RESPONSE OF COMMON BEAN (*Phaseolus vulgaris L.)* VARIETIES TO RATE OF BLENDED NPS FERTILIZER IN JARSO DISTRICT, EAST HARARGHE

MSc Thesis

BY

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Haramaya University, Haramaya

Response of Common Bean (*phaseolus vulgaris l.)* Varieties to rate of Blended NPS Fertilizer in Jarso District, East Hararghe

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APPROVAL SHEET
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As Thesis Research Advisers, we hereby certify that we have read and evaluated this thesis prepared under our guidance by **Abdi Hassen Abrahim** entitled "**Response of Common bean (***Phaseolus Vulgaris* ***L.)*** **Varieties to rate of Blended NPS fertilizer** in Jarso district, East Hararghe and we recommend that it be submitted as fulfilling of the MSc thesis requirement.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CIAT	Centro Intracional De Agriculture Tropical
CIMMYT	Centro International de Mejoramiento de maize y Trigo
CSA	Central Statistics Agency
CV	Coefficient of Variation
EIAR	Ethiopian Institute of Agricultural Research
EPPA	Ethiopian Pulse Profile Agency
GENSAT	Gen stat 18th
GFB	Gross Field Benefit
FAO	Food and Agriculture Organizations
LSD	Least Significant Difference
MARC	Melkesa Agriculture Research Center
NPS	Nitrogen, Phosphorus and Sulphur
RCBD	Randomized Complete Block Design

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BIOGRAPHICAL SKETCH

The author, Abdi Hassen Abrahim ,was born at Elahabro near to Chelenko town on June 11, 1984, in Metta District East Hararghe Zone of Oromia Regional state to his father Hassen Abrahim Mumed and mother Fatuma Isse Tahir. He attended his Primary education from 1992 to 1999 (1-8grade) at ChelenkoPrimary School, from 2000 to 2001 at Deder secondary school. And the author joined Bako ATVET Collage from 2002 to 2004 and graduated on June 2004 with Diploma in Plant Sciences. On September 2005, he was employed in the Office of Agriculture at Jarso District Extention worker's up to 2009 years and joined Ambo University from 2010 to 2014 in Winter Program and awarded a Bachelor Degree in Plant Science. He was employed in the office of Agriculture at Jarso District as Agronomist expert from 2015 to 2018.On July 2018, he joined the postgraduate program at Haramaya University, School of Plant Sciences, to pursue his study for the degree of Master of Sciences in Agronomy.

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RESPONSE OF COMMON BEAN** (Phaseolus vulgaris.L.) **VARIETIES TO RATE OF BLENDED NPS FERTILIZER IN JARSO DISTRICT, EAST HARARGHE ,ETHIOPIA

ABSTRACT

Common bean (Phaseolus vulgaris L.) is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enable households to get cash income required to purchase food and household needs when other crops have not yet matured. However, the current national average yield of common bean is far less than the attainable yield under good management conditions for most improved varieties. This low yield of common bean in Ethiopia is attributed to several production constraints. Thus, a field experiment was conducted to assess the effect of blended NPS rates on growth, yield and yield related traits common bean varieties and to estimate economically feasible rates of blended NPS fertilizer for common bean production. The experiment was conducted in Jarso district sub-site of Melka jebdu demonstration site during 2019 to 2020 main cropping seasons. Treatments consisted of factorial combinations of three common bean varieties (Babile, Fedis, and Tinike,) with five NPS fertilizer rates (0, 50, 100, 150 and 200 kg ha^{-1}) laid out in randomized complete block design with three replications. The highest days to 50% flowering (48.73 days), days to 90% physiological maturity (95.8 days), effective nodule number (33.67), number of seed per pod (4.67) were recorded from variety Tinike while the highest total nodule number (69) , number of primary branch per plant (3.53), stand count (96.53) and hundred seed weight (45.38 g) were recorded from variety Fedis. The highest level of NPS rate (200 kg ha^{-1}) resulted in higher values of number of primary branches per plant, number of total nodules, number of effective nodules, number of seeds per pod and 100 seed weight. However, the highest number of pod per plant (25.33), Grain Yield (2565 kg ha^{-1} and harvest index (41,30) , were recorded due to application of 150 kg ha^{-1} of blended NPS for variety Fedis. Variety Tinike gave the highest plant height (67.60 cm) and above ground dry biomass (6330kg ha^{-1}) with application of 200 kg NPS ha^{-1}. Agronomic Efficiency (kg seed kg^{-1} of NPS) as ratio of seed yield to NPS fertilizer rates with three common bean varieties showed highly significant ($p<0.001$) effects with the highest value (5.6 kg seed kg^{-1} of NPS) in treatment combination of 150 kg NPS ha^{-1} fertilizer. Based on this result, the highest net benefit of 53,454 ETBha^{-1} with Marginal Rate of Return of 850.5% was obtained from the treatment combination of 150 kg NPS ha^{-1}application rate with Fedis variety. Thus, it can be concluded from the result of present study that the use of variety Fedis with application of 150 kg NPS ha^{-1} could be recommended to enhance the productivity of common bean in the study area. However, the result of the present study need to be validated and proved in the same agro-ecologies and seasons with further experiments in order to give a blanket recommendation for wide range of common bean production.

KEYWORDS: Agronomic Efficiency, Common bean, NPS fertilizer, Partial Budget Analysis.

1. **INTRODUCTION**

The common bean (Phaseolus vulgaris L.) also known as haricot bean has evolved from a wild growing vine distributed in the highlands of Central America and the Andes into a major leguminous food crop growing worldwide in a broad range of environments and cropping systems (Gepts and Debouck, 1991). It is assumed that beans were introduced to Ethiopia in the 16th century by the Portuguese (Imru, 1985). Common bean is adapted to areas with altitudes ranging from sea level to nearly 3000 meter above sea level, m. a. s. l. (CIAT, 1986b). However, it does not grow well below 600 m. a. s. l. due to poor pod set caused by high temperature (Cobley, 1976).

Suitable production areas of bean in Ethiopia has been indicated as areas with altitude between 1200-2200 m. a. s. l., mean maximum and minimum temperature of less than 32c0 and greater than 10 c, respectively with a rainfall ranging from 350 to 700 mm well distributed over 70-90 days (Imru,1985; Amare and Haile, 1989).It is an important grain legume throughout the world providing a source of protein, dietary fiber, starch and minerals such as potassium, thiamine, vitamin B6 and folic acid in diets affordable by the poor *(*Garden-Robinson and McNeal, 2013).

More than 85% of the Ethiopian population, which resides in the rural area, is engaged in agricultural production as a major means of livelihood Production to meet even the consumption requirement of the households (Bezabih and Hadera, 2007). Increasing agricultural production at the household level is vital to achieve food security (Degnet an Belay, 2001). On the other hand, any marketable surplus could be sold to the non-farming and even to the farming communities (Hailu, 2008).Therefore, increasing the production and productivity in a sustainable manner could address the problem of food shortage as one of the approaches to ensure households food security (Hailu, 2008).

In general, raising agricultural output and productivity on a sustainable basis necessitates large scale adoption and diffusion of new technologies (Mohamed *et a*l., 2009). Although cereal crops are most important in Ethiopian agriculture in providing staple diet to the population, pulses are also important components of crop production. Accordingly, pulse crops provide an economic advantage to small farm holdings as an alternative source of protein, cash income, and food security (Ferris and Kaganzi, 2008).Among legumes, it constitute a significant part of human diet in Ethiopia. Apart from this, haricot bean has been cultivated as a field crop for a very long time and hence, it is the important food legume produced in the country. It is a principal food crop particularly in Southern and Eastern part of Ethiopia, where it is widely intercropped with maize and sorghum, respectively, to supplement farmer's income. The two major haricot bean producing regions are Oromiya and Southern Nations, Nationalities and People's Region (SNNPR), which produce 70 and 60 thousand tons per year, respectively, and these two regions make up 85% of the total production.

It is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enable households to get cash income required to purchase food and other household needs when other crops have not yet matured. Improved common bean production encompasses proper use of different agronomic practices which include improved variety, seed rate, spacing, fertilizer rate, and pesticide application as per recommendations. However, the current national average yield of common bean (1.48 tons) is far less than the attainable yield (2500 to 3000 kg ha^{-1}) under good management conditions for most improved varieties.

This low yield of common bean in Ethiopia is attributed to several production constraints, which include lack of improved varieties for the different agro-ecological zones, poor agronomic practices such as low soil fertility management, untimely and inappropriate field operations (Alemitu, 2011). A range of environmental factors, such as low soil nitrogen and phosphorus levels, and acidic soil conditions are important constraints for bean production in most areas where the crop is grown (Girma, 2009). In general, an increase in grain yield and other agronomic parameters of common bean were observed as the rate of nitrogen and phosphorus increased till 27 kg N ha^{-1} and 69 kg P2O5 ha^{-1} (150 kg DAP ha^{-1}) (Girma, 2009). Previous surveys estimated that over 60% of the bean production areas in Central, Southern, and Eastern Africa were affected by N deficiency.

This caused yield losses of up to 40% as compared to the N-fertilized areas. Bean N fertilizer requirement depends on soil fertility levels; for low soil nitrogen levels (below 34 kg N ha^{-1}) N fertilizer is generally recommended in order for deficiency symptoms not to manifest and for full development up to production. Moreover, up to 60 kg N ha^{-1} also promotes increased nodule number, mass and size, giving highest yields. However, nitrogenous activity declines with applied nitrogen (Davis and Brick, 2009), decreasing the sink strength, and hence, reduce the quantity of photo-assimilate partitioned to nodules and grain. Early application may also result in excessive vegetative growth leading to delayed flowering, reduced pod set, lower seed yield and a greater risk of disease infestation.

The application of inorganic phosphorus fertilizer has positive effect on the yield and yield components of common bean revealed that grain weight per plant exhibited a pronounced response to phosphorus application, mean values of grain weight per plant records of 13.0, 17.4 and 20.7 g due to phosphorus fertilization of 0, 50 and 100 kg P2O5 ha^{-1}, respectively observed significant increase in grain weight per plant (8.65 g) due to increased P application up to 75 kg P_2O_5 ha^{-1}.

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of phosphorus (Ali et al., 2008). Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. Sulphur nutrition of bean and other plants. A range of environmental factors, such as low soil nitrogen and phosphorus levels, and acidic soil conditions are important constraints for bean production in most areas where the crop is grown (Girma, 2009).

Wortmann (2006) also reported that low soil fertility status especially low level of N and P to be the major constraints of common bean production responsible for the loss of grain yield up to 1.2 million tons in Africa. Soil fertility mapping project in Ethiopia recently reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and thus recommend application of customized and balanced fertilizers (EthioSIS, 2013). To address these nutrient deficiencies, farmers in Jarso district have been using uniform misconception about Common bean's nutrient requirement even they think fertilizer is not necessary for Common bean because, it's root produce natural fertilizer by itself. This emphasizes the importance of developing an alternative means to meet the demand of nutrient in plants by using blended NPS that contains S in addition to the commonly used N and P fertilizers. However, no study had been done on response of common bean varieties to the rates of blended NPS fertilizer in Jarso district, eastern Ethiopia. Thus, an experiment was conducted with the objectives of**:**

- ✧ Evaluate the effect of blended NPS rates on yield and yield related traits of common bean varieties and
- ✧ Estimate economically feasible rates of blended NPS fertilizer for common bean production.

2. **LITERATURE REVIEW**

2.1 Origin of Beans

Common beans (*Phaseolus vulgaris L.*) are believed to originate from Mesoamerica, this comprise five species of genus Phaseolus.sp namely: Phaseolus coccineus, Phaseolus acutifolius, Phaseolus lunatus, Phaseolus polyanthus and Phaseolus vulgaris (Goldsworthy and Fisher, 1984).These species grow well under different environments ranging from temperate, arid and semi-arid, dry and humid warm as well as semi-temperate humid climatic condition. The Phaseolus vulgaris grows in all climates but commonly in warm temperate climate (Edith et al., 1997). Debouck et al.; 1996 considered Phaseolus vulgaris L. to be native to the Americas whereby from central western Mexico to northern Argentina it is found in natural state of wild ancestral types of *Phaseolus vulgaris L.* In Africa, common beans were probably introduced by Portuguese and reached Malawi through Mozambique and the coast hundred years ago (CIAT, 1981).

2.3. Beans growth habit

The bean crop growth habit characteristics are used to classify bean varieties. Morphologically the bean plant is classified as determinate when the terminal meristem bud is the reproductive part of the plant or indeterminate when the meristem buds are vegetative. In the indeterminate habit, stem elongation cease when the terminal flowering racemes of the main stem or lateral branches have developed. Indeterminate habit, flowering and pod filling continue simultaneously or alternately as long as the conditions of proper temperature and moisture availability are there (CIAT, 1981). The terminal meristem is found at the tip of stem and is the origin of cell division. In common beans plant, this type of meristem is vegetative but may become an inflorescence. Oscar et al.(2006) classified traits of common beans in four growth habits: type I as determinate bush; type II as indeterminate bush; type III as indeterminate semi-climbing and type IV as indeterminate climbing.

2.2 Importance and Use of Beans

Common bean (Phaseolus vulgaris L.) is the world's most important food legume. This is considered as a nearly perfect food mainly because of its high protein content and abundant fiber, complex carbohydrates, and other daily food needs such as vitamins (folate) and minerals (Cu, Ca, Fe, Mg, Mn, and Zn). Among major food legumes, common bean (Phaseolus vulgaris L.) is considered the third most important worldwide, after soya bean [Glycine max (L.) Merr] and peanuts (Arachis hypogaea L.). Among the pulses (annual leguminous food crops that are harvested as dry seeds) the common bean is by far the most important. It can also regulate the level of glucose and insulin in the blood (Prolla et al., 2010).

In Latin American countries, national per capita consumption of beans is typically between 12 and 18 kg per year, and this consumption does not reflect differences in urban and rural areas (Broughton et al., 2003). In Africa common bean is considered the second most important source of dietary protein and the third most important source of calories for lower income African households after cassava and maize (Pachico, 1993). It is the most important food grain legume in the world. It is an important source of protein, fat, carbohydrates, vitamins and minerals for humans and livestock. Protein content in most varieties is high and averages 25%. The crop is rich in the amino acids tryptophan and lysine, which are not typically found in the staple maize crop. Common bean therefore, provides a good alternative to animal protein to meet minimal daily requirements. In addition, common bean provides other health benefits that include weight control, reduced proneness to diabetes, colon cancer and heart problems (Nyau, 2014).

2.3. Common bean Production and its Economic Importance in Ethiopia

Pulse crops provide an economic advantage to small scale farmers as an alternative source of protein, cash income, and food security. Accordingly Common bean is an important pulse crop in Ethiopia (Ferris and Kaganzi, 2008). Apart from this common bean has been cultivated as a field crop for a very long time and hence, it is the important food legume produced in the country (Ali *et al*., 2006). Common bean is a principal food crop particularly in southern and eastern part of Ethiopia. The most commercial varieties are pure red and pure white coloured beans and these are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008).

The crop ranks second next to faba bean in the country in area of production (CSA, 2018). The major common bean producing regions are Oromia, Southern Nations Nationalities and Peoples Region (SNNPR) and Amhara. Their share to the national common bean production is 44.45% for Oromia, 31.01% for SNNPR and 21.67% for Amhara (CSA, 2018). Common bean is also one of the most important cash crops and source of protein for farmers in many lowlands and mid-altitude zones. 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 (Fissha and Yayis, 2015). National average yield of common bean in Ethiopia was 1.70 tons ha^{-1} and totally 520,979.33 tons yield was produced from 306,186.59 ha of land in 2017/18 cropping season (CSA, 2018).

There is a wide range of common bean types grown in Ethiopia including mottled, red, white and black varieties (Ali *et al*., 2006). The most commercial varieties are pure red and pure white colored beans and they are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008). With regard to economic importance of common bean, it is used as source of foreign currency, food crop, means of employment, source of cash, and plays great role in the farming system (CSA, 2017). According to EPPA (2004) in the year 2000, 2001 and 2002 Ethiopia exported 23994.4, 32932.7 and 42127.0 tons and earned 8.2, 9.98 and 13.2 million USD, respectively.

The main destination markets were Pakistan, Germany, Yemen, United Kingdom (UK), South Africa, India, and Mexico having 12.5, 7.8, 6.9, 5.79, 4, 4, and 4% share, respectively (EPPA, 2004). The country's exports of common bean has increased over the last few years, from 58,126 metric tons in 2005 to 78,271 metric tons in 2007 and Ethiopia got 63 million USD from common bean market in 2005 (Legese *et al.,* 2006).

Common bean production is very heterogeneous in terms of ecology, cropping system and yield. It predominantly grows from low land (300-1100 masl) to mid highland areas (1400-2000 masl) of the country. White beans from the northern Rift Valley were sold into export markets and red beans were exported from the southern Rift Valley areas to supply drought affected areas in northern Kenya (Ferris and Kaganzi, 2008). The major storage and trading sites in the southern Rift Valley area were concentrated in the Towns of Sodo, Awassa and Shashemene while the major collection centers for white beans being in Nazareth, prior to exportation through Djibouti (Ferris and Kaganzi, 2008). There are good prospects that this market will grow as consumers in industrialized countries seek evermore competitive suppliers (Ferris and Kaganzi, 2008).

2.4. Production Requirements of Common Beans

According to Gómez (2004), common bean is a warm-season crop with an optimum temperature of about 24°C., the crop does not tolerate frost or long periods of exposure to near-freezing temperatures at any stage of growth. Common bean does not tolerate high temperatures (>30ºC) either, as such temperatures can cause flower blasting, and dropping of buds. Well drained soils for germination are required for common bean production as the crop is sensitive to both moisture stress and water logging (Organic Seed Alliance www.seedalliance.org). Sandy, loam, sandy clay loam or clay loam with clay content of between 15 and 35 % are very suitable for bean production.

With sandy soils, problems of low soil fertility or nematode damage may occur. Soil of pH 5.8 to 6.5 are suitable for common bean, as the crop is very sensitive to acidic (pH< 5.2) soils. The crop will also not grow well in soils that are compacted, too alkaline or poorly drained . The common bean requires moderate amounts of water (300-600)mm. Adequate moisture during early part of the season is necessary and essential especially so during the pod filling stage (during and immediately after flowering); during this stage the soil should not hold less than 60% field capacity to ensure proper moisture availability (Katungi et al., 2009). Dry weather is desirable for the maturation of the bean crop and for harvesting.

2.5. Improved Common bean Varieties

Farmers in Eastern and Central Africa grow bean cultivars of wide range of seed types, often in phenotypically diverse mixtures. This genetic diversity is expected to give stability to bean production, buffering it against biotic and abiotic stresses. But, as higher yielding varieties become available, traditional cultivars are lost with a resultant decline in genetic diversity. Frequently, breeders have several promising lines of similar seed type and face the choice of either releasing and promoting only the best (several or all individually) or several or all in a multiline variety (CIAT, 1986). To have effective seed production, reliable and productive improved variety selection for specific environment is crucial. It is also very important that the community market demand of the seed before introducing and producing the productive improved seed (MARC, 1997).

Farmers' technology assessment criteria include growth habit, yield, color of grain, ease of threshing, main uses in the diet, storage, qualities, marketability, cost, ease of sale, desirability for home consumption, compatibility with existing practices, taste, nutritional value, cooking quality and resistance to pest. Any new technology presented to farmers will either improve or substitute for the technological options they currently have. It is fundamental to identify these options and understand perceptions about the advantages and disadvantages of each one then will researchers be able to assess the appropriateness of potential new technologies or practices, evaluate the likelihood that they will be adopted, and if necessary modify them to suit farmers' needs better. There are many released and adopted varieties (Awash-1, Awash-2, Awash Melka etc.); of common bean and the potential average yield was 2.6 ton ha^{-1} (MoANR, 2016).

2.8. Nutrient Requirement of Common beans

2.8.1. Phosphorus and Common Bean

Phosphorus deficiency is extensive in regions where the common bean (Phaseolus vulgaris), and apart from nitrogen, phosphorus becomes the second most important nutrient. The total amount of P percentage in most soils is about 0.04 to 0.10%, although only limited amounts is available for plant uptake. One of the reasons why P is seldom sufficient for optimal plant growth is because of its ability to react with various elements in the soil forming complexes that are not available for plant uptake. In the whole world, a quantity of 17.5 million tons of P is processed yearly from rock phosphates reserves and 85% of it is used in fertilizer production (Cordell et al. 2009). Specifically, in legumes, it plays a significant role in root growth and development, production of protein phytin and phospholipids**.** Yield of common bean is greatly increased by application of phosphorus fertilizer**).** Combined application of phosphorus and rhizobia inoculation increases grain yield of bean as well as yield parameter**.** Among the functions of P in legumes is growth of extensive root system and, seedling development.

Phosphorus application had significant enhancement on a number of parameters on pea production such as of biomass, branches, shoot/root dry weight, number of pods and seed yield . It is a critical nutrient element for plant growth, since it is involved in cellular energy transfer, respiration and photosynthesis. P is also a structural component of the nucleic acids of genes and chromosomes and of many co enzymes, phospho proteins and phospho lipids. Plants need P throughout their life cycle but most importantly during early growth stages for cell division . Application of fertilizers in a recommended amount is essential for high yield and quality of grains. Low phosphorus in the soil often limits production of common bean (Singh *et al.,* 2006).

Phosphorus deficiency is globally a major constraint to bean production on agricultural soils, and of greater importance in tropical soils because their generally high capacity to fix P in plant unavailable forms. An estimated 60% of beans in Latin America are grown on severely P-deficient soils (CIAT, 1987). Under conditions of high soil-P fixation, use efficiency of applied P fertilizers is often less than 25%, and the economies of bean production in many developing countries discourages wide spread application of P to alleviate deficiency. Phosphorus is the second limiting element after nitrogen for plant growth (Sanginga and Woomer 2009).

Phosphorus deficiency is also the major constraints to the growth of legumes in many soils . According to Amare *et al*. (2014) Beans respond to the application of phosphorus and production increase proportionally with increase of phosphorus. The authors also reported that 2326 kg ha^{-1} yield from the rate of 20 kg P_2O_5 ha^{-1} and 1922 kg ha^{-1} from the control treatment for each variety. Many research indicated that phosphorus availability in the soil is a great limitation for bean production in tropics (Morgado and Willey, 2003). According to Kathju *et al*. (1987); and Frizzone (1982), P is among the principal nutrient elements needed for growth of many legumes in arid and semi-arid agriculture regions due to low available P in the soils and advantageous effects of P. P application is key to enhance bean yield on farmers field in their study on the low fertile *Orthic Acrisols* of western Kenya. Those researchers also indicated that P application significantly enhanced the establishment of beans, number of pods per plant, and the bean grain yields.

The formation of nodes and pods was promoted with the application of P, in P deficient soil. Thus, P application from external sources/fertilizers/ is very essential to obtain optimum yield. It is considered as the most limiting nutrient for growth of legume crops in tropical and subtropical regions (Raghothama, 1999). Similarly, results of fertilizer research done between 1972-76 on beans in different parts of Ethiopia indicated that 30-50 kg P ha^{-1} gave frequently significant yield response, especially if the soil was low in available P (Ohlander, 1980**)**. Girma (2009) also stated that 69 kg P_2O_5 ha^{-1} is recommended for common bean production in semi-arid zones of Central Rift Valley. Application of fertilizer on common bean production varies depending on area of production and soil fertility.

The highest total P uptake (32.59 kg ha^{-1}) was reported at 30 kg P ha^{-1} and increased with increasing rates of P application, whereas apparent P recovery was found to be highest at 20 kg P ha^{-1}. Both agronomic and physiological P use efficiencies of the crop were highest at the rate of 10 kg P ha^{-1}. Therefore, application of 10 kg P ha^{-1} was recommended for better common bean production . Meseret and Amin (2014) were also stated that there was a significant difference among five levels P fertilizer rates where the maximum (75.5gm $plant^{-1}$) dry matter yield was reported at application of P 20 kg ha^{-1}, whereas the minimum

(28.9 gm plant^{-1}) was recorded from the control. Highest number of seeds per pod (6.46) and seed yield (2.45 t ha^{-1}) were reported from Awash-Melka variety under irrigation than other varieties with the application of P-fertilizer (Gebre-Egziabher *et al*., 2014). Varieties like Awash-1 and Mexican-142 were more early (90-94 days) to reach maturity under irrigation than under rain-fed growing condition. But application of P-fertilizer was not significant in seeds per pod, seed yield and maturity of the common bean varieties (Gebre-Egziabher *et al*., 2014)

2.8.2. Nitrogen and common bean

Common bean requires N in highest amounts because it is a component of proteins, amino acids, and enzymes among other various biological processes therefore the nutrient has a marked effect on crop growth and yield). In adequate amounts, nitrogen promotes growth, photosynthesis, nutrient uptake and improves immunity of plants to environmental stresses). However, excess N has been reported to reduce nodulation in common bean and other legumes in general therefore the recommended rates of 40-60 kg ha^{-1} have the potential to reduce nitrogen fixation. Application of fertilizer in a recommended amount is essential for high yield and quality of grains (Morgado and Willey, 2003). Due to this the use of fertilizer is considered to be one of the most important factors to increase crop yield per unit area; however, the response to the type of fertilizer and rate of application vary widely with location, climate and soil type (Marschner, 1995).

Most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops. Nitrogen deficiency occurs almost everywhere unless nitrogen is applied as a fertilizer or manure. It has been reported that there was increased yield responses of pulse for nitrogen fertilizer (Morgado and Willey, 2003). There is also quantitative relationship between crop yield and accumulation of N by plants, *i.e.* when the soil cannot supply with adequate N, the crop yield will be constrained (Sinclair and Vadez, 2002). This indicates that yield can be considered as a good measure of the collective impact of environment on plant growth (i.e., the more favorable the environment, the more the effective N applied is and hence the greater the yield) so nitrogen is the most important element limiting crop production in the tropics. Previous surveys estimated that over 60% of the bean production areas in Central, Southern, and Eastern Africa was affected by N deficiency (Sanchez, 1976). Beside this, common bean is considered to be a poor fixer of atmospheric N when compared with other crop legumes . Large N inputs (more than 100 kg N ha^{-1} $year^{-1}$) would be required to improve bean seed yields above 2,000 kg ha^{-1} $year^{-1}$. Nitrogen application linearly increased grain yield in common bean production up to the highest applied nitrogen of 100 kg ha^{-1} (Dwivedi *et al*., 1994). Similarly, Common bean grain yield with the addition of high amount N ha^{-1} increase number of pods per plant.

2.8.3. Sulphur (S) and Common Bean

Sulphur and nitrogen roles are inter-related as their roles are related to synthesis of proteins (Arshad et al., 2010).Such nutrients relationships have been established in studies in terms of their influence on dry matter and yield. Gooding and Davies (1997); reported that Sulphur fertilizer in crop production has also an important role on formation methionine and cysteine amino acids which are responsible as building block of proteins.
An increase on a percentage of N followed by yield increment of legume by S application has been reported especially in faba bean production (Vicia faba L.) (Scherer,2001).

It is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of phosphorus (Ali et al., 2008). Development of reproductive structure and production of assimilates to fill economically important sink. It is one of the crucial plant elements recorded as secondary nutrient. It is necessary for all plants and is vital for the growth and metabolism .Most of the sulphur in soil environments (> 95% of total sulphur) is bound to organic molecules, and is therefore not directly plant available. Sulphur nutrition of common bean and other plants is important since its application not only increases growth rate but also improves the quality of the seed.
The application of sulphur at the optimum rate enhances plant height, branches, pods per plant and hundred seed weight in chickpea . Total number of nodules and active nodules

significantly increased with application of S up to 20 kg S ha^{-1} for Soybean crop (Ganeshamurthy and Sammi Reddy, 2000). It is required in similar amount as that of phosphorus. Organic sulphur is present as a heterogeneous mixture forms, partly included in microbial biomass and partly in the soil organic matter, and very little is known about the chemical identity of the specific sulphur containing molecules. Sulphur is associated with production of crops of superior nutritional and market quality (Ali *et al*., 2008).

Sulphur deficiency symptoms are like those of nitrogen. However, nitrogen deficiency symptoms first appear in the older leaves; generally, sulphur deficiency symptoms first appear in the younger leaves because sulphur does not easily translocate in the plant. Sulphur deficient plants lack are stunted, pale green to yellow in colour, and have elongated thin stems. Sulphur deficiency may delay maturity in grain crops. Interveinal chlorosis may occur. Root development is restricted, and shoot to root ratios usually decrease for plants grown under sulphur deficiency. Sulphur deficiency can be adjusted easily by application of chemical fertilizers containing sulphur.

Application of different values of sulphur fertilizer had a significant effect on the height and seed number of soybean. And also reported increase in the height of soybean in consequence with the application of sulphur fertilizer may derive from increase in the metabolic activity in plant, and development of leaf area. Application of 40 kg ha^{-1} of S had the highest number of seed per plant of soybean. According to Endrias (2017) Sulphur plays a great role combined with nitrogen and phosphorus fertilizers. He showed that the increase of NPS rate from 0 kg NPS ha^{-1} to 100 kg NPS ha^{-1} increased the number of days required to reach 50% flowering from 39.61 days to 44.11 days and number of days required to reach physiological maturity from 73.56 days to 76.72 days of common bean.

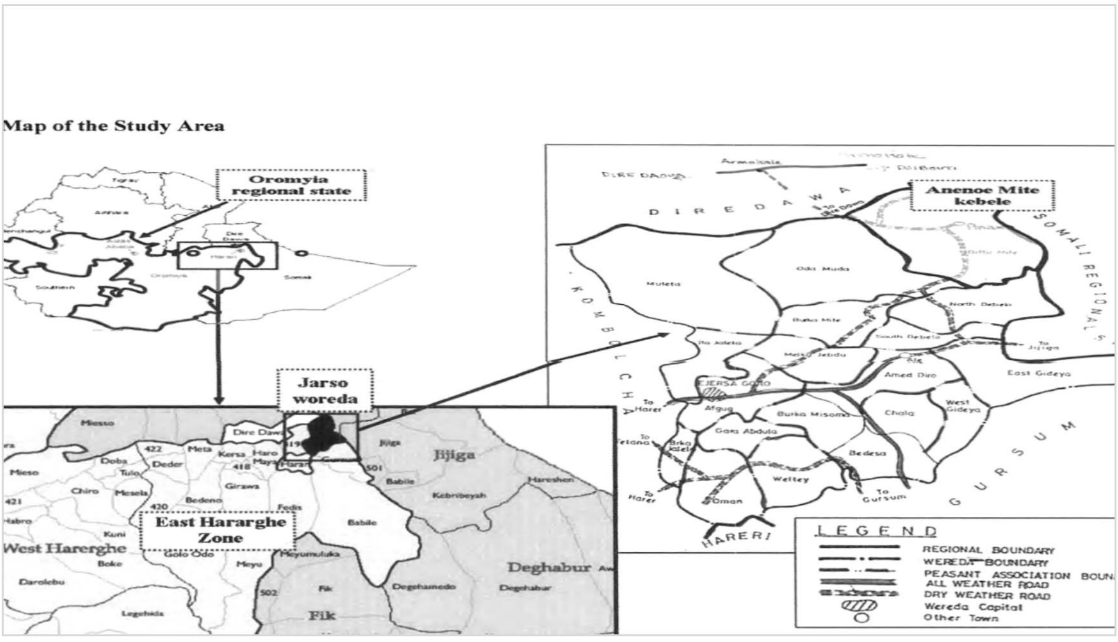
3. MATERIALS AND METHODS

3.1 Description of the Experimental Site

The experiment was conducted from July 5, 2019 to October 12, 2019 at East Hararghe Zone Jarso District Melka jebdu Kebele FTC demonstration site, Oromia Regional State. It is located in Jarso District at 09°31’4948 North latitude and 042°16’. 52 34East longitude, 570 km East from Addis Ababa, Ethiopia. The altitude of the site is about 2111ma.s.l, mean annual rain fall is (839.1mm) and has T max (27°c.), T min (11.2°c.) and average annual temperatures of 19°c. The climate of the study area is characterized mainly by warm and dry climate with relatively low precipitation. It receives a bimodal rainfall of small rains in spring and big rain in summer with April as a peak for the small rains and July for the big rain. Having June as a dry month, the rainy season extends from February to May and from July to September and the dry season stretches from October to January.

Generally, the study area is a semi-arid area with an average annual rainfall exceeds half the potential evapo-transpiration, In addition, the spatial and temporal distribution of rainfall in the study area is an unreliable to support rain fed agriculture, Generally, altitude and rainfall distribution are positively correlate. Accordingly, the mean annual rainfall in the study area varies from 950mm in the North West up lands to not more than 650 mm in the low land area

Source (GIS,2019)



3.2. Description of the Experimental Material

Original designation	Assigned local name	Growth habit	Market class	DF 50%	DM	100 seed wt	On Research field	On fermer's field
RXR-10	Tinike	Type- II	Large red kidney	47	91	42.1	2000-3000 1000-2100 2200-3000	1500-2500
ECAB-0060	Fedis	Type- II	Red mottled	47	93	47.31	1000-2500	1000-2500
ECAB0247	Babile	Type- II	Large red kidney	48	91	40.7	2400-3500	1500-3000

3.3. Soil Sampling and Analysis

Before sowing of the seed, soil sample was taken from twenty spots of a depth of 0 – 30 cm by zigzag method and one composite sample was formed. From composite sample, soil physical and chemical properties were analyzed at Haramaya University. The soil texture, pH, organic carbon, total nitrogen, available phosphorus, available S, cation exchangeable capacity and soil organic matter were analyzed. Texture of the soil was determined by the sedimentation method. Soil pH was measured potentiometericaly in 1:2.5 soil water suspensions with standard glass electrode pH meter (Van Reewuijk, 1992). The Walkley and Black (1934) method was used to determine organic matter content of the soil. Total nitrogen in the soil was determined by Modified Kjeldahl method with sulphuric acid (Dewis and Freitas, 1970). Available soil phosphorus was determined using the Olsen extraction method as described by Olsen *et al.* (1954). Available S was analyzed by turbid metric method (McGrath *et al*, 2003). Cations Exchange Capacity (CEC) was determined by titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000). Finally electric conductivity (EC) was determined by using Eshani and Sulliva (2006) method.

3. 4. Treatments and Experimental Design

The treatment consisted of three varieties of common bean (Babile, Fadis, and Tinike) and five levels of NPS fertilizer rates (0, 50, 100, 150, 200 kg ha^{-1}). The experiment was laid out as randomized complete block design (RCBD) in factorial arrangement with three replications. The gross plot area was 2.8 m×3.0 m (8.4 m^2) consisting of 7 rows of 3 m length. The spacing between plots and blocks was 0.6 m and 1 m, respectively. The one outer most row from each side and one plant from both ends of each row were considered as a border and one row was used for destructive sampling determine the nodulation parameters and above-ground dry biomass at physiological maturity. Thus, the net plot size was 1.6 m x 2.4 m (3.84 m^2) with 4 net rows.

Table2. Details of fertilizer treatments

Rate	NPS (kg ha^{-1})	Nutrient contents (kg ha^{-1})		
		N	P_2O_5	S
R1	0	0	0	0
R2	50	9.5	19	3.5
R3	100	19	38	7
R4	150	28.5	57	10.5
R5	200	38	76	14

3.5. Experimental Procedure and Crop Management.

The experimental field was plowed three times and harrowed once with an Oxen to a depth of 25-30 cm and the plots were leveled and ridges were made manually. Treatments were assigned to each plot randomly. The spacing between rows and plants were 40 cm and 10 cm, respectively. Two seeds per hill at the specified spacing were sown at a depth of about 2-5 cm to ensure adequate emergence in the month of July, 2019. NPS fertilizer was hand drilled in rows at the time of sowing. The plants were thinned to one plant per hill 9-10 days after emergence. Harvesting was done when the bottom of the common bean pods started to dry (EARO, 2006).

3.6. Crop Data Collection

3.6.1. Phenological and growth parameters

Days to 50% flowering: this was determined by counting the number of days from planting to the time when first flowers appeared in 50% of the plants in a plot by counting the number of plants.

Days to physiological maturity: It was determined as the number of days from planting to the time when 90% of the plants in each net plot showed yellowing of pods. This was done by counting the number of plants.

Number of total nodules per plant: bulk of the roots of 5 randomly taken plants from destructive rows in each plot was carefully exposed at 50% flowering and uprooted for nodulation study. Roots were carefully washed using tap water on a sieve and nodules were separated and counted.

Effective nodules per plant: For determination of effective number of nodules, the inside color of nodules was observed by cutting each nodule with the help of sharp blade and the pink colored nodules were considered as effective nodules, while green colored nodules were considered as non-effective.

Plant height: it was measured as the height of 10 randomly taken plants from the ground level to the apex of each plant at the time of physiological maturity from the net plot area.

Number of primary branches per plant: it was determined by counting the total number of branches on randomly Pre-tagged ten plants in the net plot at physiological maturity and averaged on per plant basis.

3.6.2. Yield components and yield

Crop stand count: the initial plant stand count was recorded by counting the total number of plants per net plot area immediately after thinning and final plant stand count was taken at harvesting.

Number of pods per plant: it was recorded based on10 Pre-tagged plants in each net plot area at harvest and the average was taken as number of pods per plant.

Number of seeds per pod: the total number of seeds in the pods of 10 plants was counted and divided by the total number of pods to find the number of seeds per pod.

Hundred seeds weight (g): The weight of 100 seeds was determined for each plot using a sensitive balance. The weight was adjusted to a moisture content of 10%.

Total above-ground dry biomass (kg ha^{-1}): At physiological maturity, 10 plants were randomly taken from the destructive rows of each net plot and used to determine above-ground dry biomass yield, which was measured after sun drying till a constant weight. The dry biomass per plant was then multiplied by the total number of plants per net plot and was converted into kg ha^{-1}. This value was used to calculate the harvest index as well.

Seed yield (kg ha^{-1}): it was determined after threshing the seeds harvested from each net plot. The seed yield was dried under sun for four days and was converted to kg ha^{-1}.

Harvest Index (HI): Harvest index was calculated by dividing grain yield per plot by the total above-ground dry biomass yield per plot multiplied by 100.

$$HI\ (\%) = \frac{\text{Grain Yield}}{\text{Above ground dry biomass}} \times 100$$

3.7. Agronomic Efficiency

The NPS fertilizer agronomic efficiency was calculated using the procedure described by Craswell and Godwin (1984) as: **AE (kg/kg=Gf (kg)-Gu (kg)/Na(kg)** where; AE stands for agronomic efficiency, Gf and Gu for grain yield in fertilized and unfertilized plots, respectively, and Na for quantity of NPS fertilizer applied.

3.8. Data Analysis

Data collected were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the Gen stat 18^{th} and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the treatments were found significant, the means were compared using the Least Significance Difference (LSD) test at 5% level of significance.

3.9. Partial Budget Analysis

An economic analysis was done using partial budget procedure described by CIMMYT (1988). The cost of NPS and labor cost involved in the application of the fertilizer were considered as variable costs. The net benefits /returns/ and other economic analysis were based on the formula developed by CIMMYT (1988) and given as follows:

Adjusted grain yield (AGY) (kg ha^{-1}): is the average yield adjusted downwards by a 10% to reflect the difference between the experimental yield and yield of farmers.

Gross field benefit (GFB) (ETB ha^{-1}): was computed by multiplying field/farm gate price that farmers receive (23 ETB kg^{-1}) for the crop when they sell it as adjusted yield.
GFB = AGY × field/farm gate price for the crop.

Total variable cost (TVC) (ETB ha^{-1}) : it was calculated by summing up the costs that vary, including the cost of NPS (13.00 ETB kg^{-1}) fertilizers at the time of planting (July 5, 2019) and according to Jarso, farm daily payment of labor cost for application of NPS (3 person's ha^{-1}, each 100 ETB day^{-1}). The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting and threshing were considered the same for all treatments or plots.

Net benefit (NB) (ETB ha^{-1}): was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment as: NB = GFB – TVC.

Dominance Analysis (identification and elimination of inferior treatments): was carried out by first listing all the treatments in their order of increasing costs that vary (TVC) and their net benefits (NB) are then put aside. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "D").

Marginal rate of return (MRR %): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC). **MRR= ΔNB)/ ΔTVC× 100**

Finally, among the non-dominated treatments, the treatment which gave the highest net return and a marginal rate of return greater than the minimum considered acceptable to farmers (100%) was considered for recommendation.

4. RESULTS AND DISCUSSION

4.1. Selected Physio-chemical Properties of Soil of the Experimental Site

Selected physio-chemical properties were analyzed for soil samples (0-30 cm depth) collected from experimental site before planting. The result of the soil analysis is indicated in. Marx *et al.* (1996) classified as strongly acidic (below 5.1), moderately acidic (5.2-6.0), slightly acidic (6.1-6.5), neutral (6.6-7.3), moderately alkaline (7.4-8.4), and strongly alkaline (above 8.5). Based on this soil pH analysis result (7.85) of the study site was moderately alkaline . Common bean grows on a wide range of soils but it performs best on deep, friable and well aerated soil types with optimum PH range of 6.0 to 6.8 (Demelash, 2018). Marx *et al.* (1996) showed the rating of EC as low (<1.0 ds/m), medium (1.0-2.0 ds/m), and high (>2.0 ds/m).

Based on this electrical conductivity (EC) of the soil in the study area was (5.42) rating under high range. Tekalign *et al.* (1991) also classified soil total N availability of <0.05% as very low, 0.05-0.12% as poor, 0.12 - 0.25% as moderate and > 0.25% as high. According to this classification, the total nitrogen of the study site is (0.27) high. The analysis also revealed that the available P level (15.1 ppm) in the experimental site was rated as Medium according to Olsen (1954) who stated that <10 ppm as low 10-20 ppm medium, 20-40 ppm high, and >40 ppm excessive.

In general, soils high in CEC contents are considered as agriculturally fertile. According to Landon (1991) top soils having CEC greater than 40 Cmol (+) kg^{-1} are rated as very high and 25-40 Cmol (+) kg^{-1} as high, 15-25 as medium, 5-15 low and < 5 Cmol (+) kg^{-1} of soil as very low in CEC. According to this classification, the soils of the site had high CEC of 40.8 Cmol (+) kg^{-1}. This value indicated that the soil has the capacity to hold nutrient cations and supply to the crop. Tekalign *et al.* (1991) also classified soil organic carbon (%) >3.0, 1.5-3.0, 0.5-1.5 and < 0.5 as high, medium, low and very low, respectively.

Thus, the organic carbon content of the soil in the study area (1.52%) was in medium range. Marx *et al.* (1996) rating of Sulphur showed that <2 ppm low, 2-10 ppm medium, and >10 ppm high. Based on this the available sulphate Sulphur (8.72 ppm) of the soil in the study area was in the medium range. Thus, considering the soil parameters at the experimental site of the soil is suitable for common bean production.

Table3. Results of selected soil physical and chemical properties of the study site before sowing of common bean

Soil properties	Results	Rating	Reference
Soil particle size			
Clay (%)	22		
Silt (%)	16		
Sand (%)	62		
Textural class	Sandy		
Soil pH (1:2 H_2O)	7.85	Moderately Alkaline	Marx *et al.* (1996)
Organic Matter (%)	3.54	High Medium	Marx *et al.* (1996)
EC (ds/m),	5.42	High	Marx *et al.* (1996)
Organic carbon (%)	2.06	Medium	Tekalign *et al.* (1991)
Total nitrogen (%)	0.27	High	Tekalign *et al.* (1991)
Available phosphorus (ppm)	15.1	Medium	Olsen (1954)
Available sulphurSO_4-S(ppm)	8.72 (ppm)	Medium	Marx *et al.* (1996)
Cation exchange capacity (CEC) (Cmol $^{+}kg^{-1}$)	40.8	High	Landon (1991))

4.2. Common bean Phenological and Growth Parameter

4.2.1. Days to 50% flowering

Main effects of varieties and Blended NPS rates were highly significant ($P<0.01$) on days to 50% flowering while the interaction of the factors was non-significant (Appendix Table 1). Early days to flowering (46.33 days) was recorded for variety *Fedis* that flowered 2.4 days earlier than variety *Tinike* (48.73 days) (Table 4). The difference among the varieties in days to flowering might be due to genetic differences as common bean has high diversity in such phenological characters.

Days to flowering of common bean were delayed with increment of application rate of NPS fertilizer where the highest number of days (50.33 days) to reach flowering was recorded due to application of 200 kg ha^{-1} of blended NPS while the earliest days to flowering (44 days) was recorded due to the application of 0 kg ha^{-1} of NPS. On the other hand, plot that received blended NPS 100 and 150 kg NPS ha^{-1} had non significant differences. Taminaw (2019) reported Main effects of varieties and NPS rates were highly significant on days to 50% flowering while the interaction of the factors was non-significant. In line with this result, Endrias (2017) also reported highly significance difference in the number of days required to reach50% flowering among three common bean varieties that range from 41.22 days for variety Nasir to 42.89 days for variety Red Wolaita.

Similarly, Shumi (2018) revealed that the main effects of variety and NPS rate were found to be highly significant ($p<0.01$) on days to reach 50% flowering where the highest number of days (46.67 days) to reach flowering was reported due to application of 200 kg NPS ha^{-1} for variety Nasir. Nchimbi-Msolla and Tryphone (2010) also reported significant differences in the number of days required to reach 50% flowering among 20 common bean genotypes that ranged from 26.67 to 45 days. The addition of nitrogen and phosphorus fertilizer might have contributed to the availability of soil nutrients to plant growth whereby the nitrogen fertilization delayed days to flowering.

In agreement with this result Endrias (2017) reported that application of NPS rate significantly influenced days to 50% flowering in common bean. Increasing NPS rate from 0 kg NPS ha^{-1} to 100 kg NPS ha^{-1} increased the number of days required to reach 50% flowering from 42.67 to 49.33 days. The result was also in accordance with that of Assefa *et al*. (2017) who reported significantly longest days (45.86 days) of common bean to flowering due to application of 46 kg P_2O_5 ha^{-1} and 41 kg N ha^{-1}. Similarly, Shumi (2018) reported that days to flowering of common bean were delayed with increment of application rate of NPS fertilizer where the highest number of days (46.67 days) to reach flowering was recorded due to application of 200 kg ha^{-1} of blended NPS while the earliest days to flowering (38.33 days) was recorded due to the application of 50 kg ha $^{-1}$ of NPS.

4.2.2. Days to 90% physiological maturity

The analysis of variance showed highly significant ($P<0.01$) main effect of variety and blended NPS fertilizer application rates on days to 90% physiological maturity, while their interaction did not significantly influence on days to 90% physiological maturity.(Appendix Table1). Variety *Tinike* had the longest days to reach 90% physiological maturity (95.8 days) and it was statistically at par with *Babile* (94.2 days), whereas the variety Fedis was found earliest to reach 90% physiological maturity (93.6 days) (Table 4). These variations might be attributed by genotypic differences of the respective varieties as phonological characteristics are genetically controlled.

This result was in line with Wondwosen and Tamado *(*2017) who reported that Common bean varieties showed highly significant ($p<0.01$) difference on days to 90% physiological maturity and they reported that variety Red Wolayita was the earliest (93.33 days) to 90% physiological maturity while *Awash Melka* was the late maturing variety (95.27 days). Similarly, Endrias (2017) reported that varieties Nasir and Hawassa Dume were early maturing which required 78.56 and 80 days respectively than Red Wolaita which matured on 82.56 days after planting.

Taminaw (2019) also reported that the main effects of varieties and NPS fertilize rates had highly significant ($p<0.01$) and significant ($p<0.05$) effects, respectively, on days to 90% physiological maturity while the interaction of both factors had non-significant effect .Variety *Awash Melka* had the longest days to reach 90% physiological maturity (85.05 days) and it was statistically at par with Awash 2 (83 days), whereas the variety Awash 1 was the earliest to reach 90% physiological maturity (80.78 days). The result also showed that increasing NPS application from 0 kg ha^{-1} to 200 kg ha^{-1} prolonged the time required to attain 90% physiological maturity.

Early maturity (91.67 days) which was statistically at par with 50 kg NPS ha^{-1} (87.33 days) was recorded from 0 kg NPS ha^{-1} which was 13.34 days earlier than 200 kg NPS ha^{-1} (100.67 days). This delayed physiological maturity was statistically at par with 150 and 100 kg NPS ha^{-1}, respectively. The delay in days to maturity at highest NPS rate could be due to the fact that N fertilization increases the vegetative growth of plants. The longer maturity periods might also have been caused by the promoted vegetative growth due to enhanced supply of nitrogen through NPS fertilizer application.

In line with this result, Shumi (2018) obtained delayed physiological maturity of common bean with increase in NPS fertilizer rates where the highest number of days required to physiological maturity (99.33 days) was recorded for the highest rate of blended NPS application rate (250 kg ha^{-1}) while the shortest days to physiological maturity (91.33 days) was reported without the NPS application. Similarly, Endrias (2017) reported that increasing NPS rate from 0 kg NPS ha^{-1} to 100 kg NPS ha^{-1} increased the number of days required to reach physiological maturity of common bean from 73.56 days to 76.72 days.

Table 4 Main effects of varieties and NPS fertilizer rates on days to 50% flowering and days to physiological maturity of common bean.

Treatment	D50% F	*DPM 90%*
Babile	47.53[b]	94.2[b]
Fedis	46.33[c]	93.6[c]
Tinike	48.73[a]	95.8[a]
LSD (0.05)	2.0	0.85
NPS rates (kg ha^{-1})		
0	44[d]	90.33[e]
50	46.56[c]	92.11[d]
100	45.5[c]	95[c]
150	48.56[b]	96.67[b]
200	50.33[a]	99[a]
LSD (0.05)	1.16	1.1
CV (%)	2.6	1.2

D= Days to 50% flowering; DPM=Days to physiological maturity; LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.

4.2.3. Number of total and effective nodules

The analysis of variance showed highly significant ($P<0.01$) main effect of variety and blended NPS fertilizer application rates on while their interaction did not significantly influence the number of total nodules (Appendix Table 1). Variety Fedis recorded the highest number of total nodules (69) while the lowest number of total nodules (49.93) was recorded for variety Babile whereas, the highest number of effective nodules were recorded from *Tinike(33.67)* variety which was statistically similar with *Fedis(33.07)* variety while the lowest number of effective nodules per plant (27.43) was recorded from *Babile* variety (Table 5). Phosphorus has got significant effect on legumes yield and agronomic parameters as it promotes the development of extensive root systems and good nodulation. The increase in total and effective number of nodules at the highest NPS rate may be due to the application of nitrogen, phosphorus and sulfur fertilizer that stimulate nodule formation and also enhance yield of pulse including common bean.

Phosphorus is also a vital component of adenosine diphosphate and adenosine triphos phate the "energy unit" (Cabeza *et al*., 2014) due to this the metabolic path ways such as N-fixation that occur in bacteroids, as well as the ammonium assimilation in to amino acids and ureides that occur in the plant cell fraction of nodules, require a large amount of P in energy transfer during nodule functioning (Sulieman and Tran, 2015).

This result was In line with Shumi (2018) who reported that the main effects of NPS rate had highly significant ($p<0.01$) effect on total number of nodules where the highest number of total nodules per plant (80.47) was recorded from the application of 200 kg NPS ha^{-1} while the lowest number of total nodules (40.94) was recorded from nil application of NPS fertilizer. Amare *et al*. (2014) reported that nodule number was significantly increased with increasing levels of phosphorus with the lowest (12.89) and the highest (31.85) numbers in common bean obtained from the control and application of 20 kg P_2O_5 ha^{-1}, respectively.

Number of effective nodules per plant increased with the increasing rate of blended NPS application rate. Increasing of blended NPS fertilizer from 0 to 200 kg ha^{-1} enhanced the number of effective nodules per plant (table 5). The highest number of effective nodules per plant (33.67) was recorded at the rate of 200 kg NPS ha^{-1} while the lowest number of effective nodules per plant (24.27) was recorded at the rate of 0 kg NPS ha^{-1}. The increased number of effective nodules with the increase in NPS application up to 200 kg NPS ha^{-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.

The increased number of effective nodules with the application of NPS over the control might also be from increased sulphur application which might be due to the high dose of sulphur and increasing its availability along with other major nutrients. In legume plants with a high sulfur supply show greater rates of N_2 fixation and, conversely, legumes grown on sulfur poor soils have lower nitrogenase activity and readily respond to sulfur fertilizers by increasing yield and nitrogen content (Scherer, 2008). In nodulated legumes sulfur deficiency triggers at least three types of effects: decrease of nodulation, direct inhibition of N_2 fixation, and general alteration of nodule metabolism in contrast to a high sulfur supply to plants which markedly increases nodulation and symbiotic nitrogen fixation (Varin *et al*., 2In conformity with this result, Muller *et al*. (1993) reported that application of nitrogen in the range of 22 to 33 kg N ha^{-1} enhanced both nodulation and seed yield of common bean varieties. Moreover, Ganeshamurthy, and Sammi Reddyv (2000) found a significant increase in the number of active nodules with the application of sulphur up to 20 kg ha^{-1}, at which point nodule production reached a plateau and did not increase further. Khandkar *et al.* (1985) also reported that the formation of nodules in black gram was increased in response to sulphur application up to 30 kg ha^{-1} which is involved in the formation of nitrogenous enzyme known to promote nitrogen fixation in legumes.

Table 5. Main effects of varieties and NPS fertilizer rates on numbers of total and effective nodules per plant of common bean.

Treatment	Total number of nodules	Effective number of nodules
Babile	49.93^{c}	24.27^{b}
Fedis	69^{a}	33.07^{a}
Tinike	65.27^{b}	33.67^{a}
LSD (0.05)	8.29	6.5
NPS rates (kg ha^{-1})		
0	46.44^{d}	22.56^{b}
50	60.78^{c}	30.44^{a}
100	62.67^{c}	31.44^{a}
150	67.89^{b}	33.33^{a}
200	69.22^{a}	33.89^{a}
LSD (0.05)	4.79	3.76
CV (%)	8.1	12.8

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

4.2.4. Plant height

The analysis of variance showed highly ($P<0.01$) effect of varieties, blended NPS rates and their interaction on plant height at physiological maturity (table 6). Variety Tinike showed the highest plant height (67.60cm) with combined application of 200 kg NPS ha^{-1} the shortest plants (37.52 cm) was seen for Babile without NPS fertilizer. Plant height was increased from 37.52 cm for variety Babile with 0 kg NPS ha^{-1} to 67.6 cm for variety Tinike at 200kg NPS ha^{-1}. The increase in plant height in response to the increased blended NPS application rate might be due to the maximum vegetative growth of the plants under higher N, P and S availability. Nitrogen helps in chlorophyll formation, phosphorus establishes strong root system and Sulphur enhanced the formation of chlorophyll and encouraged vegetative.

In conformity with the current result, Moniruzzaman et al. (2008) found that plant height was significantly increased up to 160 kg N ha^{-1}. Also application of phosphorus at the highest level (120 kg P2O5 ha^{-1}) increased plant height. The promotion effect of high P level on plant height of maize may be due to better development of the root system and nutrient. The increase in plant height might also be ascribed to better root formation due to sulphur, which in turn activated higher absorption of N, P, K and sulphur from the soil and improved metabolic activity inside the plant.

Similar results were reported by Jawahar *et al*. (2017) where sulphur level of 40 kg ha^{-1} was found to increase the plant height, LAI, chlorophyll content and number of branches per plant of blackgram (*Vigna mungo).* In conformity with this result, Moniruzzaman *et al*. (2008) found that plant height increase with the application of N and P_2O_5 (120 and 160 kg ha^{-1}) respectively. Similarly, Taj (1996) reported an increase in plant height of mungbean in response to nitrogen and phosphorus application (20 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}).

Table 6. Interaction effects of varieties and NPS fertilizer rates on plant height

	NPS (kg ha^{-1})				
Varieties	0	50	100	150	200
Babile	37.52^{k}	40.70^{j}	44.00^{hi}	47.63^{fg}	50.0^{ef}
Fadis	43.33^{ij}	46.73^{gh}	51.63^{de}	60.00^{bc}	65.93^{a}
Tinike	45.73^{ghi}	53.40^{d}	58.47^{c}	62.47^{b}	67.60^{a}
LSD (0.05)		1.368			
CV (%)		3.5			

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

4.2.5. Number of primary branches per plant

The analysis of variance indicated highly significant (P<0.01) effect of blended NPS fertilizer application rates on number of primary branches (Appendix Table 2) while variety and their interaction did not significantly influenced on the number of primary branches (Table 6). Increasing rates of blended NPS fertilizer from 0 to 200 kg ha^{-1} showed progressive increase in the number of primary branches per plant (table 7). Thus, the highest number of primary branches per plant (3.89) was recorded at the highest rate 200 kg NPS ha^{-1}of application and it was statistically at par with NPS rates of 200, 150, 100 , and 50 kg NPS ha^{-1}, while the lowest number of primary branches per plant (2.33) was recorded from the control treatment.

The increase in number of primary branches per plant in response to the increased rate of blended NPS application rate indicates higher vegetative growth of the plants under higher N, P and S availability. The result was consistent with the finding of Addisu (2013) who reported that number of primary and secondary branches was highly significantly different among the chickpea varieties at Bishoftu with the Desi variety Natoli had significantly higher number of primary (3.21) and secondary branches (6.73) than the Kabuli variety Acos Dubie with 2.26 and 3.49, respectively. The blended NPS rate had highly significant (P<0.01) effect on number of primary branches per plant. In line with this result, Shubhashree (2007) reported significantly higher number of branches per plant of common bean with 75 kg P2O5 ha^{-1} over the control. The increment in number of branches with increased rate of P might also be due to the importance of P for cell division, leading to the increase in plant height and number of branches. In line with this result, Moniruzzaman et al. (2008) reported that the number of branches per plant increased significantly with the increase of N up to 120 kg ha^{-1} on common bean. The increased primary branches observed under blended fertilizer might be attributed to readily available form of S that enhanced uptake of nutrients even at the initial stage of crop growth. The result was also in agreement with the finding of Jawahar et al. (2017) who reported that application of 40 kg S ha^{-1} recorded highest number of branches per plant (7.75) in blackgram (*V. mungo*)

Table 7. Main effects of varieties and NPS fertilizer rates number of primary branches per plant of common bean.

Treatment	Number of primary branches per plant
Babile	3.07^{b}
Fadis	3.53^{a}
Tinike	3.07^{b}
LSD (0.05)	77
NPS rates (kg ha^{-1})	
0	2.33^{d}
50	2.89^{c}
100	3.33^{bc}
150	3.67^{ab}
200	3.89^{a}
LSD (0.05)	0.45
CV%	14.3

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

4.3. Yield Components and Yield

4.3.1. Stand Count

The main effect of varieties and blended NPS rate had highly significant ($P<0.01$) effect on stand count at harvest while the interaction of varieties and blended NPS rate not significant effect on stand count at harvest (Appendix Table 3). Fedis Variety showed the highest stand count (96.53 %) and Babile variety was the lowest (94.73%) which was statistically at far (95. 13) with Tinike variety. The highest stand count per plot at harvest (95.22%) was obtained at applied blended NPS rate of 150 kg ha^{-} which was statistically at par with 100 kg of NPS ha^{-1} (93.89%) and the lowest (88.89) was from control. How ever, as blended NPS rate increases, stand count increased up to 150 but,decreased at 200kgha^{-1}(Table 8). The highest stand count at the highest NPS rate might be due to that increased NPS level that improves plants growth and development by better up take of all nutrients, increased translocations photosynthetic materials and reduce the mortality of plants .

Taminaw (2019) reported the number of plants at harvest compared to the initial count (stand count after thinning) was highly significant ($p<0.01$) due to the main effects of NPS fertilizer. However, the main effects of varieties and interaction of both factors were non-significant . Among the different NPS levels, the highest stand count rate (96.03%) was exhibited from highest dose of NPS (200 kg ha^{-1}), which was statistically at par with 150 kg of NPS ha^{-1} (95.79%) while the lowest plant stand count (91.8%) was obtained from plots which receive no NPS fertilization.

Table 8. Main effects of varieties and NPS fertilizer rates on Stand count percent at harvest of common bean.

Treatment	Stand count
Babile	94.73b
Fadis	96.53a
Tinike	95.13b
LSD (0.05)	1.54
NPS rates (kg ha^{-1})	
0	88.89^{d}
50	91.33^{c}
100	93.89^{b}
150	95.22^{a}
200	93.33^{b}
LSD(0.05)	0.89
CV	1

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

4.3.2. Number of pods per plant

The number of total pods was highly significantly ($p<0.01$) influenced by varieties, blended NPS rate and their interaction (Appendix Table 3).Variety Fadis with application of 150 kg blended NPS ha^{-1} fertilizer scored significantly the highest number of total pods per plant (25.33) while the lowest number of total pods per plat (20) was from variety Tinike with 100 kg blended NPS ha^{-1} application rate (Appendix Table 3). As Blended NPS fertilizer rate increases, plant height also increased**.** The increase in number of pods per plant with the increased NPS rates might possibly be due to adequate availability of N, P and S which might have facilitated the production of primary branches and plant height which might in turn have contributed for the production of higher number of total pods.

Taminaw (2019) reported the main effects of varieties, NPS fertilize rates and the interaction of both factors had highly significant ($p<0.01$) effect on number of pods per plant. Variety Awash Melka with 200 kg NPS ha^{-1}produced significantly the highest number of pods per plant (28.40), which was statistically at par with the application of 150 kg NPS $ha^{-1}$and 100 kg NPS ha^{-1} with the same variety. In contrast, variety Awash 1 with 0 kg NPS ha^{-1} rate gave the lowest number of pods per plant (13.71). In conformity with this result, Moniruzzaman et al. (2008) reported significant effect of N fertilizers on pod production per plant of French bean with the maximum number of pods per plant (25.49) obtained at 120-120-60-20-4-1 kg of N-P_2O_5-K_2O-S-Zn-B. Many scientists agree that the increment of number of pods per plant due to application of P fertilizer confirms the fact that P fertilizer promotes the formation of nodes and pods in legumes (Buttery, 1969).

In agreement with this result, Dereje et al. (2015) also found that the number of pods per plant of common bean significantly increased in response to increasing rate of phosphorus up-to the highest rate (92 kg P_2O_5 ha^{-1}). On the other hand, Jawahar et al. (2017) reported that application of 40 kg S ha^{-1} recorded the highest number of seeds per pod of blackgram. This could be due to the increasing levels of sulphur application enhanced its availability to the crop and increase photosynthetic activity of crop. In this study, varieties also exhibited highly significant ($P<0.01$) difference in the number of pods per plant. Additionally, (Wondwosen and Tamado (2017) reported increase in number of pods per plant with increased levels of NP fertilization from 0 kg N; 0 kg P_2O_5 to 36 kg N; 92 kg P_2O_5 ha^{-1} and the highest number of pods per plant (31.37) was reported from the application of 36 kg N; 92 kg P_2O_5 ha^{-1} whereas the lowest number of pods per plant (14.58) was reported from the no fertilizer plot in common bean. Similarly, Shumi (2018) reported the highest number of pods per plant (18.52) at application rate of 250 kg NPS ha^{-1} whereas the lowest number of pods per plant (8.7) from the unfertilized plot of common bean. Shubhashree (2007); and Shanka *et al*. (2015) reported significant increase in number of pods per plant on common bean due to increased P fertilization up to 69 kg P_2O_5 ha^{-1} and 92 kg P_2O_5 ha^{-1}, respectively.

Table 9. Interaction effects of varieties and NPS fertilizer rates on number of pods per plant common bean

		NPS (kg ha^{-1})			
Varieties	0	50	100	150	200
Babile	11^{k}	13.67^{j}	14.67^{ij}	16.00^{ghi}	16.67^{gh}
Fadis	15^{hij}	19^{ef}	22.33^{bc}	25.33^{a}	24^{ab}
Tinike	10^{k}	14.67^{ij}	17.67^{fg}	21^{cd}	20^{de}
LSD (0.05)		0.76			
CV (%)		5.8			

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

4.3.3. Number of seeds per pod

The analysis of variance showed highly significant ($P<0.01$) main effect of variety and blended NPS fertilizer application rates on number of seeds per pod while their interaction did not significantly influence the number of seeds per pod (Appendix Table 3). The highest number of seeds per pod (4.67) was recorded from variety Tinike and it was statistically at par with Fadis (4.53),whereas the least number of seeds per pod (3.93) was recorded for variety Babile (Table 10). The highest number of seeds per pod (5.11) was obtained blended NPS rate of 200 kg ha^{-1} applied and it was statistically at par with 150 kg ha^{-} (5) and the lowest (3.67) was from control. Consistent with the results of this study, Taminaw (2019) also reported that main effects of varieties, NPS fertilize rate and the interaction of both factors had highly significant ($p<0.01$) effect on number of seeds per pod.

The variation in the number of seed per pod among the varieties might be related to the genotypic variation of the cultivars in producing seed. Similarly, Wondwosen and Tamado (2017) reported that variety Awash Melka gave highest number of seed per pod (4.65) over Awash 1 (4.55). The increment in number of seeds per pod with increasing NPS fertilizer application rates might be due to the fact that P is essential component in seed formation. Phosphorus plays key role in protein synthesis, phospholipids and phytin all of which are important in the seed formation and development (Rahman *et al*., 2008). Likewise, Meseret and Amin (2014) reported that the number of seeds per pod of common bean was increased from 3.14 to 4.2 with increased levels of P from 0 to 92 kg P_2O_5 ha^{-1}.

4.3.4. Hundred Seeds weight

The analysis of variance showed highly significant ($P<0.01$) main effect of variety and blended NPS fertilizer application rates on hundred seed weight while their interaction did not significantly influenced hundred seed weight. Variety Fadis recorded the highest hundred seed weight (45.38 g) while the lowest hundred seed weight (35.51g) was recorded for variety Babile (Appendix Table 3). The highest hundred seed weight(42.21) were recorded at the highest application rate of 200 kg NPS ha^{-1} and it was statistically at par with 150 and 100 kg NPS ha^{-1} while the lowest hundred seed weight (35.05) were recorded from 0 kg NPS ha^{-1}(Table 10). This might be because nutrient use efficiency by crop was enhanced at optimum level of N, P and S since grain weight indicates the amount of resource utilized during critical growth periods.

The increase in 100 seed weight with fertilizer application is in agreement with the finding of Shamim and Naimat (1987) who related the increment in 100-seed weight to the influence of cell division, phosphorus content in the seeds as well as the formation of fat and albumin. The increase in hundred seed weight as a result of increased P application might be attributed to important roles the nutrient plays in regenerative growth of the crop (Zafar et al., 2013), leading to increased seed size (Fageria, 2009), which in turn may improve hundred seed weight. Similarly, Amare et al. (2014) observed significant increase in thousand seed weights of common bean as a result of phosphorus application up to 40 kg ha^{-1}. In contrast to the results of this study, Fisseha and Yayis (2015) reported that the different levels of phosphorus (46, 69 and 92 kg P_2O_5 ha^{-1}) fertilizer used had not resulted in significant difference in 100 seed weight of common bean.

Variation in hundred seed weight might have occurred due to the presence of difference in seed size among the common bean varieties as hundred seed weight increases with increase in the seed size. In line with this result, Tanaka and Fujita (1979) stated that the number of seeds per pod and weights of hundred seeds were strongly controlled genetically in field bean (*Pisum sativim*). The higher 100 seed weight for variety Ibado is associated with the size of the seed in accordance with Hawtin et al. (1980) who explained that the larger the seed, the higher its seed weight. Daniel *et al*. (2014) reported that common bean varieties had a significant variation among each other for thousand seed weight. The authors indicated that variety Gobe Rasha produced the highest seed weight (539.52 gm.), while variety Awash 1 was the least in seed weight (151.95).

Similarly Amare *et al*. (2014) stated that there were highly significant differences in 1000 seed weight with the value of 388.67 g for Ibbado and 174.90 for Dume varieties of common bean. Wondwosen and Tamado (2017) also obtained highly significant difference in hundred seed weight among the common bean varieties where the highest hundred seed weight (21.78 g) was reported for variety Red Wolayita whereas the lowest hundred seed weight (18.19 g) was obtained for variety Awash

Table 10. Main effects of varieties and NPS fertilizer rates on number of seed per pod and Hundred seed weight (g) .

Treatment	number of seed per pod	Hundred seed weight (g)
Babile	3.93^{b}	35.51^{c}
Fadis	4.53^{a}	45.38^{a}
Tinike	4.67^{a}	37.75b
LSD (0.05)	0.77	2.83
NPS rates (kg ha^{-1})		
0	3.67^{c}	35.05^{d}
50	3.78^{c}	38.26^{c}
100	4.33^{b}	40.38^{b}
150	5^{a}	41.83^{ab}
200	5.11^{a}	42.21^{a}
LSD (0.05)	0.45	1.63
CV (%)	10.5	4.3

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

4.3.5. Above-ground dry biomass yield:

Hundred seed weight was highly significantly ($p<0.01$) influenced by varieties, blended NPS rate and their interactions. *Tinike* variety with application of 200 kg blended NPS ha^{-1} fertilizer scored significantly the highest above ground dry biomass (6330 kg) while the lowest above ground dry biomass (5142 kg) was for variety *Babile* with 0 kg blended NPS ha^{-1} application rate (Table 11). The result generally showed an increase in biomass production with increase in the rate of blended NPS among the bean varieties (Appendix Table 4). The increased in biomass yield of cultivars across blended NPS rates could be attributed to the fact that the enhanced availability of N significantly increased plant height, number of pods per plant and to the overall vegetative growth of the plants that contributed to higher above-ground dry biomass yield. Taminaw (2019) reported that the main effects of varieties and NPS fertilizer rates had highly significant ($p<0.01$) effects on the above-ground dry biomass of common bean while the interaction effects of both factors had non-significant effect. The increment in dry matter yield with application of blended NPS fertilizer might also be due to the adequate supply of P from the NPS that could be attributed to an increase in number of branches per plant, which increased photosynthetic area and the number of pods per plant. The increase in the above-ground dry biomass yield in response to increasing rate of phosphorus application proves that the soil of the study area is in fact deficient in available soil P and requires external P fertilizer application for enhancing the yield of the crop.

This result was in conformity with the findings of Agegnew G et al (2006) who reported a significant linear response of above-ground dry biomass yield to phosphorus application in faba bean on acidic Nitisols. He also reported that the total above-ground dry biomass yield of faba bean significantly increased with increased rate of phosphorus fertilizer application where the soil was low in available phosphorus of acidic Nitisols. In contrast with this result, Tedesse (2012) also reported that application of Sulphur up to 60 kg S ha^{-1} and interaction of nitrogen with Sulphur did not result in significant effect on above-ground dry biomass of common bean.

Amare *et al.* (2014) reported that dry matter of common bean was significantly ($p<0.01$) affected by the main effects of variety. Similarly Daniel *et al.* (2014) were reported the highest total biomass from Nasir followed by Dimtu and the lowest biomass was from Batu. In agreement with this result, Girma (2009) also found a significant increment in biomass weight of common bean with increased rates of NP fertilizers from 0 N kg + 0 kg P_2O_5 to 36 kg N + 92 kg P_2O_5 ha^{-1}respectively. Likewise Fazli *et al.* (2008) reported that lack of S limits the efficiency of added N; therefore, S addition becomes necessary to achieve maximum efficiency of applied nitrogenous fertilizer and nitrogen helps to increases shoot dry biomass, which is positively associated with seed yield in cereals and legumes (Fageria, 2008).

Table11. Interaction effects of varieties and NPS fertilizer rates on AGDBM Yield of common bean

	NPS (kg ha^{-1})				
Varieties	0	50	100	150	200
Babile	5142^{e}	5361^{e}	5965^{d}	6194^{abc}	6243^{ab}
Fadis	5977^{cd}	6004^{cd}	6174^{abc}	6212^{abc}	6294^{ab}
Tinike	6065^{bcd}	6135^{abcd}	6205^{abc}	6264^{ab}	6330^{a}
LSD (0.05)		106.1			
CV (%)		2.3			

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

4.3.6. Seed yield

Seed yield was highly significantly ($P<0.01$) affected due to main effect of blended NPS fertilizer rate , varieties and interaction of both factors. Variety Fadis with application of 150 kg blended NPS ha^{-1} fertilizer scored significantly the highest Seed yield (2565kg ha^{-1}) while the lowest Seed yield (1383kg ha^{-1}) was for variety Babile with 0 kg blended NPS ha^{-1} application rate (table 12). (Appendix. Table 4). Differences in seed yield among the common bean varieties might be related to the Genotypic variations in P use efficiency. Hence, the cultivars which produced higher grain yield might have either better ability to absorb the applied P from the soil solution or translocate and use the absorbed P for grain formation than the low yielding cultivar.

In agreement with the results of this study, Gobeze L et al (2015) and Mourice et al (2012) observed significant variations in grain yield for common bean due to genotypic variations for P use efficiency which may arise from variation in P acquisition and translocation and use of absorbed P for grain formation in common bean. The result might be attributed to the fact that applying NPS fertilizer increases crop growth and yield on soils which are naturally low in NPS and in soils that have been depleted. Similar results were reported by Murut G et al (2014) that P application at the rate of 46 kg P_2O_5 ha^{-1} gave higher number of pods per plant and yield as compared to unfertilized plots in common bean. This result is also in agreement with that of Negash F et al (2015). Who reported that the application of 27 kg N and 69 kg P_2O_5 ha^{-1} had significantly improved grain yield of common bean. It might also be due to increased levels of S, its availability along with major nutrients and higher uptake of crop and influencing growth and yield components of the crop, which ultimately lead to effective, assimilate partitioning of photosynthates from the source to sink in post-flowering stage and resulted in highest seed yield. Differences in seed yield among the common bean cultivars might also be related to their response to applied NPS.

In conformity to this result, Dwivedi et al (1994) found increased yield of common bean due to increasing levels of nitrogen up to 100 kg $ha^{-1}$with the difference between 80 and 100 kg N ha^{-1} being not significant. Boroomanndan P et al. (2009) also reported that seed yield of soybean increased significantly at 40 kg N ha^{-1} compared to the control treatment. However, application of 80 kg N ha^{-1} decreased seed yield, indicating that there is a limit to the maximum level of nitrogen to be supplied to avoid its detrimental effect on the plant. Similarly, Wondwosen and Tamado (2017) reported highly significant ($p<0.01$) difference in seed yield among common bean varieties with the highest seeds yield 3127.00 kg ha^{-1} was recorded for variety Awash Melka with 27 kg N: 69 kg P_2O_5 ha^{-1} whereas the lowest value of seeds yield (574.00 kg ha^{-1}) obtained from variety Awash 1.

Similarly the result of Daniel *et al*. (2014) also reported a significance variation among common bean varieties in their response to seed yield. The highest yield also reported from the varieties Nasir and Dimtu with the values of 2866.8 and 2709.3 kg ha^{-1}, treated level respectively. On the other hand the lowest yielder with the value of 678.2 kg ha^{-1} was Batu. Similarly, Shanka *et al*. (2015); and Mourice and Tryphone (2012) reported significant variations in grain yield for common bean due to genotypic variations for P use efficiency which may arise from variation in P acquisition and translocation and use of absorbed P to grain. The increase in seed yield with NPS application might be related to higher primary branch per plant, number of pods per plant, number of seeds per pod and 100 seed weight. The increase in grain yield due to higher rates of NPS fertilizer clearly indicates the need of balanced fertilizer to achieve maximum grain yield; which is consistent with the basic principles of plant nutrition (Marschner, 1995).

Table12. Interaction effects of varieties and NPS fertilizer rates on grain yield of common bean

	NPS (kg ha^{-1})				
Varieties	0	50	100	150	200
Babile	1383^{j}	1526^{i}	1870^{gh}	1818^{f}	1952^{e}
Fadis	1734^{fg}	2033^{e}	2279^{c}	2565^{a}	2434^{b}
Tinike	1608^{hi}	1737^{fg}	1933^{e}	2189^{cd}	2076^{d}
LSD (0.05)		44.78			
CV (%)		3			

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

4.3.7. Harvest index:

Harvest index was highly significantly (P<0.01) affected by the variety, blended NPS Fertilizer rate and interaction effect of both factor (appendix Table 4). The highest harvest index (41.30 %) was recorded from *Fadis* variety with the application of 150kg NPS ha^{-1} whereas the lowest (26.5 %) was obtained from *Tinike* variety with the application of 0kg NPS ha^{-1} (table 13). These variations might be attributed to genotypic differences of the common bean varieties on seed yield and above ground dry biomass. In conformity with this result, Endrias (2017) reported the highest harvest index (40.40%) for variety Nasir while the lowest harvest index (34.57%) was for variety Red Wolaita (34.57%). Similarly Daniel *et al.* (2014) reported the highest harvest indices for the common bean varieties Beshbesh (0.50) and Nasir (0.48). Taminaw (2019) also reported that the main effects of varieties and NPS fertilizer application rate had highly significant (p<0.01) effect on harvest index of the crop while the interaction effect was not significant. The result of this study was also in agreement with Fageria (2008) who reported significant improvement of common bean in harvest index within the range of

0.44 to 0.74 due to nitrogen application up to 50 kg ha^{-1}. Similarly Dhanjal *et al*. (2001) stated that in the increase of harvest index values from 31.60, to 33.86% was due to increasing N level zero to 60 and 120 kg N ha^{-1}, respectively on common bean.

Table13. Interaction effects of varieties and NPS fertilizer rates on Harvest Index (%) of common bean

	NPS (kg ha^{-1})				
Varieties	0	50	100	150	200
Babile	26.93^{hi}	28.5^{gh}	28^{ghi}	29.3^{fg}	31.17^{ef}
Fadis	29.02^{g}	32.29^{de}	36.90^{b}	41.30^{a}	38.70^{b}
Tinike	26.5^{j}	28.37^{ghi}	31.3^{e}	34.93^{c}	33.83^{cd}
LSD (0.05)		0.854			
CV (%)		3.5			

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

4.4. Agronomic Efficiency

The agronomic data upon which the recommendations are based must be relevant to the farmers' own agro-ecological conditions, and the evaluation of those data must be consistent with the farmers' goals and socio-economic circumstances. For instance agronomic efficiency (kg seed kg^{-1} of NPS) as ratio of seed yield to NPS fertilizer rates with three common bean varieties showed highly significant ($p<0.001$) effects with the highest value (5.6 kg seed kg^{-1} of NPS) in treatment combination of 150 kg NPS ha^{-1} fertilizer with *Fadis* variety and it was statistically at par with 100 kg NPS ha^{-1} from the same variety while the lowest agronomic efficiency (2.4) were recorded from 0 kg NPS ha^{-1} with *Tinike* variety (Table 14). The net benefit was computed for common bean varieties, application of blended NPS fertilizer and interaction of varieties with application of blended NPS fertilizer. The economic analysis revealed that highest net benefit (53,354 Birr ha^{-1}) was obtained from combination of variety Fadis treated with 150 kg NPS ha^{-1} while the lowest net benefit (27,387.8 Birr ha^{-1}) was obtained from variety Babile grown without fertilizer (Appendix Table 5). Therefore, production of Fadis variety with the application of 150 kg NPS ha^{-1} with 850.5 MRR% was found the most productive variety for economical production compared to Babile and Tinike varieties. Anteneh *et al*. (2015) also stated highest AE of nitrogen in common bean was observed in soil having fertility soil with moderate N content and lowest AE of nitrogen in the same soil high N content. Similarly Alemu *et al*. (2018) reported that Agronomic efficiency (AE) was significantly affected by P rates. In their report, the highest AE was obtained when it was grown at application of 23 kg P_2O_5 ha^{-1} while the lowest was recorded from 46 kg P_2O_5 ha^{-1}. Lower levels suggest changes in management could increase crop response or reduce input costs up to the optimum level (Fixen *et al*., 2015).

Table14. Agronomic efficiency as ratio of seed yield to NPS fertilizer rates with three common bean varieties.

	NPS (kg ha^{-1})			
Varieties	50	100	150	200
Babile	2.85^{cd}	2.73^{cd}	2.9^{cd}	2.8^{cd}
Fadis	4.1^{b}	5.5^{a}	5.6^{a}	3.5^{bc}
Tinike	2.6^{cd}	3.1^{bcd}	3.9^{b}	2.4^{d}
LSD (0.05)	0.44			
CV (%)	21			

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

4.5. Partial Budget Analysis

The partial budget analysis of the 15 treatments is shown in (Table 13). Based on this result, the highest net benefit of 53454 Birr ha^{-1} with MRR of 850.5% was obtained from the treatment combination of 150 kg NPS ha^{-1}application rate for variety Fadis. According to CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be above 100%. Therefore, the most attractive NPS fertilizer application rate for producers or farmers with higher net return was 150 kg NPS ha^{-1}fertilizers application rate. In agreement with this result, Shumi (2018) obtained highest net benefit (34167.56 Birr ha^{-1}) with the application of 150 kg NPS ha^{-1} for common bean.

Table15. Summary of partial budget analysis of the response of common bean varieties to the application of NPS fertilizer

Treatment Combination Variety + NP S (kg ha^{-1})	Adjusted seed yield (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	NPS cost (Birr ha^{-1})	NPS application cost (Birr ha^{-1})	TVC (Birr ha^{-1})	Net Benefit (Birr ha^{-1})	MRR (%)
Babile + 0	1244.9	27387.8	0	0	0	27387.8	-
Babile + 50	1523.1	33508.2	650	100	750	32858.2	841.6
Babile + 100	1683	37026	1300	100	1400	35726	441.2
Babile + 150	1799.9	39591.2	1950	100	2050	37641.2	294.6
Babile + 200	1831.7	40297.4	2600	100	2700	38697.4	8.6
Fadis + 0	1560.8	37459.2	0	0	0	37459.2	-
Fadis + 50	1451.79	42908	650	100	750	42158	722.9
Fadis + 100	2051	49224	1300	100	1400	47924	717.9
Fadis + 150	2308.5	55404	1950	100	2050	53454	850.8
Fadis + 200	2190.2	52564.8	2600	100	2700	49964.8	536.8
Tinike + 0	1446.9	31831.8	0	0	0	31831.8	-
Tinike + 50	1630.1	35862.2	650	100	750	35212.2	520.2
Tinike + 100	1817.6	39987.2	1300	100	1400	38687.2	534.6
Tinike + 150	1849	40678	1950	100	2050	38728	6.3
Tinike + 200	1868.3	41102.6	2600	100	2700	38502.6	34.7

MRR (%) = Marginal Rate of Return; Fertilizer application cost = 100 Birr ha^{-1}; NPS cost =13.00 Birr kg^{-1}; Common bean grain local selling price =23Birr kg^{-1}; TVC = Total variable cost; D= Dominated Treatment

5. SUMMARY AND CONCULUSION

Common bean (*Phaseolus vulgaris L.*) is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enable households to get cash income required to purchase food and other household needs when other crops have not yet matured. Improved common bean production encompasses proper use of different agronomic practices which include improved variety, seed rate, spacing, fertilizer rate, and pesticide application as per recommendations. However, the current national average yield of common bean is far less than the attainable yield under good management conditions for most improved varieties.

This low yield of common bean in Ethiopia is attributed to several production constraints, which include lack of improved varieties for the different agro-ecological zones, poor agronomic practices such as low soil fertility management, untimely and inappropriate field operations. Thus, a field experiment was conducted to assess the effect of blended NPS rates on yield and yield related traits of common bean varieties and to estimate economically feasible rates of blended NPS fertilizer for common bean production.

Treatments consisted of factorial combinations of three common bean varieties (*Babile, Fedis, and Tinike,)* with five NPS fertilizer rates (0, 50, 100, 150 and 200 kg ha^{-1}) laid out in Randomized Complete Block Design with three replications. All parameters were highly significant ($p<0.01$) on Main effects of varieties and NPS rates. Plant height, number of pod per plant , above ground dry biomass , grain yield and ,harvest index were highly significantly ($p<0.01$) affected due to interaction of both factors while days of flowering 50%, days physiological maturity, total number of nodule per plant , effective number of nodule per plant, number of primary branch per plant ,stand count , number of seed per pod and 100 seed weight were non-significant effect. The highest days to 50% flowering (48.73 days), days to 90% physiological maturity (95.8 days), effective nodule number (33.67) , number of seed per pod (4.67) were recorded from variety *Tinike* while the highest total nodule number (69) , number of primary per plant (3.53) and hundred seed weight (45.38 g) were recorded from variety *Fedis.* The highest level of NPS rate

(200 kg ha^{-1}) resulted in higher values of number of primary branches per plant, number of total nodules, number of effective nodules, number of seeds per pod and 100 seed weight. However, the highest number of pod per plant (25.33) , Grain Yield (2565 kg ha^{-1} and harvest index (41,30), were recorded due to application of 150 kg ha^{-1} of blended NPS for variety Fedis. Variety *Tinike* gave the highest plant height (67.60 cm) and above ground dry biomass (6330kg ha^{-1}) with application of 200 kg NPS ha^{-1}.

Agronomic efficiency (kg seed kg^{-1} of NPS) as ratio of seed yield to NPS fertilizer rates with three common bean varieties showed highly significant ($p<0.001$) effects with the highest value (5.6 kg seed kg^{-1} of NPS) in treatment combination of 150 kg NPS ha^{-1} fertilizer with *Fedis* variety and it was statistically at par with (5.5 kg seed kg^{-1} of NPS) in treatment combination of 100 kg NPS ha^{-1} from the same variety while the lowest agronomic efficiency (2.4) were recorded from 0 kg NPS ha^{-1} with *Tinike* variety (table 14). Based on this result, the highest net benefit of 5 3454 ETB ha^{-1} with MRR of 8 5 0 . 5 % was obtained from the treatment combination of 150 kg NPS ha^{-1} application rate with Fedis variety. Thus, it can be concluded from the result of present study that the use of variety *Fedis* with application of 150 kg NPS ha^{-1} could be recommended to enhance the productivity of common bean in the study area. However, the result of the present study need to be validated and proved in the same agro-ecologies and seasons with further experiments in order to give a blanket recommendation for wide range of common bean production.

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7. APPENDICE

Appendix 1Table1. Mean squares of analysis of variance for phonological and growth parameters of common bean as affected by varieties and NPS fertilizer rates

Sources of variation	Df	Means squares	
		DFF	DPM
Replication	2	7.02	1.49
Variety	2	22.8**	29.76**
NPS fertilizer rates	4	49.56**	108.4**
Variety x NPS rates	8	0.49ns	1ns
Error	28	1.48	1.29
CV (%)		2.6	1.2

*df= degree of freedom; ns= non-significant; * = Significant at 5% level of significance; ** = Significant at 1% level of significance; DFF =Days to 50% flowering; DPM = Days to physiological maturity;*

Appendix Table 2. Mean squares of analysis of variance for phonological and growth parameters of common bean as affected by varieties and NPS fertilizer rates

Sources of variation	Df	Means squares			
		TNN	EN	PH	NPBP
Replication	2	10.87	84.04	2.6	0.02
Variety	2	1531.47**	415.4**	719.6**	1.09**
NPS fertilizer rates	4	740.14**	187.6**	522.1**	3.5**
Variety x NPS rates	8	20.33ns	22.26ns	20.15**	0.2ns
Error	28	24.5	15.16	3.35	0.21
CV (%)		8.1	12.8	3.5	14.3

*df= degree of freedom; ns= non-significant; * = Significant at 5% level of significance; ** = Significant at 1% level of significance; EN= Effective nodules; TNN= Total number of nodules NEN= None effective nodules ; PH= Plant height; NPBP= Number of Primary branches per plant*

Appendix Table 3. Means squares of analysis of variance for yield components of common bean as affected by varieties and NPS fertilizer rates

		Means squares			
Sources of variation	Df	SC	NPP	NSP	HSW
Replication	2	3.2667	1.87	0.02	0.01
Variety	2	26.8667**	176.07**	2.29**	401.71**
NPS fertilizer rates	4	54.9667 **	116.64**	4.03**	78.42*
Variety x NPS rates	8	0.6167 ns	4.93**	0.23ns	3.07ns
Error	28	0.8619	1.03	0.77	2.86
CV (%)		1	5.8	10.5	4.3

*df= degree of freedom; ns= non-significant; * = Significant at 5% level of significance; ** = Significant at 1% level of significance; SC= Stand count; NPP= Number of pod per plant; NSP= Number of seed per plant; HSW= hundred seed weight;*

Appendix Table 4. Means squares of analysis of variance for yield components and yield of common bean as affected by varieties and NPS fertilizer rates

*df= degree of freedom; ns= non-significant; * = Significant at 5% level of significance;*

		Means squares		
Sources of variation	df	AGDBM	SY	HI
Replication	2	98256	8459	2.67
Variety	2	781397**	714789 **	129.18**
NPS fertilizer rates	4	539204**	642546 **	94.0**
Variety x NPS rates	8	146802**	17255**	6.69**
Error	28	20112	3585	1.30
CV (%)		2.3	3	3.5

*** = Significant at 1% level of significance; AGDBM= above ground dry biomass; SY= seed yield; HI= Harvest index*

Sources of variation	Df	Means squares
		AE
Replication	2	0.45
Variety	2	*23.9***
NPS fertilizer rates	4	*9.8***
Variety x NPS rates	8	1.3*
Error	28	0.34
CV (%)		21

Appendix Table 5. Means squares of analysis of variance for agronomic efficiency of common bean as affected by NPS fertilizer rates with three varieties

*df= degree of freedom; ns= non-significant; * = Significant at 5% level of significance; ** = Significant at 1% level of significance; AE= agronomic efficiency*

Appendix Table 6. Partial budget analysis summary of common bean as affected by varieties and NPS fertilizer rates

Treatments	Variable costs		
	Fertilizer application cost (Birr ha^{-1})	NPS cost (Birr ha^{-1})	Total variable cost (Birr ha^{-1})
Babile + 0	0	0	0
Babile + 50	100	750	850
Babile + 100	100	1400	1550
Babile + 150	100	2050	2250
Babile + 200	100	2700	2950
Fadis + 0	0	0	0
Fadis + 50	100	750	850
Fadis + 100	100	1400	1550
Fadis + 150	100	2050	2250
Fadis + 200	100	2700	2950
Tinike + 0	0	0	0
Tinike + 50	100	750	850
Tinike + 100	100	1400	1550
Tinike + 150	100	2050	2250
Tinike + 200	100	2700	2950

Fertilization application cost = 100 Birr ha^{-1}; NPS cost= 13 Birr kg^{-1}