GROWTH, NODULATION AND YIELD RESPONSES OF CHICKPEA (*Cicer arietinum* L.) VARIETIES TO DIFFERENT RATES OF NPSB BLENDED FERTILIZER AND INOCULANTS IN MESKAN DISTRICT, CENTERAL ETHIOPIA

MSc THESIS

MOHAMMED HAMID

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MSc Thesis

Mohammed Hamid

A Thesis

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Amsalu Nebiyu (PhD, Associate Professor) Major advisor:	_______________ Signature	__________ Date
Asnake Fikre (PhD) Co-advisor:	_______________ Signature	_____________ Date

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DEDICATION

This thesis is dedicated to my mother Mehdiya Abdulshikur for her affection,encouragement, supplication and partnership in the success of my life and realization of my dream.

STATEMENT OF AUTHOR

First, I declare that this thesis is a result of my genuine work and that all sources of materials used for writing it have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for the Degree of Master of Science in Jmma University and is deposited at the library of the university to make it available for readers. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Place: Jimma University

Date of Submission; October 2019

BIOGRAPHICAL SKETCH

The author, Mohammed Hamid Beshir was born on October 12, 1990 at Butajira town, Gurage Zone, Souther nation nationalities people regional State. He attended his primary school at Weja and Enseno respectively, his Secondary and Preparatory Schools at Butajira. He joined Haramaya University, College of Agriculture and Natural Resource Management in 2001 E.C and graduated with BSc Degree in Plant Sciences in 2003 E.C.

After his graduation, he joined Meskan woreda Agricultural Development Office now Meskan Woreda Agriculture and Natural Resources Office in 2004 E.C and worked as agronomist and during his stay in Woreda Agriculture and Natural Resources Office, he has served in different positions including work process representative until he joined School of Graduate Study of Jimma University in 2010 E.C to pursue his study leading to Master of Science in Agronomy.

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LIST OF ABBREVIATIONS

AE	Agronomic efficiency
ANOVA	Analysis of variance.
ATA	Agricultural Transformation Agency.
ATP	Adenosine triphosphet.
BARC	Bako Agricultural Research Center.
BNF	Biological nitrogen fixation.
CEC	Cation exchange capacity.
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistics Agency of Ethiopia
DZARC	DebreZzeit Agricultural Research Center.
FAOSTAT	Food and Agriculture Organization of the United Nations
MRR	Marginal rate of return
PGPR	Plant growth promoting rhizobacteria
RCBD	Randomized complete block design
SNNPRS	South Nation Nationalities Peoples Regional state.

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ABSTRACT

Lack of improved varieties and adequate information on the use of Rhizobium strain and NPSB blended fertilizer is the major yield limiting factors of chickpea production on vertisols in the Meskan area. Hence, a field experiment was carried out during the main cropping season of 2017/18 in Meskan District, to evaluate the growth, nodulation, yield and yield component of two improved chickpea (Cicer arietinum L.) varieties to different rates of NPSB blended fertilizer and Rhizobium inoculant and thereby to determine the optimum fertilizer rate. Factors studied were two levels of Rhizobium inoculation (with and without) for high yield of varieties, two chickpea varieties (Arerti and Habru) and four levels of blended NPSB fertilizer (0, 30, 60, 90 kg ha^{-1}*). The experiment was conducted in a 2×2×4 factorial combination in randomized complete block design with three replications. Data on growth, nodulation, yield and yield components were recorded and subjected to analysis of Variance (ANOVA). ANOVA showed that crop phenology (days to 50% flowering and days to physiological maturity), the growth (plant height, leaf area, number of primary branches, shoot dry weight, root dry weight), nodulation (number of nodules, nodule dry weight, number of effective nodules) and yield and yield components (number of pods, number of seeds, hundred seed weight, harvest index, grain yield and agronomic efficiency) were significantly affected by the different factor combinations. The highest mean value of seed yield (3814kg ha*$^{-1}$*) was obtained from combined application of rhizobium inoculation and 60 kg NPSB ha*$^{-1}$ *from variety Habru which resulted in 77.11% increase over the control (*873.33kg *ha*$^{-1}$*).The partial budget analysis revealed that the maximum (ETB* 66740.19 *ha*$^{-1}$*) net benefit were obtained from combined application of* rhizobium *inoculation and 60 kg NPSB ha*$^{-1}$*from variety Habru with MRR of 5754.64% and minimum (ETB* 12886*ha*$^{-1}$*) net benefit were obtained from the control, respectively. The result showed a net benefit advantage of 80.6% (ETB 53854 ha*$^{-1}$*) when compared the maximum and minimum net benefit. Hence, Rhizobium inoculation with application of 60 kg NPSB ha*$^{-1}$ *could be tentatively recommended for chickpea production in Meskan area. However, the experiment should be repeated over years and locations to give a valid recommendation.*

Key word*: Agronomicy efficiency, blended fertilizer, Inoculation, MRR*

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the only cultivated species within the genus *Cicer* (Namvar and Sharifi, 2011). The crop is a self-pollinated diploid species with chromosome number of $2n = 2x = 16$ (Arumuganathan and Earle, 1991). There are two main types of chickpea germplasm, namely desi (small, angular and colored seeds) grown mostly in the Indian subcontinent and kabuli (large to medium-size, rams-head shaped and light brown to white seeds, smooth to scarcely rugose) grown mainly in the Mediterranean Basin (Singh, 1997). It is grown in many parts of the world and an important source of human food and animal feed (Millan *et al*., 2006).

In Ethiopia, chickpea is the third leading food legume in the production area coverage and its production next to faba bean and common bean (Pande *et al.,* 2011). It is an integral part of the cropping systems of the farmers because the crop fits well in the crop rotation, double and mixed cropping system. It has multiple uses and can grow under the condition of low soil fertility and varying conditions of soil and climate (Fikre, 2014). Chickpea returns significant amount of nitrogen to soil and improves the N balance. Moreover, when chickpea is used in crop rotation, it breaks disease cycles of important cereal pathogens (Pande *et al.,* 2011).

The agro-climatic conditions in Ethiopia are suitable for growing chickpeas. It is widely grown across the highlands and semi-arid regions of Ethiopia (Anbessa and Bejiga, 2002). It is cultivated at altitudes ranging from 1400 to 2300 meters above sea level (m.a.s.l.) and with annual rainfall ranging from 700 to 2000 mm on Vertisols having pH ranges of 6.4-7.9. The crop largely grows under residual moisture at the end of the main rainy season in water-logging areas (Bekele *et al*., 2007).

In 2014, Ethiopia produced 60% of Africa's total chickpea production (Ojiewo, 2016). The total area of chickpea in Ethiopia covers about 242 000 ha over the past decades (CSA, 2017), with Desi varieties grown mainly for the local market and the larger seeded, Kabuli varieties largely for export. Yet, productivity of chickpea remains low, with national average yield of 2.1 t ha^{-1} (CSA, 2017), which is far below the potential yield of 4–5 t ha^{-1} reported on experimental stations (Fikre, 2016), and the regional average yield is 1.1 t ha^{-1} (CSA, 2006/7). The yield gap is mostly due to poor crop management and cultural practices such as no use of fertilizer, lack of improved varieties that are adapted to different environmental conditions, inappropriate use of rhizobium strain, soil fertility decline and lack of appropriate technologies such as recommended fertilizer rate and inadequate pest and disease management (Asfaw, 1994).

In Meskan District, Agricultural Transformation Agency (ATA) recommended site specific blended fertilizer applications for all crops. But, in the study area relatively no investigations have analyzed the application rates of the new recommended crop specific nutrient blended fertilizer NPSB (18.9 kg N, 37.7 kg P_2O_5, 6.95 kg S, and 0.1kg B) (EthoSIS, 2014). Besides, in the study area limited research has been done on the interaction effects of various agronomic practices such as rhizobium inoculation and its effect in different chickpea varieties differ in size, and surface of seed, and plant morphology (Purushothaman *et al*, 2014).

Inoculation of legumes is necessary in the absence of compatible Rhizobium or where indigenous Rhizobial populations are low or inefficient in fixing nitrogen (Catroux *et al.*, 2001). In a rain-fed field experiment greater number of nodules in inoculated treatments compared with non-inoculated ones that relied on indigenous Rhizobia. Since chickpea is a relatively new crop for Meskan area, with hardly any production, it is likely that compatible and effective native Rhizobia may be lacking in the soils of this area. Therefore, inoculation with commercial rhizobia may increase effective nodulation and N fixation and hence improve yields and provide a substitute to an inorganic fertilizer (Romdhane *et al.* 2009)

For more than a few years unlike studies have been undertaken on inoculation trial of several pulse crops in Ethiopia (Angaw and Asfaw, 2006). hence, field trial showed positive response of faba bean (*Viciafaba* L.) and chickpea (*Cicer arientinum* L.) to inoculation and NP fertilizer application. They also showed that inoculation increased the productivity of different pulse crops in some parts of Ethiopia. Several authors also indicated the positive effect of *Rhizobium* inoculation alone and in combination with NP fertilizer on different soil types (Ayneabeba *et al*., 2001)

In Ethiopia, inoculation is not a new technology (Habtamu *et al.,* 2017). However, it is not widely used by the farmers but *Rhizobium* strains are being selected and distributed to the farmers to facilitate fixation of the target legumes crop. Inoculation significantly improved nodule number per plant as compared with uninoculated treatment; this is because of inoculated bacteria strain had good nodulation inducing capacity over the native soil *Rhizobium* population (Habtamu *et al.,*2017). Inoculation of *Rhizobium* strain (CP-41) significantly increased hundred seed weight and seed yield ha^{-1} of chickpea (Endalkachew *et al.,* 2018) The maximum hundred seed weight (21%) and increased seed yield (50%) were recorded from inoculation of chickpea with *Rhazobium* strain CP-41 in four different Woredas (districts), namely Gimbichu (Central), Damote-Gale (South), and Ginir (South-east Ethiopia) (Tena *et al*., 2016). Anteneh (2016) reported, the highest grain yield (3286.27 and 2951.36 kg ha-1) at Haramaya and Hirna, respectively, with inoculation of common bean with *Rhizobium* strain. However, the recommended rate of fertilizer might vary according to crop type, location, soil type and amount of fertilizer application from farmer to farmer lack of awareness and financial capacity. So far a number of researches have been done on chickpea but effect of NPSB blended fertilizer and inoculation, especially in the study area is scanty.

Currently, new blended fertilizer NPSB (18.9N, 37.7P_2O_5, 6.95S and 0.1B) and rhizobium inoculants are distributed to the growers in study area; but, their rate of application is not experimentally determined for chickpea varieties. Thus, this study was carried out with the objectives of

- To determine the combined effect of inoculation and NPSB fertilizer application on growth, yield and yield component of chickpea varieties.

2. LITERATURE REVIEW

2.1. Description of Chickpea

Chickpea (*Cicer arietinum* L.) is believed to have been originated in the present-day south eastern Turkey and adjoining Syria (Saxena and Singh, 1987). It is the only one annual cultivated species among the nine annuals from the genus *Cicer*. The cultivated chickpea belongs to family *Fabaceae* (formerly Leguminosae) and subfamily Faboideae (Vander, 1987). Existence of a pea-shaped third type characterized by medium to small seed size and creamy color has also been recognized which may be the result of intercrossing between Desi and Kabuli types that has resulted in a sort of intermediate group types (Upadhyaya *et al*., 2008). Extra-large Kabuli attracts heavy premium prices and is more preferred in European, North American, South African and Middle East markets with a greater export needs (Shiferaw *et al*., 2007).

The lateral roots develop nodules with the symbiotic rhizobium bacteria, capable of fixing atmospheric nitrogen in plant-usable form (Gan *et al*, 2010). The plant stem is erect, branched, viscous, hairy, herbaceous, green, and solid. The branches are usually quadrangular, ribbed, and green. There are primary, secondary, and tertiary branches. The primary branches form an angle with a vertical axis, ranging from almost a right angle (prostrate habit) to an acute angle (erect). Generally stems are incurved at the top, forming a spreading canopy (Cubero, 1987). The entire surface of the plant shoot, except the corolla, is densely covered with fine hairs known as trichomes. Many are glandular and secrete a highly acidic substance containing malic, oxalic and citric acids. These acids play an important role in protecting the plant against insect pests. Chickpea is annual crop that can complete its life cycle in 90 to 180 days depending on the prevailing meteorological conditions (Gaur, 2010).

Chickpea plant is drought-resistant, but genetic variation exists by date of maturity. Longer delay in flowering time may be an signal of the variety susceptibility to drought, and this character may be also used as an integrative trait to categorize which type of chickpea is tolerant and susceptible to drought (Tesfahun *et al*., 2018). It might be attributed to the fact that flowering time in chickpea is considered to be varietal characteristics, which is genetically controlled. Some studies showed that the differential response to flowering among varieties was distinct. For instance, Tripathi *et al*. (2013) reported that differences among varieties of chickpea in days to 50% flowering.

Most of the improved chickpea varieties with their appropriate agronomic practices have been demonstrated to farmers, they also constitute leader farmers in the production and marketing of high-value improved Kabuli type chickpeas. However, recent study in some woredas indicated that taken together this implies the available high yielding varieties with market preferred traits have not fully reached farmers (Takele and Dechassa,, 2018).

2.2. Production and Yield Trends of Chickpea in Ethiopia

Ethiopia having greatly increased production in recent years now accounts for over 2% of world production, and stood 6th on the global ranking of chickpea producing countries (FAOSTAT, 2015).The country is also the largest chickpea producer in Africa, with a share of about 60% of total chickpea produced in the continent (FAOSTAT, 2014). About 75% of the area all over the world is covered by the Desi types and the remaining 25% by the Kabuli types (Kassie *et al*., 2009). The main producers of the Desi types are India, Pakistan and Ethiopia, while Mexico, Iran, Afghanistan, Spain and Chile are the major producers of the Kabuli types (Kassie *et al*., 2009). In Ethiopia, currently the desi type chickpea accounts for about 42 percent of production and is grown across a wide range of ecologies (recent technology survey, unpublished).

Although chickpea is widely grown in Ethiopia, the major producing areas are concentrated in two states i.e. Amhara and Oromia. These two states cover more than 90% of the entire chickpea area and constitute about 92% of the total chickpea production. The top nine chickpea producing zones (North Gonder, South Gonder, North Shoa, East Gojam, South Wollo, North Wollo, West Gojam and Gonder Zuria) belong to the Amhara region and account for about 80% of the country's chickpea production. In the Oromia region, the major producing zones are West Shoa, East Shoa and North Shoa, which account for about 85% of the total area and production (ICRISAT, 2015). The area under chickpea cultivation has more than doubled from 109,000 ha in 1993 to about 230,000 ha in 2012 in Ethiopia while the yields jumped from about 550 to 1,730 kg ha^{-1} during the same period (ICRISAT, 2015). In 2016/2017 cropping season, the country produced 444,145.93 tons of chickpea on 225,607.53

ha of land with an average productivity of 1.97 tons ha^{-1}. Oromia region accounted for 181,606.06 tons of chickpea from 81,286.46 ha of land with productivity of 2.23 tons ha^{-1} in the same cropping year. Particularly in East Shoa Zone of chickpea was 2.85 tons ha^{-1} and occupied 13,352.88 ha of land and a total of 38,013.95 tons of chickpea was produced (CSA, 2017). This showed the suitability of the area for chickpea production specially on black soil.

2.3. Nutritional and Economical Importance of Chickpea

Chickpea is a nutrient-rich food, providing rich content (20% or higher of the Daily Value) of protein, dietary fibre, folate and certain dietary minerals such as iron and phosphorus. Thiamin, vitamin B6, magnesium and zinc contents are moderate, providing 10–16% of the daily value (El-Adawy, 2002). Chickpea is a good source of carbohydrates and protein, and the protein quality is considered to be better than that of other pulses and also it has significant amounts of all the essential amino acids except sulfur containing types, which can be complemented by adding cereals to the daily diet (Jukanti *et al.*, 2012). It is very high in dietary fiber and hence, a healthy source of carbohydrates for persons with insulin sensitivity or diabetes. The nutrient composition of chickpea seed constitutes fat (4-10%), carbohydrates (52-70%), minerals [calcium (0.2%) and phosphorous (3.0%)] (Ozer *et al.*, 2010). Chickpea is a highly nutritious and an inexpensive source of protein that is estimated at 24% and ranges from 15-30% (Hulse, 1994) depending on variety and environmental conditions (Nleya *et al.*, 2000).

Chickpea is a less labor-intensive crop and its production demands low external inputs as compared to cereals. In Ethiopia, chickpea is widely grown across the country and serves as a multi-purpose crop (Shiferaw *et al.*, 2007). It enhances more intensive and productive use of land, particularly in areas where land is scarce and the crop can be grown as a second crop using residual moisture. The crop reduces malnutrition and improves human health especially for the poor who cannot afford livestock products. It also increases livestock productivity as the residue is rich in digestible crude protein content compared to cereals. The growing demand in both the domestic and export markets provides a source of cash for smallholder producers (Kassie *et al.*, 2009). Chickpea is one of the newly emerging export commodities being promoted for expansion in Ethiopia (Shiferaw *et al.*, 2007). Ethiopia is the leading producer, consumer and exporter of chickpea in Africa and has 4.5% share of the global chickpea market and more than 60% of Africa's global chickpea market share (ICRISAT, 2015).

2.4. Nutrient requirement of chickpea for growth, nodulation and production

Phosphorus is the second most critical plant nutrient overall, but for pulses it assumes primary importance owing to its important role in root proliferation, and thereby atmospheric nitrogen assimilation. Phosphorus is involved in metabolic and enzymatic reaction and is a constituent of ATP and ADP. The evolution of science, particularly in the past century, has clearly demonstrated the significance of phosphorus for all animal and plant life on the earth (Ryan *et al*., 2012). Among various nutritional requirements for production, nitrogen (N) is known to be an essential element for plant growth and development. Nitrogen deficiency limits plant growth and development. It also limits cell division, chloroplast development, enzyme activity and reduces dry matter yields (Salvagiotti *et al*., 2008). Biofertilizers are living microorganisms, which when applied through seed or soil treatment; promote growth by increasing the supply or availability of nutrients to the host plant (Moin Uddin *et al*., 2014). In plants, they also increase the content of growth hormones such as indole acetic acid and gibberellic acid, leading to enhancement in the growth of plants (Asad *et al*., 2004)

2.5. Response of Chickpea to Fertilizer Application

2.5.1. Nitrogen application

Maintaining soil fertility and use of plant nutrient in sufficient and balanced amount is one of the key components in increasing crop yield (Caliskan *et al*., 2008). Among various nutritional requirements for production, nitrogen (N) is known to be an essential element for plant growth and development. Nitrogen deficiency limits plant growth and development. It also limits cell division, chloroplast development, enzyme activity and reduces dry matter yields (Salvagiotti *et al*., 2008). The most important role of N in the plant is its presence in the structure of protein and nucleic acids which are the most important building block and information substances of every cell. In addition, N is also found in chlorophyll that enables the plant to transfer energy from sunlight by photosynthesis. Thus, the supply of N to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Consequently, it influences cell size, leaf area and photosynthetic activity (Caliskan *et al*., 2008 and Salvagiotti *et al*., 2008).

Growth is generally a function of environmental factors (such as temperature and solar radiation) and mineral nutrition, along with genotype and production practices (Alam and Haider, 2006). Growth analysis is one way to verify the crops ecological adaptation to new environments, the competition between species, crops management effects and the identification of the productive capacity of different genotypes. The dynamics of dry matter distribution to various plant organs, their yielding and productivity may be characterized by using various indices of growth analysis (Kibe *et al.*, 2006). Some investigations revealed that, plant height decreased with decreasing rate of nitrogen level in combined application of nutrients (Sutharsan *et al*., 2016); and the increasing of LAI was attributed to the rise in leaf number and total leaf area per plant (Kibe *et al.*, 2006). The maximum values of LAI in inoculated and noninoculated plants were observed in application of 75 (23.45% increase over control) and 100 kg urea ha^{-1}(20.67% increase over control), respectively. Plants treated with 0 kg urea ha^{-1} revealed the lowest LAI at both levels of inoculation. Similarly, the lowest LAI was recorded at zero fertilizer application which is in agreement with findings of Faisalabad *et al*., (2010).

Nitrogen (N) deficiency is frequently a major limiting factor for high yielding crops all over the world (Namvar *et al.*, 2011). Thus, the supply of N to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Consequently, it influences cell size, leaf area and photosynthetic activity (Salvagiotti *et al.*, 2008). Therefore, adequate supply of N is necessary to achieve high yield potential in crops. In general, N deficiency causes a reduction in growth rate, general chlorosis, often accompanied by early senescence of older leaves, and reduced yield (Erman *et al.*, 2011). This result was similar with the finding of Lema *et al*. (2013) who reported N and P fertilizer have significantly affected the NNP, NDWP and yield components of chickpea relative to the control. The highest NNP and NDWP were obtained from 11.5 kg N ha^{-1} followed by 23 kg N ha^{-1} treatments while, the least NNP and NDWP were recorded in the untreated control (N0) treatment. The result implied that both N treatments had stimulating effect on nodulation of chickpea (Lema *et al*., 2013). Nodule number and nodule dry mass were significantly affected by various levels of NPSZnB applications increase number of nodule per plant and heavier dry mass of nodule were obtained with NPSZnB blended fertilizer applications increase and decrease the number of nodule per plant in common bean and lighter dry mass of nodule were obtained with 0 kg

NPSZnB ha^{-1} blended fertilizer applications (Lake and Jemaludin, 2018). This result also was in line with the finding of Tsai *et al*. (1993) as reported that application of nitrogen in the range of 22 to 33 kg N ha^{-1} enhanced nodulation

The most important role of N in the plant is its presence in the structure of protein and nucleic acids which are the most important building and information substances of every cell. In addition, N is also found in chlorophyll that enables the plant to transfer energy from sunlight by photosynthesis. Thus, the supply of N to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Consequently, it influences cell size, leaf area and photosynthetic activity (Salvagiotti *et al.*, 2008). Therefore, adequate supply of N is necessary to achieve high yield potential in crops. In general, N deficiency causes a reduction in growth rate, general chlorosis, often accompanied by early senescence of older leaves, and reduced yield (Caliskan *et al.*, 2008).

Thus, in soils with N deficiency, there is a need to apply small dose of N fertilizer to legumes to overcome the deficiency and harness their growth and this low dose of N applied externally is called starter dose. In this regard, Thakur *et al.* (2011) recommend that legume like chickpea requires low rates of N which is between 15-20 kg ha^{-1} in nitrogen deficient soils. This is due to the fact that the crop needs small amount of soil N for its growth until Rhizobia-chickpea association is established and symbiotic N-fixation is commenced. From all these results, it can be inferred that it is essential to apply N and P fertilizer to legumes supposed to be grown in soils which are deficient in these nutrients.

In this regard, most Ethiopian soils are poor in N and P contents indicating that areas growing legumes are also low in N and P (Wassie and Tekalign, 2017). However, the degree of deficiencies of N and P varies depending soil type, crop variety and environmental variables. This implies that there is a need to test and establish optimum N and P rates for adequate production of chickpeas

2.5.2. Phosphorus application

Phosphorus (P) is a major soil factor limiting the production and productivity of crops including chickpea in Ethiopia. It is a very vital nutrient required for efficient N_2 fixation because symbiotic N_2 fixation is very high power demanding process in the form of ATP which has P as its major component. Thus, in soils of low extractable P, Poor nodulation and poor vigor of plants occur (Giller, 1998). Acute deficiency of P leads to even no nodule formation indicating how N_2 fixation is sensitive to P (Giller, 1995). According to Islam *et al.* (2012), the yield of chickpea was increased by 65 and 88 % due to the application of P fertilizers in Pakistan and Jordan respectively. However, the optimum P-requirement for adequate production of chickpea varies from soil to soil, variety to variety, region to region and agro ecology. The variation may also be due to stimulatory effect of phosphorus on growth hormones, induce early flowering in chickpea. The findings of Wondimu *et al*. (2008) who reported that increasing the NP application rate from 0 kg N, 0 kg ha^{-1} P_2O_5 to 36 kg N, 92 kg ha^{-1} P_2O_5 significantly shortened the time required to attain 50% flowering (Mahmood and Honermeier, 2015). Shabeer *et al*. (2015) who reported that significant variation was observed by application of different level of Phosphorus on different variety of chickpea and also application of p promote earliness. In addition, Liu *et al*. (2005) have reported that boron increases soya bean photosynthesis rate.

Acharya *et al*. (2007) observed that Phosphatic fertilizer promotes flowering and seed formation and advancing crop maturity. In addition to this, nitrogen deficiency induces an early end of pea flowering (Sagan *et al*., 1993). However, Tewari *et al*. (2010) reported no significant effects of P application on number of days to reach 50% flowering on common bean. Similarly, Tesfaye *et al*. (2015) also reported that interaction of P with variety to be non-significant in common bean. Meseret and Amin (2014) reported highest number of branches per plant was increased at rate of 20 kg P ha^{-1}. Dejene *et al*. (2017) reported that phosphorus have significantly increased plant height at application of 30 kg ha^{-1} P on common bean. Moreover, Tomar *et al*. (2004) also found the positive interaction effect of P and S. Furthermore, the presence of boron in the blended fertilizer might have also significantly increased plant height due to its important role in the cell division and nitrogen absorption from the soil, enhancing plant growth eventually plant height increased.

Some specific growth factors that have been associated with P are: stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen N-fixing capacity of legumes and improves in crop quality (Griffith, 2010)

2.5.3. Sulfur application

Sulfur(S) is the fourth major element required for plant growth next to N, P, and K and most crops absorb as much S as it absorb P. Sulphur deficiency has been reported in the recent years even in many previously sulphur sufficient areas of the world. Scherer (2009) reported that S is becoming deficient due to cultivation of high yielding variety, use of high grade S free fertilizer and absence of industrial activities.

Leguminous plant species require a large quantity of S, probably because of their high protein content. Average S removal for producing 1 tone of food grain is estimated to be 3-4 kg by cereals (wheat and rice), 5-8 kg by sorghum and millet, 8 kg by pulses and legumes and 12 kg by oilseeds (Mudahar, 1985). Therefore, S deficiency in legume crops affects yield formation, quality and the nutritional value of seeds (Sexton *et al.*, 1998). This is mainly because methionine is usually the most limiting essential amino acid in legume seeds (Friedman, 1996). Scherer (2008) has noted that root and nodule development of legumes root is promoted by S fertilization. Scherer and Lange (1996) also reported that S deficiency decreased N demand, which in turn decreased the number and mass of nodules. In contrast, an increase in N demand resulted in higher number and mass of nodules. Similarly, different authors reported that the dry weight of nodules increased with *Rhizobium* inoculation (Sipai *et al*., 2018). Ganeshamurthy and Reddy (2000) who found a significant increase in the number of active nodules with the application of sulphur up to 20 kg ha^{-1} because sulfur is involved in the formation of nitrogenous enzyme known to promote nitrogen fixation in legumes (Scherer *et al.*, 2006). This result was supported by Attar *et al.* (2012) who reported that various levels of P fertilizer applications significantly affected both nodule number and dry mass of common bean.

Kacar (1984) reported that S has positive effects on root growth in plants and positively affects nodulation in legume crops in particular. S is also a vital part of the ferredoxin, an iron-sulphur protein occurring in the chloroplasts. Ferredoxin has a significant role in nitrogen dioxide and sulphate reduction, the assimilation of N by root nodule bacteria and frees living N-fixing soil bacteria (Scherer *et al.*, 2008). Legume crops obtain N mainly from symbiotic N_2 fixation, which may be affected by S deprivation and found a lower N accumulation and a yield reduction when S was limiting. S application and inoculation have immense potential of increasing the amount of N fixed by legumes then it is improving fertility status of soil and also S affects growth of leguminous plant through its effect upon N_2 fixation by Rhizobium microorganisms because of relatively high S content of the nitrogenase (Habtegebrial *et al.*, 2007). Amanuel *et al. (*2000) reported that S deficiency may affect N_2 fixation. Growth and nitrogen (N) fixation rates by legume could be increased by highly efficient, competitive and persistent strains of Rhizobium.

Application of both phosphorus and sulphur resulted in increase in nitrogen fixation up to 38% and 33% over control, respectively. Nutrient uptake of nitrogen, phosphorus and S increased significantly with the application of P and S and positively correlated with nitrogen fixation. The same author also reported that, there is direct involvement of sulphur in the process of nitrogen fixation whereas effect of phosphorus on nitrogen fixation is indirect mainly through enhanced growth and dry matter production. Togay *et al*. (2008) reported that chickpea variety applied with phosphorus, sulphur and inoculation resulted in higher grain yield. S application significantly increased the uptake of Fe, Mn, Zn and Cu in grain. Despite the importance of this element in crop production, it is still not included in fertilizer recommendations of Ethiopia especially for legume crops like chickpea.

2.5.4. Boron application

Micronutrients play an important role in increasing yield of pulses and oilseed legumes through their effects on the plant itself and on the nitrogen fixing symbiotic process. The deficiency of these nutrients has been very pronounced under multiple cropping systems due to excess removal by structure of crops and hence their exogenous supplies are urgently required. Boron is very important in cell division and in pod and seed formation. Boron ranks third place among micronutrients in its concentration in seed and stem as well as its total amount after zinc (Robinson, 1994). In addition, Boron as micronutrients play an important role in regulating plant metabolic processes like in carbohydrate metabolism, flower retention, pollen fertility and germination, pod setting, seed development, yield and its components. Thus, the requirement of boron appears more essential for reproductive development than vegetative (Chandrakumar, 2013).

Moreover, Togay *et al*. (2008) reported that S has positive effects on root growth in plants and positively affects nodulation in legume crops in particular. S is also a vital part of the ferredoxin, an iron-sulphur protein occurring in the chloroplasts. Ferredoxin has a significant role in nitrogen dioxide and sulphate reduction, the assimilation of N by root nodule bacteria and frees living N-fixing soil bacteria (Scherer *et al.*, 2008). The critical level of boron with reference to crops in general was reported to be 0.15 to 0.20 ppm depending on soil types (BARC, 2005). Bharti *et al*. (2002) reported that mean seed yield of chickpea increased with the application of boron 2.5 kgha^{-1}. Islam (2005) who observed that seed yield of chickpea increased significantly due to application of 1 to 1.5 kg B ha^{-1}.

2.6. Response of chickpea to Rhizobium Inoculation

Crop legumes, grown in rotation with cereal crops, can improve yields of the cereals and contribute to the total nitrogen (N) pool in soil. Legumes especially chickpea occupies special position regarding nutrition as well as soil fertility and improvement. It has the ability to grow well in poor soils as well as to improve them because of its efficient N fixation system. It can happily grow on marginal, poorly fertile sandy loam land, almost exclusively under rain-fed conditions in areas of low rainfall without any chemical or biological fertilizer. Soil factor exert greater influence than bacterial inoculation on plant growth, nitrogen fixation and nutrient uptake of plant (Neumann et al., 2012). This is due to the presence of rhizobium inoculation which promotes vegetative growth then it encourages shoot. Several authors also reported the positive effect of S and Zn application promotes in shoot dry weight (Hussain *et al.,* 2011). Many authors have reported that legume nodules having dark pink or red colors due to presence of leg hemoglobin are an indication for effectiveness of the Rhizobial strains used, which is well correlated with nitrogen fixation (Butler and Evers, 2004)

Sustainable production depends upon the manipulation of all genetic and environmental factors that influence crops by exploiting high yielding varieties and manipulation of its symbiotic system. The plant growth promoting rhizobacteria (PGPR) induce plant's nutrient acquisition, disease tolerance and play a vital role in crop yield (Lugtenberg and Kamilova, 2009). This result was in line with Nodule counts were recorded and overall inoculation enhanced the nodulation of chickpea, though the nodule counts vary in the different inoculated variety. Nodule counts of 22–48 per plant were recorded in the inoculated treatments whereas this varied from 6 to 21 in non-inoculated control plots (variety) (Lema *et al*., 2013). Growth and yield of the plant have been improved by repeated inoculation of highly effective rhizobia (Hynes *et al.,* 2009) and/or co-inoculation with PGPR (Ganeshamurthy *et al.,* 2011). The colour of nodules from un-inoculated was pink and green in chickpea (Romdhane *et al.,* 2009).

Implementation of PGPR based biofertilizer technology presents economic, environmental and agronomic benefits and could be used to a larger degree to partially replace the synthetic fertilizers (Adesemoye and Kloepper, 2009) to improve economic yield under natural conditions. Repeated incorporation of rhizobia with more effective strains coupled with the addition of "helper bacteria" can add to the BNF of the crop. Strain x variety interaction is as important as that of strain or crop variety alone (Abi-Ghanem *et al.,* 2011). Selection of best microbial strains and plant variety is important because a strong effect of cultivar x microbe has been reported on BNF in soybean (Israel *et al.,* 1995), beans, lentils and peas (Abi-Ghanem *et al.,* 2011).

Strain x nutrient interaction is also important. According to Endalkachew *et al*. (2018) increased chickpea grain yield due to application of P was evident on most target farms, with only few exceptions where yields on inoculated plots were similar or inferior to those on the corresponding control plots. However, grain yields on control plots and responses to the treatments on individual farms varied greatly. Thus, observed yield on control plots ranged from 521 to 3054 kg ha^{-1}, whereas the yields with P and/or Inoculation ranged from 640 to 4500 kg ha^{-1}. These yields can be considered with reference to the national average yield, which is currently about 1800 kg ha^{-1} (CSA, 2016)

3. MATERIALS AND METHODS

3.1. Description of the Experimental Site

The study was conducted in Meskan District which is situated in the Gurage Zone of the Southern Nations, Nationalities and Peoples Regional State. The study was particularly conducted at Yimer-Wachosositgna Kebele Farmers Training Center in the 2017/2018 main cropping season. The site is geographically located at 139 km South of Addis Ababa at an elevation of 1800 meters above sea level latitude of 08° 06' 0944"N and longitude of 38° 22' 341" E. Rainfall distribution is bimodal where the short rainy season is from March to May and the long rainy season is from June to October. The experimental site receives an average rain fall of 1001-1200 mm with a temperature range between 7.5 to 17.5 °C. The site has clay loam soil texture with a pH value of 6.83 (Table 1).

3.2. Experimental Material

3.2.1. Chickpea varieties

The experimental materials included two chickpea varieties, namely *Arerti* and *Habru*, which were selected from among the top high yielding chickpea varieties released by Debre Zeit Agricultural Research Centre (DZARC). Both varieties are Kabuli type. Table 1 presents description of the varieties used for the experiment at Meskan in 2017/18 main cropping season.

Table 1. Description of varieties used in the present study

Variety	Type	Year of release	Area of adaptation		Maturity day	Seed color	Seed size	Yield (kg/ha)		Production status
			Altitude (m)	Rainfall				On research	On farm	
Arerti	Kabuli	1999	1800-2600	700-1200	105-155	White	Medium	1600-5200	1800-4700	under production
Habru	Kabuli	2004	1800-2600	700-1200	91-150	White	Large	1400-5000		

Source:- Debre Zeit Agricultural Research Center (2004)

3.2.2. NPSB blended fertilizer

NPSB blended fertilizer (N = 18.9 kg, P_2O_5 = 37.7 kg, S = 6.95 kg, B = 0.1 kg) was used as an inorganic fertilizer.

3.2.3. Inoculant

A Rhizobium inoculant (CP-17) known to be the best strain for chickpea in relation to agronomic and yield performance was collected from Holeta Agricultural Research Center.

3.3. Treatment and Experimental Design

The experiment had three factors. Factor one was NPSB blended fertilizer (0, 30, 60 and 90 kg ha^{-1} corresponding to 0, 33.3%, 66.6%, 100% of the recommended), factor two was variety (Arerti and Habru) and factor three was Rhizobium inoculation (with inoculation and without inoculation). The treatments were arranged in a 4×2×2 factorial combination in randomized complete block design with three replications. According to the stipulations of the design, each treatment was assigned randomly to the respective experimental units within a block and the total number of treatments combinations was 16. The size of each experimental plot was 5.4 m^2 (3 m×1.8 m) with six rows of chickpea (each 3 m long) and inter and intera- row spacing of 30 cm and 10 cm, respectively. The total experimental area was 676 m^2 (65 m x 10.4 m). There were 6 rows per plot, 30 plants per row and total 180 number of plants per plot. A net plot size 2.8 m×1.2 m (3.36 m^2) was used for the final harvest. The spacing between each plot and block was 1 m and 1.5 m, respectively**.**

3.4. Experimental Procedures and Trial Management

Land preparation was done according to the local farmers practice. Thus, the land was ploughed four times using oxen before planting and the last plough was done as farmers practice before sowing to make it ready for sowing and insuring seedbeds are well leveled. Sowing was done on August 19, 2018 by putting two seeds per 10 cm interval and was thinned to one plant after emergence of the seediling and 30 cm between row.

Rhizobium ciceri, strain (CP-17), was selected and used because of its ability to enhance nodulation and grain yield under wide ecological conditions of chickpea. These strains have been tested under a wide range of ecological conditions in Ethiopia (Tena *et al.,* 2016). Seeds were inoculated at the rate of 5 g of inoculant per kg of seed. Therefore 7.776 g of the inoculant was used at sowing for seed inoculating purpose. Seed inoculation was performed before sowing using the procedure developed by Fatima *et al*. (2007). To make sure the sticking of the applied inoculant to the seeds, the required quantity of seed was suspended in 1:1 ratio in 10% sugar solution and allow to air dry for a few minutes and then the inoculated seeds were sown at suggested rate and spacing to the respective plots. To avoid contamination, plots with un-inoculated seeds were planted first followed by the inoculated ones. Application of the blended fertilizer was done at the time of sowing in a furrow, 5 cm away from the row and covered with soil after application. Other agronomic practices pertaining to the crop have been kept uniform and carried out as per the recommendation (MoAG).

3.5. Soil Sampling and Analysis

Before planting, one composite soil sample from the experimental site was collected in a zigzag pattern from the depth of 0-30 cm. Uniform volume of soil was obtained in each subsample by vertical insertion of an auger. The soil was air dried to a constant weight, ground by using a pestle and mortar and allowed to pass through a 2 mm sieve. Working samples were obtained from each submitted samples and analyzed for organic carbon, total N, soil pH, available phosphorus, cation exchange capacity (CEC) and textural analysis using standard laboratory procedures at Debre zeit Agricultural Research Center’s soil Laboratory.

Analysis of particle size distribution was done by hydrometer method (differential settling within a water column) according to FAO (2008, and classified into clay, silt and sand. The pH of the soil was determined according to FAO (2008) using 1:2.5 (weight or volume) soil sample to water ratio using a glass electrode attached to a digital pH meter. Organic carbon content was determined using Walkley and Black’s (1934) method. Total nitrogen (TN) was analyzed by Micro- Kjeldhal digestion method with sulphuric acid (Dewis and Freitas, 1975). Available phosphorus was determined by the Olsen’s method using a spectrophotometer (Olsen *et al*., 1954). Cation exchange capacity (CEC) was determined after saturating the soil with 1N ammonium acetate (NH4OAc) and displacing it with 1N NaOAc (Chapman, 1965)

3.6. Data collection parameters

3.6.1. Physico-Chemical Soil Properties of the Experimental Site

Texture is an important soil physical characteristic because it determines water intake rate (infiltration), water holding capacity in the soil, the ease of tilling, the amount of aeration, and also influence soil fertility. It is one of the inherent soil properties and less affected by management and which determines nutrient status, organic matter content, air circulation and water holding capacity of a given soil (FAO, 2000). The results from analysis of top 30 cm deep surface soil of the experimental site (Table 2) indicated that the soil is clay in texture with pH of 6.58 organic carbon of 1.6% total N content of 0.12(%), available P content of 25.24 µg g^{-1} available S content of 18.6(ppm), and CEC 39.04 cmol (+)/kg $soil^{-1}$.

According to the rating of Tekalign (1991), soil pH is classified as very strongly acidic (< 4.5), strongly acidic (4.5-5.2), moderately acidic (5.3-5.9), slightly acidic (6.0-6.6), neutral (6.7-7.3), moderately alkaline (7.4-8.0) and strongly alkaline (>8.0). Based on this classification, the pH of the soil of the study site (6.58) is slightly acidic at the study area. The same authors classified soil organic carbon content of very low (<0.86), low (0.86-2.59), moderate (2.59-5.17) and high (>5.17). According to this classification, the study site had low OC content before sowing (Landon 1991). The soil texture was found to be clay.

According to Havlin *et al*. (1999), total nitrogen content (TN) of a soil can be classified as very low (<0.1%), low (0.1-0.15%), medium (0.15- 0.25%), and high (>0.25%). According to this classification, the total nitrogen content of the soils of the study site was found to be low in total nitrogen content (Table 2).

Indicative ranges of available phosphorus have been established by Olsen et al. (1954), including < 5 mg kg^{-1} (very low), 5-15 mg kg^{-1} (low), 15-25 mg kg^{-1} (medium) and > 25 mg kg^{-1} of soil (high). Based on this criterion, the available phosphorus content of the site was low. The cation exchange capacity (CEC) is referred to be low (5-15 cmol kg^{-1}), medium (15-25 cmol kg^{-1}), and high (25-40 cmol kg^{-1}). For this parameter, soils of experimental field had high CEC (Table 2). The nutrient class range for sulfur identified by Karltun (2013) indicated that soils containing >100, 80-100, 20-80, 10-20, <10 $mgkg^{-1}$ of sulfur ranging as very high, high, medium, low and very low, respectively. Thus, the experimental soil is low in available S(18.6). Similarly, the extractable B (0.67 mg/kg) is also bellow the critical level (0.8 mgkg^{-1} soil) in accordance with Karltun *et al*. (2013) (Table 2).

Table 2. Physico-chemical analysis result of soil experimental site

Parameter	**Texture**	**pH**	**TN** (%)	**OC** (%)	**Av.P** (ppm)	**Av.S** (ppm)	**B** (mg/kg)	**CEC** (cmolkg^{-1})
Value	Clay	6.58	0.12	1.6	14.23	18.6,	0.67	39.04

Where Cmol = Cent mole, pH = hydrogen power, OC (%) = percent of organic carbon, T N = Percent of total nitrogen, Av.p (ppm) = available P in parts per million, Av. S = Available sulphur, CEC = Cation exchange capacity.

3.6.2. Crop phenology

Days to 50% flowering (DF): DF was recorded as number of days from emergence to the time when 50 percent of the plant population in each plot produce flowers (Janagrad*et al.*, 2009).

Days to maturity (DM): Number of days from emergence to physiological maturity was recorded when 90% of the plants per plot had turned golden yellow and 90% of the plants had their pods filled with seeds and hardened by touching (Masumba,1984).

3.6.3. Growth parameter

Plant height: Five plants were randomly taken from the four middle rows, and their height from the ground to the tip was measured using a ruler at physiological maturity and average value was taken.

Leaf area: Leaf area was determined by measuring the area of three leaves from top, middle and lower parts of three plants randomly selected from each plots using CI-202 portable area meter (CID, inc. U.S.A).

Number of primary branches (NPB): From the five randomly uprooted plants the number of primary branches were counted and averaged to determine number of branches per plant (NPB/plant).

Shoot dry weight (SDW): After measuring the shoot fresh weight, the plants was kept at 65^{0}C in oven until getting constant weight. The mean value from five plants was taken as shoot dry weight per plant.

Root dry weight (RDW): Five plants were taken for determination of the dry weight of roots at flowering. After taking the fresh weight of root parts, the sample were dried in an oven at 65°C to constant weight and then the dry weight was measured using sensitive balance and average of the plant root was taken (g).

3.6.4. Nodulation parameter

For determining of nodulation parameters sampling was performed by number of plants per sample excavating the roots of plants randomly from two central rows of each plot at 50% flowering stage of the crop. Uprooting was done by spade and shovel and soil was removed from the root system by hand. The adhering soil was removed by washing the roots gently with water over a metal sieve. Nodules remaining in the soil were picked up by hand. The plants from each plot were used to record the following observations.

1. **Total number of nodules per plant:** This parameter was determined as the total number of nodules per plant and was recorded at 50% flowering from five randomly selected plants from four interior rows of each plot.

2. **Nodule dry weight per plant:** The collected nodules was labeled and placed in perforated paper bags. The nodule dry weight per plant was measured after drying the collected nodules in an oven with a temperature of 65 °C for 48 hrs. The average of five plants were taken as a nodule dry weight per plant

3. **Number of effective nodules per plant**: After dissecting nodule with pink to brown color were considered as effective and those with green and white color nodules were sorted as non-effective nodules.

3.6.5. Yield and yield components

1. **Number of seeds per pod**: From five arbitrarily taken plants five pods were separated and threshed and then number of seeds was counted from five pods per plant and total number of pods to calculate average number of seeds per pod divided total number of seeds.

2. **Harvest index (HI):** Harvest index per plot was calculated as the ratio of dry seed yield per plot to the above ground dry biomass yield per plot.

$$(\text{Harvest Index})(\%) = \frac{\text{Dry Seed yield}(\text{g})\ perplot}{\text{Above ground dry biomass yield per plot}(\text{g})} * 100$$

The total above ground dry biomass of 5 randomly selected plants was tagged and the older leaves were composed prior to dropping and kept till physiological maturity. Finally tagged plants have been harvested close to the soil surface at physiological maturity and oven dried to a steady weight. Then the biomass yield per five plants was transformed to per hectare and expressed in ton ha^{-1}.

3. Number of pods per plant: Number of pods for the five plants was counted and then the mean number of pods per plant was obtained at physiological maturity

4. Grain yield per plant (kg ha^{-1}): Four rows from center of each plot were harvested and threshed to determine crop yield and then the seeds were adjusted to moisture level of 10%. Finally, the yield per plot was converted to kilogram per hectare (Hong and Ellis, 1996)

$$Adjusted\ Yield = \frac{(100 - mc) \times unadjusted\ yield}{100 - 10}$$

5. Hundred seed weight: This was recorded by weighing 100 randomly taken dry seeds harvested from the net plot using a sensitive balance and the weight was adjusted to 10% seed moisture content.

6. Agronomic efficiency (AE) of the fertilizer: AE of the blended fertilizer was estimated from grain yield of fertilized and unfertilized (control) plots as:

$$\text{AE (kg kg}^{-1}) = \frac{GF - GU}{NA}$$

Where: Gf = the grain yield of the fertilized plot (kg), Gu = grain yield of the unfertilized plot (kg), and NA = quantity of fertilizer applied (kg) (Fageria and Baligar 2005)

3.7. Data Analysis

All the collected data were first checked for meeting the Analysis of variance (ANOVA) assumptions these were normality, additivity ,independent and homogeneity and then subjected to ANOVA using SAS 9.3. ANOVA was run following the GLM procedure of SAS and the interpretation was made following the procedure described by Montgomery (2014). Whenever ANOVA showed significant differences between treatments, Least Significance Difference ($LSD_{5\%}$) test was used to separate and compare means.

3.8. Economic Analysis

The economic effect of NPSB blended fertilizer application and inoculant use on chickpea was evaluated using a partial budget analysis. Inorganic NPSB blended fertilizer and *Rhizobium* inoculant costs were considered as the variable costs. An economic assessment was done using partial budget procedure described by CIMMYT (1988). The variable costs of NPSB fertilizer ETB 1300 per 100 kg ha^{-1} and *Rhizobium* inoculant at time of planting were taken from Holeta Agricultural Research Center. The price of the current chickpea grain at harvest (ETB 2100 per 100 kg) was taken from Office of Trade and Industry Marketing Case Team of Meskan District and local wage rate of ETB 50 $person^{-1}$ day^{-1}. The average yield was adjusted downward by 10% to reflect the farmer's field yield as described by CIMMYT (1988), while the marginal rate of return for each blended NPSB blended fertilizer rate was calculated as a change of net benefit divided by change of variable cost and multiplied by100 (CIMMYT, 1988).

4. RESULT AND DISCUSSION

4.1. Crop Phenology

4.1.1. Days to 50% flowering

ANOVA showed that days to 50% flowering was highly significant ($P<0.01$) affected by the two way interaction of variety and blended fertilizer rate; whereas, main effect of variety, rates of NPSB fertilizer, rhizobium inoculation and the two way interactions between rhizobium inoculation and rates of NPSB fertilizer and variety and rhizobium inoculation as well as the three way interaction between variety, inoculation and blended fertilizer had nonsignificant effect on day rates to 50% flowering (Appendix Table 1).

Thus, variety Habru treated with 60 kg NPSB ha^{-1} was earlier (49.17 days) to flower which was statistically in parity with the effect of the same variety at 30 and 90 kg NPSB ha^{-1}) and The longest days to 50% flowering (55.67) was observed on variety Arerti without fertilizer application(Table 3). The data obtained in this study revealed that with an increase in the rate of the blended fertilizer date of flowering was faster (Table 3). This might be attributed to variation in the genetic makeup among cultivars/ relating to their inherent phenological setups and the effect of phosphorus in NPSB blended fertilizer on enzymatic activity and hormones responsible in flower initiation. Moreover, significant variations among different levels of NPSB application might be due to enhancing property of (NPSB) in many aspects of plant physiology like process of photosynthesis, flowering, seed formation and maturation. This means that time of beginning of flowering is always delayed by P deficiency; with acute deficiency many plants might be died before flowering. This agrees with Shabeer *et al.*(2015) who reported that significant variation in what was observed by application of different level of phosphorus for different variety of chickpea and also application of p promotes earliness. In addition, Liu *et al*. (2005) who have reported that boron increases soya bean photosynthesis rate.

The present finding corroborates the findings of Acharya *et al*. (2007) who observed that phosphatic fertilizer promotes flowering, seed formation and crop maturity. In addition to this, nitrogen deficiency induces an early end of pea flowering (Sagan *et al*., 1993).

Delay in flowering time may encounter the variety to drought, and this character may be also used as an integrative trait to identify which type of chickpea should be grown in the face of drought (Tesfahun *et al*., 2018). It might be attributed to the fact that flowering time in chickpea is considered to be varietal specific, which is genetically controlled. Previous studies showed that the differential response to flowering among varieties was distinct. For instance, Tripathi *et al*. (2013) reported differences among varieties of chickpea in days to 50% flowering. Similarly, the variation may also be due to stimulatory effect of phosphorus on growth hormones, induce early flowering in chickpea. This result was in line with the findings of Wondimu *et al*. (2008) who reported that increasing the NP application rate from 0 kg N, 0 kg ha^{-1} P_2O_5 to 36 kg N, 92 kg ha^{-1} P_2O_5 significantly shortened the time required to attain 50% flowering (Mahmood and Honermeier,2012).

However, Tewari *et al*. (2010) who reported no significant effects of P application on number of days to reach 50% flowering on common bean. Similarly, Tesfaye *et al*. (2016) also reported that interaction of P with variety to be non-significant in common bean (Zhou et al., 2011). Apart from this, the micronutrients also play an important role in regulating plant metabolic processes. Such as Boron is an important micronutrient plays role in carbohydrate metabolism, flower retention, pollen fertility and germination, pod setting, seed development, yield and its components. Thus, the requirement of boron appears more essential for reproductive development than vegetative (Nalini , 2013).

Table 3. Chickpea date of 50% flowering as influenced by interaction effect of variety and rate of NPSB blended fertilizer at Meskan in 2017/18

Variety	Level of Fertilizer(kgha^{-1})	Date of Flowering
Arerti	0	55.67^{a}
Arerti	30	51.67^{b}
Arerti	60	50.00^{c}
Arerti	90	49.33^{c}
Habru	0	51.67^{b}
Habru	30	49.33^{c}
Habru	60	49.17^{c}
Habru	90	49.83^{c}
	LSD (5%)	0.98
	CV(%)	2.93

Means with the same letter are not significantly different at P>0.05 level of probability following LSD, LSD= Least significant difference, CV = Coefficient of variation,

4.1.2. Days to 90% maturity

ANOVA showed a highly significant difference (P <0.01) for days to 90% maturity due to the main effects of inoculation, variety and their interactions. On the other hand the main effect of rate of NPSB fertilizer, the rest of two way interaction as well as the three way interaction on days to 90% Maturity had nonsignificant (Appendix Table 1)

The number of days to reach 90% physiological maturity for the two varieties (Arerti and Habru) was modified by inoculation for sample took 119 days under inoculation compared to 117.83 days without inoculation(Table 4). The possible reason for delayed physiological maturity of chickpea variety with seed inoculation might be due to varietal difference in their response to inoculation and effect of *Rhizobium* inoculants led to higher nitrogen fixation that in turn increased N uptake by plants as the result improved vegetative growth of chickpea. In agreement with this result, Gan *et al.* (2010) reported delayed maturity with inoculation of chickpea. Similarly, Beza *et al*. (2017) reported the rhizobium inoculated seeds were lately mature whereas; uninoculated seed were early matured.

Table 4. Chickpea Date of maturity as influenced by interaction effect of inoculation and varieties at Meskan in2017/18.

Variety *Inoculation		**Date of maturity (90 %)**
Arerti	Without	117.83^{a}
Arerti	with	119.08^{a}
Habru	Without	112.33^{b}
Habru	with	119.42^{a}
LSD (5%)		**3.29**
CV (%)		**3.33**

Means with the same letter are not significantly different at P>0.05 level of probability following LSD, LSD=Least significant difference, CV = Coefficient of variation

4.2. Growth Parameters

4.2.1. Plant height

The analysis of variance showed highly significant ($P<0.01$) effects of the three way interaction of variety x blended fertilizer rate x *Rhizobium* inoculation, main effect of rhizobium inoculation, rates of NPSB fertilizer and two way interactions on plant height. Whereas, the two way interactions of inoculations and rate of blended fertilizer and variety had non significant effect on plant height (Appendix Table-1).

Thus, the tallest plant height (43.27cm) was recorded for variety Habru at 90 kg NPSB ha^{-1} with seed inoculation. while the shortest plant height (36.67cm) was recorded for the variety Arerti treated without inoculation (+ 0 kg NPSB ha^{-1})(Table 6). This signified that increase in plant height in response to the increased P application rate in blended NPSB might be due to the maximum vegetative growth of the plants under higher P availability, N (in NPSB) can be helpful in improving growth and development of chickpea and Sulfur is also a major component of ferreoxin in chloroplast which is relevant for the proper photosynthetic activity.

Tomar *et al*. (2004) found the positive interaction effect of P and S. Furthermore, the presence of boron in the blended fertilizer might have also significantly increased plant height due to it plays important role in the cell division and nitrogen absorption from the soil, enhancing plant growth eventually plant height increased. This result is in agreement with the result done by Sutharsan *et al*. (2016) who reported that plant height decreased with decreasing rate of nitrogen level in combined application of nutrients.

4.2.2. Number of primary branches

The analysis of variance (ANOVA) showed that number of primary branches of chickpea was significantly ($P<0.05$) influenced by the two way interactions of blended fertilizer rate and *Rhizobium* inoculants. On the other hand, all the rest interaction and main effects had non significant effects on number of branches (Appendix Table 1).

Branching is basically a genetic character and plays an important role in enhancing seed yield. The plot received 90 kg NPSB ha^{-1} and rhizobium inoculation produced the highest (3.75) number of primary branches per plant which is statically similar with 30,60kg blended fertilizer rates with inoculation and 0 kg NPSB ha^{-1} fertilizer without inoculation(Table 5). While, the plot received 0 kg NPSB ha^{-1}+without rhizobium inoculation produced the lowest (3.28) number of primary branches per plant. This might be due to the fact that lack of the available growth resources and more competition of the limited nutrition resources for branching as on the other hand, optimal supply of P in the early stage of plant growth enhanced the crop lateral growth. On the other hand, the possible reason for lower number of primary branches per plant at 0 kg NPSB ha^{-1} might be due to the fact that the legumes require phosphorus for optimal symbiotic performance.

The current result is in accordance with those findings of Dutta and Bandyopadhyay (2009) and Ahmed *et al*. (2010) who reported positive and significant effects of inoculation and P fertilization on the number of branches of chickpea. Similarly, Chalk *et al*. (2010) reported that legume growth and the function of the legume and *Rhizobium* symbiosis might be affected by a multitude of nutrient disorders, including both deficiencies and toxicities.

Table 5. Chickpea number of primary branches as influenced by interaction effect of inoculation with rates of NPSB fertilizer at Meskan in2017/18

NPSB Fertilizer(kg/ha)	Inoculation	Number of primary branches
0	without	3.28^{b}
30	without	3.50^{ab}
60	without	3.4^{bab}
90	without	3.32^{b}
0	with	3.40^{ab}
30	with	3.30^{b}
60	with	3.37^{b}
90	with	3.75^{a}
	LSD (5%)	0.36
	CV(%)	9.15

Means with the same letter are not significantly different at P<0.05 level of probability following LSD, LSD=Least significant difference, CV=Coefficient of variation

4.2.3. Leaf area

The analysis of variance(ANOVA) showed the leaf area of chickpea was significantly (P<0.01) influenced by main effect of rhizobium inoculation and the three way interaction of variety, rate of NPSB blended fertilizer and *rhizobium* inoculants. whereas, main effect of variety and rates of NPSB fertilizer two way interaction of variety and inoculation and variety and fertilizer and two way interaction of variety and inoculation and variety fertilizer had non significant effect on leaf area of chickpea (Appendix Table 1).

In all treatments, leaf area (LA) was highest with Rhizobium inoculation and with increased rate of NPSB blended fertilizer (Table 6). Thus, the highest (30.60cm^{2}) value of LA was recorded at the interaction 90kg NPSB ha^{-1}, Habru variety with rhizobium inoculation; whereas, the lowest (17.88 cm^{2}) LA was recorded from control without inoculation and fertilization treatment which reduces LA by 58.43%. This implies that the increase in leaf area at 90 kg NPSB ha^{-1} might be due to phosphorus which is required in relatively large amounts by legumes and also the possible reason for LA increment at interaction could be due to the positive effect of inoculants and increased with the growth of N fertilizer rate in NPSB on biological and chemical characteristics of soil nutrient and water absorption by the root.

So, the current study is in line with the increasing of LA was attributed to the rise in leaf number and total leaf area per plant (Kibe *et al.*, 2006). Plants that were treated with 0 kg urea ha^{-1} showed the lowest LA at both levels of inoculation. Similarly, the lowest LAI was recorded at zero fertilizer application which is in agreement with findings of (Faisalabad *et al*., 2010). The depletion of LA at the later stages was possibly due to the senescence and falling of older leaves. Similar results were also reported by Malik *et al*. (2006).

4.2.4. Shoot dry weight

The analysis of variance(ANOVA) showed that all the main, two way and the three-way interaction of varieties, rhizobium inoculation and different levels of blended NPSB fertilizer showed highly significant ($P<0.01$) variation for shoot dry weight of chickpea per plant (Appendix Table 1).

The dry weight of shoot increased due to Rhizobium inoculation. In general, regardless of the inoculation applied, thus considerably highest shoot dry weight of 11.33g per plant was recorded with highest rates of application of blended fertilizer (60 and 90 kg NPSB ha^{-1})with rhizobium inoculation from variety Habru followed by 10.43g recorded with highest application of 60 kg NPSB ha^{-1} with rhizobium inoculation from same variety. But, the lowest (4.23g), (4.43g) and (4.63g) of shoot dry weight was recorded without application of NPSB and without rhizobium inoculation (control) from variety Arerti (Table 6). The data showed that shoot dry weight at the experimental site was higher due to the moisture availability at the time of sowing could result in better germination and ultimately good crop stand and higher shoot dry weight as well as application of nitrogen through NPSB fertilizer

In general, shoot dry weight exhibited an increasing trend of the plant inoculated and NPSB blended fertilizer treated. Significantly the highest (11.33 g plant$_{-1}$) shoot dry weight was found from inoculated seed, which resulted in 62.66 % increase over the control check. This is due to the presence of rhizobium inoculation which promotes vegetative growth. In line with this finding, several authors also reported the positive effect of S and Zn application promotes in shoot dry weight (Hussain *et al.,* 2011).

Similarly, the increment in number of branches per plant might be importance of P for cell division activity, leading to the increase of plant height and number of branches and consequently increased the plant dry weight (Tesfaye *et al.*, 2007).

4.2.5. Root dry weight

The analysis of variance(ANOVA) showed that all the main, two way and the three-way interaction of varieties, rhizobium inoculation and different levels of blended NPSB fertilizer showed highly significant ($P<0.01$) variation for root dry weight of chickpea per plant (Appendix Table 1).

The dry weight of root increased due to Rhizobium inoculation. In general, regardless of the inoculation applied, thus considerably highest root dry weight of 3.19 g per plant was recorded with highest rates of application of blended fertilizer (60 kg NPSB ha^{-1})with rhizobium inoculation from variety Habru. But, the lowest (2.26 g) of root dry weight was recorded without application of NPSB and without rhizobium inoculation from variety Habru (Table 6). The data showed that root dry weight at the experimental site was higher due to the moisture availability at the time of sowing could result in better germination and ultimately good crop stand and higher shoot dry weight as well as application of nitrogen through NPSB fertilizer. In agreement with this finding, several authors also reported the positive effect of S and Zn application promotes in shoot dry weight (Hussain *et al.,* 2011).

Table 6 : Growth of chickpea as influenced by Rhizobium inoculation, variety and NPSB blended fertilizer rates at meskan in 2017/18

Variety	**Inoc**	**Fertilizer (kgha^{-1})**	PLH (cm)	LA(cm^{2})	SDW (gm)	RDW(gm)
Ararti	without	0	36.67^{e}	17.88^{i}	4.43^{g}	2.67^{bcd}
		30	38.53^{cd}	26.07^{abcdef}	6.13^{f}	3.12^{a}
		60	39.73^{cb}	21.34^{fghi}	6.30^{fe}	2.67^{bcd}
		90	37.73^{ed}	29.89^{abc}	6.77^{def}	2.62^{bcd}
Arerti	with	0	40.60^{b}	23.76^{defghi}	4.23^{g}	2.74^{abcd}
		30	40.67^{b}	$24.55^{bcdefgh}$	7.23^{cde}	2.43^{bcd}
		60	40.87^{b}	29.43^{abcd}	7.43^{cd}	3.00^{abc}
		90	40.63^{b}	27.37^{abcde}	8.03^{c}	2.68^{bcd}
Habru	without	0	38.40^{cd}	19.90^{ghi}	4.63^{g}	2.26^{d}
		30	39.00^{cd}	25.75^{bcdefg}	6.23^{f}	2.74^{bcd}
		60	38.93^{cd}	24.12^{cdefg}	7.23^{cde}	2.41^{cd}
		90	40.80^{b}	19.65^{hi}	5.90^{f}	2.92^{abc}
Habru	with	0	40.50^{b}	30.46^{ab}	5.93^{f}	3.00^{ab}
		30	40.70^{b}	23.06^{efghi}	9.83^{b}	3.07^{a}
		60	40.60^{b}	23.54^{defghi}	11.33^{a}	3.19^{a}
		90	43.27^{a}	30.60^{a}	10.43^{ab}	$2.81^{b\ cd}$
LSD(5%)			**1.45**	**5.96**	**4.95**	**0.59**
CV(%)			**2.92**	**14.43**	**8.56**	**12.99**

Means with the same letter are not significantly different at P<0.05 level of probability following LSD, LSD= Least significant difference, CV= Coefficient of variation PLH= plant height, LA=leaf area, SDW= shoot dry weigh, RDW=root dry weight.

4.2.2. Nodule parameters

4.2.2.1. Nodule number

The analysis of variance (ANOVA) showed that the main effect of variety, rhizobium inoculation, rates of NPSB fertilizer as well as the two way interaction of variety and inoculation had significant ($P<0.05$) on number of nodule per plant. while, the remaining two ways and three way interaction of inoculation and rates of NPSB and variety and rates of NPSB fertilizer had no significant effect on number of nodule per plant (Appendix Table 2)

Thus, the highest number of total nodules per plant (38.74) was obtained from the application of blended NPSB rate of 90 kg NPSB ha^{-1} .while, the lowest number of total nodules (27.13) was recorded from application of blended 0 and 30kg NPSB ha^{-1} fertilizer (Table 7). This implies that as the levels of soil nitrogen from application of nitrogen in NPSB fertilization increase and nitrogen fixation derived probably from better inoculation cause and the number of nodules increase which might be due to better root development with increasing levels of these nutrients.

The increase in number of total nodules up to 90 kg NPSB ha^{-1} might also be due to phosphorus which is required in relatively large amounts by legumes for growth and to promote leaf area, biomass, yield, nodule number and nodule mass in different legumes. Consistent with this result of Amare *et al*. (2014) who 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 treatment and application of 20 kg P_2O_5 ha^{-1}, respectively. Yadav (2011) reported the synergistic effect of phosphorus and sulphur on number and weight of nodules per plant with the maximum number of nodules per plant was recorded at the highest level of phosphorus (40 kg P_2O_5 ha^{-1}) along with sulphur (20 kg S ha^{-1}) on cluster bean.

This result is similar with the finding of Lema *et al*. (2013) who reported N and P fertilizer have significantly affected the NNP and NDWP of chickpea relative to the control. The highest NNP and NDWP were obtained from 11.5 kg N ha^{-1} followed by 23 kg N ha^{-1}treatments. While, the least NNP and NDWP were recorded in the untreated control (N0) treatment. The result implies that both N treatments had stimulating effect on nodulation of chickpea (Lema *et al*., 2013) that application of starter dose of N fertilizer to legumes enhances nodulation and N-fixation by symbiotic N-fixing bacteria (Thaku *et al*. 1989; Giller and Cadisch, 1995). Similarly, P treatments produced significantly higher NNP and NDP in chickpea compared with the control (P0). This is due to the presence of Rhizobium inoculation. This result was proportionate with Nodule counts were recorded and overall inoculation enhanced the nodulation of chickpea, though the nodule counts vary in the different inoculated variety. Nodule counts of 22–48 per plant were recorded in the Inoculated treatments whereas this varied from 6 to 21 in non-inoculated control plots (variety) (Lema *et* *al*., 2013). This might suggest the presence of inferior naturally existing inoculant bacteria which made the association, Similarly Nodule number and nodule dry mass were significantly affected by various levels of NPSZnB applications increase number of nodule per plant and heavier dry mass of nodule were obtained with NPSZnB blended fertilizer applications increase and decrease the number of nodule per plant in common bean and lighter dry mass of nodule were obtained with 0 kg NPSZnB ha^{-1} blended fertilizer applications(Lake and Jemaludin,2018). This result agreed with the finding of Tsai *et al*., (1993) that reported application of nitrogen in the range of 22 to 33 kg N ha^{-1} enhanced nodulation

Regarding interaction of varieties and inoculation, the highest number of nodules per plant (45.93) was recorded from variety Habru with rhizobium inoculation. However, the lowest number of nodules (20.29) was obtained from Arerti variety without inoculation(table-7). This implies the fact that inoculated Habru variety produced the highest number of nodules per plant might be related with vigorous growth habit of the variety to establish more roots than Arerti variety. Vigorously growing Habru variety required more nitrogen for producing the highest number of primary and secondary branches hence due to high N requirement of the variety root growth and number of nodule production would be promoted. In agreement with Beza (2017) the highest nodule number per plant (15.7) from the combined application of 15 kg S and 1.5 kg Zn ha^{-1} while the lowest (10.9) was from *Rhizobium* inoculation and 1.5 kg Zn ha^{-1}.

Table 7: Numbers of nodules per plant of chickpea as affected by NPSB blended fertilizer rates and interaction of Rhizobium inoculants with variety at Meskan District in 2017/18

		Number of nodule per plant	
NPSB Fertilizer(kgha^{-1})			
0		24.77^{c}	
30		27.13^{c}	
60		33.10^{b}	
90		38.74^{a}	
LSD(5%)		**5.36**	
Variety*	**Inoculation**		weding
Arerti	without	20.29^{c}	20.29^{c}
Arerti	with	35.84^{b}	35.84^{b}
Habru	without	21.68^{c}	21.68^{c}
Habru	with	45.93^{a}	45.93^{a}
LSD(5%)		**6.90**	
CV(%)		**20.78**	

Means followed by the same letter are not significantly different at P>0.05 level of probability following LSD, LSD= Least significant difference, CV = Coefficient of variation

4.2.2.2. Nodule fresh weight

The analysis of variance showed the two way interaction effect of Rhizobium inoculation and blended NPSB fertilizer rate, variety and Rhizobium inoculation and variety blended NPSB fertilizer rate and the three way interaction of variety by inoculation by different levels of blended NPSB fertilizer showed highly significant (P<0.01) effects on nodule fresh weight. However, the main effect of variety had non significant effect on nodule fresh weight of chickpea per plant(Appendix Table 2)

Regarding the three way interaction the highest number of nodules fresh weight (18.99) was recorded from variety habru with rhizobium inoculation and application rate of 90kg NPSB ha^{-1} However, the lowest number of nodules fresh weight (3.94 and 3.82) were obtained from Arerti and Habru variety without inoculation., respectively (table 8). This could be differential response of genotype to the interaction effect of NPSB fertilizer rate and *Rhizobium* inoculants that eventually led to higher dry weight of total nodules through increased BNF availability. In agreement with Beza (2017) the presence of P application with *Rhizobium* strains that individually or in combination affected root development, nodule weight per plant and nitrogen fixation parameters.

Table 8. Nodules fresh weight of chickpea as affected by the three way of variety, Rhizobium inoculation and rates of NPSB blended fertilizer and interaction of with variety at Meskan District in 2017/18

Variety	Inoculation	**Fertilizer(Kg/ha)**	**Nodule fresh weight**
Arerti	without	0	3.94^{g}
		30	4.25^{g}
		60	7.80^{ef}
		90	12.35^{bc}
Arerti	with	0	5.41^{fg}
		30	11.94^{cd}
		60	14.61^{b}
		90	9.23^{e}
Habru	without	0	3.82^{g}
		30	6.10f^{g}
		60	10.00^{cde}
		90	9.41^{e}
Habru	with	0	9.61^{de}
		30	6.11^{fg}
		60	10.15^{cde}
		90	18.99^{a}
		LSD(5%)	**2.47**
		CV(%)	**16.56**

4.2.2.3. Nodule dry weight

The dry weight of total nodules per plant in chickpea was highly significantly (P<0.01) influenced by the two way interaction of NPSB blended fertilizer rate and *Rhizobium* inoculants, variety and application of NPSB blended fertilizer rates and variety and

Rhizobium inoculants and inoculation (Appendix Table 2). It was also affected by the variety and inoculation with factors ($P<0.01$)

Thus, the highest (8.63mg) dry weight of total nodules per plant was obtained from to *Rhizobium* inoculation and 90 kg NPSB ha^{-1}, while the lowest (4.26mg) total nodules dry weight values were obtained from no *Rhizobium* inoculation and 0 kg NPSB ha^{-1} application ,the highest dry weight (5.74mg) of total nodules per plant with *rhizobium* inoculation from Habru, while the lowest (3.65 mg) dry weight of total nodules per plant was obtained from not inoculated variety Habru variety. Finally, regarding interaction of variety with fertilizer application the highest dry weight (5.80mg) was obtained in response to variety Habru when integrated with 90 kg NPSB ha^{-1} while the lowest (2.83 mg) was obtained in response to Variety Arerti without fertilization (Table 9).

This is probably due to the positive role of S in NPSB in promoting nodulation and enhancement of photosynthesis in plants. In addition the possible reason for this result might be due to the differential response of genotype to the interaction effect of phosphorus and *Rhizobium* inoculants that eventually led to higher dry weight of total nodules through increased BNF availability. This is also due to the presence of P application with *Rhizobium* strains that individually or in combination affected root development, nodule weight per plant and nitrogen fixation parameters.

Consistent with this idea, Scherer (2008) has noted that root and nodule development of legumes root is promoted by S fertilization. Scherer and Lange (1996) also reported that S deficiency decreased N demand, which in turn decreased the number and mass of nodules. In contrast, an increase in N demand resulted in higher number and mass of nodules. Similarly, different authors reported that the dry weight of nodules increased with *Rhizobium* inoculation (Sipai *et al*., 2016). Again, Ibsa *et al.* (2013) also reported that *Rhizobium* inoculation and P fertilizer significantly increased nodule dry weight per plant of chickpea

Table 9. Chickpea nodule dry weight as influenced by combined effect inoculation with variety, inoculation with fertilizer and variety with Fertilizer at Meskan District in 2017/18

		Nodule dry weight
variety *	**Inoculation**	
Ararti	without	4.56^{ba}
Ararti	with	4.44^{ba}
Habru	without	3.65^{b}
Habru	with	5.74^{a}
LSD(5%)		**1.82**
Inoculation*Fertilizer(kgha^{-1})		
without	0	4.26^{cb}
without	30	2.06^{d}
without	60	5.72^{b}
without	90	4.39^{cb}
with	0	3.27^{cd}
with	30	3.06^{cd}
with	60	5.40^{b}
with	90	8.63^{a}
	LSD (5%)	**1.54**
Variety*Fertilizer(kgha^{-1})		
Ararti	0	2.83^{dc}
Ararti	30	2.32^{d}
Ararti	60	5.63^{ba}
Ararti	90	7.22^{a}
Habru	0	4.69^{bc}
Habru	30	2.80^{dc}
Habru	60	5.49^{ba}
Habru	90	5.80^{ba}
	LSD (5%)	**1.95**
	CV (%)	**21.96**

Means with the same letter are not significantly different at P>0.05 level of probability following LSD, , LSD= Least significant difference, CV = Coefficient of variation ,

4.2.2.4. Number of effective nodule

The analysis of variance showed that the two way interaction effect of Rhizobium inoculation and rates of NPSB fertilizer application had significant ($P<0.05$) effect on number of effective nodules per plant in chickpea. Where the rest of main effect and interaction effect had nonsignificant effect (Appendix Table 2). Thus, the highest number of effective nodules per plant (3.33) was recorded at the rate of 90 kg NPSB ha^{-1} with inoculation, while the lowest number of effective nodules per plant (1.33) was recorded at the rate of 0 kg NPSB ha^{-1} and without inoculation (Table 10). This implies that differences in performance of chickpea varieties with combined *Rhizobium* inoculants compatibility and effect of phosphorus fertilizer application resulted in improved symbiotic relation between root bacteria and legume plant by providing power. As a result, their interaction increased the rate of nitrogen fixation that improved the effectiveness of nodules. The current finding is in line with many authors have been reported that legume nodules having dark pink or red colors due to presence of leg hemoglobin are an indication for effectiveness of the rhizobial strains used, which is well correlated with nitrogen fixation (Butler and Evers, 2004). Similarly, Bashir *et al*. (2011) reported that phosphorus plays a vital role in increasing plant tip and root growth, decreasing the time needed for developing nodules to become active (effective) for the benefit to the host legume. Similarly, Morad *et al.* (2013) reported that legume seed inoculation with proper *Rhizobium* strain together with recommended amounts of phosphorus at early growth stage could stimulate effective root nodulation and could increase the biological nitrogen fixation

Table 10. Numbers of effective nodules per plant of chickpea as affected by interaction of rhizobium inoculation and rate of NPSB at Meskan District in 2017/18

Inoculation	**Fertilizer(kg/ha)**	**Number of effective nodule**
Without	0	1.33^{c}
Without	30	1.83b^{c}
Without	60	3.16^{a}
Without	90	2.83b^{a}
With	0	3.33^{a}
With	30	2.66^{b}
With	60	3.33^{a}
With	90	3.33^{a}
LSD (5%)		**1.26**
CV (%)		**29.78**

Means by the same letter are not significantly different as judged by LSD test at 5% level of significance. LSD=least significant difference; CV=coefficient of variation,

4.2.3. Yield and Yield Components of Chickpea

4.2.3.1.Number of Pods per Plant

The analysis of variance (ANOVA) showed highly significant (P<0.01) main effect of Rhizobium inoculation, different rate of NPSB blended fertilizer and their interaction effect for number of pods per plant. On the other hand, the three way interaction had highly significant effect on number of pod per plant. Similarly, the two way interaction of varieties with Rhizobium inoculation had significant effect on number pod per plant. However, main effect of variety and interaction effect of blended fertilizer rates and variety does not show a significant difference for number of pods per plant(Appendix Table 3).

The result of the current experiment revealed highly significant (P<0.01) three way interaction effect of variety, NPSB fertilizer application rate and Rhizobium inoculation on the total number of pods per plant (Appendix Table 3). Thus the highest (59.53) total number of pods per plant was recorded at application rate of 60 kg NPSB ha^{-1} with Rhizobium inoculation from variety Habru and as par with Arerti at 90 kg ha^{-1} NPSB with inoculation .

While, the lowest (23.06) the same with Arerti at 0, without inoculation and Arerti with 0 and inoculation on number of total pods was obtained from the unfertilized plot with Rhizobium inoculation by variety Arerti. Plant growth behavior of legume crops including chickpea can be determined by number of pods per plant. So, this indicate that increase in number of pods per plant with the increased NPSB rates might possibly be due to adequate availability of N, P, S and B 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 per plant In agreement with the result of Moniruzzaman *et al*. (2008) significant effect of N fertilizers on pod production per plant of French bean was resulted in the increment of number of pods per plant. Similarly, Somayeh and Hashem (2015) reported that the effects of application of 25 kg P ha^{-1} significantly increased the number of pods of faba bean per plant.

Inoculation with *Rhizobium* bacteria significantly increased the number of total pods per plant (Table 12). Plants that were inoculated with *Rhizobium* showed about 8% more pods per plant than non-inoculated plant. Togay *et al*. (2008) observed that the number of pods per plant affected statistically significant with *Rhizobium* inoculation in chickpea. China (2018) also application of NPSZnB led to the production of about 16% number of pods per plant than the number of pods produced by plants that received no fertilizer (control)

4.2.3.2.Number of seed per pod

Analysis of variance showed that the main effect of variety significantly ($P < 0.01$) influenced the number of seeds per pod. As well as the main effects of blended NPSB application rates had highly significant ($P<0.01$) effect on the number of seeds per pod. However, the main effect of Rhizobium inoculation and all the two/three way interaction effect did not significantly affect this parameter of the plant (Appendix Table 3).

The highest number (1.4) of seeds per pod was recorded from variety Arerti. Whereas, the least (1.2) number of seeds per pod was recorded for variety Habru. This indicates that the trait is mainly controlled by genetic factors than the management and this could be further linked to differences in seed size among the varieties. In line with the results of this study, Number of seeds per pod is considered to be an important factor that directly imparts potential yield in leguminous crops. This finding is similar with the result of Tesfahun *et al. (*2018) who reported that varieties effect on the number of seed per pod had a significant effect;

highest seeds per pod were formed by Mariye whereas the minimum seeds were obtained by the variety Arerti. This result might be obtained due to seed size of the variety Arerti of chickpea compared to other variety of chickpea. Mourice and Tryphonne (2012) observed significant variations in number of seeds per pod among common bean genotypes. The variation in number of seeds per pod could be attributed to the variation in the size of seeds of the cultivars where variety Habru with the large seed size produced lower number of seeds per pod. In agreement with this result, Fageria and Santos (2008)reported that the number of seeds per pod of different common bean genotypes varied in the range of 3.1 to 6 and attributed the difference due to the genetic variation of cultivars.

The maximum number of seeds per pod (1.66) was recorded from 90 kg NPSB ha^{-1} fertilizer whereas the least number of seeds per pod (1.11) was recorded from nil application of or 0 kg NPSB ha^{-1} fertilizer signifying that, the higher number (~45% incrment) of seeds with optimum rates of phosphorus fertilizer might be due to the cumulative effect of NPSB fertilizer on the processes of cell division, cell enlargement, root development, flowering, fruiting, seed formation and serve as balanced nutrition. This is in accordance with the fact that adenosine triphosphate (ATP) is a source of energy for physiological processes like biological nitrogen fixation (Giller, 2001). The result of the present study was in agreement with the findings of Shubhashree (2007) who reported that the number of seeds per pod of French bean increased significantly with the levels of phosphorus added. The result was also in line with that of Meena *et al.,* (2003) who reported that P fertilization increased the number of grains per pod of chickpea significantly.

Table 11. Number of seeds per pod of chickpea varieties as affected by the main effect of varieties and blended NPSB fertilizer in Meskan District during 2017/2018.

Variety	**Number of seed per plant**
Arerti	1.39^{a}
Habru	1.20^{b}
LSD(5%)	**0.17**
Fertilizer(kg ha^{-1})	
0	1.12b
30	1.15^{b}
60	1.66^{a}
90	1.28^{b}
LSD (5%)	**0.24**
CV (%)	**21.69**

Means with the same letter are not significantly different at P<0.05 level of probability following LSD, LSD= Least significant difference, CV = Coefficient of variation

4.2.3.3. Harvest index

Analysis of variance indicated that, harvest index was highly significant (P < 0.001) affected by the three way interaction of variety, Rhizobium inoculation and blended NPSB application rates, main effects of Rhizobium inoculation and main effects of blended NPSB application rates as well as all of two way interaction except variety with Rhizobium inoculation. But, the main effects of varieties had no significant effect on the harvest index; while, the main effects of blended NPSB application rates had highly significant (P<0.01) effect on the harvest index(Appendix Table 3)).

Regarding the three way interaction effect of Rhizobium inoculation, variety and different rate of NPSB fertilization, thus maximum (0.68) harvest index was recorded by variety Habru from Rhizobium inoculation when integrated with 60kg NPSB ha^{-1} fertilization while minimum(0.49) was recorded from variety Arerti integrated with the rate of 30kg ha^{-1} NPSB fertilization without Rhizobium inoculation.

The higher NPSB fertilizers rate had high influence on vegetative growth than nutrient translocation from plant biomass to seed and also signifying that the higher NPSB fertilizers rate had high influence on vegetative growth than nutrient translocation from plant biomass to seed that means if increase in NPPP with the increased NPSB rates which facilitated the production of NPB contributed for the production of higher number of NPPP / This might be due to the variety Habru produced the high number of total pods per plant and yield that in turn resulted in to higher Harvest index.

In line with this result, Singh and Kumar (2004) reported the highest harvest index of lentil was obtained when 45 kg P ha^{-1} and 30 kg S ha^{-1} were applied. Indicating that harvest index is a measure of physiological productivity potential of a crop or variety. It is the ability of a crop to convert the dry matter into economic yield. The higher the harvest index value, the more the production efficiency and vice versa. So the highest harvest index also implies higher partitioning of dry matter into grain. Thus, selection for varieties having high seed to biomass ration such as Habru could enhance chickpea yield. Overall, the results from this study showed significant variation among the evaluated varieties with respect to studied agronomic characters. The present study disagree with Tesfahun *et al*.(2018) regarding the interaction effect of variety and blended fertilizer rates, as they did not find significance for harvest index. This may be due to the absence of rhizobium+ inoculation. The increment in harvest index with rates of fertilizer is in agreement with the findings of Dhanjal et al. (2001) who also reported improvement in harvest index values of 31.60, 31.99 and 33.86% due to increasing N level zero to 60 and 120 kg N ha^{-1}, respectively. However, Gifole *et al.* (2011) reported no significant response of harvest index of common bean to P application.

4.2.3.4. Hundred Seed weight

The analysis of variance revealed that the three way interaction effect of variety, inoculation and blended NPSB application rates, main effects of variety and main effects of blended NPSB application rates were highly significant($P<0.01$) as well as all of two way interaction except variety with fertilization. But, the main effects of varieties and its interaction with different rates blended NPSB application had no significant effect on the hundred seed weight (Table 12).

Among various parameters contributing towards final yield of a crop, hundred-seed weight is of prime importance. A highly significant variation was observed between varieties for hundred-seed weight. Seed size is one of the most important yield related traits in chickpea crop and determines the final seed weight. The recorded variations for 100 seed weight could be attributed to small seed size.

Regarding variety, the higher (34.24g) hundred seed weight was recorded by Habru while, the lower(32.56g)was by Arerti. In addition, main effect of NPSB fertilization showed a highly significant difference ($P<0.01$) for hundred seed weight. maximum hundred seed weight (34.98g) was recorded from 90 kg NPSB ha^{-1} fertilization while, minimum (32.05g) was recorded from 0kg NPSB ha^{-1}. Indicating that the higher NPSB fertilizers rate had high influence on vegetative growth than nutrient translocation from plant biomass to seed.This is could be nutrient use efficiency by crop enhanced at optimum level of NPSB since grain weight indicates the amount of resource utilized and regarding the main effect of Rhizobium inoculation maximum hundred seed weight (34 g) while minimum (32g) was recorded from inoculated and uninoculated seed.

Regarding the three way interaction effect of Rhizobium inoculation, variety and blended fertilizer rates, Maximum hundred seed weight (38.4g) was recorded from inoculation(R1)* Habru*90kg ha^{-1} NPSB fertilization followed by (36.06g) which was recorded from inoculation*variety*60kgha^{-1} NPSB. This might be that the higher NPSB fertilizers rate had high influence on vegetative growth than nutrient translocation from plant biomass to seed, while minimum score (30.13 g) was recorded from Arerti without inoculation at the rate of 0kg ha^{-1} NPSB fertilization. This might be because nutrient use efficiency by crop was enhanced at optimum level of N, P, S and B 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 indicated the increment in 100-seed weight due 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 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 be impacted by improved 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*).

4.2.3.5. Grain yield

The data in relation to grain yield ha^{-1} of chickpea varieties as influenced by rates of NPSB levels and Rhizobium inoculation are presented in Table-3 and its analysis of variance as indicated (Appendix Table -3). The analysis of variance suggested that the effect of Rhizobium inoculation, various NPSB levels, varieties as well as all their interaction on Grain yield ha^{-1} was statistically and highly significant ($P<0.01$).

Regarding fertilization, it is evident from the results (Table-12) that highest seed yield (2973kg ha^{-1}) was recorded when the chickpea was fertilized with highest NPSB level of 90 kg ha^{-1}, followed by second NPSB levels of 60 kg and 30 kg NPSB ha^{-1} with seed yield of 2433kg ha^{-1} and 1574 kg ha^{-1}, respectively. The seed yield ha^{-1} was diminished to 2433 kg and 1574 kg ha^{-1} when the NPSB levels were reduced to 60 kg and 30 kg ha^{-1}, respectively. However, the lowest seed yield of 1354 kg ha^{-1} was recorded in control, where no NPSB was applied. Regarding, the main effect of varieties, the maximum seed yield (2305 kg ha^{-1}) was produced by variety Habru, while lowest seed yield (1862 kg ha^{-1}) was observed in variety Arerti

Regarding, the three way interaction of "variety Habru ×rhizobium inoculation× 60 kg NPSB ha^{-1} resulted in maximum seed yield (3814 kg ha^{-1}).While, the minimum seed yield (873kg ha^{-1}) was noted in the interaction of "variety Arerti × without inoculation × 0 kg NPSB ha^{-1} (control) .This might be due to symbiosis between legumes, rhizobium inoculation and (NPSB) fertilizer resulted in increased nodulation and primary branches which contribute for the grain yield. In agreement with increased chickpea grain yield due to application of P and/or Inoculation was evident on most target farms, with only few exceptions where yields on inoculated plots were similar or inferior to those on the corresponding control plots (Endalkachew *et al*, 2018).

The seed yield ha^{-1} was gradually increased with increasing NPSB levels, which suggested that the soil under experiment was deficient of this nutrient element and the crop responded its increased application positively. These results have been further supported by the findings of Frossard *et al*. (2000) who reported that application of phosphorus at higher levels resulted in increased crop growth, particularly positive impact was noted on branching, pods, seeds pod-1, seed index and increased seed yield. A pronounced effect of P application on chickpea yields has also been reported by Fairhurst and Witt (2002). The number of pods and seed index was improved under higher P applications (Kumar and Sreenivasulu, 2004). Gruhn *et al.* (2000) reported higher grain yield in gram due to P application. Kumar and Sreenivasulu (2004) reported that higher P levels along with recommended dose of N increased seed yield substantially. Similarly, Ramesh *et al.* (2010) obtained maximum net returns from chickpea crop when supplied with higher phosphorus levels along with recommended N application. In a similar study, Islam *et al*. (2011) recommended P application at the rate of 80 kg ha^{-1} for achieving higher chickpea yields.

The development and use of high yielding, tolerant cultivars may offer as one of the suitable components of eco-friendly practice. Keita *et al*. (200) screened out a number of varieties of Cicer arietinum which were found high yielding and free from insect pest while Erler *et al.* (2009) reported quite a different behaviour of chickpea varieties in response to different input application. In a similar investigation, Hossain (2009) examined a series of varieties and all varieties responded differently to P application. The results indicated that significantly higher values were practiced for growth and yield attributes by means of highest grain and straw yield (2240 kgha^{-1} and 2420 kgha^{-1}) of ensuing chickpea.

Table 12. Effect of combined application of different rates NPSB blended fertilizer, varieties and Rhizobium inoculation on yield and yield components of chickpea at meskan in 2017/18

Variety	Inoc	Fert(Kg/ha)	NPPP(No)	HI%	HSW(g)	GY(kg/ha)	AE(kg/kg)
Arerti	without	0	30.47^{gf}	0.63^{cd}	31.00^{ed}	873^{m}	-
		30	23.07^{g}	0.53^{edf}	30.33^{e}	1161^{k}	11.78^{d}
		60	38.07^{def}	0.50^{f}	33.13^{bcde}	2445^{e}	7.83^{e}
		90	40.33^{de}	0.53^{ef}	33.93^{bcd}	3687^{b}	1.77^{f}
Arerti	with	0	32.00^{gef}	0.57^{ed}	31.00^{ed}	1291^{j}	-
		30	57.27^{ba}	0.67^{b}	33.40^{bcde}	1026^{l}	16.75^{c}
		60	44.27^{dc}	0.51^{ef}	35.73^{ab}	2376^{fe}	18.08^{c}
		90	49.53^{bc}	0.54^{edf}	32.00^{cde}	2044^{h}	8.37^{e}
Habru	without	0	36.20^{def}	0.64^{cb}	30.13^{e}	1067^{l}	-
		30	38.27^{def}	0.53^{ef}	34.13^{bcd}	1569^{i}	16.70^{c}
		60	36.20^{def}	0.55^{edf}	34.53^{bc}	2080^{h}	16.86^{c}
		90	36.47^{def}	0.54^{edf}	35.60^{ba}	2834^{c}	1.77^{f}
Habru	with	0	37.00^{def}	0.64^{cb}	34.67^{bc}	2187^{g}	-
		30	34.27^{ef}	0.52^{ef}	30.40^{e}	2541^{d}	9.57^{ed}
		60	59.53^{a}	0.68^{a}	36.06^{ab}	3814^{a}	26.19^{b}
		90	38.20^{def}	0.59^{cd}	38.40^{a}	2347^{f}	31.25^{a}
	LSD(5%)		**9.1**	**0.06**	**3.3**	**0.92**	**2.48**
	CV(%)		**13.88**	**6.09**	**5.95**	**2.65**	**14.06**

Means in a column with the same letter are not significantly different at P>0.05 level of probability following LSD, LSD= Least significant difference, CV = Coefficient of variation NDW= Nodule dry weight NPPP=number of pod per plant, HI= harvest index , HSW=hundred seed weight , AE= agronomic efficiency

4.2.3.6. Agronomic Efficiency of the applied fertilizer

The analysis of variance (ANOVA) revealed that except the main effect of variety and the interaction effect of Rhizobium inoculation and varieties had nonsignificant. However, the main effect of applied rates of NPSB fertilizer, the main effect of rhizobium inoculation, the two way interaction of variety with rates of NPSB, rhizobium inoculation with rates of NPSB as well as the three way interaction showed significant effect ($P<0.001$) on agronomic efficiency of chickpea (Appendix Table 4). This means that both rate of main effect of NPSB blended fertilizer and inoculation with their interaction as well as the three way interaction affected significantly agronomic efficiency of chickpea in this experiment(Table 12).

Thus, the highest (31.25kgkg^{-1}) agronomic efficiency was obtained under plot supplied with interaction of 90kgNPSB ha^{-1} with rhizobium inoculation from variety Habru; whereas, significantly minimum (1.77kgkg^{-1}) agronomic efficiency was recorded from interaction effect of 90kg NPSB ha^{-1} without inoculation on the variety Arerti (Table-12). This could be due to application of NPSB in line with Rhizobium inoculation increases the better availability of desired and essential nutrients in the crop root zone ensuing from its solubilisation caused by the organic acids produced from the decaying organic matter and also the increased uptake by chickpea root specially nitrogen and sulphur there effect to one another and responsible to increase vegetative growth then affects agronomic efficiency and the relative similarity of percentage of nutrient in NPSB blended fertilizer could be another cause. The present study indicated that the capability of yield increase per kilogram of applied combination at rate of NPSB fertilizer and rhizobium inoculation. Ayuba *et al*. (2005) found that available P increased significantly while total P was as high as 7.21 ppm following treatment by inoculants influenced agronomic efficiency. Asefa *et al*., (2014) showed that the interaction effect of source of fertilizer recommended dose of N (75%) + FYM (25%N) + S 40kg ha^{-1} recorded maximum Stover yield of soya bean.

4.3. Correlation of grain yield and yield components of chickpea

Correlation analysis for the different parameters indicated in the table 13 .Grain yield had positively and significantly associated with shoot dry weight($r = 0.405^{**}$), number of effective nodules($r = 0.348^{*}$), nodule fresh weight($r = 0.335^{*}$), number of nodule per plant($r = 0.314^{*}$) and hundred seed weight($r = 0.440^{**}$). This implies the higher shoot dry weight per plant due to high number of nodule with high number of effective nodule there effect had contributed to hundred seed weight then increase grain yield through increasing the seed weight per plant and to increase grain yield by simultaneous improvement of those positive and significant associated parameter. This finding agrees with the result of Kebere *et al.*

(2006) who reported shoot dry weight, number of effective nodules, nodule fresh weight, number of nodule per plant and hundred seed weight had significantly and positively associated with grain yield.

On the other hand, grain yield had negative and significant correlation with date of flowering(r=-0.593**) indicating that the crop is cultivated by residual moisture. This is an indicator for strong negative influence of phenological traits on yield and yield related traits, as prolonged time of flowering and maturity significantly influence the formation of pods and seeds of chickpea genotypes, and this in turn would affect the yielding performance of the crop. Consequently, the shortest (earliest) variety better performed the experiment conducted area and similar agro ecology. This result is similar with the finding of Temesgen (2007) who reported date of flowering had negatively and significantly associated with grain yield while, the remaining parameters were non-significant.

Plant height(r=0.445**) and number of nodule per plant(r=0.0.330*)significantly and positively associated with date of maturity. This implies that extended date of maturity (higher translocation of photo-assimilate to strong sink) contributed to increase height through increasing the number of nodule per plant. Similarly, shoot dry weight(r = 0.300*), nodule dry weight (r = 0.317*), nodule fresh weight(r=0.340*), number of nodule per plant(r = 0.491**) and number of seed per pod (r=0.310*) showed positive and highly significant correlation with leaf area. This implies high indicating high light interception and assimilation and large root volume indicating good nutrient and water uptake contributed to increase yield by increasing quantity of grain yield per unit of nutrient applied (agronomic efficiency). And also number of primary branch had showed positive and significant correlation with number of effective nodule(r= 0.345*) while, number of effective nodule is positively and significantly correlated with nodulation contributing component like number of nodule per plant (r = 0.331*) and nodule fresh weight(r = 0.946**) had significant and positive association with nodule dry weight, number of seed per pod (r = 0.380**), number of pod per plant(r= 0.373**) had significant positive correlation with number of nodule per plant, harvest index(r=0.552**) had significant and positive correlation with number of pod per plant and number seed per pod significantly and positive correlation with hundred seed weight(r=0.383**).

Table 13. Correlation of grain yield and yield components of chickpea

Characters	DF	DM	PLH	LA	NPB	SDW	RDW	NEN	NDW	NFW	NNPP	NPPP	NSPP	HI	HSW	YLD
DF	1.000	0.330*	-0.068	-0.243	0.022	0.478**	-0.055	-0.096	-0.296*	-0.298*	-0.220	-0.328*	-0.214	0.094	-0.310*	0.593**
DM		1.000	0.445**	-0.038	0.178	0.093	0.022	0.244	0.104	0.065	0.330*	0.094	0.067	0.129	0.047	-0.055
PLH			1.000	0.179	0.376**	0.374**	0.054	0.405**	0.259	0.189	0.601**	0.349*	0.161	0.064	0.182	0.074
LA				1.000	0.065	0.300*	0.164	0.117	0.317*	0.340*	0.491**	0.169	0.310*	-0.138	0.226	0.201
NPB					1.000	0.085	-0.217	0.345*	0.027	0.090	0.275	0.022	0.083	-0.012	0.196	-0.034
SDW						1.000	0.110	0.057	0.471**	0.429**	0.693**	0.474**	0.252	0.255	0.402**	**0.405****
RDW							1.000	-0.104	0.062	0.055	0.172	0.095	-0.215	0.257	-0.016	0.068
NEN								1.000	0.058	0.036	0.331*	0.129	0.248	-0.099.	0.177	**0.348***
NDW									1.000	0.946**	0.542**	0.245	0.511	0.037	0.293	0.322
NDW										1.000	0.537**	0.264	0.544**	0.063	0.357*	**0.335***
NNPP											1.000	0.373**	0.380**	0.239	0.465**	**0.314***
NPPP												1.000	0.021	0.552**	0.273	0.180
NSPP													1.000	-0.175	0.383**	0.217
HI														1.000	0.177	-0.147
HSW															1.000	**0.440****
YLD																1.000

*DF= date of flowering, DM = date of maturity, NPB=numberof primary branch,LA=Leafarea ,NEN=numberofeffective nodule,NNPP=number of pod perplant,RDW=root dry weight,NSPP=number of seed per pod,HSW=hundred seed weight ,GY=grain yield, HI=harvesting index, soot dry weight, *=Correlation is significant at 0.05 probablity level and **= Correlation is significant at 0.01 level*

4.4. Economic Analysis

The parietal budget analysis was used to identify treatments with the optimum return for the farmer's investment. The results of the partial budget analysis for NPSB blended fertilizer rate as compared to inoculants and their combination effect on nodulation, growth and yield response of chickpea (Table 14).

The highest gross farm gate benefit 72090.69 ETB ha^{-1} was gain from yield obtained at combined effect of 60kg NPSB ha^{-1} + inoculants from variety Habru and the second gross benefit 46210.5 was obtained from interaction effect of 60kg NPSB ha^{-1} + without rhizobium inoculation from variety Arerti.

Therefore, the marginal rate of return was done based on a treatment to be considered as worthwhile to farmers, that is 50% and 100% marginal rate of return (MRR) is the minimum acceptable rate of return (CIMMYT, 1988). Hence, it is important to compare treatments to remove undesirable treatments in view of economic profitability rather than only looking at the highest grain yield, because it may not be attractive if they required very much higher cost.

Therefore, the highest net benefit was 66740.19 ETB ha^{-1} obtained at plot treated with 60kg NPSB ha^{-1} + Inoculants with variety Habru in combination. The adoption of this treatment would give an additional gain of 5754.64 % from every Birr invested in chickpea production. While the second highest 48379.8 ETB ha^{-1} net benefit with additional gain of 4185.89 % from every Birr invested was obtained at interactive application of 60 kg NPSB ha^{-1} + without inoculation from variety Arerti.

Therefore, interaction effect of 60 kg NPSB ha^{-1} + Inoculants was more economically attractive than all other treatment (Table-14). Application of 60 kg NPSB ha^{-1} + Inoculants resulted in the highest mean grain yield increase as compared to all other treatments.

It could be considered as the most profitable treatment. It has the highest return to the money invested in its production; it maximized profit and output and minimized costs (Table -14). All interaction effect from rate of fertilizer, inoculants and variety were economically viable and had positive marginal rate of returns. The economic analysis has led to 60 kg NPSB ha^{-1} +

inoculation with variety habru is suitable for potential adoption by farmers if additional study required to be undertaken on the same experiment to confirm for further use. Generally, significant maximum grain yields were obtained from 60kg NPSB ha^{-1} blended fertilizer interacted with Inoculants and variety as well as it had maximum marginal rate of return.

Table 14. Summary of economic analysis of the response of chickpea varieties for rates of blended NPSB fertilizer and rhizobium inoculation at meskan in 2018/2019

Treatments			Grain yield					
Variety	Inoculation	Fert (kg/ha)	UGY/kg/ha	AGY/kg/ha	GFB (ETBha^{-1})	TVC (ETB ha-1)	NB (ETBha-$^{1)}$	MRR (%)
Arerti	without	0	873.33	786.00	16506	3620	12886	
Habru	without	0	1067.33	960.57	20171.97	3620	16551.97	-
Arerti	With	0	1290.67	1161.60	24393.6	4100	20293.6	779.50
Habru	With	0	2187.00	1968.30	41334.3	4100	37234.3	-
Arerti	without	30	1161.00	1044.90	21942.9	4405.5	17537.4	D
Habru	without	30	1568.67	1411.80	29647.8	4405.5	25242.3	-
Arerti	without	60	2445.00	2200.50	46210.5	4790.97	41419.53	4185.89
Habru	without	60	2079.67	1871.70	39305.7	4790.97	34514.73	-
Habru	With	30	2540.67	2286.60	48018.6	4965.5	43053.1	D
Arerti	With	30	1025.67	923.10	19385.1	4965.5	14419.5	-
Arerti	without	90	2044.00	1839.60	38631.6	5176.5	33455.1	D
Habru	without	90	2833.67	2550.30	53556.3	5176.5	48379.8	D
Arerti	With	60	2375.67	2138.10	44900.1	5350.97	39549.13	D
Habru	With	60	3814.33	3432.89	72090.69	5350.97	66740.19	5754.64
Arerti	With	90	3686.67	3318.00	69678	5736.5	63941.5	D
Habru	With	90	2346.67	2112.00	44352	5736.5	38615.5	-

Where, UGY = Unadjusted grain yield; AGY = adjusted grain yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit; MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments.

5. SUMMARY AND CONCLUSSION

Use of appropriate combination of variety, NPSB application rate and *Rhizobium* inoculation are the major agronomic practices that can improve the productivity of chickpea. Thus, a field experiment was conducted at Meskan District in 2017/18 with the objectives of assessing the response of chickpea varieties to rate of NPSB fertilizer and *rhizobium* inoculation to determine the economic feasibility of rate of NPSB fertilizer with and without rhizibium inonoculation for achieving higher yield of chickpea and two chickpea varieties (Arerti and Habru), with and without inoculation and four rates of (0, 30, 60 and 90 kg of NPSB ha^{-1}) were conducted in factorial RCBD with three replication.

Combined use of rate of blended NPSB fertilizer with Rhizobium inoculation was an important complementary strategy in improving chickpea growth, nodulation and yield as well as reducing production cost. The analysis of variance had revealed that the interaction effect of blended NPSB fertilizer with Rhizobium inoculation on growth components such as plant height, leaf area, number of primary branches per plant, shoot dry weight, and root dry weight was highly significant. This could be reason for highly significant increase on nodulation, yield, and yield component as the rate increases. Nodulation variables such as nodule number was significantly influenced by main effect of NPSB blended fertilizer and interaction of variety and rhizobium inoculation, nodule dry weight was significantly influenced by all two way interaction and number of effective nodule was influenced by interaction effect of Rhizobium inoculation and fertilization. Similarly, Interaction effect of fertilizer and Rhizobium inoculation with different variety had significant effect on the above listed parameters.

The variety Habru showed superiority over Arerti by giving 59.53 pods plant^{-1}, 0.68 harvest index, 38.4g hundred seed weight and 3814kg ha^{-1} seed yield. The development and use of high yielding and tolerant cultivars may offer as one of the suitable components of eco-friendly practice. Correlation analysis indicated that grain yield had positively and significantly associated with shoot dry weight, number of effective nodules, nodule fresh weight, number of nodule per plant and hundred seed weight had significantly and positively associated with grain yield.

The interaction effect of variety, rhizobium inoculation and rates of NPSB fertilizer revealed the highest net benefit (66740.19 ETB) from Habru variety at application of 60 kg NPSB ha^{-1} with Rhizobium inoculation with the highest marginal rate of return (5754.64%) .The lowest (ETB 12886 ha^{-1}) net return was recorded from the variety Arerti supplied with 0 kg NPSB ha^{-1} without seed inoculation.

This shows economic feasibility of the three treatments because the marginal rate of return from treatment of highest net benefit is (5754.64%) which is > 100%. So, 60kg NPSB ha^{-1} + Rhizobium inoculation could be considered as the most profitable treatment. It has the highest return to the money invested in its production; it maximized profit and output and minimized costs.

Based on the results of this study, it can be concluded that chickpea varieties highly varied in their agronomic performance mainly due to variation in their genetic background. rates of NPSB fertilizer and *Rhizobium* inoculantion

Although the experiment was conducted at one site and for one season and combined variety, rate of NPSB fertilizer and *Rhizobium* inoculants were used, it is reasonable to point out that Habru at application rate of 60 kg NPSB ha^{-1} with *Rhizobium* inoculantion produced the highest seed yield of chickpea as alternative variety Habru on application rate of 30kg NPSBha^{-1}with inoculation. However, similar studies should be conducted by including other chickpea varieties in different locations over growing seasons and using different *Rhizobium* inoculants with consideration of economic analysis in order to come to a conclusive recommendation.

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APPENDXICES

Appendix Table- 1. Mean square values of 50% flowering date, 90% physiological maturity date and plant height, Number of branch plant-1; leaf area index ,shoot dry weight and root dry weight.

		DF		DM		PLH		NPB		LA		SDW		RDW	
Source	**DF**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**
Rep	2	2.02	0.41	15.65^{NS}	0.3711	0.50	0.5323	0.07	0.396	20.38	0.2317	4.88	<.0001	0.23	0.1685
INOC	1	0.33	0.70	243.00	0.0004	63.25	<.0001	0.06	0.382	136.38	0.0033	53.13	<.0001	0.44	0.0684
VAR	1	33.33	0.00	96.33	0.0176	0.42	0.4668	0.23	0.095	2.25	0.6831	22.55	<.0001	0.04	0.5603
FERT	3	45.06	<.0001	10.36	0.5720	2.34	0.0456	0.08	0.392	30.66	0.0970	26.80	<.0001	0.03	0.8837
INOC*VAR	1	0.00	1.00	70.08	0.0404	9.45	0.0015	0.32	0.051	11.16	0.3661	19.64	<.0001	0.73	0.0211
INOC*FER	3	3.72	0.19	0.06	0.9997	2.16	0.0577	0.23	0.048	49.65	0.0220	3.37	<.0001	0.14	0.3406
VAR*FER	3	11.28	0.01	43.06	0.0557	0.85	0.3671	0.19	0.081	34.21	0.0729	1.64	<.0001	0.13	0.3731
INOC*VAR*FER	3	6.06	0.06	17.58	0.3444	7.46	0.0001	0.12	0.217	64.23	0.0076	0.45	<.0001	0.38	0.0422
ERROR	30	2.22		19.59		0.75		0.08		13.22		0.03		0.12	
Total	47														
CV		2.93		3.33		2.91		8.09		14.60		2.27		12.64	

NB:* and** at 5% and1% probability level, respectively. DF= Degree of freedom; NS= Not Significant; Var = variety; Fert =Fertilizer, Inoc = inoculation, CV=coefficient of variation.

Appendix Table- 2. Mean square values of nodule number, nodule fresh weight ,nodule dry weight and number of effective nodule

		NNPP		NFW		NDW		NEN	
Source	DF	M S	Pr > F	M S	Pr > F	M S	Pr > F	M S	Pr > F
Rep	2	3.84	0.9116	11.15	0.0035	1.06	0.3655	0.40	0.7118
INOC	1	4752.12	<.0001	31.69	0.0001	11.56	0.0021	4.69	0.0526
VAR	1	394.45	0.0043	4.08	0.1227	0.46	0.5086	0.52	0.5064
FER	3	472.78	<.0001	147.45	<.0001	37.86	<.0001	3.13	0.0620
INOC*VAR	1	227.07	0.0259	61.29	<.0001	14.79	0.0006	3.52	0.0906
INOC*FER	3	64.28	0.2208	54.75	<.0001	16.19	<.0001	3.41	0.0480
VAR*FER	3	65.77	0.2122	12.03	0.0007	5.58	0.0040	1.13	0.4139
INOC*VAR*FER	3	12.79	0.8184	13.60	0.0003	1.60	0.2182	1.47	0.3015
ERROR	30	41.34		1.61		1.02		1.15	
Total	47								
CV		**20.78**		**16.56**		**21.64**		**27.93**	

NB:* and** at 5% and1% probability level, respectively. DF= Degree of freedom; NS= Not Significant; Var = variety; Fer =Fertilizer,Inoc = inoculation, CV=coefficient of variation.

Appendix Table 3. Mean square values of hundred seed weight, harvest index ,number of seed pod-1,number of pod plant-1 and grain yield

		HSW		**HI**		**NSPP**		**NPPP**		**YIELD**	
Source	**DF**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**	**M S**	**Pr > F**
Rep	2	1.90	0.6331	0.003	0.1180	0.13	0.2066	2.44	0.9265	0.38	0.2950
INOC	1	14.74	0.0671	0.034	<.0001	0.06	0.3920	999.19	<.0001	0.05	0.6836
VAR	1	33.67	0.0074	0.022	0.0001	0.05	0.0095	0.24	0.9313	234.44	<.0001
FER	3	37.30	0.0002	0.011	0.0001	0.49	0.0022	242.57	0.0006	681.79	<.0001
INOC*VAR	1	0.37	0.7663	0.008	0.0121	0.50	0.180	160.60	0.0322	147.84	<.0001
INOC*FER	3	4.79	0.3361	0.016	<.0001	0.44	0.41	144.25	0.0098	330.12	<.0001
VAR*FER	3	7.92	0.1447	0.035	<.0001	0.08	0.4293	146.58	0.0091	48.84	<.0001
INOC*VAR*FER	3	22.46	0.0039	0.022	<.0001	0.07	0.4838	398.74	<.0001	11.42	<.0001
ERROR	30	4.08		0.002		0.08		31.82		0.29	
Total	47										
CV		6.05		5.85		21.69		14.30		2.62	

NB:* and** at 5% and1% probability level, respectively. DF= Degree of freedom; NS= Not Significant; Var = variety; Fer =Fertilizer,Inoc = inoculation, CV=coefficient of variation.

Appendix Table 4. Mean square values of agronomic efficiency of applied fertilizer,

Source	**DF**	**Mean Square**	**F Value**	**Pr > F**
Rep	2	1.17	0.51	0.6082
INOC	1	1590.22	689.29	<.0001
VAR	1	0.13^{NS}	0.06	0.8138
FERT	3	887.35	384.63	<.0001
INOC*VAR	1	8.40	3.64	0.066
INOC*FER	3	345.72	149.86	<.0001
VAR*FER	3	301.79	130.81	<.0001
INOC*VAR*FER	3	51.47	22.31	<.0001
ERROR	30	2.30		
Total	47			
CV		14.06		

NB:* and** at 5% and1% probability level, respectively. DF= Degree of freedom; NS= Not Significant; Var = variety; Fert =Fertilizer,Inoc = inoculation, CV=coefficient of variation.