictures during experimentation time.

BIOGRAPHICAL SKETCH

The Author, Enjamo Nagesso, was born on April 5, 1982 in Bilate Zuria district, Sidama region, Ethiopia from his father Mr. Nagesso Sato and his mother Ms. Kure Kuma. He attended primary school at different schools of the vicinity. He attended Leku junior secondary & High School education at Shebedino district of the Sidama region. He completed secondary education in 2002. He joined Wolaita ATVET College in 2003 and graduated with a diploma in Natural Resource Management in 2005. Upon graduation, he was employed at Boricha district Agriculture and Rural Development office on September 1, 2006. Since then, he worked as natural resource management development agent. Then he got a chance to join the Yardstick International Open & Distance College and graduated with Degree of Bachelor of Science (BSc.) in Agricultural Extension in 2009. After graduation, he was joined to work from February 01/2011 to end of December 2017 as an expert of crop development. He also worked from January 10/2018 to December 19/ 2018 vice head of Boricha district office of Agriculture & from December 20/2019 until now he is working at Bilate Zuria district as head of agricultural office. In July 2017, he joined Hawassa University, to pursue his MSc study in Plant Science with specialization in Agronomy.