RESPONSE OF COMMON BEAN (*Phaseolus vulgaris* L.) VARIETIES TO DIFFERENT RATES OF PHOSPHORUS FERTILIZER AT NEGELLE BORENA, SOUTHERN ETHIOPIA

M.Sc. THESIS

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JULY, 2021

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A THESIS SUBMITTED TO SCHOOL OF PLANT AND HORTICULTURAL SCIENCES, SCHOOL OF GRADUATE STUDIES, HAWASSA UNIVERSITY,

HAWASSA, ETHIOPIA

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

HAWASSA UNIVERSITY, HAWASSA ETHIOPIA

JULY, 2021

COLLEGE OF AGRICULTURE

SCHOOL OF PLANT AND HORTICULTURAL SCIENCES

ADVISORS' APPROVAL SHEET-1

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This is to certify that the thesis entitled "**Response of Common Bean(*Phaseolus Vulgaris* L.) Varieties to Different rates of Phosphorus Fertilizer at Negelle Borena, Southern Ethiopia"** submitted in partial fulfillment of the requirements for the degree of Master of science with specialization in **Agronomy** to graduate program of the **School of Plant and Horticultural Sciences,** College of Agriculture, and is a record of original research carried out by **Gadisa Beyene Fufa Id** No: GP/Agro/K/012/10 under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation has been duly acknowledged. Therefore I recommend that it be accepted as fulfilling the thesis requirements.

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We, the undersigned, members of the Board of Examiners of the final open defense by **Gadisa Beyene Fufa** have read and evaluated his/her thesis entitled **"Response of Common Bean(*Phaseolus Vulgaris* L.) Varieties to Different rates of Phosphorus Fertilizer at Negelle Borena, Southern Ethiopia"** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of requirements for the degree **Masters of Science** in plant sciences with specialization in **Agronomy**.

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ACKNOWLEDGMENT

Firstly, let me praise the Lord GOD for the opportunity and capacity given to me to see my hope fulfilled. My heartfelt appreciation and respect go to my advisors Dr. Andargachew Gedebo (PhD) and Mr.Tewodros Ayalew (Assoc. Prof) for their genuine and energetic encouragements, professional expertise and guidance starting from preparation of research proposal to research work completion. I would like to express my deepest thanks to Guji Zone Agriculture and Natural Resource Office, for their permission for the time to attend post graduate study.

DEDICATION

This manuscript is dedicated to my Father Ato Beyene Fufa and my mother W/ro Malkitu Mosisa and my wife W/ ro. Zenebech Ketema who encouraged and supported me enthusiastically for such a success.

STATEMENT OF THE AUTHOR

I declare that this thesis is my authentic work and all sources of materials used for the thesis have been acknowledged. This thesis has been submitted in partial fulfillment of the requirements of Masters of Science Degree at Hawassa University and deposited at the University Library to be available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of source is made.

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LIST OF ACRONYMS AND ABBREVIATIONS

CEC	Cation Exchange Capacity
CIAT	Centro International Agriculture Tropical
Cmol	Centi-mole
CSA	Central Statistical Agency
dS	Decisiemen
EC	Electrical Conductivity
LSD	Least Significance Difference
Mg	Milli gram
MoANR	Ministry of Agriculture and Natural Resource
N	Nitrogen
NaCl	Sodium Chloride
P	Phosphorus
Ppm	Parts per million
RCBD	Randomized Completely Block Design
SAS	Statistical Application Software
TSP	Triple Super Phosphate

TABLE OF CONTENTS

CONTENTS **Page**

LIST OF TABLES

Tables **Page**

LIST OF FIGURES

LIST OF APPENDIX TABLES

Appendix tables **Page**

RESPONSES OF COMMON BEAN (*Phaseolus Vulgaris* L.) VARIETIES TO DIFFERENT RATES OF PHOSPHORUS FERTILIZER AT NEGELLE BORENA, SOUTHERN ETHIOPIA

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ABSTRACT

Even though its production and demand is highly increasing in Ethiopia due to its fast maturity and nutritional value, Common bean productivity is constrained by soil phosphorus along with proper use of variety. In view of this problem, a field experiment was conducted at Negelle Borena, Southern Ethiopia under rain fed in 2020 cropping season to determine the optimum phosphorus rate needed to get the highest and economically feasible yield of Common bean variety. The experiment was designed in factorial combinations of five levels of Phosphorus (0, 23, 46, 69 and 92 kg ha^{-1}) and three haricot bean variety (Hawassa Dume, Omo-95 and Nassir) in a Randomized Complete Block Design with three replications. Data on days to flowering, days to maturity, number of nodules plant^{-1}, number of leaves plant^{-1}, plant height, number of primary branches plant^{-1}, number of pod plant^{-1}, number of seed pod^{-1}, hundred seed weight, above ground biomass, grain yield and harvest index were recorded and subjected to analysis of variance using SAS software. The results revealed that both P rates and common bean variety had significant effect on days to flowering, days to maturity, number of leaves plant^{-1}, number of primary branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, total above ground biomass, hundred seed weight and grain yield.The interaction effect of phosphorus fertilizer rate and Common bean variety significantly influenced total of nodule number and effective nodules number plant^{-1}. All parameters tested were positively correlated except days to 50% flowering, days to maturity and leaves number plant^{-1}was Negatively correlated but plant height was not siginificant with grain yield . The highest grain yield (2.38 tons ha^{-1} and 2.11 tons ha^{-1}) was recorded from 46 kg P ha^{-1} rate and Hawassa Dume Common Beanvariety, respectively.The highest net return (37,630 ETB ha^{-1}) with acceptable marginal rate return (1140.54 %) was obtained from Hawassa Dume variety with 46 kg P_2O_5 ha^{-1}application. This implies that the growers at the study area can get additional benefit of 11.4054 ETB for every 1 ETB expense by this treatment, followed by Hawassa Dume variety with 23 P_2O_5 kg ha^{-1} supply having a net return of 27,080ETB ha^{-1}. The lowest net economic return was recorded in the Omo-95 variety with zero-P application (17,550Birr ha^{-1}). Thus, it can be concluded that application of 46 kg P ha^{-1}and Hawassa dume haricot bean variety were found superior both in productivity and economically at Negelle Borena area.

Keywords: Common bean Varieties, Growth, Nodulation, Phosphorus rates, and Yield compone

1. INTRODUCTION

Common Bean (*Phaseolus Vulgaris* L.) is known as dry bean, Haricot bean, French bean, snap bean, kidney bean and field bean (Voysest and Dessert, 1991). Nowadays, the crop is grown worldwide for its dry and green bean (MoANR, 2016). Its dry bean is the most important and popular as a cash and food for farmers in many lowlands and mid-altitude of Ethiopia (CSA, 2005). It has been known as an export crop for long period of time contributing to the foreign exchange earnings of the country. It is also grown as a food crop to be consumed as 'nifro' (boiled grain mixed with sorghum or maize), “wot” (local stew) and boiled split beans mixed with “kocho” (food from Enset plant) (MoANR, 2016).

Nutritionally, Common bean grain legumes, as a protein-rich food, play an important role in human nutrition, especially in developing countries. And they contribute up to 33% of the dietary protein needs of humans (Vance *et al.,* 2002). Additionally, Gebre-Egziabher *et al.*, (2014); and Tekle *(*2014) reported common bean grains are rich in protein (over 22%), carbohydrates, oil, fiber and sucrose. It is also one of the best sources of iron (23-30% of daily) (Schwartz *et al.,* 1996) and used for reduction of coronary heart diseases, against cancer (Oomah *et al.,* 2005), decreasing diabetes and obesity and high antioxidant capacity (Mitchell *et al.,* 2009). It is also used as a means of employment (CSA, 2005).Although relatively low as compared to its ability to fix nitrogen makes it important in cropping systems as it can improve soil fertility. The crop ranks third in contributing 9.5% of the total export value of agricultural commodity income of Ethiopia (FAOSTAT, 2010).

According to FAO (2019) estimates, the global bean production (covering not only the common bean) has risen from 16.6 million tons in 1988-90 (3-year-average) up to the record of 29.3 million tons in 2015-17 due to an increase of both cultivation areas and productions, with the Americas and Asia as the most important producing regions. India is the top dry bean producer country in the world with 5.8 million tons during 2013-17 period (from the three annual average) followed by Myanmar country with 4.9 million ton production from the three annual average (FAOSTAT, 2019).

From African countries, United Republic of Tanzania is the leading producer followed by Uganda, Kenya and Ethiopia in their ranking order of dry bean production (FAOSTAT, 2019). The average actual yield of the crop ranges from 1.26 to 2.5 ton ha^{-1} (CSA, 2015). This actual yield is lower than that of potential yield of the crop. However, the farmers can increase productivity of the crop by using improved production technologies like superior variety, fertilizer, plant population and proper management practices (Walelign *et al* 2015)

In midland parts of southern of Ethiopia, Guji zone, production and an average annual productivity of the crop is about 15,850 ha and 1.52 ton ha^{-1} (CSA, 2017). However, specifically, Negelle Borena is one of southern parts of the country sharing far apart low productivity of Common Bean(1350- 1700 kg ha^{-1}) (Guji Zone Agriculture Resource Office, 2020) to that of reported potential productivity (2500-3000 kg ha^{-1}) of improved variety of the crop under good management practices (MoANR, 2008).

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 is no large atmospheric source that can be made biologically available to the crops (Bashir *et al.*, 2011). It is well known that inadequate P availability restricts root growth, the process of photosynthesis, translocation of sugars and N_2-fixation by legume plants (AbdulAziz, 2013).Common bean is a nutrient-demanding crop due to its sensitivity to environmental stresses. Application of fertilizer in a recommended amount is essential for high yield and quality of grains. The use of fertilizer is considered to be one of the most essential factors to raise crop yield per unit area basis (Morgado and Willey *et al*; 2003). However, the response to the type of fertilizer and rate of application vary widely with location, climate and soil type (Marshner, 2002).The low yield of crops are attributed to low soil fertility, untimely and inappropriate field operations, erratic rain fall, drought, diseases, weed and insect pests (Graham *et al*. 2003). Similarly, according to Mulugeta (2011) limited production and productivity of common bean in Ethiopia is also attributed to lack of improved varieties for the different agro-ecological zones, poor agronomic practices such as low soil fertility management, recommended seed and fertilizer rates, spacing and pesticide application.

Thus, various constraints were reported for the low productivity of common bean, out of which use of local variety and lack of high yielding variety selection; and inappropriate use of fertilizer rates like phosphorus are the most important ones in and around Negelle Borena area. Therefore, recommending suitable and high yielding variety of the crop under abundant availability of resources like phosphorus fertilizer and suitable agro-ecological condition can increase common bean yield for the area under study.

According to Wortmann (2006) low level of P is the major constraints for common bean production among the fertilizers responsible for the loss of grain yield up to 1.2 million tons per year globally. Similarly, Girma (2016) also showed that low soil P levels are important constraints for common bean production in most areas of Ethiopia where the crop is grown. Phosphorus deficiency which is one of the fertilizer components recommended that is to be applied in the whole Ethiopian country soil is responsible to increase in grain weight plant^{-1} of common bean (Veeresh. 2003).

Farmers of the study area produce common bean primarily in mono-cropping as an alternative food source and for market sale. As it is true for soils in most parts of Ethiopia, the area soils of the study area is deficient for most of the plant nutrients. In and around study area, improved common bean technologies are being promoted by the government. The technologies promoted include improved varieties, recommended fertilizer rates and types, improved agronomic practices and weed control practices. However, most farmers of the area cannot afford the cost of chemical fertilizer to apply as per the recommendations. Application of the correct level of fertilizer is necessary to achieve maximum yield of common bean crop. The application P at 46 kg P2O5 ha-1 has significantly increased bean yield and all growth parameters, except plant height over the rest of the levels (Birhan, 2006). Thus, based on the result obtained, it was possible to conclude that phosphorus fertilizer rate of 46 kg P2O5 ha-1 was promising to enhance yield of common bean in Malle woreda and similar areas which have the same soil property (Degife and Samuel, 2019).

As a result, farmers apply below the recommended dose of fertilizer due to this the productivity of common bean is declining from year to year. Thus, there is also knowledge limitation to identify high yielding, accessible and management responsive varieties.

Due to this, most of the producers are using local variety which is consequently resulting poor production quality and quantity of the crop. The variation in phosphorus rates with environment and variety needs area-specific recommendation for common bean. Since, Negelle Borena area possesses different environmental condition to that of the recommended, it is important to identify optimum phosphorus rate recommendations and the suitable variety of the crop for maximized common bean production at the area.

General Objective

To evaluate the Response of common bean (*Phaseolus vulgaris L.*) varieties to different rates of Phosphorus fertilizer at Negelle Borena, Southern Ethiopia

Specific Objectives

To assess the effect of different phosphorus fertilizers rates on the growth and nodulation performance of common bean varieties

To evaluate the varietal performance, their yield response to different rates phosphorus application, and determine the suitable combination for higher yield.

To determine economically optimum of the phosphorus rate for common bean production at Negelle Borena.

2. LITERATURE REVIEW

2.1. The Crop Origin and Distribution

Common bean originated from the New World; two centers of origin were known Andean and Mesoamerican (Hornakova *et al*., 2003; Logozzo *et al.,* 2007). The domestication happened individually in South America and Central America/Mexico, leading to two different domesticated gene pools, the Andean and Mesoamerican, respectively (Papa and Gepts, 2003; Petry *et al*., 2015).This crop is innate to Mexico and Guatemala where the greater part of the diversity of varieties is found (Arenas *et al*., 2013).

According to Gomez (2004) Common Bean is the most widely distributed of the related species and has the widest range of genetic resources and is often used as food crop throughout the world, especially in Latin America and Africa. Other archaeological evidence indicated that common bean was domesticated 5000 BC in Peru and in 6000 BC in Southern Mexico (Freytag and Debouck, 2002). Then, from its centre of origin common bean was taken to Europe, Africa and Asia in the 16th century by the Spanish and Portuguese travelers. Similarly, it is believed to be introduced into Ethiopia in the same century by the Portuguese (Wortman and Elude, 1997). The crop is known widely distributed throughout the world and consequently, it is grown in all continents except Antarctica (Singh, 1999).

2.2. Botanical Description of Haricot bean

Common Bean belongs to Rosales order, Leguminosae family, Papilionoideae sub family, *Phaseolus* L. genus, and *Phaseolus vulgaris* L. species (Purseglove, 1968; CIAT, 1986). Most beans are herbaceous annual, although, under tropical conditions, some beans (such as large limas) may behave as short-lived perennials (Cobley, 1976). The common bean shows variation in growth habits from determinate bush to indeterminate, extreme climbing types. The bushy type bean is the most predominant type grown in Africa (Gepts, 1998; Buruchara, 2007). Similarly, Singh and Schwartz (2010) reported that determinate type of traits which is associated with reduced branching, fewer internodes, insensitivity to day length, and improved allocation of biomass to reproductive growth is the most commonly preferred one. Its better adaption to shorter growing season is it's another character favoring the use of determinate growth habit (Kwak, 2012).

The crop has a taproot system with lateral roots which is colonized by *Rhizobium* bacteria to result an irregular root nodule. The stems are typically hairy and short, hooked hairs always present on the younger portions of the stems (Debouck and Hidalgo, 1986). Its leaves are trifoliate and alternate on the stems but its leaflets are entire or somewhat hairy with small stipules. It's flower borne on axillary racemes (Purseglove, 1968). The flower has an elongate twisted keel containing the style and ten stamens (Buruchara, 2007).

Self-pollination is the norm in the common bean, and it probably occurs automatically at or before the flower opens in the morning. However, it takes 8-9 hours for the pollen tube to grow and fertilize the ovules, during which time honey bees and bumble bees can visit the flower and cross-pollinate it (Free, 1993).

Seeds of the crop are non-endospermic and vary in size and color from the small black wild type to the large white, brown, red, black or mottled seeds which are 7-16 mm long (Cobley, 1976). Seeds may be round, elliptical, somewhat flattened or rounded elongate in shape and a wealthy assortment of coat colors and pattern exists (Buruchara, 2007).

2.3. Agro-Ecological Requirement of Common Bean

Common bean (*Phaseolus Vulagris* L.) is a warm season crop. It is sensitive to frost, water logging and strong winds. The crop is adapted to climatic condition ranging from 600 to 3000 meter above sea level depending on the variety (Gupto *et al.*, 1997). The crop is grouped under the lowland pulses category. It is best adapted in areas with a warm temperature (mean air temperature 18 to 24°C) that is best suited for its production (Walelign *et al*., 2015).

In Ethiopia, it can be grown in areas 1400 to 2000 meter above sea level elevations receiving an annual rainfall of 350 to 1100 mm. It requires about 300 to 400 mm of water during its growth period. The crop is susceptible to both scarcity and excess of moisture. Lack of moisture especially during flowering and seed filling phases is most detrimental to yield and thus; it is advisable to maintain available soil moisture above 50% (Walelign *et al*., 2015).

According to Liebenberg *et al.* (2009), the crop requires 18°C to28 °C optimum temperature for growth and well pods development. However, excessive temperatures (greater than 28°C) cause flowers to abscise, and low temperatures (lower than 18°C) delay pod production and can result empty pods. Temperatures from 20°C to 28° C are needed for germination of the crop (Teshale *et al*., 2005). Seeds of the bean show poor germination in soils colder than 15°C (Scarisbrick *et al*., 1976).

The crop can be successfully grown on sandy loam or coarser to silt loam soils texture which hold water well, and have good aeration and water filtration (Norman, 2014). It can be also grown in non-acidic and well drained soils. The soil pH ranging between 6 and 7.5

is ideal for production of the crop but it should not be below 5 or above 8 (Walelign *et al*., 2015).

2.4. Common bean Production in Ethiopia

Ethiopia is known as the homeland of several crop plants and ranked as 13th among pulse producing countries in the world (FAO, 2015). The country produced about 1.3 million tons in 2014 (CSA, 2015). Common bean is widely grown in areas between 1400 – 2000 m a.s.l. It is mainly produced in areas such as East Hararghe, West Wellega, East Shewa, West Arsi, Sidama, Wolayita, Wollo and East Gojam (EIAR, 2014). The crop is grown either as a sole crop and/or intercropped with other cereal or perennial crops (Walelign, 2015).

There are a wide range of common bean types grown in the country, including the mottled, red, white and black varieties. The leading white bean varieties are the Awash 1, Awash melka and Mexican 142 varieties. The pure red and pure white colored beans are the most common commercial varieties (Ferris and Kaganzi, 2008). Common bean is ranked as the second largest pulse crop in the country in terms of production with a share of 17%, next to Faba beans (Negash, 2007). For instance, the production share of the crop has consistently been 19% of all the pulses for the last two years and its production has increased by more than twofold from 138 to 513 thousand tones between 2005 and 2014 (CSA, 2015).

In midland parts of southern of Ethiopia, Guji zone, production and an average annual productivity of the crop is about 15,850 ha and 1.52 ton ha^{-1} (CSA, 2017). However, specifically, Negelle Borena is one of southern parts of the country sharing far apart low productivity of haricot bean (1350- 1700 kg ha^{-1}) (Guji Zone Agriculture Resource Office, 2020)to that of reported potential productivity (2500-3000 kg ha^{-1}) of improved variety of the crop under good management practices (MoANR, 2008).

2.5. Economic Importance and Utilization of Common Bean In Ethiopia

Common bean is one of the most important cash crops for farmers in many lowlands and mid-altitude of Ethiopia (Abate, 2012). With regard to economic importance of common bean, it used as source of foreign currency, food crop, means of employment and plays great role in the farming system (CSA, 2005). The country's export earnings is estimated to be over 85% of export earnings from pulses, exceeding that of other pulses such as lentils, faba bean and chickpea (Negash R , 2007). This crop is commonly used for human consumption, animal feed and for soil fertility amelioration through BNF and green manure. Common beans are often consumed as dried cooked seeds or as leaf vegetable in combination with such energy sources as maize, plantains or root crops as a source of protein to complement these starchy foods (Broughton *et al*., 2003).

According to FAOSTAT (2010) report overall, common bean ranks third as an export commodity in Ethiopia, contributing about 9.5% of total export value from agriculture. Common bean is also highly preferred by Ethiopian farmers because of its fast maturing characteristics that enables households to get cash income required to purchase food and other household needs when other crops have not yet matured (Gabre , 2012).

Ethiopia has a geographic comparative advantage over other competitive countries. It takes nine weeks for sea shipments of beans from China to reach EU markets, whereas it only takes three weeks from Ethiopia (Ferris and Kaganzi, 2008). ERCA report shows that common bean exports increased in total value from 19 million $ in 2005 to 134 million $

in 2014, with a quantity of 43 thousand MT in 2005 to 171 thousand MT in 2014, exhibiting a growth of more than threefold (ERCA, 2014)

The common bean has both agronomic and dietary importance and its utilization patterns vary dramatically by geographic region and among cultures (Uebersax, 2006). This crop is commonly used for human consumption, animal feed and for soil fertility enhancement through BNF and green manure (Daff, 2010). Succulent common bean plants can be used as green manure when ploughed into the soil to increase organic matter of soil. In addition, intercropping common bean with non-legume crops such as cereals (maize, millet or sorghum), bananas and plantains or root and tuber crops is common practice in developing countries to sustain low input agricultural systems (Broughton *et al.*, 2003).

It often consumed as dried cooked seeds or as leaf vegetable in combination with such energy sources as maize, plantains or root crops as a source of protein to complement these starchy foods (Broughton *et al*., 2003). Its green leaves and young pods also contain high levels of essential nutrients (Rocha- Guzman *et al*., 2007; USAID, 2012).

The major health benefit of common beans is their rich source of cholesterol lowering fiber. In addition to this, the high fiber content of beans prevents blood sugar levels from rising too rapidly after meal, making the legume an especially good choice for individuals with diabetes, insulin resistance, or hypoglycemia (Bennink, 2005). The common beans contribution to heart antioxidants, folic acid and B6 help lower levels of homocysteine, an amino acid that is an intermediate product in an important metabolic process called the methylation cycle. Elevated blood levels of homocysteine are an independent risk factor for heart attack, stroke or peripheral vascular disease, and are found in between 20 – 40% of patients with heart disease (Messina, 1999).

Common bean generates income to the growers after harvest as it is transported to urban centers where it fetches good prices (Mkuchu *et al*., 2003).Therefore; it improves the soil N level benefiting the followed crop, which reduces production costs. If its residues are left on the field they improve both the soil structure and texture (Barret, 1990).And the presence of common bean in the daily diet has several health benefits such as reduction of cholesterol level (Rosa *et al.*, 1998), reduction of coronary heart diseases, favorable effects against cancer (Oomah *et al*, 2005)

Like other legumes, Green bean associates with *Rhizobium* bacteria in the soil, which form root nodules through nitrogenase activity and the bacteria within the nodules fix atmospheric nitrogen which the crop uses as a nitrogen source by reducing the need for externally applied nitrogen fertilizer (Ramos, 2003). However, the nitrogen-fixing capacity of the crop is less than other agronomically important legumes like soybeans which have larger nodules with higher nitrogenase activity (Isoi and Yoshida, 1991) .Vásquez-Arroyo (1998) reported that common bean roots are colonized by a wide native *Rhizobium* species and strains but some of which have little or no nitrogenase activity. The reduced nitrogen-fixing capacity of the crop is associated with drought, fungicides, flooding and either high or low temperatures conditions (Graham, 1981). Moreover, low soil phosphorus, manganese and pH level are also associated with sub-optimal nitrogen-fixing capacity (Ramos, 2003). Similarly, Redden and Herridge (1999) observed that available phosphorus in the soil can enhance nitrogen fixing capacity of bacteria because of phosphorus requirements during sugar formation and translocation in nitrogen fixing bacteria.

2.6. Response of Common Bean Varieties to Different Phosphorus Fertilizer rate

Next to nitrogen, phosphorus is the most important element for adequate grain production (Brady *et al*., 2002). (Wang et al.,1998) reported that phosphorus is one of the most significant determinants of plant growth. Growth and development of crops depend largely on the development of root system. Phosphorus enhances root development, which improves the supply of other nutrients and water to the growing parts of the plants, resulting in an increased photosynthetic area and thereby more dry matter accumulation.Negash *et al*. (2018) also reported that with increasing inorganic fertilizer application depending fertility status of the soil; number of branches plant^{-1}, number of pod plant^{-1}, biological yield and pod yield of the crop also increase. Moreover, according to Havlin *et al*. (1999) an adequate supply of P nutrition is used for seed and fruit formation, increases root growth, reduce maturity time, improve quality of fruit, forage, vegetable and grain of crops, and increase disease resistance of the crop.

Plants suffering from phosphorus deficiency are retarded in growth and shoot to root dry matter ratio is usually low. The formation and quality of fruits and seeds are depressed in plants suffering from P deficiency (Mengel *et al*., 1987). Poor nodulation and poor plant vigour are observed in beans grown in P deficient soils (Giller *et al*., 1998). In addition to crop production P has widespread influence on both natural and agricultural ecosystem than any other essential element (Brady *et al*., 2002). Phosphorus sufficiency for crop growth does not always exist in most soils because of losses due to erosion and high fixation (Miller *et al*., 1995; Brady *et al*., 2002). Legumes including Common Bean have high P requirement due to the production of protein containing compounds, in which N and P are important constituents. High seed production of legumes primarily depends on the amount of P absorbed (Khan *et al*., 2003). Therefore, the yield of Common Bean can be increased with P application (Gemechu *et al*., 1990). Amare *et al*. (1987) also reported that nodulation and fixation of N for Common Bean can be improved with the application of P. As all those scholars indicated phosphorus fertilizer application can improve both nodulation (nitrogen fixation of haricot bean) as well as yield response of the crop.

2.6.1. Effect of Phosphorus Fertilizer on Nitrogen Fixation of the Crop

Common Bean satisfy its nitrogen requirement for growth and development by fixing nitrogen from the air (Blumenthal *et al*., 2008). The process of nitrogen fixation requires the presence of the right species of the nitrogen fixing bacteria in the soil, and they are often attracted to the roots by chemical signals from the Common Bean root (Rienke *et al*., 2010). Once in contact with the root hairs, a root compound binds the bacteria to the root hair cell wall. The bacteria release a chemical that causes curling and cracking of the root hair, allowing the bacteria to invade the interior of the cells, and begin to change the plant cell structure to form nodules (Haque *et al*., 2012).

Like other legumes, its ability of fixing atmospheric nitrogen in symbiosis with rhizobia makes it largely important economically and environmentally in the world. Common Bean builds soil fertility through their nitrogen fixation which makes it more preferable economically by reducing the cost of buying nitrogen fertilizer. Improving soil structure, deep rooting, erosion protection and contributing to greater biological activity and sustainability is it's another advantage it has in agro-ecosystem (Giller *et al*., 1995).

The amount of nitrogen that the crop can fix depends on the variety, productivity of rhizobia bacteria, acidity, salinity, mineral nutrition (available phosphorus), alkalinity, soil temperature, moisture and water (Sameh *et al*., 2014). Out of those temperature and water availability may not be under the farmer's control, but nutrition stress (especially phosphorus and Nitrogen) can be corrected by fertilizing those deficient elements (Burton, 1972). Even though the crop nitrogen fixing capacity from the air is low due to all those factors (Hardarson and Atkins, 2003), when a nutritional stress including phosphorus is corrected, the crop responds directly to the nutrient and indirectly to the increased nitrogen nutrition resulting from enhanced nitrogen fixation (Burton, 1972).

According to Redden and Herridge (1999) and Weisany *et al*. (2013), this might be due to bacterial growth, nodule formation and nitrogen fixing activity highly dependent on phosphorus which is essential for sugar formation and translocation. Therefore, deficient phosphorus nutrient during production of the crop need correction by application of it since it is also a principal Common Bean yield limiting nutrient along with nitrogen nutrient that tends to be obtained as a result of nitrogen fixation enhancement by phosphorus fertilizer application (Pereira *et al*., 1989). Moreover, Amare (1987) also reported that Common Bean nodule formation can be improved with the application of phosphorus fertilizer.

2.6.2. Effect of Phosphorus on Growth, Yield and Yield Component of Common Bean

The beneficial effects on the yield of different crops have been noticed from the soil application of deficient macronutrients (Khan *et al*., 2004). Like other legumes, Common Bean requires nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur for growth and development (Arain, 2012). Phosphorus is among the most needed elements for crop production in most tropical soils, which tend to be phosphorus deficient (Adetunji, 1995).

Phosphorus deficiency is one of the largest constraints to crop production in many tropical soils, owing to low native content and high phosphorus fixation capacity of the soil (Warren, 1992). It also primarily results from depletion through cultivation (Kumar *et al*., 2012). Thus, phosphorus deficient soil and low availability impose major restrictions on the vegetative as well as reproductive growth and development of the crop if not applied as fertilizers (Zhang *et al*., 2014).

Phosphorus is one of the primary essential nutrients which can limit plant growth and yield including legumes in tropical soils (Khan *et al*., 2007). It has a vital role in plant nutrition which enhancing nitrogen absorption, influencing pods and seeds formation in legumes and contributing significantly to plant energy processes (Anetor and Akinrinde, 2006).

It is also important for regulation of enzymatic activities and is constituent for energy transformation (Schulze *et al*., 2006). Nucleic acids, proteins, lipids, sugars and adenylate are some of the molecules containing phosphorus and it is required for the well-functioning of plant cells (Zhang *et al*., 2014).

According to Faegheh and Hashem (2015) phosphorus has an effects on plant growth and yield by promoting root growth, and stimulating lateral branching which increases plant ability to absorb nutrients from the soil; and increasing flower formation and fruit setting; and involving in sugar and starch utilization, photosynthesis, cell division and organization, nodule formation, bacterial growth and nitrogen fixation. Therefore, phosphorus application as fertilizer can increase the biological activity, which can result in improvements to plant height, number of nodules per plant, number of pod per plant and enhanced straw quality (Kumar *et al*., 2012). Similarly, Faegheh and Hashem (2015) reported that plant height and number of pod plant^{-1} of French bean were increased from

46 to 55 cm and 55 to 85, respectively with an increase of phosphorus fertilizer application rate from 0 to 100 kg P_2O_5 ha^{-1}. Accordingly, plants supplied with adequate amount of phosphorus were reported to form good root system as a result crop of which, water uptake is promoted resulting in strong stem, early maturity and higher yield. Moreover, number of leaves $plant^{-1}$ of common bean increase with an increase of phosphorus fertilizer rate of application from 0 to 40 kg P_2O_5 ha^{-1} (Jaisankar and Manivannan , 2018) which could be attributed to the functional growth of new leaves and tissue of the crop (Ali *et al*., 2008).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

A field experiment was conducted during 2020 cropping season at Negelle Borena, Liban district in Oromia Regional State. The site is located south of Addis Ababa about 600 km distance, at X-Y at Coordinate of 0564159 latitude and 0588428 UTM longitudes and its altitude is about1477 meter above sea level. It is found in the agro-ecology of dry plateau of the southern part of Ethiopian system (Mekasha *et al*., 2014/5).

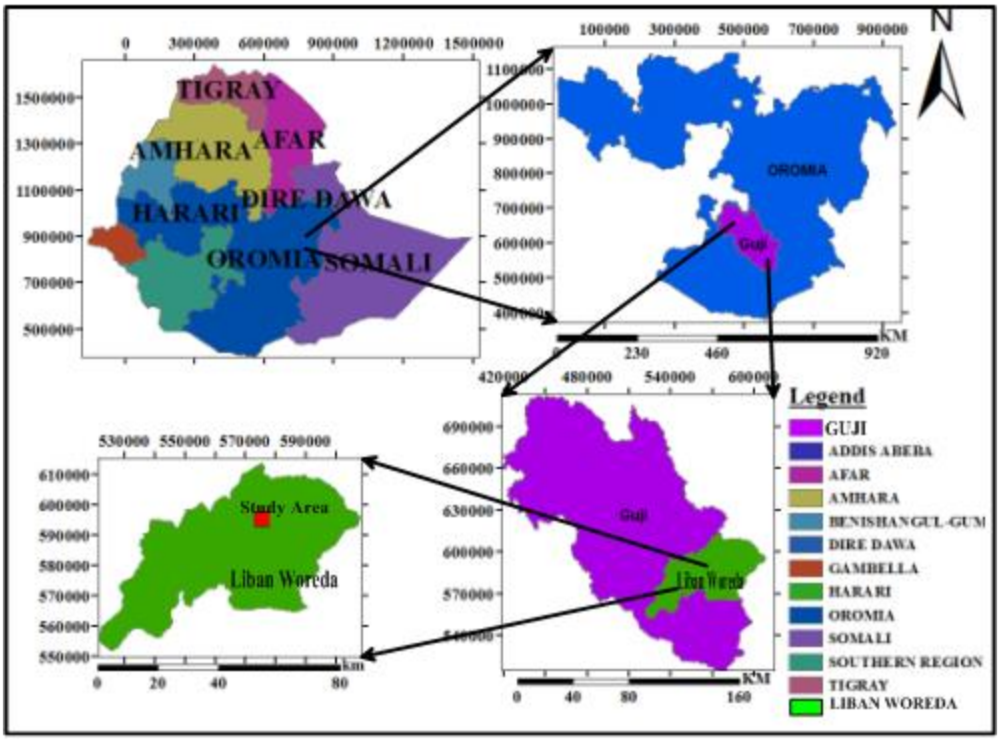


Figure 1: Map of Experiment Site (Source: Google map from internet).

The area is characterized by bimodal rainfall pattern where main rainy season occurs during the months of late March, April, May and June and the short rain starts in late September and extends to first November. The highest amount of rainfall is obtained in the month of April and 800 mm mean annual rainfall is obtained. The annual means minimum and maximum temperatures are 13.1°C and 27.7°C, respectively. The soil textures of the area ranges from sandy loam to sandy clay loam with some clay loam and few clay soils (Yazachew and Kasahun, 2011).

3.2. Source of Planting Materials and Phosphorus Fertilizer

Hawassa Dume, Nassir and Omo 95 haricot bean varieties were used as test crop in this experiment. The varieties were selected and procured from Hawassa Agricultural Research Center based on their high grain yielding ability, and acceptability by farmers and seed availability. The Triple Supper Phosphate (TSP) fertilizer was obtained from Bore Agricultural Research Centre.

3.3. Treatments and Experimental Design

The treatments consisted of three haricot bean varieties (Hawassa Dume, Omo-95 and Nassir) and five phosphorus fertilizer rates in the form of TSP (0, 23, 46, 69 and 92 kg P_2O_5 ha^{-1}) in factorial arrangement

The experimental design was Randomized Completely Block (RCBD) with three replications. The gross plot size of each plot was 2.8 m × 2 m (5.6 m^2). The plot had seven rows each having 40 cm and 10 cm inter-row and intra-row spacing, respectively. From seven rows of a plot the two rows (one row from each side) were considered as the border rows. The blocks were separated by 1.5 m width whereas the plots within a block were separated by 1 m. In accordance with specifications of the design each treatment was assigned randomly to experimental units within a block.

3.4. Soil Sampling and Analysis

Pre-planting soil sample was taken randomly in a zigzag fashion from the experimental plots at the depth of 0 to 20 cm. The soil samples taken by an auger from the whole experimental field were then bulked to form a composited sample in a bucket. Then, the collected samples were air-dried at room temperature under shade and ground to pass through a 2 mm sieve for laboratory analysis of soil pH, and available phosphorus. One hundred gram of this 2 mm sieved soil material passed through 0.5 mm sieve was used for soil organic carbon (OC) and total nitrogen (Hillel, 2004) determination. The other composite soil samples were analyzed for selected physicochemical properties mainly textural analysis (sand silt and clay), cation exchange capacity (CEC) (cmol (+) kg^{-1}) and exchangeable potassium, calcium and magnesium using the appropriate laboratory procedures at Oromia Water Works Design and Supervision Enterprises.

Soil textural class was determined by Bouycos Hydrometer Method. The textural class was designated based on the mass ratio of the particles size with the help of USDA soil textural triangle (Aderson and Ingram, 1993). EC testing is reliable way to assess how salts are affecting plant growth and it was measured in water suspension with soil to water ratio 1:5 (W/V) by potentio-metric method (Slavich and Petterson, 1993). Organic carbon was estimated by wet digestion method and organic matter was estimated by multiplying the organic carbon percent by a factor of 1.72 (Walkley and Black, 1954). The soil pH was measured using potentio-metric method in 1:2.5 soil-water suspensions with standard glass electrode pH meter (Van Reeuwijk, 1992).

CEC is the capacity of the soil to hold exchangeable cations. It is a measurement of the magnitude of the negative charge per unit weight of soil, or the amount of cations a particular sample of soil could hold in an exchangeable form. It is a major controlling agent of stability of soil structure, nutrient availability for plant growth, soil pH and the soil's reaction to fertilizers (Foth, 1990). CEC was determined by leaching the soil with neutral 1N ammonium acetate (FAO, 2008).

Total N was determined by treating the sample with a mixture of concentrated sulfuric acid and digestion catalysis following the modified Kjeldhal method (Okalebo *et al*., 2002). Available phosphorus was determined by Olsen's method (Olsen and Sommers, 1982).

3.5. Experimental Procedures and Crop Management

The seeds of common bean variety (Hawasa Dume, Omo 95 and Nassir) were generously provided by Hawasa Agricultural Research Center. The experimental site was ploughed by tractor on February 22, 2020. After laying out the site by spacing 1.5 m and 1 m between blocks and plots, respectively, ridge was prepared manually on April 8, 2020. Seeds were sown two seeds hole^{-1} in 7 rows at each plot and also seeds that are free from insect, disease and mechanical injuries were selected and sown at 5 cm planting depth and in 40 x 10 cm spacing on April 8, 2020. The phosphorus fertilizers decided for each experimental unit was applied in side band method of application at the time of sowing. The source of nitrogen fertilizer used for experiment was urea [CO (NH2)2] 46%N) at the rate of 23 kg N ha^{-1} Then, after germination, thinning out from the germinated crop was done so as to maintain the population density of plants in each plot.

The research work took three months to complete till final harvesting on July 8, 2020. The experimental site was hand weeded manually three times during the growing season of experimental crop. The first hand weeding (was done at 21 days after planting to avoid competition during early stage of crop growth. The second and final (third) weeding was carried out at one month, and one month and two week, respectively.

3.6. Data Collection

3.6.1. Phenological and Growth parameters

3.6.1.1 Phenological parameters

Days to 50% flowering was recorded as the number of days from emergence to the day when 50% of the plants in a plot set flower.

Days to physiological maturity: was recorded as the numbers of days from emergence to 90% of the plants in each plot matured. This was when the plants indicated yellowing of leaves and pods in each plot.

3.6.1.2. Growth parameters

Plant height (cm): was measured from the base of the plant at the ground level to the tip of the main stem. Five plants from the central rows of each plot were randomly selected for measuring plant height at mid flowering stage. Then the average values of these plants were recorded as plant height of the crop.

Number of leaves plant^{-1}: was counted and recorded from five randomly selected plants of each plot at 50% flowering stage of the crop.

Number of primary branches plant^{-1}: 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 mean from five plants was taken as the number primary branches plant^{-1}.

Number of Nodule plant^{-1}: Bulk of roots of randomly taken five plants from border rows in each plot were carefully exposed at 50% flowering by uprooting using spade. Then, roots were carefully washed using tap water on a sieve and nodule was separated and the total numbers of nodules were determined by counting and then the averages of the five plants were taken as number of nodule plant^{-1}.

Number of effective Nodule plant^{-1} :effectiveness of all the counted nodules were checked by cutting the nodule using blade material according to Shuichi and Hirozo (1955) for color judgment as percentage in which pink color is effective and cream white color is ineffective nodules.

3.6.2. Yield and yield Component parameters

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} was counted and recorded from five randomly selected plants in each plot at the final harvesting time (when 90% of pods became dried) of the crop.

Hundred seed weight (g): was recorded by weighting hundred randomly taken matured seeds from each plot using a digital balance and the weight was adjusted to 10% seed moisture content.

Grain yield (t ha^{-1}): three central rows of each plot were harvested and threshed manually. The yield obtained after threshing was weighed and recorded. Then, the recorded value was converted to hectare basis to analyze.

Total above ground biomass (t ha^{-1}): At harvest, plants from three central rows were manually harvested. The harvested plants were sun-dried in an open air for a week and weighed to determine above ground total biomass yield and the average above ground total biomass yield was reported in ton ha^{-1}.

Harvest index was determined as the ratio of grain yield to above ground biomass (grain +Straw) from the rows of net plot area. Thus, harvest index was calculated as:

$$\text{Harvest Index} = \left(\frac{\text{Grain Yield (kg ha}^{-1})}{\text{Above Ground Biomass(kg ha}^{-1})}\right) \text{x } 100$$

3.7. Statistical Data Analysis

The collected data were subjected to analysis of variance (ANOVA) using PROC GLM in 9.1 SAS software version. The significant level of treatment means were compared using least significant difference (LSD) test at 5% probability level. Correlation analysis was done using Pearson's simple correlation coefficients for the intended parameters.

3.8. Partial Budget Analysis

Partial budget analysis was carried out for economic analysis of the effect of P fertilizer application and use of improved seed of common bean varieties. The potential response of Common Bean varieties towards the added triple super phosphate fertilizer corresponding to fertilizer rates ultimately determines the economic feasibility.

According to CIMMYT (1988) the marginal rate of return (MRR) refers to the net income obtained by incurring a unit cost. For each pair of ranked treatments, percent of marginal rate of return (MRR) was calculated as:

$$\text{MRR (\%)} = \frac{change\ in\ NB\ (NBb - NBa)}{change\ in\ TVC\ (TVCb - TVCa)} \text{ x } 100$$

Note: - **NBa** - NB with the immediate lower TVC

NBb - NB with the next higher TVC

TVCa - the immediate lower TVC and

TVCb - the next highest TVC.

The percent of MRR between any pair of un-dominated treatments was the return per unit of investment in fertilizer. Thus, MRR of 100% implied a return of one Birr on every Birr spent on the given variable input. The dominance analysis used to select potentially profitable treatments (either triple super phosphate or Common Bean variety or interaction of triple super phosphate and Common Bean variety). The discarded and selected treatments were called dominated and un-dominated treatments, respectively.

The net benefit (NB) was calculated as: $NB = (AY \times P) - TVC$

When,

APY×P = Gross field benefit

AY = Adjusted yield and

P = Common Bean variety price

The actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment.

4. RESULTS AND DISCUSSION

4.1. Physico-chemical properties of the experimental site soil

Soil analysis result indicated that textural class of the experimental site soil was sandy clay with 48% sand, 16% silt and 36% clay particle size of the soil distribution (Table 1). The degree of weathering, nutrient and water holding capacity of the texture is suitable for common bean production which was in agreement with that of Norman (2014) who reported that common bean best adapted for high production under well-draining soils such as sandy loam to clay loam soil.

CEC of experimental soil was 21.2 cmol (+) kg-1 (Table 1). According to Landon (1991) the CEC of the soil is classified as < 6, 6 - 12, 12 - 25, 25 - 40 and > 40 cmol (+) kg^{-1} and rated as very low, low, moderate, high and very high, respectively. Therefore, CEC of the experimental site soil was rated as moderate.

The estimated EC of experimental site soil (0.193 dS/M) was in the range of low salinity (Table 2). According to (Brian *et al.,* 2005) classification estimated EC of soil based on their effect on plants into low salinity at 0 - 2 dS/m. Sensitive plants affected at 2 - 4 dS/m, many plants affected at 4 - 8 dS/m, tolerant plants affected at 8 - 16 dS/m and high salinity tolerant plants at > 16 dS/m. In agreement with the result observed from the soil analysis, Ayers and Westcot (1989) reported that yield potential of common bean progressively decrease from 100% to 0% with an increase of estimated EC of soil from 1 - 6.3 dS/m.

According to Tekalign (1991) total nitrogen of the soil was classified into < 0.1% as very low, 0.1 - 0.2% low, 0.2 - 0.5% as moderate, 0.5 - 1 high and > 1% as very high. Accordingly, the total N (%) of the experimental site soil (0.14%) was rated as low

(Table 1). This low nitrogen content of experimental site indicates that nitrogen fertilizer application was needed for production of the crop.

Table 1**:** Physico-Chemical Properties of the Experimental Soil before planting

Soil Property	Unit	Value	Rating
Soil textural properties			
Sand	%	48	-
Silt	%	16	-
Clay	%	36	-
Textural class of the site soil		-	Sandy clay
Soil chemical properties			
Electrical conductivity (ECe)	(dS/m)	0.193	Low
Cat-ion exchange capacity soil	(cmol (+)/kg	21.2	Medium
Organic carbon	(%)	1.58	Medium
Organic matter	(%)	2.73	-
pH (H_2O)	(W/V)	7.5	Mildly alkaline
Total nitrogen	(%)	0.14	Low
Available phosphorus	(mg/kg (ppm))	9.5	low
exchangeable Na	(mg/kg (ppm))	0.07	-
exchangeable K	(mg/kg (ppm))	1.1	High
exchangeable Ca	(mg/kg (ppm))	15.22	High
exchangeable Mg	(mg/kg (ppm))	4.32	High

dS/m = decisiemens per meter, ppm ppm = parts per million, mg/kg = milli gram/kilogram, W/V = weight of soil/volume of water, cmol = centi-mole/kilogram,%=percent

The experimental site soil analysis result (1.58%) was rated as medium in organic carbon content (Table 1). According to Hazelton and Murphy (2007) who classified soil organic carbons into < 0.60, 0.6 – 1.0, 1.0 – 1.80, 1.80 – 3.0 and > 3 as very low, low, medium, high and very high, respectively. Therefore, organic carbon which was a measureable component of soil organic matter of the experimental site soil has an important role in the physical, chemical and biological function of agricultural soils. Organic matter in turn contributes to nutrient retention and turnover, soil structure improvement, moisture retention and availability in production of the crop area(Landon 1991)

Soil pH analysis result for experimental site indicated that it was 7.5 (Table 1). Landon (1991) provided guidelines for interpreting soil pH values for environmental evaluation as pH > 9.0, 9.0 – 8.5, 8.4 – 7.9, 7.8 – 7.4, 7.3 – 6.6, 6.5 – 6.1, 6.0 – 5.6, 5.5 – 5.1, 5.5 – 5, 5.0 – 4.5 very strongly alkaline, strongly alkaline, moderately alkaline, mildly alkaline, neutral, slightly acid, moderately acid, strongly acid, and very strongly acid respectively. Therefore, pH of the site can be categorized as mildly alkaline soil (Table 1) which was in the range of suitable soil pH (6.5 - 7.5) for production of common bean (Norman ,2014).

The result of soil analysis showed that available phosphorus was 9.5 mg kg^{-1} which was rated as it is P (Table 1). This available P in the experimental soil was rated as in the range of low available according to Tekalign (1991) description of soils with available P < 10, 11 - 31, 32 - 56, > 56 ppm as low, medium, high and very high, respectively.

4.2. Effects of P Rates on Phenology of Common Bean Varieties

4.2.1. Days to flowering

Analysis of variance revealed that the number of days to flowering was significantly differed between varieties, and between application rates of phosphorus. However, the interaction effect was not significant (Appendix 1).

Variety Hawasa dume reached 50% flowering earlier than the remaining varieties. However, the remaining two varieties did not differ for days to flowering(Table 2). The variation among the varieties for days to 50% flowering could be attributed to the differences in the genotypic makeup of the varieties. In line with the current result Wondimu and Tana (2017) and Fahad et al. (2014) observed significant differences among the common bean varieties for days to flowering and physiological maturity.

Phosphorus fertilizer rates also significantly ($P < 0.001$) affected days to flowering. The earliest days to flowering was registered from the plots that received P at the rate of 92 kg P $ha^{-1,}$ while the longest days to flowering observed in the control plots (Table 2). In agreement with this result, Wondimu and Tana (2017) observed earlier flowering with increasing phosphorus application rate from 0 kg P ha^{-1} to 92 kg P ha^{-1} with the earliest for flowering from the application of P with the rate of 92 kg P ha^{-1}.Similarly, Tessema and Alemayehu (2015) and Iqbal *et al (2003*) reported significant variations in days to flowering among different levels of P application. This might be due to stimulatory effect of phosphorus on growth hormones to induce early flowering in haricot bean; the fact that P fertilizer fastens flowering, photosynthesis and assimilate partitioning of crop from source to sink which is mainly determined by the ability of crop to utilize P (Tessema and Alemayehu, 2015; and Iqbal et al., 2003)

4.2.2. Days to maturity

Days to 90% maturity differed significantly ($P < 0.001$) among varieties and significantly ($P < 0.05$) between application rates of phosphorus. However, the interaction effect was not significant (Appendix 1).

The earliest days to maturity was recorded from variety Hawassa Dume while the latest from Omo-95 (Table 2). These variations in days to 90% physiological maturity could be attributed to genotypic differences. This is in agreement to Fahad *et al*. (2014) who reported significant difference for days to physiological maturity in common bean varieties. Similarly, Wondimu and Tana (2017) reported that common bean varieties showed highly significant difference on days to 90% physiological maturity where Red Wolayita variety was the earliest (93.33 days) in 90% physiological maturity while Awash Melka was the late maturing (95.27 days).

Among P-fertilizer application rates, the earlier maturity (86.42 days) was recorded at 92 kg P ha^{-1} application which was statistically similar with the result attained by 69 kg P ha^{-1} and 46 kg P ha^{-1} application while late maturity (89.16 days) was recorded at 0 kg P ha^{-1} application (unfertilized plot). However, there was no significance difference between 0 kg P ha^{-1} and 23 kg P ha^{-1} applications (Table 2). The differences in days to maturity might be due to the effect of phosphorus on cell division, hormone and flowering and then induce early maturity of the crop. Similarly, Havlin *et al.* (1999) also indicated that ample phosphorus nutrition could reduce the time required for grain ripening. Additionally, Marschner (2002) reported that P could reduce the days to physiological maturity by controlling some key enzyme reactions that involve in hastening crop maturity.

Table 2: Phenological Performance of Common bean Varieties in Response to Phosphorous Application at Negelle Borena in 2020

Factors	Days to 50% flowering	Days to 90 % maturity
Varieties		
Hawassa dume	39.93 [b]	83.89[c]
Omo-95	42.6 [a]	92.31[a]
Nasir	42.93 [a]	86.87[b]
LSD 0.05	**0.79**	**1.39**
P rate (kg P ha^{-1})		
0	43.44[a]	89.16[a]
23	42.11[b]	88.4[ab]
46	41.67[bc]	87.22[bc]
69	41.11[bc]	87.24[bc]
92	40.78[c]	86.42[c]
LSD (0.05)	**1.02**	**1.79**
CV	**2.53**	**2.12**

Means followed by the same letter in the same column are not significantly different from each other at 0.05 level of significance, whereas the opposite is true for different letters. **Ns**- Stands for non-significant, LSD & CV= Least significant difference & Coefficient of variation respectively

4.3. Effect of P application on Growth and Nodulation of Common bean Varieties

4.3.1. Number of nodules plant^{-1}

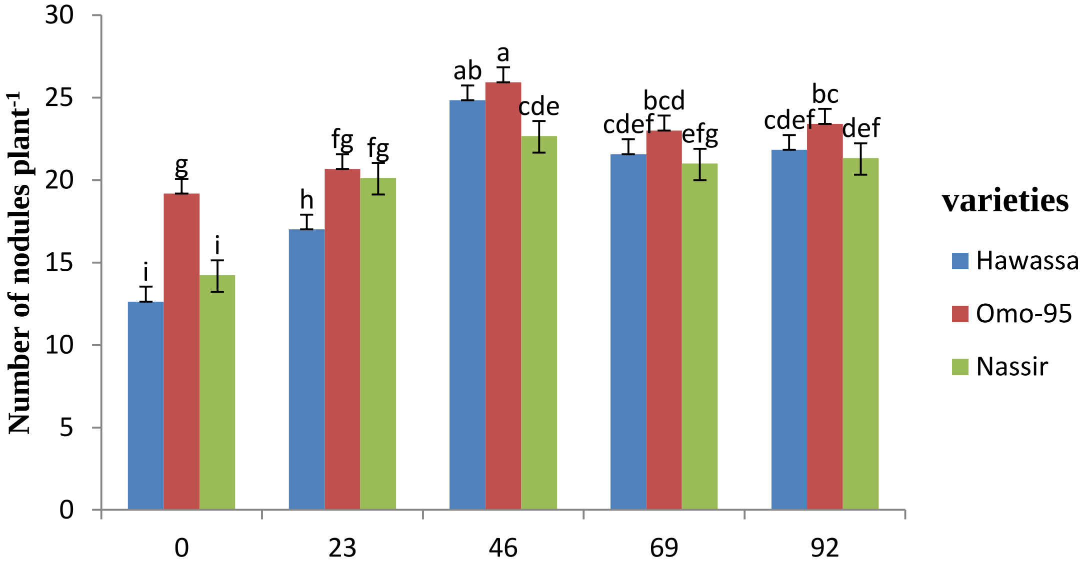
The number of nodules plant^{-1} was highly significantly ($P < 0.01$) influenced by the interaction effects of common bean variety and phosphorus P rates (Appendix 1).

Omo-95 variety exhibited greatest total number of nodules plant^{-1} (22.43) followed by Nassir varieties (19.87). However, Hawassa Dume variety exhibited lowest (19.57) nodule number plant^{-1} 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}. Significant difference ($P< 0.01$) was also exhibited on nodule number plant^{-1} among different levels of applied P .The application of 46kg P ha^{-1} recorded the highest nodule number plant^{-1} (24.47) which was followed by the application of 69 kg P ha^{-1} (21.85) ,92 kg P ha^{-1}(22.19), 23 kg P ha^{-1}(19.23)and zero application (15.34) The increased nodule number due to supplied P might be related due to the availability of adequate P which possibly promotes early root growth and the formation of lateral fibrous and healthy roots. In line with these results Tarekegn and Walelign (2014) reported enhanced nodule number plant^{-1} due to application of optimum P level when compared to the control. This effect of the phosphorus fertilizer on number of nodules plant^{-1} could be due to the important effect of phosphorus for better root development and nitrogen fixation in common bean. This result was similar to Leidi and Rodríguez, (2000) Tang *et al(*2001) reported that phosphorus fertilization improves early root formation, facilitating increased nodulation and enhanced common bean productivity. Similarly, the increased nodule number due to supplied P might be related due to the availability of adequate P which possibly promotes early root growth and the formation of lateral fibrous and healthy roots. And also ,Israel(1987) and Muthamia *et al*. (2015) report that nodule number increases with the addition of P, implying more efficient nitrogen fixation.

The variety x phosphorus levels interaction was significantly ($p<0.05$) affected number of nodule plant^{-1} on common bean varieties (Fig. 2). This implies that common bean varieties responded differently to the combinations of supplied P levels. Number of nodule plant^{-1} of each haricot bean variety increased with an increasing Phosphorus fertilizer application rates; although, the extent of increment in both haricot bean variety and application of Phosphorus fertilizer rates was different.

The number of nodule plant^{-1} of each haricot bean variety (Hawassa dume, Omo-95 and Nassir) was progressively increased with an increasing Phosphorus fertilizer application rate from 0 kg P ha^{-1} (unfertilized plot) up to 46 kg P ha^{-1} but with further application of the fertilizer reduction in number of nodules plant^{-1} in each variety was observed. Among those variety, Omo-95 variety registered the higher number of nodules plant^{-1} over the other variety. The highest (25.93) number of nodules plant^{-1} was observed from Omo-95 variety by 46 kg P ha^{-1} interaction, while the least (12.63) number of nodules plant^{-1} was recorded from the interaction of Hawassa dume and 0 kg P ha^{-1} (Fig 2).

The correlation analysis values (using P-rates) showed that number of nodule plant^{-1} positively correlated with number of effective nodule (r = 0.20ns), primary branch number plant^{-1} (r=0.29ns), , number of pod plant^{-1} (r=1.00***), hundred seed weight (r=0.62***),above ground biomass (r=0.61ns) and grain yield (r=0.58***). However, days to flowering (r=-0.42**), days to maturity (r =- 0.41**), leaves number plant^{-1} (r=-0.39**) and seed pod plant^{-1} (r=-0.18ns) was Negatively correlated with nodule number, (Appendix table-3)



LSD (5%): 1.84 and CV (%): 5.36

Figure 2: Interaction effects of varieties with phosphorus on number of nodule plant^{-1}. Vertical lines on bars represent standard error of the statistical means.

4.3.2. Number of effective nodules plant $^{-1}$

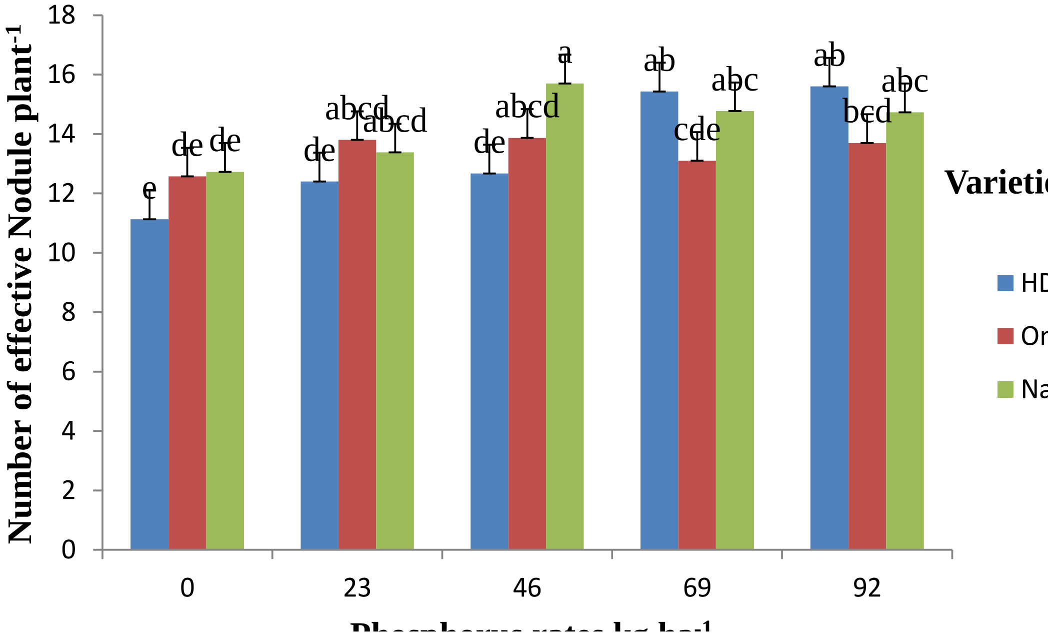
Number of effective nodules plant^{-1}was significantly ($P < 0.05$) affected by common bean variety, phosphorus rates and an interaction (Appendix Table 2).

Nassir variety exhibited greatest total number of effective nodules plant^{-1} (14.35) followed by Hawassa Dume varieties (13.44). However, Omo-95 variety exhibited the lowest (13.40) nodule number plant^{-1} .The observed differences in effective 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}.

Significant difference (P< 0.01) was also exhibited on nodule number plant^{-1} among different levels of applied P). The application of 92kg P ha^{-1} recorded highest effective nodule number plant^{-1} (14.67) which was followed by the application of 69 kg P ha^{-1} (14.43) ,46 kg P ha-1(14.07), 23 kg P ha^{-1}(13.34)and zero application (12.14).The observed differences in effective 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 those common bean varieties, Nassir showed relatively higher number of effective nodules over Hawassa dume and Omo-95, while lower number of effective nodules was observed with Hawassa dume variety up to 46 kg P ha^{-1} application rate. Thus, the highest (15.7) and the lowest (11.13) number of effective nodules were attained at 46 kg P ha^{-1} with Nassir variety and at 0 kg P ha^{-1} (control plot) with Hawassa dume variety interaction (Fig 3). At 0, 23, 46 kg P ha^{-1}, the highest (12.73, 13.83 and 15.7) and lowest (11.13, 12.4 and 12.67) number of effective nodules plant^{-1} were attained from Nassir and Hawassa dume variety, respectively. At 69 kg P ha^{-1} both Omo-95 and Nassir variety showed decreasing in number of effective nodules as compared to the value observed at 46 kg P ha^{-1} application rate (Fig 3).This variation in number of effective nodules plant^{-1} might be due to the vital role of phosphorus in increasing the number and size of nodule and the amount of nitrogen assimilated per unit of nodules. In agreement with this result, Bashir et al. (2011) reported that phosphorus plays a vital role in increasing plant tip and root growth, decreasing the time needed for developing nodules to become active (effective) for the benefit to the host legume.

The variety x phosphorus levels interaction was significantly ($p<0.05$) affected number of nodule plant^{-1} on common bean varieties (Fig. 3). This implies that common bean varieties responded differently to the combinations of supplied P levels. Number of effective nodules plant^{-1} of each common bean varieties increased with an increasing phosphorus fertilizer application rate up to 46 kg P ha^{-1} but further increasing of P fertilizer application showed decreasing trend for both Omo-95 and Nassir variety, while, with Hawassa dume variety progressive increment with an increasing phosphorus application rate from control plot to 92 kg P ha^{-1} was observed(fig 3).



LSD (5%): 1.98 and CV (%): 8.62

Figure 3: Interaction effects of verities with phosphorus on number of effective nodule. Vertical lines on bars represent standard error of the statistical means.

4.3.3. Number of primary branches plant^{-1}

Number of primary branches of common bean was significantly ($P \leq 0.05$) affected by phosphorus application rates; while, common bean variety and its interaction with phosphorus fertilizer application rate had no significant ($P > 0.05$) effect on number of primary branches plant^{-1} of the crop (Appendix 1).

The application of P fertilizer significantly affected the number of primary branches plant^{-1}. The highest (6.43) number of primary branches was recorded from 46kg P ha^{-1}, whereas the lowest number of primary branches was recorded from the control treatment. However, there was non- significance between 92, 69, 46 kg P ha^{-1}(Table3) .This might be due to the role of phosphorus in cell divisions which leads to development of new tissue (branches);

and enhanced uptake of nutrients even at the initial stage of crop growth. In line with this result, Meseret and Amin (2014) observed that number of branch plant^{-1} increased with increasing phosphorus application rates. In the same way, the increment in number of branches plant^{-1} might be importance of P for cell division activity, leading to the increase of plant height and number of branches and consequently increased the plant dry weight (Tesfaye,2007;Liu, 2007).

Table 3: Growth performance of common bean varieties in response to Phosphorous application at Negelle Borena in 2020

Factor	Number of primary branches	Number of leaves	Plant height (cm)
Varieties			
Hawassa dume	6.14	18.21^{c}	76.15^{b}
Omo-95	6.06	22.69^{a}	78.86^{a}
Nassir	5.58	21.67^{b}	80.28^{a}
LSD 0.05	**Ns**	**0.83**	**2.06**
P rate (kg P ha^{-1})			
0	5.22^{b}	19.11^{c}	78.84
23	5.49^{b}	19.18^{c}	78.48
46	6.43^{a}	20.82^{b}	78.54
69	6.31^{a}	22.41^{a}	78.14
92	6.18^{a}	22.76^{a}	78.14
LSD (0.05)	**0.67**	**1.07**	**Ns**
CV	**11.75**	**5.34**	**3.52**

Means followed by the same letter in the same column are not significantly different from each other at 0.05 level of significance, whereas the opposite is true for different letters.

Ns- Stands for non-significant, LSD & CV= Least significant difference & Coefficient of variation respectively.

4.3.4. Number of leaves plant^{-1}

Analysis of variance indicated that varieties and P rates had highly significant ($P < 0.001$) effect on number of leaves plant^{-1}. However, the interaction of common bean with P fertilizer rates didn't show significant effect on number of leaves plant^{-1} (Appendix 1).

Regarding the main effect of varieties, the highest (21.69) number of leaves plant^{-1} were recorded from Omo-95 variety and the lowest (18.21) from Hawassa Dume variety (Table 3). The observed difference in number of leaves plant^{-1} among varieties might be due to inherent genotypic differences. In line with the result Jibril (2020) observed that local variety had the highest (37) leaf number, while improved variety (Goberesha) had the lowest (20.92).

The highest number of leaves plant^{-1} (22.76) was recorded from the highest (92 kg P ha^{-1}) P rate, while the lowest number of leaves plant^{-1} (19.11) was recorded from the control (0) treatment. Thus, number of leaves plant^{-1} was progressively increased with the increase in P rate up to 69 kg P ha^{-1}. But further increase in Phosphorus application had no significant effect on number of leaves plant^{-1} (Table 3). The result was in line with the finding of Jaisankar and Manivannan (2018), who reported that number of leaves plant^{-1} increased from 48.01 to 66.5 with an increasing phosphorus application rates from 0 to 40 kg P ha^{-1}. This could be attributed to functional growth of new leaves and tissue by phosphorus (Faegheh and Hashem, 2015; Ali *et al*., 2008).

4.3.5. Plant height

Analysis of variance revealed highly significant ($P < 0.01$) differences among the Common Bean varieties in plant height. However, application of phosphorus rates and its interaction with variety was not significantly influenced plant height (Appendix 1).

The tallest plant height was recorded from Nassir variety, while the shortest was from Hawasa dume (Table 3). The height difference among varieties of the crop might be due to their genotypic variation Magani and Kuchinda (2009).

4.4. Effects of Phosphorus rates on Yield and Yield Components of Common Bean

4.4.1. Number of pods plant^{-1}

Common bean varieties differed significantly ($P < 0.001$) in number of pods plant^{-1}. Similarly, the effect of P fertilizer application was significant ($P < 0.001$) on number of pods plant^{-1}, while the interaction effect of P with variety was not significant (Appendix Table 2).

The highest number of pods plant^{-1} (17.14) was attained from Hawasa dume variety ,while the lowest (15.01) from Nassir (Table 4). This could be due to the genotypic difference among varieties of the crop to produce higher number of pods. Similarly Wondimu and Tana´s (2017) findings showed highly significant difference among common bean varieties on number of pods plant^{-1}. Moreover, in consistent with the results of this study, Mourice and Tryphonne (2012) observed significant variations in number of pod^{-1}among common bean genotypes.

In case of P application effect, progressive increment was observed with an increase of the fertilizer from 0 kg P ha^{-1} to 46 kg P ha^{-1} rate of application but further increase of fertilizer application had no significant effect. Accordingly, the highest number of pods $plant^{-1}$ (18.44) was showed by 46 kg P ha^{-1} rate, while the lowest number of pods $plant^{-1}$ (14.07) was recorded by unfertilized plot .The increment of number of pods $plant^{-1}$ due to application of P fertilizer confirms the fact that P fertilizer promotes the formation of nodes and pods in legumes. 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 increasing rate of phosphorus up-to the highest rate (40 kg P ha^{-1}). This result might be attributed to the fact that phosphorus enhance the formation and development of canopy and pod setting in common bean. Additionally, it might be due to adequate availability of phosphorus that might have contribution in synthesis of dry matter by increasing number of leaves $plant^{-1}$ and then, might be in turn partitioned to the more sinker reproductive part of the crop in order to produce high number of pods. Moreover, Singh and Singh (2000), Buttery (1969) described significant increase in number of pods $plant^{-1}$, due to increased P fertilization. The increment in the number of pods per plant might be due the metabolic role that P plays in promoting the reproductive growth of the crop (Rafat and Sharifi, 2015).

4.4.2. Number of seeds pod^{-1}

Differences were observed among varieties significantly ($P < 0.001$) in number of seeds pod^{-1} of the tested crop (Appendix Table 2). Accordingly, Omo-95 variety had higher number of seeds (7.41) than that of Hawasa dume (5.67) and Nassir (5.91) Table 4). Accordingly, Jibril (2020) reported similar results that showed difference in number of seeds among common bean varieties. Similarly, it was reported by Wondimu and Tana (2017) that a significant difference was observed among Common Bean varieties. In agreement with this result, Fageria and Santos (2008) also reported that the number of seeds pod^{-1} of different common bean genotypes varied in the range of 3.1 to 6. This could be from the inherent variation in the genetic makeup for photosynthesis and translocation of dry matter to grain yield production.

Phosphorus fertilizer rates also showed significant ($P < 0.001$) effect on number of seeds pod^{-1} of common bean but its interaction with variety of the crop was not influenced significantly the number of seed pod^{-1} (Appendix Table 2).

With progressive increment of P-fertilizer application rate increased number of seed pod^{-1} of the crop was observed. Accordingly, there was progressive increment in number of seed pod^{-1} with an increasing P application rate from 0 up to 46 kg P ha^{-1} but further increasing had no statistical difference. The highest number (7.19) of seed pod^{-1} by 69 kg P ha^{-1} application and the lowest number of seed pod^{-1} (4.9) by the control was attained (Table 4). In line with this result, Meseret and Amin (2014) reported that analysis of variance for seeds pod^{-1} showed significant response to phosphorus rates and the highest number of seeds pod^{-1} (5.85) was obtained at applied P rate of 20 kg ha^{-1}, whereas the lowest seed pod^{-1} (3.14) was recorded at the control treatment. Similarly, Tessema and Alemayehu (2015) also observed that with increasing phosphorus rate from 0 - 39.6 kg ha$^{–1}$, number of seeds pod^{-1}of common bean increased from 3.27 - 3.77. This variation might be, due to the effect of phosphorus fertilizer application on physiological processes of the crop (increasing number of leaf and initiating root growth and development) and the conversion of dry matter produced into pods and then to higher formation of seeds. In addition, Shubhashree (2007) reported that number of seeds pod^{-1} increased significantly to response to phosphorus enance. The increment of seeds pod^{-1} with increasing P fertilizer application up to optimum level might be due to the role of P on fruiting and seed formation and more pothosynthesis translocation to seed formation.

4.4.3. Hundred seed weight

The results of analysis of variance indicated that hundred seed weight was significantly ($P < 0.001$) affected by the main effect of varieties. The effect of P also was significant. However, the interaction of varieties and phosphorus fertilizer application rates were not significantly affected hundred seed weight of the crop (Appendix Table 2).

Out of those varieties, the highest (27.63) hundred seed weight was recorded from Hawassa dume, while the lowest (23.53) hundred seed weight was recorded from Omo-95 variety of the crop (Table 5). This variation might be attributed by genotypic difference of the varieties. In line with the result, Masa *et al.* (2017), Tamado et al. (2007), Jibril (2020) and Wondimu and Tana (2017) found significant difference on the hundred seed weight due to different bean genotypes.

Similarly, significantly ($P \leq 0.001$) different hundred seed weight was observed as a result of influence of phosphorus application rates. Hence, the highest hundred seed weight (26.76) of the crop was attained by 46 kg P ha^{-1} application rate, while the lowest hundred seed weight (23.61) was attained by the control plot (Table 4). This might be due to the influence of phosphorus on cell division, phosphorus content in the seeds and the formation of fat in the seed of haricot bean. Similarly, Amare *et al.* (2014) observed significant increase in thousand seed weights of common bean as a result of phosphorus application. According to Zafar et al.(2013) the increase in hundred seed weight was reported as a result of increased P application might be attributed to important roles that P played in regenerative growth of the crop leading to increased seed size which in turn may improve hundred seed weight. In a similar study, Amare *et al.* (2014) and Dereje *et al*. (2016) observed significant variations in hundred seed weights of common bean cultivars as a result of P application. Thus, application of P might improve the seed quality of beans.

The correlation analysis values (using P rates)indicated that hundred seed weight was positively correlated with nodule number plant^{-1} (r=0.62***), number of effective nodule (r=0.15^{ns}) primary branch number plant^{-1} (r=0.24^{ns}),number of pod plant^{-1}, (r=0.62***),Total above ground biomass (r=07ns) and grain yield, (r=0.67***) .However, hundred seed weight was negatively correlated with days of flowering (r=-0.67***), days of maturity, (r=-0.63***) and leaf number plant^{-1} (r=-0.52***) (Appendix table-3)

Table 4: Effect of Phosphorus application rate on yield and yield components of Common Bean varieties

Factors	Number of pods plant^{-1}	Number of seeds pod^{-1}	Hundred seed weight (g)	Above ground biomass (t ha^{-1})	Grain yield(t ha^{-1})	Harvest index
Variety						
Hawassa dume	17.14^{a}	5.67^{b}	27.63^{a}	3.23b	2.11^{a}	64.79^{a}
Omo-95	15.01^{c}	7.41^{a}	23.53^{c}	3.5 a	1.85^{b}	53.38^{b}
Nassir	16.19^{b}	5.91^{b}	24.48^{b}	3.47 a	1.87^{b}	53.75^{b}
LSD 0.05	**0.77**	**0.44**	**0.55**	**0.21**	**0.15**	**2.64**
P rate (kg ha^{-1})						
0	14.07^{c}	4.90^{b}	23.61^{c}	2.56 c	1.43^{c}	55.05
23	16.31^{b}	5.46^{b}	24.17^{c}	3.47 b	1.7^{b}	59.35
46	18.44^{a}	6.97^{a}	26.76^{a}	3.54 b	2.38^{a}	57.88
69	16.01^{b}	7.19^{a}	26.32^{a}	4.07 a	2.36^{a}	58.14
92	15.74^{b}	7.14^{a}	25.2^{b}	3.38 b	1.85^{b}	56.11
LSD 0.05	**1**	**0.57**	**0.71**	**0.27**	**0.19**	**Ns**
CV	**6.43**	**9.34**	**2.93**	**8.2**	**10.38**	**6.15**

Means followed by the same letter in the same column are not significantly different from each other at 0.05 level of significant, whereas the opposite is true for different letters.

4.4.4. Above ground biomass

Common bean varieties showed significant ($P < 0.05$) difference in above ground biomass yield. The effect of P also was significant. However, their interaction had no significant effect on above ground biomass yield (Appendix Table 2).

The highest (3.5) and lowest (3.23) biomass yield were recorded from Omo-95 and Hawasa dume variety, respectively. The highest (3.5) recorded biomass value was statistically similar with the biomass value (3.47) obtained from Nassir variety of the crop (Table 4). This might be due to genotypic response of common bean variety in order to produce biological yield.

Similarly, above ground biomass yield of the crop was significantly ($P < 0.001$) influenced by P application rates. The highest (4.07) and lowest (2.56) above ground biomass yield was recorded from 69 kg ha^{-1} and 0 kg ha^{-1}, respectively (Table 4). Biomass yield of the crop progressively increased with an increasing P application rate from 0 or unfertilized up to 69 kg P ha^{-1}, while further increasing application rate result in declining of aboves ground biomass (Tables 4).

This result is in agreement with that of Gustfson (2010) who reported the increase in dry biomass yield of common bean in response to the increased P application which may be ascribed to the phenomena on sufficient supply of P is associated with increased root growth and leaf expansion that may lead to high dry matter accumulation through enhancing effective exploitation by the roots for the immobile nutrients such as phosphorus. Similar ,results showed that P supply was significantly increased above ground total biomass yield of common bean (Gebre-Egziabher *et al.*, 2014; Meseret and

Amin, 2014).The result the variation in dry biomass yield of the cultivars across P levels might be attributed to enhanced availability of P for root growth and number of nodules by which it increases nutrient absorption that contribute to full development of above ground parts of the plants and genotypic variations of the cultivars in leaf area index and number of branch, which may affect photosynthesis and photo-assimilate synthesis (Fujita et al., 1999). Consistent with these results, Dereje *et al.* (2016) reported significant increases in biomass yield in response to P application. In a similar study, Mourice and Tryphone (2012) reported that common bean cultivars produced different dry matter at different P levels.

4.4.5. Grain yield

Analysis of variance revealed that varieties and application of P highly significantly (P< 0.001) affected the grain yield. But, the interaction effect of P x variety were not significant for seed yield (Appendix Table 2).

The highest grain yield obtained from Hawassa dume variety exceeds the yield obtained from Nassir and Omo-95 by 11.4% and 12.3%, respectively (Table 4). The result obtained conforms the grain yield reported by (Gebre-Egziabher *et al.*, 2014; Girma *et al.,* 2017; Tarekegn and Serawit. 2017). Perhaps, the yield variation among varieties could be related to yield potential of those bean varieties.

Accordingly, the yield attained at 46 kg P ha^{-1} (2.38) which exceed unfertilized plot yield (1.43) by 39.92% was recorded .However, the yield obtained from 46 kg P ha^{-1} did not differ from 69 kg P ha^{-1} application,(Table 4). This increased grain yield from P application could be due to its role in developing a 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. Additionally ,similar result may be attributed to the fact that application of P fertilizer increases crop growth and yield on soil which is naturally low in P and in soils that have been depleted (Mullins, 2001). The application of P fertilizer had positive effect on yield. because fertilized plots gave better yield compared to control plot (P 0 $kgha^{-1}$). In line with this result, Shahid *et al*. (2009) and Tarekegn *et al*. (2017) indicated that sufficient available P is required by legumes to enhance plant growth, promote nodulation, early maturity and grainyield.

The correlation analysis values (using P rates)revealed that grain yield positively correlated with number nodule number $plant^{-1}$, (r=0.58***), number of effective nodule (r=0.23ns), primary branch number $plant^{-1}$ (r=0.52***), number of pod $plant^{-1}$ (r=0.58***), seed pod $plant^{-1}$ (r=0.19ns), hundred seed weight, (r=0.67***), above ground biomass yield, (r=0.61***) .However, days of flowering (r=-0.39**) and days of maturity (r=-0.31**)and leaves number $plant^{-1}$ (r=-0.08 ns)were negatively correlated with grain yield(Appendix table-3).

4.4.6. Harvest index

The physiological ability of a crop plant to convert proportion of dry matter into economic yield is measured in terms of harvest index. The analysis of variance on harvest index showed that there was a significant difference in the effect of varieties, but there was no significant difference on P application and their interactions (Appendix Table 2).

The highest harvest index was observed from Hawasa dume variety, while the lowest was recorded from Omo-95 variety (Table 4). The observed differences among varieties may be attributed to the genotypic differences with regard to efficiency in dry matter partitioning. In agreement with this result, Ano (2005) reported that the differences in harvest index might be due to the inherent varietal characteristics, environmental factors and other cultural practices.

4.5. Partial Budget Analysis

From the result of this study, the mean yield of all 15 treatments tested was obtained. According to CIMMYT (1988), the average yield was adjusted down ward by 10%. This is because that, the researcher have assumed that using the same treatments the yield from experimental plots and farmers field vary, thus average yield obtained from the treatment tested should be adjusted down ward. According to the economic analysis data (Table 6) both un-dominated treatment marginal rates were above 100% that is in a range of acceptance (CIMMYT, 1988).

Net benefit were calculated by determining variable costs for fertilizer (TSP) at 18.50 ETB kg^{-1} ,and Labor (300 birr ha^{-1}) due to treatment effects. Hawassa Dume variety with 46 kg P_2O_5 ha^{-1} ranked the highest among the treatments with the highest marginal rate of return in percent. Therefore, from the budget summary of economic analysis, the highest net return (37,630ETB ha^{-1}) with acceptable marginal rate return (1140.54 %) was obtained from Hawassa Dume variety with 46 kg P_2O_5 ha^{-1}application. This implies that the grower on the study area can get additional benefit of 11.4054 ETB for every 1 ETB expense by this treatment, followed by Hawssa Dume variety with 23 P_2O_5 kg ha^{-1} supply having a net return of 27,080 ETB ha^{-1}. The lowest net economic return was recorded in the Omo-95 variety with zero-P application (17,550 Birr ha^{-1}) (Table 5). Therefore, use of Hawassa Dume variety with 46 kg P_2O_5 ha^{-1}application was found to be economically feasible at,Nagelle Borena of Ethiopia(CIMMYT, 1988).

Table 5: Partial budget analysis of response of haricot bean variety to different phosphorus fertilizer rate

Teatement	Yield(t ha-1)	Adjusted yield (t ha-1)	GB(Birr)	P cost (birr ha-1)	LC(birr ha-1	TVC(Birr ha-1)	Net Benefit	Dominance	MRR (%)
H.D	1.47	1.323	22491	0	0	0	22491	UD	-
Omo-95	1.3	1.17	17550	0	0	0	17550	D	-
Nassir	1.5	1.35	20250	0	0	0	20250	D	-
H.Dx23P	1.85	1.665	28305	925	300	1225	27080	UD	374.61
Omo-95X23P	1.62	1.458	21870	925	300	1225	20645	D	-
NassirX23P	1.6	1.476	22140	925	300	1225	20915	D	
H.DX46P	2.62	2.34	39780	1850	300	2150	37630	UD	1140.54
Omo-95X46p	2.29	2.061	30915	1850	300	2150	28765	D	
Nassirx46P	2.23	2.007	30105	1850	300	2150	27955	D	
H.DX69P	2.61	2.349	39933	2775	300	3075	36858	D	
Omo-95X69P	2.28	2.052	30780	2775	300	3075	27705	D	
Nassirx 69	2.18	1.962	29430	2775	300	3075	26355	D	
H.D x92 P	2.01	1.809	30753	3700	300	4000	26753	D	
Omo-92 X92	1.75	1.575	23625	3700	300	4000	19625	D	
Nassir X92	1.78	1.602	24030	3700	300	4000	20030	D	

GB=Gross benefit, LC=Labor cost, TVC=Total variable cost, MRR= Marginal rate of return, D= Dominated, UD=Undominated, HD=Hawassa Dume (sealed yld seed (17 kg^{-1} birr) O-95=Omo-95(saled yld seed (15 kg^{-1} birr)N=Nassir saled yld seed(15 kg^{-1} birr respectively), P= Phosphorus fertilizer(brought 18.5).

5. SUMMARY, CONCLUSION AND RECOMMENDATION

High production of a given crop could be achieved through manipulating soil fertility, plant population, spacing, variety selection and crop management practices. Among those agronomic management practices contributing to maximizing yield of crops, recommendation of fertilizer application rates per a given area for a given improved variety of crops require special focus to come up with profitable and sustainable crop production. Specifically, short term crops including common bean production require applying full packages which is supported by research output for the producers to get high profit of the crop to strengthen the food security needs of the burgeoning world human population. But unavailability of informations of full package of those production factors is suffering most producers to get high yield of the crop.

To meet this requirement, the present experiment was conducted in 2020 cropping season under rain fed condition at Negelle Borena, southern Ethiopia, with the objective of determining the optimum rate of P fertilizer needed to achieve the best quality and economically optimum yield of common bean varieties. Factorial combinations of three haricot bean varieties (Hawasa Dume, Omo-95 and Nasir) and five levels of P fertilizer (0, 23, 46, 69 and 92 kg P ha^{-1}) were laid out in Randomized Complete Block Design (RCBD) with three replications.

The result of the experiment revealed that the highest number of leaves $plant^{-1}$ (22.69), days to maturity (92.31 days), above ground biomass (3.5 kg) and number of seeds pod^{-1} (7.41) recorded for Omo-95 variety of haricot bean while the highest number of pods per plant (17.14), harvest index (64.79), hundred seed weight (27.63g) and grain yield (2.11) was recorded from Hawassa dume variety. But, the highest plant height (80.28cm) and number of days to flowering (42.93 days) were observed at Nassir variety.

With regard to phosphorus effect, the highest number of days to flowering (43.44 days) and number of days to maturity (89.16 days) was recorded control plot; the highest number of primary branch (6.43), number of pod plant^{-1} (18.44), hundred seed weight (26.76g) and grain yield (2.38 t ha^{-1}) at 46 kg P ha^{-1}; the highest above ground biomass (4.07kg) and the highest number of seed pod^{-1} (7.19) at 69 kg P ha^{-1}; and the highest number of leaves plant^{-1}(22.76) at 92 kg P ha^{-1} were observed. The interaction of common bean variety and P fertilizer application rate also significantly affected number of nodule and number of effective nodules plant^{-1}, and the highest number (25.93) and (15.7) were recorded at 46 kg P ha^{-1} for Omo-95 and 46 kg P ha^{-1} for Nassir variety, respectively.

Similarly, correlation analysis values (using P rates) was conducted and showed that number of nodules plant^{-1} positively correlated with number of effective nodules, primary branches number plant^{-1} , number of pods plant^{-1} , hundred seed weight ,above ground biomass and grain yield. However, days to flowering, days to maturity , leaves number plant^{-1} and seeds pod^{-1} negatively correlated with nodule number. The correlation analysis indicated that hundred seed weight was positively correlated with number of nodules plant^{-1} number of effective nodules, primary branches number plant^{-1}number of pods plant^{-1}, above ground biomass and grain yield.However ,days of flowering days, days of maturity and leaf number plant^{-1} were negatively correlated with that hundred seed weight . The correlation analysis values (using P rates)revealed that grain yield positively correlated with number nodule number plant^{-1}, number of effective nodule , primary branch number plant^{-1} , number of pod plant^{-1} , seed pod plant^{-1} , hundred seed weight, and above ground biomass yield.However, days of flowering ,days of maturity and leaves number plant^{-1} were negatively correlated with grain yield.

The highest net return (37,630 ETB ha^{-1}) with acceptable marginal rate of return (1140.54 %) was obtained from Hawassa Dume variety when 46 kg P ha^{-1}was applied. This implies that the growers of the study area can get additional benefit of 11.4054 ETB for every 1 ETB expense, followed by Hawssa Dume variety with 23 P_2O_5 kg ha^{-1} resulted in a net return of 27,080 ETB ha^{-1}.The lowest net economic return was recorded in the Omo-95 variety with zero-P application (17,550 Birr ha^{-1}).

Therefore, based on the result it can be concluded that Hawassa dume variety and 46 kg P ha^{-1} rate were suitable for common bean production in the study area and similar agro-ecologies under rain fed. However, this experiment was conducted in a single growing season and location and thus, repeating the experiment with similar experiment across locations and years is suggested to come up with conclusion reccommendation.

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7. APPENDIXES

Appendex Tables 1: **Analysis of variance for phenological and growth parameters of Common Bean Varieties**

(Days to 50% flowering (DF) and days to maturity (DM) ,number of nodules plant^{-1} (NNP) , number of effective nodules plant^{-1} (NENP) , ,number of primary branches plant^{-1} (NPB), number of leaves plant^{-1} (NLP) and plant height (PH)

Source of variation	DF	DF	DM	NNP	NENP	NPB	NLP	PH
Replication	2	0.69^{ns}	3.37^{ns}	1.11^{ns}	8.86***	0. 23^{ns}	1.32^{ns}	19.07^{ns}
Varieties	2	40.56***	273.05***	37.13***	4.3*	1.37^{ns}	82.88***	65.93**
P rate	4	9.67***	10.52*	109.23***	9.4***	2.62*	26.73***	0.79^{ns}
V * P rate	8	1.66^{ns}	1.24^{ns}	6.11***	3.52*	0.13^{ns}	1.53^{ns}	0.82^{ns}
Error	28	1.11	3.46	1.12	1.4	0.48	1.24	7.6

*, ** and *** indicates that the parameter was significant at 5 %, 1 % and 0.1% probability levels, respectively. The abbreviation ns, DF, P and V - stands for non-significant at (P > 0.05), degrees of freedom and Common Bean variety, respectively.

Appendex Tables 2: **Analysis of variance for yield and yield components of Common Bean varieties**

(number of pods per plant (NPP), number of seeds per pod (NSP), hundred seed weight (HSW), (above ground biomass (AGB), and grain yield (GY) and harvest index (HI),

SV	DF	NPP	NSP	HSW	AGB	GY	HI
Replication	2	0.04^{ns}	0.12^{ns}	0.28^{ns}	0.01^{ns}	0.05^{ns}	10.78^{ns}
Varieties	2	17.07***	13.38***	69.05***	0.33*	1.57***	630.32***
P rate	4	22.08***	9.56***	16.36***	2.66***	0.32**	26.46^{ns}
V * P	8	2^{ns}	0.79^{ns}	0.87^{ns}	0.05^{ns}	0.02^{ns}	25.78^{ns}
Error	28	1.1	0.35	0.55	0.08	0.04	12.42

* , ** and *** indicates that the parameter was significant at 0.05 ,0.01 % and 0.001% probability levels, respectively and ns- stands for non-significant at (P > 0.05). The abbreviation SV- stands for source of variation, DF- stands for degrees of freedom, V- stands for Common Bean variety.

Appendex Tables 3**:**Correlation Values among parameters (Using P rates)

	DF	DM	NNP	NEN	BN	LPP	NPP	SPP	HSW	ABM	GY
DF											
DM	0.52***										
NNP	-0.42**	-0.41**									
NEN	-0.20ns	-0.33*	0.20ns								
BN	-0.25ns	-0.18ns	0.29ns	0.07ns							
LPP	0.31*	0.44**	-0.39**	0.27ns	0.19ns						
NPP	-0.42**	-0.41**	1.00***	0.20ns	0.29ns	-0.39**					
SPP	0.03ns	0.46**	-0.18ns	0.06ns	0.40**	0.64***	-0.18ns				
HSW	-0.67***	-0.63***	0.62***	0.15ns	0.24ns	0.52***	0.62***	-0.18ns			
ABM	0.01***	0.12ns	0.06ns	0.25ns	0.30*	0.39**	0.06ns	0.43**	0.07ns		
GY	-0.39**	-0.31*	0.58 ***	0.24ns	0.52 ***	0.08ns	0.58***	0.19ns	0.67 ***	0.61***	

(Days to 50% flowering (DF) and days to maturity (DM) ,number of nodules plant^{-1} (NNP) , number of effective nodules plant^{-1} (NENP) ,number of primary branches plant^{-1} (NPB), number of leaves plant^{-1} (NLP) ,number of pods per plant (NPP), number of seeds per pod (NSP), hundred seed weight (HSW), (above ground biomass (AGB), and grain yield (GY)

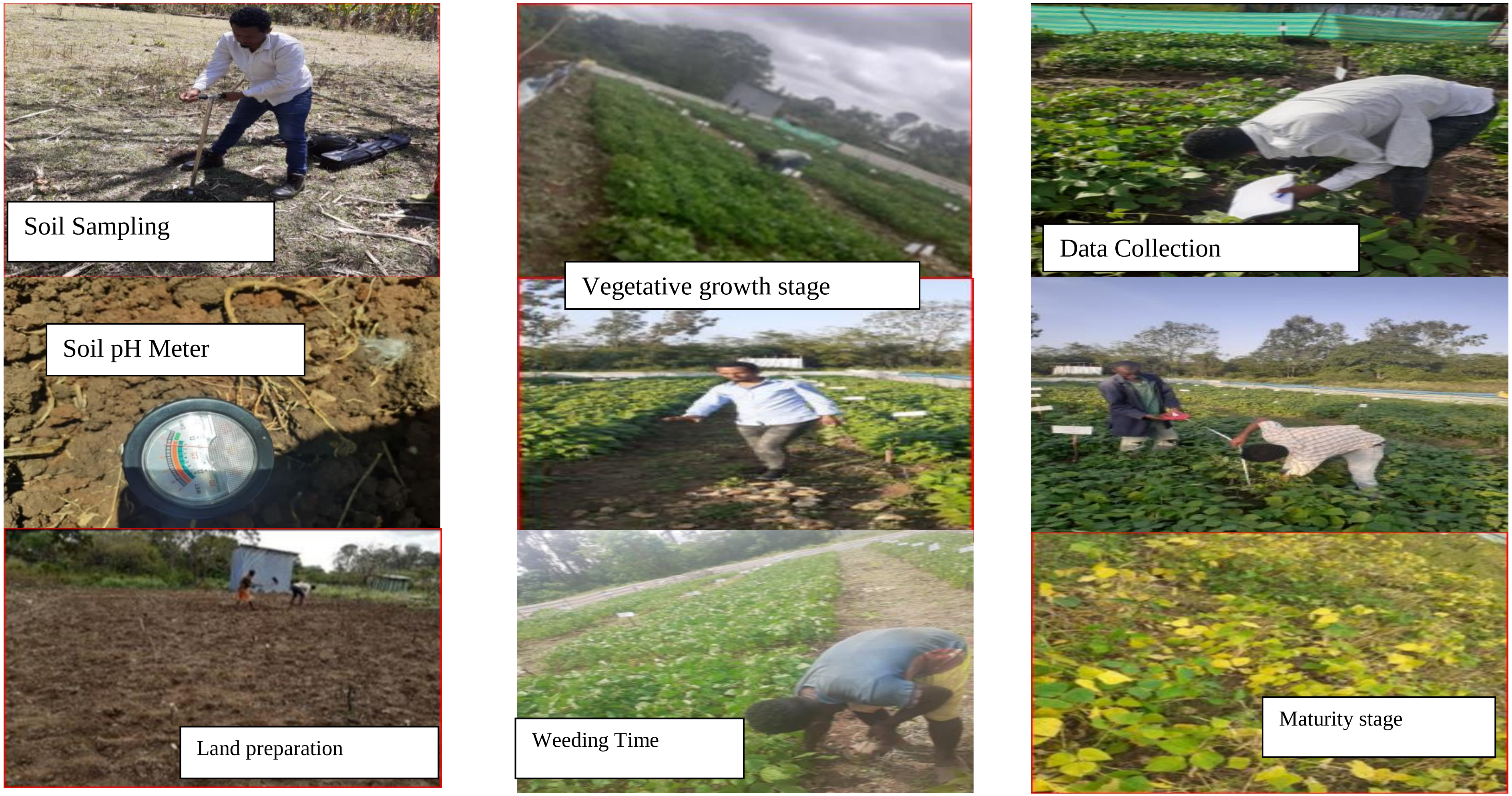

Figure 3: Some pictures during experimentation time

BIOGRAPHICAL SKETCH

The author, Gadisa Beyene was born on April, 1990 at 03 kebele, Shambu Town, Horo Guduru Wollega Zone, Oromia region, Ethiopia. He attended his Elementary, high and preparatory school education at Model, Shambu Senior and Secondary and Preparatory, respectively. He joined Mizan Tep University in 2011 to attend Department of Plant Science and graduated in Bachelor of Science degree in plant science in July 04,20 2012. After his graduation, he was employed by Guji Zone Agriculture and Natural Resource Office and served for 8years. Starting from 2014 he was employed by Guji Zone Agriculture and Natural Resource Office as an Irrigation Agronomist and working there until he joined the School of Graduate Studies of Hawassa University to attend Masters of Science in Agronomy in 2018.