EFFECTS OF INOCULATION OF *Sinorhizobium ciceri* and PHOSPHORUS FERTILIZER RATES ON NODULATION, YIELD COMPONENTS AND YIELD OF CHICKPEA (*Cicer arietinum* L.) VARITIES AT HARAMAYA, EAST ETHIOPIA

M.Sc. THESIS

By

SUFI AHMED

JANUARY, 2020

HARAMAYA UNIVERSITY, HARAMAY

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By

SUFI AHMED

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POST GRADUATE PROGRAM DIRECTORATES

HARAMAYA UNIVERSITY

As thesis research advisor, we hereby certify that we have read and evaluated this Thesis prepared under our guidance by Sufi Ahmed entitled: **Effects of Inoculation of *Sinorhizobium ciceri* and Phosphorus Fertilizer Rates on Nodulation, Yield Components and Yield of Chickpea (*Cicer arietinum* L.) Varities at Haramaya, East Ethiopia**

we recommended that it be submitted as fulfilling the thesis requirement for the degree of Master of Science in Agriculture (Agronomy).

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As members of the board of examiners of the M.Sc Thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Sufi Ahmed and examined the candidate .We recommended that the thesis be accepted as fulfilling the thesis requirement for the degree of Master of Science in Agriculture (Agronomy).

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Dedication

This thesis manuscript is dedicated to my lovely daughter Sumeya Sufi

Statement of the author

First, I want to assure that this thesis is my genuine work and all sources of materials and information used for the work have been duly acknowledged. This Thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Haramaya University and is deposited at the University Library to be made available to borrowers under rules of the Library. I want to declare that this thesis is not submitted to any other institution elsewhere for the award of any academic degree, diploma, or certificate. Without waiting for special permission users can quote from this thesis as long as the source is appropriately acknowledged. Extended quotation or partial or whole reproduction of this manuscript is possible through requests which may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other cases, however, permission must be obtained from the author.

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Biographical sketch

The author was born for his mother Mrs Zehara Ahmed and his father Ato Ahmed Mumed in October 1978 E.C in Aweday town, East Hararghe, Ethiopia. He attended his elementary school at the Fendisha Elementary School from 1987 to 1991E.C. He pursued his senior secondary school education at Hamaresa from 1992 to1996 Junior senior Secondary School, from 1997 to 1998. Then he joined the Menschen fur Menschen Foundation Agro technical and Technology College and graduated with a B.Sc. degree in Crop production in July 2002 E.C. After graduation, he was employed by the Ministry of Agriculture Oromiya at East Hararghe as crop protection and vegetable expert. Currently he is employed by Aweday Town Administration Environmental protection office as a Forest protection and management expert. He joined the summer program of the School of the Graduate Studies of Haramaya University in June 2009 E.C through sponsorship for his course work studies & for his research work from financial grant obtained from the Haramaya University to pursue a study leading to M.Sc. degree in Agronomy.

Acronyms and abbreviations

BNF	Biological nitrogen fixation
CSA	Central Statistics Agency
DCB	Dried crushed bone
DZARC	DebreZeit Agricultural Research Centre
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
FAOSTAT	Food and Agricultural Organization statistics

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Table of contents

List of table

Table **Page**

List of tables in the appendix

Effects of Inoculation of *Sinorhizobium ciceri* and Phosphorus Fertilizer Rates on Nodulation, Yield Components and Yield of Chickpea (*Cicer arietinum* L.) Varieties at Haramaya, Easter Ethiopia

ABSTRACT

An experiment was conducted at Haramaya University, eastern Ethiopia in 2019 main cropping season, to assess the response of chickpea varieties to Rhizobium and P fertilizer rate. The study was conducted to assess the effect of phosphorus fertilizers and Sinorhizobium ciceri inoculation, on growth, nodulation, yield components and yield of chickpea varieties at Haramaya, East Ethiopia and to evaluate the cost -benefit of inoculation and phosphorus fertilizer for chickpea production. Three chickpea varieties Dubie Ejere and Teketay), four rates of phosphorus (0, 50, 100 and 150 kg of P ha^{-1}) with and without inoculation were tested in Randomized Complete Block Design (RCBD) in factorial arrangement with three replication. Analysis of variances indicated a statistical differences ($P \leq 0.05$) for most of the parameters studied namely days to 50% emergency, 50% flowering, 90% physiological maturity, primary branches, secondary branches, total number of nodules, effective nodule number, dry weight of total nodule, dry weight of effective nodule, total number of pods, number of seeds per pod, seed yield (kg per ha), harvest index and above ground weight. The shorter days to 50% emergency was recorded by interaction of Teketay variety supplied with 100kg P rates with and without Rhizobium bacteria (7.33days) and (7.67 days) respectively. Moreover, shorter days to 50% flowering was recorded by Interaction effects of Teketay variety, 100kg P ha $^{-1}$, 150kg P and 50 kg P with rhizobium resulted shorter days to flowering (42.33 days, 47 days and 49.67 days) respectively. Teketay variety was found higher plant height (55.17cm) followed by Ejere variety (53.50cm) while Dubie variety height was 45.42cm. Similarly, the higher plant height recorded for the interaction of Teketay variety inoculated with rhizobium and with 150 kg per ha (60.67cm) and 100kg per ha (57.33cm) respectively. Ejere variety produced the highest number (4.625) of primary branches followed by Dubie (4.43) and Teketay (4.45) respectively. Inoculation of chickpea seed with Rhizobium inoculants enhanced the number of primary branches per plant from 4.31 to 4.69. Teketay variety produced the highest number (15.80) of secondary branches followed by variety Ejere (15.08). Teketay variety resulted in higher number of total nodules (80.42), effective number of nodule (75.52), dry weight of total nodule (0.26g) and dry weight of effective of nodule (0.14g) per plant respectively. . The maximum number of pod per plant was recorded from Teketay variety (108.3) followed by Ejere variety (90.2) and the Dubie variety (56.4).Inoculation of chickpea seed with Rhizobium inoculants enhanced the number of seeds per pod from 1.733 to 1.926. Moreover, the maximum number (2.00) of seeds per pod was recorded from seeds inoculated with Rhizobium inoculants and fertilizer rates of 150 kg P ha^{-1} followed by 100 Kg P ha^{-1}(1.972). The maximum hundred seed weight was recorded under Teketay variety (35.06 g) followed by Ejere variety (32.85). The maximum seed yield was recorded with Teketay variety inoculated with rhizobium inoculants supplied with 150kg P per ha (3574kg per ha) followed by same variety supplied with 150 kg per ha without inoculants (3444kg per ha). The results indicated that the integrated use of chemical fertilizers and Rhizobium inoculants increase the growth, yield and yield parameters due to biological nitrogen fixation. Inoculation of Sinorhizobium cicerand P rate of 150 kg perh could be recommended for Haramaya soils to maximize yield.

Key word: Rhizobium, inoculants, phosphorous rates, variety.

1. Introduction

Chickpea (*Cicer arietinum* L.) is globally the third most important food legume after common bean and soybean (Namvar and Sharifi, 2011). It belongs to the family Fabaceae (earlier Leguminoseae) and sub family papilonaceae (Kupich, 1977). It is most probably originated in an area of present day south-eastern Turkey and adjoining Syria where three mild annual species of *C. bijigum*, *C. aerhinosperum*, and *C. reticulatum* are found (Saxena and Singh, 1987).

The average range of maximum temperature in the major chickpea growing regions of the world is from 21-29^{0}C during the day and 15-21^{0}C during night. The crop needs daily mean temperature above 15^{0}C to allow fertilization of flowers and pod setting (Trang and Gidden, 1985), but there are indications that certain varieties are better adapted than others to high temperature conditions.

Chickpea is currently grown on about 11 million hectares worldwide with 65% and 8% share belonging to India and Pakistan, respectively. Average annual production of chickpea is about 9 million tones with 95% of chickpea cultivation and consumption occurring in the developing countries. It is widely cultivated by smallholders in Mediterranean and semi-arid climates but in Africa is largely restricted to the cool highlands of Ethiopia (Anbessa and Bejiga, 2002). However, it also grows in Sudan under irrigation and rain-fed systems and is an increasingly important crop in Tanzania. In 2014, Ethiopia produced almost 60% of Africa's total chickpea (FAOSTAT, 2014; Ojiewo, 2016).The diverse agro-climatic conditions in Ethiopia make it very suitable for growing chickpeas. Chickpea is widely grown across the highlands and semi-arid regions of Ethiopia and serves as a multi-purpose crop. The country is also considered as the secondary Centre of diversity for chickpea (Anbessa and Bejiga, 2002). The total area of chickpea in Ethiopia has increased from 168,000–230,000ha over the past decade, making Ethiopia the largest producer of chickpea in Africa and the 6th largest in the world (CSA, 2014), and desi varieties grown mainly for the Dubie market and the larger seeded, Kabuli varieties largely for export yet productivity of chickpea remains low, with national average yield of 1.7 t ha^{-1} (BTL, 2013; FAOSTAT, 2014; CSA, 2016, 2017), far below the potential yield of 4–5 t ha^{-1} reported on experimental stations (Bejiga and van der Maesen, 2006; Fikre, 2016).

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Being a legume crop, chickpea can obtain a significant portion of its nitrogen requirement through symbiotic N_2 fixation when grown in association with effective and compatible *Rhizobium strains* (Stephen *et al,* 2002). *Rhizobial* inoculants are used for seed inoculation of legume seeds to ensure successful nodulation when compatible and effective rhizobia are absent in the soil. Inoculation with *rhizobia* must be followed when: i) there are no native *rhizobia,* ii) the native *rhizobia* are ineffective and iii) the native rhizobia are harmful (Some *Bradyrhizobium* produce toxins that cause chlorosis, yellowing in plants (Coyne, 2001).

Ethiopia is considered as one of the most vulnerable countries in sub-Sahara Africa (SSA) with regard to soil fertility depletion because of its mountainous topography and intensive farming systems based on small cereals. Indeed, national averages of nutrient balances were estimated at 41 kg N, 6 kg P and 26 kg K per ha per year, which is among the highest nutrient depletion rates for sub-Saharan Africa (Stoorvogel and Smaling,1993). Most Ethiopian soils, similar to the agricultural soils of other countries in the tropics, are generally low in nitrogen (N) and phosphorus (P). These two nutrients are often limiting the crop production in Ethiopia (Asgelil, 2000). Various authors reported increased yield responses of pulses to seed inoculation of *Rhizobium* (Dorosinksy and Kadyrov, 1975; Moawad *et al*., 1988; Desta, 1988) and phosphate-solubilizing bacteria (PSB) (Gaur, 1985). When inoculated, these organisms colonize the rhizosphere and enhance plant growth by providing it with N and P (Kundu and Gaur, 1980). In India, combined inoculation of *Rhizobium* and PSB has been reported to increase yield, nutrient uptake, nodulation (Alagawadi and Gaur, 1988; Dubey, 1997), and nitrogenase activity (Alagawadi and Gaur, 1988; Asfaw, 1988).

Despite being more efficient than cereals in utilizing native soil P under deficient conditions because of its mycorrhizal and rhizosphere acidifying root system, chickpea grown in P-deficient soils responds well to P fertilization (Rashid and Bughio, 1993 as cited by ICPNS (2000). In Ethiopia, there is very little information on inoculation of *Rhizobium* on crop productivity (Wassie, 1999). Hence, it is of great practical importance to study the effect of these bacteria on nodulation, plant growth and nutrition and legume crop yields. BNF is the biochemical mechanism where *rhizobia* bacterial symbiont of legumes fix inert atmospheric nitrogen into a plant usable form under the presence of enzyme nitrogenase. The nitrogenase enzyme is a biological catalyst which is present in the bacteriod and mediates the reaction. BNF is an economically attractive and ecologically sound source of nitrogen and helps in decreasing the dependence on external inputs (Zorawar and Guriqbal, 2017).Thus biofertilizers, such as *Rhizobial* bacteria is an alternative cheap and environmentally friendly source of N. Adoption of such technologies by farmers will help in minimizing production costs and at the same time, avoid the environmental hazards (Galal *et al.,* 2001).

Therefore, in view of this a field study on chickpea was carried out at the research station of Haramaya University with the following objectives:

1.1. Objectives of the study

- ✓ To assess the effect of phosphorus fertilizers and *Sinorhizobium ciceri* inoculation, on growth, nodulation, yield components and yield of chickpea.
- ✓ To evaluate cost -benefit of inoculation and phosphorus fertilizer for chickpea production.

2. Literature review

2.1. Biological nitrogen fixation (BNF)

Biological nitrogen fixation (BNF) represents a significant potential source of N input in agricultural soils in the country. The major N_2-fixing systems, the symbiotic systems, can play a substantial role in improving the fertility and productivity of low-N soils (*Abaidoo et al*., 1990). Biological N_2 fixation by *rhizobia* in legume root nodules is one widely studied mechanism by which plants benefit from association with interacting partners. In *Rhizobium* legume symbiosis, both plant cultivar and *Rhizobium* strain can affect nodulation (Keneni *et al*., 2012, *Mutch et al*., 2003).

The bacteria benefit the plants by fixing N_2 in exchange for fixed carbon (C), which is either provided directly to the bacteria or indirectly in root exudates. Generally, it is assumed that a pulse crop well inoculated with the bacteria can fix sufficient quantities of N to eliminate the need for N fertilizer inputs in the crop year (Walley *et al*., 2006). Nitrogen supplied through BNF is less likely to leach or volatilize in pre-cropping or during cropping than N supplied as inorganic 3fertilizer (Jensen and Hauggaard-Nielsen, 2003).

Depending on cultivar, bacterial strain, and environmental factors, the chickpea and *Mesorhizobium* sub sp. *ciceri* association can produce up to 176 kg N ha^{-1} annually. Using high yielding varieties of chickpea along with effective *Rhizobial* strains can enhance yields and minimize the need for nitrogenous fertilizer. *Rhizobial* species that produce nodules in chickpea are solely specific to chickpea. Therefore, inoculation with effective strains is advised in soils with a weak or nonexistent bacterial presence (Rupela and Saxena 1987). The isolation and screening of highly efficient and competitive strains of native *Rhizobial* populations for use as inoculants proves very beneficial. Often the most competitive and persistent inoculant strains in a particular field environment are those isolated from similar environments (Chatel and Greenwood, 1973). Chickpea forms symbiotic associations with effective *Rhizobium* strains. Under favourable conditions, symbiotic N fixation can provide up to 85% of the N required by a chickpea crop (Walley *et al*., 2005; Chemining'wa and Vessey, 2006). Inoculating chickpea with *Rhizobium* in the absence of fertilizer N increased grain yield by 37% (Gan *et al.*, 2009) and water use efficiency by 9-33% (Gan *et al.*, 2010). 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 rainfed field experiment, Ben Romdhane *et al.*, (2009) reported greater number of nodules in inoculated treatments compared with non-inoculated ones that relied on indigenous *rhizobia.* Since chickpea is a relatively new crop in the region of the study area with hardly any production, it is likely that compatible and effective native *rhizobia* may be lacking in these soils.

Therefore inoculation with commercial *rhizobia* may increase effective nodulation and N fixation and hence improve yields and provide a substitute to inorganic fertiliser. Although several studies have demonstrated the effects of inoculating chickpea with *Rhizobium* on soil fertility improvement as well as chickpea growth and yield (Walley *et al*., 2005; Ben Romdhane *et al*., 2009; Gan bgvc *et al*., 2009, 2010; Lopez-Bellido *et al*., 2011) few studies have quantified the effect of inoculation on radiation interception and the efficiency with which the crop utilizes the intercepted radiation. Also, the effectiveness of *Rhizobium* inoculation tend to vary with cultural practices (Walley *et al*., 2005; Lopez-Bellido *et al*., 2011).

2.2. Effect of rhizobium

Rhizobium, a gram negative rod shaped bacteria, are the soil inhabiting microscopic organisms which live in a symbiotic association with legume plants. *Rhizobia* are a unique group of bacterial symbionts of legumes that fix inert atmospheric nitrogen in the presence of enzyme nitrogenase. Among all the N_2 fixing microorganisms, symbiotic relationships between legumes and rhizobia are responsible for the largest contributions of biologically fixed N to farming systems (Unkovich *et al.* 2008). The *Rhizobium* inoculation helps to enhance the growth, number of nodules plant^{-1}their dry weight, grain yield and quality by regulating the plant physiology in chickpea (Laranjo *et al.*, 2014). N fertilizers contribute significantly to environmental pollution and have capability to disrupt every form of life to a great extent. Several studies reported that dependence on the nitrogenous fertilizers can be reduced by *Rhizobia* inoculation (Namwar *et al*., 2013) which can be very much instrumental to escape the environmental hazards of nitrogenous inputs. Furthermore, it has been reported that, apart from nitrogen fixation, *Rhizobial* strains promote plant growth through other mechanisms such as phosphate solubilization ability in some legumes. Production of phtohormones (viz. Indole acetic acid), siderophores and lowering of plant ethylene levels due to presence of Acetyl CoA carboxylase (ACC) deaminase activity (Sridevi and Mallaiah, 2009). Wondwosen , 2016 also reported that biological nitrogen fixation (BNF) can reduce the need for inorganic nitrogen fertilizer. More specifically, chickpea can fix up to 140 kg N ha^{-1} in a growing season (Kyei-Boahen *et al.*, 2002) and its inclusion in crop rotations of cereal dominated farming systems can also reduce disease severity of non-legume crops through disrupting the disease cycle.

Rudresh *et al.*, (2005) reported that the inoculation of seed with *Rhizobium* resulted in higher plant height, number of branches and shoot biomass in chickpea in comparison to without inoculation. The *Rhizobium* inoculation in chickpea consistently produced more plant height, root length, dry weight of root and shoot, nodule number and dry weight $plant^{-1}$ and ultimately grain yield as compared to uninoculated control. In a pot experiment, Giri and Joshi (2010) studied the effect of *Rhizobium* inoculation in chickpea. They revealed that inoculaton increased the shoot length, shoot weight, root length and root weight to the tune of 13.04%, 10.26%, 15.07% and 11.42% as compared to control. They reported that irrespective of 3 genotypes, *Rhizobium* inoculation significantly improved the plant height, root length and dry weight of plants.

In another study, Shahzad *et al.*, (2014) 9 in an irrigated farming system reported that inoculation of chickpea with *Rhizobium* significantly enhanced the plant height, shoot biomass, root length and root dry weight over inoculated control. Similarly, Singh *et al.*, (2015) reported 4.4%, 8.4%, 9.4% and 6.9% higher plant height, primary and secondary branches and grain yield respectively in *Rhizobium* inoculated chickpea in contrast to inoculated control. The number and dry weight of root nodules are index of degree of infection leading to nodule development (Bhattacharjy*a et al.* 2009).

The positive effect of *Rhizobium* inoculation on number and dry weight of nodules plant^{-1} in chickpea is very well documented by various researchers. *Rhizobium* inoculation presented excellent nodulation status in contrast to poor nodulation in control (Khattak *et al.* 2006). Some studied show the influence of *Rhizobium* strains on nodulation and grain yield in chickpea and recorded higher nodule number and dry weight with different *Rhizobium* strains viz. RG-3 (68 and 1.48 g), RG-48 (70.3 and 1.67 g) and GHUR-25 (71.67 and 1.70 g) over the inoculated control (27.33 and 0.49 g). *Rhizobium* treated chickpea exhibited improved number of nodules plant^{-1} (66.8%), nodule dry weight (66%) and nodule leg hemoglobin content (26.6%) in contrast to uninoculated control (Tagore *et al.*, 2013). These findings are in line with that of Ma*ya etal.*,(2012) in chickpea. Similarly, Bhuiyaan *et al.*, (2008) studied the effect of *Rhizobium* inoculation and varieties on nodulation in chickpea and revealed that irrespective of variety, the inoculation significantly enhanced the nodule number and dry weight plant^{-1}.

In a pot experiment, Maliki and Sandhu (2014) reported that inoculation of chickpea with *mesorhizbium* strain Ca-181 significantly enhanced the nodule number, nodule fresh weight and nitrogenize activity in comparison to control. Kumar *et al* (2014) recorded higher nodule number, fresh and dry weight with different *Rhizobium* strains (CAT-4059 and CAT-5078) over the inoculated control. The pathways by which the morphological, developmental and reproductive features of plants in a crop stand contribute to yield are called yield components (Reddy, 2012).

Many researchers have reported positive effect of *Rhizobium* inoculation on various yield components viz. number of pods plant^{-1}, seeds pod^{-1} and 1000-seed weight and ultimately yield in chickpea. El Hadi and Elsheikh (1999) studied the effect of *Rhizobium* inoculation on the grain yield of chickpea and reported that inoculation with *Rhizobium* increased yield by 72 and 70% in the first and second year, respectively, in comparison to inoculated control. The most important N_2 fixing agents in agricultural systems are the symbiotic associations between legumes and the microsymbiont rhizobia bacteria (Giller, 2001). Depending on the availability and effectiveness of the native rhizobia, one way of improving N_2 fixation in grain legumes is inoculation of the crop seeds with effective strains of rhizobia. Despite being mentioned by some as a promiscuous host (Rivas *et al.*, 2007), there is consensus that both nodulation and growth of chickpea can be improved by inoculation (Giller, 2001). The growth and yield of chickpea can be improved by inoculating seeds with competitive strains of rhizobia and this can be an economically feasible way of increasing productivity of chickpea (Ben Romdhane *et al*., 2008). Depending on cultivar, effectiveness of bacterial strain and environmental factors the association of chickpea and *Mesorhizobium cicer* produced up to 176 kg N ha^{-1} annually in India (Rupela *et al*., 1987).

Compared to inoculated control, the increase in number of pods $plant^{-1}$ number of seeds pod^{-1}, 1000-seed weight and seed yield was increased by 21.7%, 10.5%, 0.07% and 36.8% respectively in Rhizobium inoculated chickpea. Aslam *et al.*, (2010) reported significantly higher number of pods $plant^{-1}$ (34.63), grains pod^{-1} (1.78), 1000-grain weight (28.27 g) and grain yield (3696 kg ha^{-1}) in a *Rhizobium* inoculated chickpea increased by 5%, 4.7%, 2.2% and 17.6% respectively, in comparison to uninoculated control. Moreover, enhancement in the protein content of grain was also recorded with inoculation. Some reports indicate increase in the 100-seed weight and grain yield increased by 13.27% and 16.89% when chickpea was inoculated with *Rhizobium* culture as compared to the uninoculated control. Namwar *et al.*, (2011) reported that significantly higher number of pods and grains plant-^{1}, 100-grain weight and grain yield was recorded in chickpea inoculated with *Rhizobium* in comparison to unincoulated control.

In another experiment, Maleki *et al.*, (2014) reported increase in the number of pods $plant^{-1}$, grain weight and grain yield in *Rhizobium* inoculated chickpea in contrast to uninoculated control. Further, as compared to uninoculated control, higher grain and straw yield and ultimately higher HI was recorded with *Rhizobium* inoculation in chickpea inoculation in a clayey and slightly acidic soil (Ogola, 2015). The increase in the yield components through seed inoculation might be due to higher nodulation and more nutrient availability, resulting in vigorous plant growth and dry matter accumulation, which in turn resulted in higher seed yield Erman *et al.*, (2011) conducted a field trial to study the effect of *Rhizobium* on the quality of produce in chickpea and reported that *Rhizobium* inoculation significantly enhanced the seed nitrogen, phosphorus and calcium content increased by 6.1%, 23.1% and 11.6% respectively over uninoculated control. As compared to inoculated control, *Rhizobium* inoculation significantly enhanced the total N and P uptake increased by 31.1% and 39.6% respectively in chickpea over inoculated control (Das *et al* 2012).

The increase in the concentration of N and P in shoots of chickpea with *Rhizobium i*noculation. Moreover, nitrogen and phosphorus uptake by grain was also enhanced as compared to uninoculated control which improved the quality of chickpea produce. Use of *Rhizobium i*noculants also helps in improving available N and P in the soil after crop harvest which can be utilized by the next crop and hence enhances the residual soil nutrient status. Zaidi *et al.*, (2003) reported that available P and N content of soil at the harvest was increased increased by 9.7% and 15.3% in *Rhizobium* inoculated plots as compared to uninoculated control. Moreover, higher soil microbial biomass carbon was found in *Mesorhizbium* inoculated chickpea (Bhattacharjya and Chandra, 2013). (Birhanu and Pant, 2012).

Chandra and Pareek (2015) reported 0.6%, 6.5% and 4.3% higher organic carbon, available N and available P respectively, in a *Rhizobium* inoculated chickpea. This enhancement may be attributed to production of more crop biomass due to inoculation and consequently higher return of organic residues and exudates into the soil enhancing microbial biomass and activities (Babu *et al.*, 2015).

Birhanu and Pant (2012) also reported that chickpea inoculation with *Mesorhizobium* strains gave higher nodule number, nodule dry weight, and biological yield compared to uninoculated plants in Shoa-Robit, Ethiopia.

2.3. Effect of phosphorus and rhizobium

Rhizobium inoculation increased the phosphorus use efficiency because inoculation may influence the P solubilizing mycorrhizal fungi, which are responsible for solubilization of applied and native phosphorus in soil (Cassman *et al.*, 1981). Aslam *et al.*, (2000) studied the effect of phosphorus levels (0, 60, 90 and 120 kg P_2O_5 ha^{-1}) applied to chickpea in combination with various *Rhizobium* strains [viz. Thal-8, TAL-620 and their mixture (1:1)]. Mixture of both *Rhizobium* strains gave the most promising results and significantly increased nodulation, growth and yield even with 60 kg P_2O_5 ha^{-1} while further increase in the phosphorus dose decreased the yield. Finally they concluded that *Rhizobium* inoculation along with phosphorus may decrease the requirement of phosphorus dose without any compromise in yield. Similarly, Ali *et al.*, (2004) conducted a field experiment to determine the effect of *Rhizobium* and P fertilization on chickpea. They revealed that application of phosphorus by 90 kg P_2O_5 ha^{-1} enhanced the grain yield and straw yield by 93.1 and 72.5 per cent in *Rhizobium* inoculated (3088 and 7496 kg ha^{-1}) chickpea compared to control (1599 and 4344 kg ha^{-1}), however, this was statistically at par with 120 kg P_2O_5 ha^{-1} and *Rhizobium* inoculation. Khan *et al.*, (2003) revealed that application of phosphorus by 90 kg P_2O_5 ha^{-1} significantly enhanced grain yield in *Rhizobium* inoculated chickpea compared to control and 90 kg P_2O_5 ha^{-1} alone. Further, grain yield at 90 kg P_2O_5 ha^{-1} × *Rhizobium* was found to be statistically at par with 120 kg P_2O_5 ha^{-1} × *Rhizobium*. They revealed that extra cost of 30 kg P_2O_5 ha^{-1} can be saved by Rhizobium inoculation along with application of 90 kg P_2O_5 ha^{-1}.

Bekere and Hailemariam (2012) studied the interactive effect of *Rhizobium* inoculation and P levels in soybean and reported that significant increase in nodule volume $plant^{-1}$,nodule dry weight, shoot nitrogen content, shoot dry matter, number of pods $plant^{-1}$ was realized when 60 kg P_2O_5 ha^{-1} was accompanied with *Rhizobium* seed inoculation as compared to application of 60 kg P_2O_5 ha^{-1} alone. However, application of 40 kg P_2O_5 ha^{-1} along with *Rhizobium* inoculation was found to be statistically at par with 60 kg P_2O_5 ha^{-1} and *Rhizobium* inoculation. Hence, there was saving of 20 kg P_2O_5 ha^{-1} Hussain *et al.*, (2012) carried out a pot experiment to study the effect of P with and without *Rhizobium* inoculation in mung bean and revealed that 150 per cent of recommended P dose with *Rhizobium* inoculation increased N and P concentration significantly in roots (1.74 and 0.113 mg), shoots (1.79 and 0.223 mg), grains (4.14

and 0.300) and P uptake (290.06 and 25.19 mg plant^{-1}). However, treatment of 100 per cent of recommended dose of P along with *Rhizobium* proved as economical P dose.

2.4. Effects of rhizobia inoculation total N uptake and seed protein content

Total N accumulation in legume plants is one of the best parameters to measure N fixation under experimental conditions. Wondwosen *et al*., (2016) reported that the *Rhizobial* inoculation and N application significantly (P≤0.05) increased total N uptake and seed protein concentration in both pot and second-year field experiments. Compared to uninoculated control treatment, total N uptake was increased by 135, 117, 69 and 22% by inoculation with Cp41, CpSK, and CpNSTC, respectively, in the pot experiment. Similarly, total N uptake was increased by 100, 72, 49 and 24% by Cp41, CpSK, N added treatment, and CpNSTC respectively, over uninoculated control treatments during the 2012/2013 field experiment. The maximum seed protein content (23.3%) was recorded in N fertilizer added treatment, followed by Cp41 strain inoculated treatment (23.2%) under pot experimentation. The maximum seed protein content (20%) was recorded in Cp41 strain inoculated treatment, followed by N fertilizer added treatment and CpSK (18%), during the second-year field experiment. Aslam *et al.*, (2010) reported that inoculants significantly increased grain protein content.

2.5. N Derived from the atmosphere and N fixed by symbiotic rhizobia bacteria

Wondwosen *et al.*, (2016) reported that *Rhizobial* inoculation of chickpea showed great during variation in N derived from the atmosphere and amount of seed N fixed. The mean percentage N derived from the atmosphere varied from 51.5 to 67.9, induced by isolate Cp41 and CpNSTC, respectively, under pot experiment. Similarly, the highest N derived from the atmosphere (53.7%) was recorded in plants inoculated with strain Cp41, whereas the lowest N derived from the atmosphere (29.8%) was shown by the host inoculated with CpNSTC during the second-year field experiment.

Seed inoculation significantly influenced the amount of seed N fixed. It increased from 89 with the CpNSTC inoculant to 261 (mg/pot) with Cp41 inoculant treatments under pot experiments. Similarly, an increase in the amount of seed N fixed, from 29.1 to 62.1 kg/ha was recorded with CpNSTC inoculant and with Cp41 inoculant treatment, respectively the second-year field experiment. These results were comparable with those of Kyei-Boahen *et al.*, (2005), who reported that the proportion and amount of seed N derived from N_2 fixation were higher for inoculated plants as compared with uninoculated controls across locations. There was no significant difference between varieties regarding N derived from the atmosphere and N fixed. Kyei-Boahen *et al.*, (2002) also found that desi and kabuli chickpea types responded similarly to *Rhizobia* inoculation.

Moreover, Wondwosen *et al.*, (2016) indicated that chickpea yield can be improved through proper *Mesorhizobium* inoculation. Inoculation by different strains had a pronounced effect on grain yield, yield component, nodulation, total N uptake, grain protein content, %N on the seed, and amount of seed N fixed as compared to non-inoculation treatments.

Indigenous *Mesorhizobium* strain Cp41 was found to be more significant in its effect for most of the studied parameters, followed by Cp8, CpSK and Cp97, respectively, as compared to the uninoculated control. Indigenous *Mesorhizobium* strain Cp105 and CpNSTC inoculants were found to be ineffective symbiotic nitrogen fixers. This finding agreed with Yadav *et al.,* (2011), in that a *Mesorhizobium* strain indigenous to the growing field Dubie proved to be a highly effective symbiotic nitrogen fixer for uptake of nutrient content and grain yield of chickpea. Others (Evans, 2005) found indigenous *Rhizobium* strains to be more highly effective symbiotic nitrogen fixers for the uptake of nutrient content and grain yield than introduced commercial inoculants.

3. Materials and methods

3.1. Description of the study area

The experiment was conducted at Haramaya University experimental field. The experimental site is situated in Haramaya District, eastern Hararghe Administrative Zone, Oromia regional state, Ethiopia. The area is located at latitude of 9^0 26’ N, longitude of 42^0 03’ E; altitude of 2050 m above mean sea level. The site is representative of a sub-humid mid latitude agro-climatic zone. Rainfall distribution is bimodal, the short rainy season is from March to April while the long rainy season is from June to October. The coolest season of a year of the district is between Octobers to January.

The monthly range of variation in meteorological parameters during the year 2014 (*http://hararconnection.com/hnrs.htm*) are: (i) rainfall 33.4 mm (March) to 211.2 mm (September) (ii) mean minimum temperature 8.1°C (January) to 12.5°C (June) (iii) mean maximum temperature 16.3°C (August) to 28.3°C (May) (iv) relative humidity 51% (March) to 84% (September).The area experiences mean annual precipitation of 780 mm. The mean annual maximum and minimum temperatures are 23.4^0 and 8.25 ^{0}C, respectively (Melese, 2006). The location has Clay loamy soil types with pH values of 7.0.

3.2. Experimental materials

3.2.1. Chickpea variety

The experimental materials tested include three chickpea varieties namely, Teketay, Ejere and Dubie. Among theses two of them Teketay and Ejere were selected among the 10 top high yielding chickpea varieties released by Debre Zeit Agricultural Research Centre (DZARC). Desi and Kabuli type.

3.2.2. Inoculant

Lignite carrier based inoculants of *Sinorhizobium ciceri*, EAL 001 from Mojo East Shoa, Oromiya by Soil Microbiology Laboratory of National Soil Research Center Addis Ababa was used for inoculation of Chickpea.

3.2.3. Phosphorus fertilizer

As source of phosphorus, Triple super phosphate (TSP) containing 46% P_2O_5 were used.

3.3. Soil sampling and analysis

Pre-sowing surface soil samples were collected at 0-30cm diagonally from five spots in the experimental field, then were composited and processed for soil analysis before sowing. Composite soil samples were analysed for organic carbon, total N, soil pH, available phosphorus, cation exchange capacity (CEC) and textural analysis using standard laboratory procedures at Haramaya University soil Laboratory.

Particle size distribution analysis was done by hydrometer method (differential settling within a water column) according to FAO (2008). 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 (1934). Soil organic matter was calculated indirectly from the organic carbon determination (OM% = 1.72 × % OC). Total nitrogen (TN) was analyzed by Micro- Kejeldhal 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 measured after saturating the soil with ammonium acetate (NH_4OAc) and displacing it with NaOAc (Chapman, 1965).

3.4. Treatments and experimental design

The treatments were consisted of three varieties (*Teketay*, *Ejere and Dubie* and four rates of phosphorus (0, 50, 100 and 150 kg ha^{-1} TSP), two levels of bacteria (with and without inoculants). The experiment was laid out as a Randomized Complete Block Design (RCBD) in factorial arrangement 3 × 4 × 2 = 24 treatment combinations and replicated three times. The gross plot size was 2.1 m × 2.4 m (5.04 m^2). A distance of 0.4meter was left between each sub-plot to enable easy management and data collection. During planting, 30 cm between rows and 10 cm intra row spacing were used. Each plot consisted seven rows out of which the outer two rows of one plot from each row was considered as border and one row was used for destructive sampling. The net plot size of the three central rows 0.9 m × 2.4 m (2.16 m^2).

Table 1. Treatments combinations

No	**Without bacteria**		**With bacteria**
1	Teketey + 0kg TSP ha^{-1}	13	Teketey+0kgTSP ha^{-1}+*Sinorhizobium ciceri*
2	Teketey + 50kg TSP ha^{-1}	14	Teketey+50kgTSP ha^{-1}+*Sinorhizobium ciceri*
3	Teketey +100kg TSP ha^{-1}	15	Teketey+100kgTSP ha^{-1}+*Sinorhizobium ciceri*
4	Teketey +150kg TSP ha^{-1}	16	Teketay + 150kgTSP ha^{-1}+Sinorhizobium ciceri
5	Ejere+ 0kg TSP ha^{-1}	17	Ejere + 0kgTSP ha^{-1}+*Sinorhizobium ciceri*
6	Ejere+ 50kg TSP ha^{-1}	18	Ejere+ 50kgTSP ha^{-1}+*Sinorhizobium ciceri*
7	Ejere+ 100kg TSP ha^{-1}	19	Ejere+ 100kgTSP ha^{-1}+*Sinorhizobium ciceri*
8	Ejere+ 150kg TSP ha^{-1}	20	Ejere+ 150kgTSP ha^{-1}+*Sinorhizobium ciceri*
9	Dubie + 0kg TSP ha^{-1}	21	Dubie + 0kgTSP ha^{-1}+*Sinorhizobium ciceri*
10	Dubie + 50kg TSP ha^{-1}	22	Dubie + 50kgTSP ha^{-1}+*Sinorhizobium ciceri*
11	Dubie + 100kg TSP ha^{-1}	23	Dubie + 100kgTSP ha^{-1}+*Sinorhizobium ciceri*
12	Dubie + 150kgTSP ha^{-1}	24	Dubie + 150kgTSP ha^{-1}+*Sinorhizobium ciceri*

3.5. Experimental procedure and field management

The experimental field was prepared starting from the second week of September with tractor and leveled by manpower. The inoculation and planting was done accordingly at the third week of September based on the recommended procedure.

Seeds were inoculated with lignite-based inoculants of *Sinorhizobium ciceri* at the rate of 7 g/kg of seeds as per the treatment. Carrier based cultures were mixed with small amount of 10% solution of sucrose in cool and clean water to form a thick slurry. The slurry was poured over the dry seeds so as to uniformly coat the seeds with the inoculant. All inoculations were done just before planting under shade to maintain the viability of microbial cells.

P was applied according to the treatments at the time of sowing. Weeds were removed by hand weeding and hoeing according to the recommended practice. Harvesting was done when the leaves started to senesces and started shedding, and pods turned yellow.

3.6. Crop data collection and measurement

3.6.1. Phenological and growth parameters

3.7. Data collected

3.7.1. Crop phenology

Days to 50% emergence: Initial stand count at 15 DAS, 50% flowering and 90% maturity were recorded when crop reached the respective phonological stages..

Days to 50% emergence: This was recorded from each plot after more than 50% of the plants emerged.

Initial stand count: The total number of seedlings emerged were counted from the whole seven rows in each plot after 15 DAS.

Days to 50% flowering: Days to 50% flowering was recorded when more than 50% of the plants in each plot attained flowering.

Days to physiological maturity: It was recorded as the number of days from planting to the period when 90% of the stems and pods of the plants in a plot lost their green color and turned to light golden yellow.

Plant height (cm): Five competitive plants from the central rows were randomly selected for measuring plant height at physiological maturity. Plant height was recorded in centimeters by measuring the plant from the surface of soil to the apical bud. The average heights of five plants were recorded from each plot

Number of primary and secondary branches per plant: From the five randomly uprooted plants from rows of the destructive sampling at physiological maturity, both the number of primary and secondary branches were counted and averaged to give number of branches per plant (NBPP).

3.7.2. Nodulation:

The data on nodulation parameters were taken at mid flowering stage of chickpea. Five competitive plants were randomly taken from second border rows from each side of the plot for nodulation parameters (number of nodules, nodule volume and nodule dry weight per plant) and dry weight of plants at mid flowering. In each plot whole root system of a plant were completely exposed and carefully uprooted for determination of nodulation parameters. The roots were gently washed under running tap water over a sieve to avoid loss of detached roots. The nodules from all plants were removed and separately spread on the sieve for some minutes until the water drained off.

Nodules per plant: The total number of nodules was counted at flowering stage and the mean values of five plants were recorded as the average number of nodules per plant.

Numbers of Effective Nodules: Effective nodules were separated by their colors where a cross section of an effective nodule made with a pocket knife showed a pink to dark-red color, whereas a green color indicated non-effective nodulation.

Nodule volume: The collected nodules were immersed in a previously measured volume of water in a measuring cylinder. The volume of water displaced by nodules from five plants were considered as nodule volume and converted to average nodule volume per plant.

Dry Weigh of Total and Effective Nodules: After determination of nodule volume, the nodules were dried in an oven dried at 70°C for 48 hours and their dry weight recorded to give nodule dry weight per plant (NDWPP) at flowering stage. The average of five plants were taken as nodule dry weight per plant.

3.7.3. Yield components and yield of chickpea

Number of total pods per plant: The total numbers of pods were counted from five randomly selected plants from the net plot area at harvest and the means were recorded as number of total pods per plant.

Number of seeds per pod: Five randomly selected plants were threshed then numbers of seeds were counted from five pods per plant and total numbers of seeds were divided by total number of pods to compute average number of seeds per pod.

Above ground dry biomass yield (kg ha^{-1}): This was determined by drying the above ground biomass including the seed yield, from the six plants from rows of the destructive sampling at physiological maturity using sun drier to constant weight and the weight was converted to the number of plants per net plot then kg per hectare.

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

Seed yield (kg ha^{-1}): This was determined from three central rows of the net plot, and the seed yield was adjusted to moisture level of 10%. Finally, yield per plot was converted to per hectare basis and the average yield was reported in kg ha^{-1}

Harvest Index (%): This was recorded as the ratio of dry seed yield per plot to the above ground dry biomass yield per plot taken at physiological maturity.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield} \times 100}{\text{Total above ground dry biomass}}$$

3.8. Data analysis

Analysis of variances for the data recorded and measure was conducted using the General Linear Model (GLM) using GenStat Release 15 (GenStat, 2012). Mean separation was done using Least Significance Difference (LSD) test at 5% level of significance.

3.9. Partial budget analysis

An economic assessment was done using partial budget procedure described by CIMMYT (1988). The variable costs including the phosphorus fertilizer (P) cost was taken at time of planting from Haramaya Woreda Agriculture office and the price of the current chickpea grain at harvest data was taken from Haramaya District Agricultural Bureau office. The cost of *Rhizobium inoculants* was taken from Soil Microbiology Laboratory of National Soil Research Center Addis Ababa. Labor cost per treatment was recorded and used for this analysis.

4. Results and discussion

4.1. Soil characterization of the experimental Site

The physical and chemical properties of the soil of the experimental site namely texture of soil, pH, Total N, OC, available P, CEC were analysed from the composite soil samples collected from (0-30 cm) depth before planting. The result indicated that texture of the soil in the experimental site was dominated by clay loam fraction; Based on particle size distribution, the soil contains 53% sand, 33% clay and 14% silts (Table 2). According to the soil textural class determination triangle, the soil of the experimental site was found to be clay loam soil which is economically very important, highly cultivated, and very fertile, had high water and nutrient holding capacity.

The soil reaction of the experimental site was nearly neutral (pH 7.0). According to Mahler *et al.* (1988) the suitable pH range for chickpea lies between 5.7 and 7.2 in which the availability of nutrient is optimum. Soil pH is an important factor for plant growth, as it affects nutrient availability, nutrient toxicity, and has a direct effect on the protoplasm of plant root cells (Alam *et al.*, 1999). It also affects the abundance and activity of soil organisms (from microorganisms to arthropods) responsible for transformations of nutrients (Nicol *et al.*, 2008).

Total N and OC of the experimental site were found to be below the critical levels for chickpea growth and development, while the available P was at medium level. On the other hand the CEC was found higher than critical level. Chickpea grows well in soils with more than 25 ppm available P, 0.1% N, 25 meq/100g CEC and 1.25% OC. The analysis revealed that the soils available P was 23.215 mg/kg (Table 1). Tekalign *et al*. (1991) described soils with available P <10, 11-31, 32-56, >56 mg/kg as low, medium, high and very high, respectively. This might be due to the availability of soil solubilizing bacteria in the soil and it also associated with the frequent planting of leguminous plant in the experimental field. Thus, the soil of the experimental site was considered as medium in available P content which is satisfactory for optimum chickpea growth and yield. According to Foster (1973), the P response is likely in soils with greater than 20 mg/kg soil extractable P.

Tekalign *et al.* (1991) classified the soil total N availability of <0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and >0.25% as high, respectively. The Netherlands commissioned study by Ministry of Agriculture and Fisheries (1995) classified soil contents for OC (%) >3.50, 2.51-3.5, 1.26-2.50, 0.60-1.25 and <0.60 as very high, high, medium, low and very low, respectively. According to this classification analysis of soil samples from planting depth indicated low level of total N (0.0763%) showing as this nutrient is a limiting factor for optimum crop growth. Organic carbon content of the soil was 0.885% indicating that the soil had low organic carbon content which has low potential of this soil to supply N to plants as it can be used as an index of N availability.

Cation exchange capacity (CEC) is an important parameter of any soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Landon (1991), top soils having CEC greater than 40 cmol (+)/kg are rated as very high and 25-40 cmol (+)/kg as high, 15-25, 5-15 and < 5 cmol (+)/kg of soil are classified as medium, low and very low, respectively in CEC. Based on this classification the soil of experimental site with very high CEC of 53.2 meq/100g soil has a better capacity to retain the cations. The reason might be due to the availability of clay loamy soil built with a large number of negative charges in the clay – colloid surfaces of the soil (Table 2).

Table 2. Selected physicochemical properties of the experimental soil before planting

Physical properties				Chemical properties				
Particles size distribution (%)			Textural class	pH	Total N (%)	OC (%)	Av.P (PPm)	CEC (meq/100g)
Sand	Silt	Clay	Clay loam	7.0	0.0763	0.885	23.22	53.2
53	14	33						

4.2. Phenological and growth parameters of chickpea

4.2.1. Days to 50% emergence

The analysis of varieties showed that the main effects of varieties and P rates resulted in a significant differences ($P \leq 0.05$) on the days to 50% emergence of chickpea (Table 3 and 4). However, the main effects of rhizobium application, interaction effects of varieties V × P rate, V × Rhizobium inoculants, P rate × Rhizobium inoculants, and three way interaction effects of varieties, P rate and Rhizobium inoculation showed significant differences ($P \leq 0.05$) on days to50% emergence.

The effect of varieties significantly influenced days to 50% emergence of the chickpea varieties. The longest day (10.46days) was recorded under Dubie variety followed by Ejere variety (10.42days) whereas variety Teketay resulted in the shortest days (8.29 days) to 50% days to emergence (Table 3 and 4). Significant statistical differences was obtained between the Dubie and Teketay variety at $P \leq 0.05$. The large seed size could be the reason for late emergence of Teketay variety that affects moisture availability for imbibition by the seed to germinate. In line with the findings Asrat *et al*. (2003) reported varietal differences of soybean on days to 50% emergence.Similarly, Phosphorus rates significantly influenced the days to 50% emergency of the chickpea varieties.

The shortest days (9.22 days) was recorded from Teketay variety supplied with 150 kg P ha^{-1} to 50% days to emergence followed by 100 Kg P ha^{-1} (9.67 days). Longest days (10.00) to5 0% emergence was recorded from the application of 0 Kg P ha^{-1} and 50 kg P ha^{-1} which were statistically non-significant ($P>0.05$). Significant difference ($P \leq 0.05$) was observed between 150 and 0 Kg P ha^{-1}rates (Table 3 and 4).The reason for this result might be due to Phosphorus fertilizer that served as a catalyst in numerous biochemical reactions and promoted rapid cell division that encouraged early root formation and improved absorption of H_2O and nutrient healthy roots growth. The results of this study also indicated statistically significant differences ($P \leq 0.05$) on the interaction effects of *Rhizobium cicer,* P rates and variety. Hence, the shortest days (7.33) was resulted from Rhizobium inoculation, 100kg P/ha and Teketay variety followed by same variety without Rhizobium inoculation and 100kg P/ha (7.67 days) and same variety without Rhizobium inoculation and 50kg P/ha (8.00 days) (Table 5). The reason for this result might be due to Phosphorus fertilizer serves as a catalyst in numerous biochemical reactions, promotes rapid cell division, encourage early root formation and improve healthy roots growth. This was in agreement with Asrat *et al*. (2003) who reported varietal differences of soybean on days to 50% emergence.

Table 3. Days to 50% emergency of chickpea as affected by main effect of P rates and varieties.

Treatments	Days to emergence
Variety	
Dubie	10.46a
Teketay	8.29b
Ejere	10.42a
LSD (0.05)	**0.572**
P rates (kg ha^{-1})	
0	10.00a
50	10.00a
100	9.67a
150	9.22a
LSD (0.05)	**0.661**
CV (%)	5.8

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Table 4. Days to 50% emergence of chickpea as affected by interaction effect of P rates and *Rhizobium* inoculants

Phosphorus rate (kg ha^{-1})	*Rhizobium* WI	WoI
0	10.00a	10.00a
50	9.89a	9.44a
100	9.22a	9.22a
150f	10.00a	10.00a
LSD (0.05)	0.935	
CV (%)	10.1	**10.**

Means within a column followed by the same letter are not significantly different at 5% level of significance.
WI=with inoculants, oI=without inoculants

Table 5. Days to 50% emergences of chickpea as affected by interaction effect of varieties, P rates and Rhizobium inoculants.

Variety	P rates (kg ha^{-1})	*Rhizobium* WI	WoI
Dubie	0	10.33ab	10.67a
Dubie	50	10.67a	10.00abc
Dubie	100	10.33ab	10.33ab
Dubie	150	10.67a	10.67a
Teketay	0	8.67cdef	8.67cdef
Teketay	50	8.33def	8.00ef
Teketay	100	7.33f	7.67ef
Teketay	150	9.00bcde	8.67cdef
Ejere	0	11.00a	10.67a
Ejere	50	10.67a	10.33ab
Ejere	100	10.00abc	9.67abc
Ejere	150	10.33ab	10.67a
LSD (0.05)		1.619	
CV (%)		10.1	

Means within a column followed by the same letter are not significantly different at 5% level of significance.*WI=with inoculants; WoI=without inoculant*

4.2.2. Days to 50% flowering

The analysis of varieties showed that the main effects of variety, P an rhizobium inoculants and the two way interactions (variety, P x rhizobium inoculants showed significant ($P \leq 0.05$) effects on days to 50% flowering, but the effect variety x Px rhizobium inoculants was not significant (Appendix Table).

Days to 50% flowering of chickpea was also significantly influenced by the interaction effect of V, P application rate and *Rhizobium* inoculants. Dubie variety treated under0 kg P ha^{-1} with seed inoculation resulted in the longest day (64days) to reach to 50% flowering, while the Teketay variety supplied with 100 kg P $ha^{-1}$with rhizobium and 50 kg P ha^{-1} without *rhizobium* inoculants resulted in the shortest days to flower (42.33 and 42.33 days), respectively (Table 8).

The possible reason for this result might be due to variation in genetic makeup among cultivars and hence P fertilizer serves as a catalyst in numerous biochemical reactions and influences the efficiency of the *rhizobium* legume symbiosis that facilitate formation of nodules on the roots within which the bacteria fix atmospheric nitrogen into ammonia thereby led to vigour growth of chickpea

Table 6. Days to 50% flowering of chickpea as affected by interaction effect of varieties, P rates and Rhizobium inoculants.

		Rhizobium	
		WI	WoI
Variety	P rates (kg ha^{-1})		
Dubie	0	64.00a	56.00bcd
Dubie	50	63.67a	56.67bcd
Dubie	100	58.00 bc	48.33ef
Dubie	150	58.67abc	55.33cd
Teketay	0	57.67bc	50.33ef
Teketay	50	49.67ef	42.67gh
Teketay	100	42.33gh	42.67gh
Teketay	150	47.00fg	40.67h
Ejere	0	61.00ab	53.67cde
Ejere	50	5 1.67def	51.33def
Ejere	100	55.33cd	48.00f
Ejere	150	48.67ef	51.33def
LSD (0.05)		5.48	
CV (%)		5.3	

Means within a column followed by the same letter are not significantly different at 5% level of significance.

WI=with inoculants, WoI=without inoculants.

Table 7. Days to 90% physiological maturity of chickpea varieties as influenced by the main effects of varieties, P rates and Rhizobium inoculants

Treatments	Days to 90% physiological maturity
Variety	
Dubie	120.04a
Teketay	112.38b
Ejere	113.42b
LSD (0.05)	0.72
P rates (kg ha^{-1})	
0	116.89a
50	115.83a
100	114.11a
150	114.28a
LSD (0.05)	0.83
Rhizobium	
WI	116.89
WoI	113.67
LSD (0.05)	0.59
CV (%)	1.1

Means within a column followed by the same letter are not significantly different at 5% level of significance.   WI=with inoculants; WoI= without inoculants.

4.2.3. Days to 90% physiological maturity

Number of days to physiological maturity of the tested chickpea varieties was significantly ($P \leq 0.005$) affected by the main effects of varieties, Phosphorus application rate and Rhizobium inoculants. Similarly, interaction effect of P × R and V × P application rate × Rhizobium inoculation resulted in a significant differences among the treatments tested ($P \leq 0.05$). However the interaction effect of V× P and V × R did not show significant effect on the trait (Table 6, 9 and 10).

Variety Teketay reached to the days to physiological maturity earlier (112.38 days) as compared to variety Ejere (113.42 days) and Dubie variety took the longest days (120 days) among the tested varieties (Table 9). However, significant difference was observed among all tested traits and this can be attributed to the fact that days to maturity in chickpea is the result of genetic makeup of the chickpea varieties. This is in agreement with Triparti *et al*. (2012) reported differences among varieties of chickpea in days to physiological maturity.

Significant variations were observed among the different levels of Phosphorus as to their effects on physiological maturity of tested chickpea varieties. The highest day (119.44) was recorded from the application of 100 kg P ha^{-1}followed by 150 Kg P ha^{-1}that resulted in 117.56 days to maturity? However, the application of 100 Kg P ha^{-1}that resulted in 114.1 days and statistically at par with 150 kg P ha^{-1} (114.3 days) scored the shortest days to reach to maturity of the traits, respectively (Table 4). Significant difference was observed among the tested P rates except between 100 and 150 Kg P ha^{-1}application rates.

Seed inoculation with Rhizobium significantly influenced the days to physiological maturity in chickpea. Inoculation of Rhizobium increased number of days to physiological maturity from 113.67 days to 116.89 days as compared to un inoculated treatment (Table 6, 9 and 10).The interaction effect of phosphorus application rate and *Rhizobium* inoculants significantly affected the days to physiological maturity in chickpea (Table 9).

The longest day (119.44days) to maturity was recorded from the application rate of 0 kg P ha^{-1} with rhizobium inoculation followed by 50 Kg P $ha^{-1}$and 150 Kg P ha^{-1} with *rhizobium* inoculation resulted in 117.56 and 115.67 days respectively, which resulted in a statistically significant differences ($P \leq 0.05$). The possible reason for delayed physiological maturity with seed inoculation might be due to the cumulative effect of P fertilizer application combined with *Rhizobium* inoculants enhanced nitrogen fixation and thereby increased N uptake by plants that contribute to improved vegetative growth of chickpea.

Such positive responseof chickpea shoot development to inoculation and P fertilization was also reported elsewhere on chickpea by Ali *et al*., 2004, Elkoca *et al*., 2007; Verma *et al*., 2013).

The interaction effect of V, P application rate and Rhizobium inoculants significantly influenced ($P \leq 0.05$) days to physiological maturity of chickpea. The application of 0 kg P ha^{-1}, Rhizobium inoculant and Teketay variety resulted in the longest day (115.33 days) to reach physiological maturity followed by the application of 50 kg P ha^{-1}, Rhizobium inoculant and Teketay variety.

The possible reason for delayed physiological maturity might be due to variation in genetic makeup among varieties and cumulative effect of P fertilizer application with combined *Rhizobium* inoculants resulted in higher nitrogen fixation that in turn increase N uptake by plants which eventually improved vegetative growth of the chickpea. However, Teketay variety supplied with 100 kg P ha^{-1} without rhizobium inoculation took the shortest days (109.67 days) to maturity (Table 6, 9 and 10).

Table 8. Days to physiological maturity of chickpea as affected by interaction effect of P rates and Rhizobium inoculants.

	zobium	
Phosphorus rate (kg ha^{-1})	WI	WoI
0	114.89bc	114.33bc
50	115.67bc	114.11bc
100	119.44a	113.33c
150	117.56ab	112.89c
LSD (0.05)	1.18	
CV (%)	1.1	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants, WoI=without inoculants.

Table 9. Days to physiological maturity of chickpea affected by interaction effect of varieties, P rates and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	125.3a	115.00ef
Dubie	50	123.0 b	119.67cd
Dubie	100	120.33c	119.00cd
Dubie	150	120.33 c	117.67de
Teketay	0	115. 33 fg	113.33fgh
Teketay	50	114.0fghi	110.67kl
Teketay	100	11 2.0ijk	109.67l
Teketay	150	113.67fghi	110.3kl
Ejere	0	117.67def	114.67fgh
Ejere	50	115.67fg	112.0ijk
Ejere	100	112.3ijk	111.3jkl
Ejere	150	113.0hij	110.67ijk
LSD (0.05)		2.04	
CV (%)		1.1	

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants; WoI=without inoculants

4.2.4. Plant height

Analysis of variance showed significant ($P \leq 0.05$) main effects of varieties, Phosphorus application rate and Rhizobium inoculation, and the three way interaction effect of V × P application rate × Rhizobium inoculation on plant height of chickpea varieties. However the interaction effect of V× P and V × R, and P × R did not show significant effect on the trait (Table11 and 15).

The plant height of chickpea as affected by varietal differences indicated significant among the tested three varieties. Teketay variety was found to have tallest (55.17 cm) plant in height followed by Ejere variety scored 53.50 cm while the Dubie variety was the shortest (45.42 cm). Teeter variety (55.17cm) was significantly taller than Dubie variety (45.42cm). The variation in height might be due to genetic characteristics of the varieties for this trait. This result was in agreement with Shams (2009) and Rasul *et al*. (2012) who reported significant differences among the genotypes of chickpea in plant height.

The study revealed that application of different rates of Phosphorus has significantly affected the plant height of chickpea varieties.According to the experimental result the tallest plant height (54.28 cm) was recorded from *Kabuli* chickpea supplied with 150 kg P ha^{-1}which was statistically at par with 100 kg P ha^{-1}(52.78 cm) treatment level that followed by 50 Kg P ha^{-1}(50.78 cm).The application of 0 Kg P ha^{-1} resulted in the shortest height (47.61 cm) (Table 11). In the other way, significant difference was observed among the tested P rates except between the application of 100 and 150 Kg Pha^{-1}.

Seed inoculation with *Rhizobium* significantly influenced the plant height of chickpeas. Accordingly inoculation of *Rhizobium* increased the plant height from 50.61 cm to 52.11 cm (Table 11 and 15).The increment of plant height due to *Rhizobium* inoculation might be due to the adequate amount of nitrogen fixed by the bacteria which promoted vegetative growth of the plants. This result was in agreement with Togay *et al*. (2008) who reported that inoculation with *Rhizobium* significantly increased the plant height. Saini *et al*. (2004) and Ogutcu *et al*. (2008) also reported the same results in chickpea. Significant increase in plant height, primary branches and secondary branches might be due to enhanced nitrogen fixation assisted by seed inoculation with *Rhizobium* inoculants. Similar results among chickpea had also been reported by Dutta and Bandyopadhyay(2009), Ahmed *et al*. (2010) and Shukla *et al.*(2013). Raza *et al*. (2004) and Sajid *et al*. (2011) also found that *Rhizobium* inoculation increased plant height of mungbean and groundnut, respectively.

The interaction effect of V, P application rate and Rhizobium inoculation significantly influenced the plant height of chickpea. Teketay variety inoculated with Rhizobium and applied withb150kg P per ha resulted in the highest plant height (60.67cm which was statistically similar in value with Ejere variety (57.8.00cm). In the other way, Dubie variety treated with 0 kg P ha^{-1} without and with rhizobium inoculation scored shortest plant height (44.83cm and 46.00cm) respectively (Table 11 and 15).The variation in increment of plant height could be due to variations in genetic makeup among cultivars, nitrogen fertilizer fixed by the bacteria through inoculation and the effect of P fertilizer application on meristematic cell activities that played a vital role in vegetative growth of chickpea.

Table 10. Plant height of chickpea affected by interaction effect of varieties, P rates and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	43.00i	43.06i
Dubie	50	45.33ghi	43.67hi
Dubie	100	45.00ghi	45.67ghi
Dubie	150	47.67fghi	47.00ghi
Teketay	0	52.33bcdef	49.00defg
Teketay	50	55.33b	53.67bcd
Teketay	100	57.33ab	56.00ab
Teketay	150	60.67a	57.00ab
Ejere	0	49.67cdefg	48.67defgh
Ejere	50	53. 67bcd	53.00bcde
Ejere	100	55.33b	54.83bc
Ejere	150	57.00ab	56.83ab
LSD (0.05)	5.13		
CV (%)	6.1		

Means within a column followed by the same letter are not significantly different at 5% level of significance.
WI=with inoculants; Wo RI=without inoculants

4.2.5. Number of primary branches per plant

Significant (P≤ 0.05) differences in the number of primary branches per plant was observed due to the main effects and interaction effects. The main effects of varieties and Rhizobium inoculation, and the interaction effect of V × R and V × P application rate × Rhizobium inoculation revealed significant effect on number of primary branches per plant. However the main effects of P rate and interaction effect of V× P and P × R did not indicate significant effect on the trait (Table 12, 13, and 14).

The effect of varieties on number of primary branches on the other hand showed significant difference among chickpea varieties. Ejere variety produced the highest number (4.625) of primary branches followed by the Dubie ()Shumbira dimtu (4.43) and Teketay (4.45). Significant difference ($P \leq 0.05$) was observed between Ejere and Dubie (Shumbira dimtu) varieties while there was no significant difference between variety Teketay and Dubie (Shumbira dimtu) (Table 12, 13 and 14).The possible reason is due to genetic makeup of the cultivars. In agreement with this result, significant variations in number of primary and secondary branches per plant among different genotypes of chickpea were reported by Ali *et al*. (2008) and Syed *et al*. (2012).

The seed inoculation with *Rhizobium* inoculant significantly influenced the number of branches in chickpea. Hence seed inoculation with *Rhizobium* inoculants enhanced the number of primary branches of chickpea from 4.314 to 4.689 (Table 12).The increase in primary branches might be due to enhanced nitrogen fixation by seed inoculation with *Rhizobium* inoculants that initiate bacteria in root nodule to fix N that assist . This result has happened due to the roles played by the fixed Nitrogen through inoculation that reflected on enhancements of primary branches.

The interaction effects of variety and seed inoculation with *Rhizobium* inoculant on number of primary branches per plant were also found significant at $P \leq 0.05$(Table 13). The highest number of primary branches per plant was produced by Teketay inoculated with *Rhizobium* inoculants (4.79) followed by Ejere variety with *Rhizobium* inoculants (4.77). This is in agreement with the report of Dutta and Bandyopadhyay (2009) and Ahmed *et al*. (2010) which stated a positive and significant effects of inoculation and P fertilization on the number of branches of chickpea.

The interaction effect of V, P application rate and Rhizobium inoculants was significantly influenced ($P \leq 0.05$) number of primary branches of chickpea. The application of 100 and 150kg P per ha with rhizobium inoculation resulted in the highest number of primary branches of Teketay (5.0) and Ejere (4.9).

The Dubie ()Shumbira dimtu variety supplied with 0, 50 and 100 kg P ha^{-1} without *Rhizobium* inoculation yielded the lowest number of branches (4.2, 4.2 and 4.3) respectively (Table 12).This can be attributed to the variation in genetic nature among chickpea varieties with the cumulative effect of phosphorus fertilizer rate on chickpea varieties and *Rhizobium* symbiosis which resulted in the initiation of bacteria in root nodule to fix N that assist vigorous growth of cultivars toproduce more primary branches.

Table 11. Number of primary branches per plant of chickpea varieties as influenced by the main effect of varieties and Rhizobium inoculants

Treatments	NPB/plant
Variety	
Dubie	4.43b
Teketay	4.45ab
Ejere	4.63a
LSD (0.05)	0.11
Rhizobium	
WI	4.69
WoI	4.31
LSD (0.05)	0.09
CV (%)	4.4

Means within a column followed by the same letter are not significantly different at 5% level of significance.

NPB=number of primary branch; WI=with inoculant; WoI= without inoculant

Table 12. Number of primary branches per plant of chickpea varieties as influenced by the interaction effect of varieties and Rhizobium inoculants

Variety	*Rhizobium* WI	WoI
Dubie	4.51b	4.35b
Teketay	4.79a	4.11c
Ejere	4.77a	4.48b
LSD (0.05)	0.16	
CV (%)	4.4	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with ino culant; WoI= without inoculant.

Table 13. Number of primary branches per plant of chickpea affected by interaction effect of varieties, P rates and Rhizobium inoculants.

Variety	P rates (kg ha^{-1})	`*Rhizobium* WI	WoI
Dubie	0	4.56cdef	4.2ghi
Dubie	50	4.56cdef	4.2ghi
Dubie	100	4.8abc	4.3fghi
Dubie	150	4.1hi	4.7abcd
Teketay	0	4.57cdef	4.43defg
Teketay	50	4.70abcd	4.00i
Teketay	100	5.00a	4.00i
Teketay	150	4.9ab	4.00i
Ejere	0	4.8abc	4.3fghi
Ejere	50	4.7abcdd	4.3fghi
Ejere	100	4.67cde	4.58cdef
Ejere	150	4.90ab	4.38efgh
LSD (0.05)		0.32	
CV (%)		4.4	

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants, WoI=without inoculant

4.2.6. Number of secondary branches per plant

Analysis of variance indicated significant ($P \leq 0.05$) differences among treatment levels of variety, P application rates and rhizobium inoculants on the number of secondary branches of chickpea. Hence, the main effects of varieties, Phosphorus application rate and Rhizobium inoculation, and the three way interaction effect of V × P application rate × Rhizobium inoculation show significant effect on number of secondary branches per plant. However, the interaction effect of V× P and V × R, and P × R was found non-significant (Table 15 and 16).

The effect of varieties on number of secondary branches indicated significant differences among chickpea varieties. Teketay variety produced the highest number (15.80) of secondary branches followed by variety Ejere (15.08) and the Dubie variety produced lowest number (11.97) of secondary branches (Table 15). However, significant difference in secondary branches was observed among all tested kabuli and desi chickpea varieties. The possible reason could be due to distinction in genetic makeup of the cultivars. In agreement with this, significant variations in number of primary and secondary branches per plant among the different genotypes of chickpea were reported by Ali *et al*. (2008) and Syed *et al*. (2012).

Phosphorus application rates resulted in a non significant results ($P>0.05$) on the number of secondary branches per plant in chickpea varieties. The maximum number (14.37) of branches per plant was produced by both kabuli and desi chickpea received 50 Kg P ha^{-1} which was statistically at par with 100 kg P ha^{-1} (14.34). (Table 15). This result was in line with Ogutcu *et al*. (2008) and Togay *et al*.(2008) who reported that inoculation with *Rhizobium* significantly increased number of branches in chickpea. Similar results in chickpea have also been reported by Dutta and Bandyopadhyay (2009), Ahmed et al. (2010) and Shukla *et al.* (2013). Namvar *et al*. (2013) also found that the greatest number of branches per plant was recorded in inoculated chickpea plants.

The interaction effect of V, P application rate and Rhizobium inoculants also significantly influenced ($P<0.05$) the number of secondry branches. Teketay variety supplied with 50kg P ha^{-1} and with Rhizobium inoculants produced the highest number (18.20) of secondary branches per plant followed by the same variety supplied with 150 Kg P ha^{-1} (17) and Ejere variety supplied with 50 Kg P ha^{-1} (16.43). The response of secondary branches per plant to the interaction effect of variety, phosphorus and *Rhizobium* inoculants might be due to higher vegetative growth of the plants under higher N by BNF availability as a result of cumulative effect of phosphorus fertilizer rate on chickpea varieties and *Rhizobium* symbiosis hence chickpea produces most of its primary and secondary branches during the early vegetative growth period. This study was in line with Dutta and Bandyopadhyay (2009) and Ahmed *et al*. (2010) who reported positive and significant effects of inoculation and P fertilization on number of branches of chickpea.

Table 14. Plant height and number of secondary branches per plant of chickpea varieties as influenced by the main effect of varieties, P rate and Rhizobium

Treatments	PHT	NSB/plant
Variety		
Dubie	45.42b	11.97b
Teketay	55.17a	15.80a
Ejere	53.50a	15.08a
LSD (0.05)	1.812	0.903
P rates (kg ha^{-1})		
0	47.61c	14.27a
50	50.78bc	14.37a
100	52.78ab	14.34a
150	54.28a	14.14a
LSD (0.05)	2.093	1.042
Rhizobium		
WI	52.11	14.35
WoI	50.61	14.22
LSD (0.05)	1.48	0.74
CV (%)	6.1	10.9

Means within a column followed by the same letter are not significantly different at 5% level of significance.PHT=plant height, NSB=number of secondary branch

Table 15. Number of secondary branches per plant of chickpea affected by interaction effect of varieties, P rates and Rhizobium inoculants.

Variety	P rates (kg ha^{-1})	Rhizobium WI	Rhizobium WoI
Dubie	0	11.67ij	13.10ghi
Dubie	50	13.33ghi	9.57
Dubie	100	11.30i	12.57hi
Dubie	150	12.77hi	11.43ij
Teketay	0	14.47bcdefgh	16.87abc
Teketay	50	18.20a	14.23defgh
Teketay	100	15.10bcdefgh	14.97bcdefgh
Teketay	150	17.00ab	15.57bcdefg
Ejere	0	13.63fghi	15.90abcdef
Ejere	50	14.47bcdefgh	16.43abcd
Ejere	100	15.90abcdef	16.23abcde
Ejere	150	14.33cdefgh	13.77efghi
LSD (0.05)		2.55	
CV (%)		10.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants, WoI=without inoculants

4.3. Nodulation per plant

Analysis of variance showed significant (P≤0.05) differences in nodulation of tested kabuli and desi chickpea varieties. Main effects of varieties, P application rate and Rhizobium inoculation, and all the interaction effect of V × P, V × R, P × R and V × P application rate × Rhizobium inoculation showed significant effect ontotal numbers of nodules, numbers of effective nodules, dry weigh of total nodules and dry weigh of effective nodules (Table 17). Nodulation and growth of chickpea can be improved by inoculation (Giller, 2001). The inoculation of seeds with *Rhizobium* is known to increase nodulation, N uptake, growth and yield parameters of legume crops (Erman *et al.*, 2011; Namvar *et al.*, 2011).

Table 16. Numbers of total nodules, numbers of effective nodules, dry weigh of total nodules of chickpea varieties as influenced by the main effect of varieties, P rate and *Rhizobium*

Treatments	TNN/plant	ENN/plant	DWTN/plant
Variety			
Dubie	61.96c	57.50c	0.19b
Teketay	80.42a	75.62a	0.26a
Ejere	76.71b	71.50b	0.15c
LSD (0.05)	2.02	1.944	0.03
P rates (kg ha^{-1})			
0	69.39b	64.72b	0.1544b
50	71.89ab	67.06ab	0.2150ab
100	74.61ab	69.83ab	0.2456a
150	76.22a	71.22b	0.192ab
LSD (0.05	2.01	2.25	0.04
Rhizobium			
WI	73.39	68.47	0.24
WoI	72.67	67.94	0.16
LSD (0.05)	0.71	1.59	0.02
CV (%)	14.3	4.9	27.9

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculants.

4.3.1. Total numbers of nodules per plant

The effect of varieties on total numbers of nodules revealed a significant differences among chickpea varieties. Teketay variety produced the highest numbers (80.42) of total nodules followed by Ejere (76.71) and Dubie (61.96) varieties respectively (Table 17).

Phosphorus application rates had significant effect on total numbers of nodules. The maximum numbers of total nodules was produced by *kabuli* and desi chickpea varieties that received 150 Kg P ha^{-1} (76.22) followed by 100kg P ha^{-1} (74.61) and 50Kg P ha^{-1}(71.89) which were resulted in statistical significant differences ($p \leq 0.05$)

over control (61.96) (Table 17). This could be due to P fertilization stimulates root growth, photosynthesis and increases hydraulic conductibility of roots. Several reports showed that nodulation and nitrogen fixation of most leguminous crops is associated positively with phosphorus fertilization (Bereke and Haile Mariam, (2012); Muhammad, (2010).

Seed inoculation with *Rhizobium* inoculant significantly (P $\leq$0.05) influenced total numbers of nodules in chickpea. Inoculation of chickpea seed mixed with Rhizobium increased the total number of nodules (72.67 to 73.39) as compared with uninoculated seed (Table 17). In line with this results Tagore *et al.* (2013) and Hussain *et al.* (2011) reported significant increase of number of nodules per plant in inoculated common bean, chickpea and mash bean, respectively.

The interaction effect of variety and P application rate on total numbers of nodules was found significant at P$\leq$0.05. Teketay variety supplied with 150 Kg P ha^{-1} produced the maximum number (84.50) total number nodules followed by same variety supplied with 100 kg P ha^{-1} (82.83) and 50 Kg P ha^{-1} (79.00) (Table 18).
Similarly, the interaction effect of variety and seed inoculation with *Rhizobium* inoculant on total numbers of nodule was found significant differences at P$\leq$0.05. Teketay variety inoculated with *Rhizobium* inoculants produced the maximum number of total nodules (81.00) followed by same variety without Rhizobium inoculants (79.83) and Ejere variety without Rhizobium inoculants (76.83) (Table 19).

Significant effect was observed between the interaction of phosphorus fertilizer rate application and seed inoculation with *Rhizobium* inoculants on the total number of nodules per plant of the *kabuli and desi* chickpea varieties. The highest number of nodules per plant recorded when the seeds were inoculated with *Rhizobium* inoculants at fertilizer rate of 150 kg P ha^{-1}(77.56) followed by *Rhizobium* inoculants at fertilizer rate of 100 kg P ha^{-1}(75.00) and 150kg P ha^{-1} without Rhizobium (74.89) whereas the lowest number of total nodules per plant recorded when the chickpea was not supplied with phosphorus and without Rhizobium inoculants (69.33) (Table 20).

The increase in number of nodules per plant with phosphorus application could be due to that P is required for plant growth, nodule formation and development, and vital for N_2 fixation. The increase in the number of nodules was probably due to the interaction effect of seed inoculation with *Rhizobium* strain and application of phosphorus increased nodulation activities of root in chickpea. Similarly, Fatima *et al.* (2007) reported in soybean that nodule formation was more sensitive to P deficiency than plant growth and application of phosphorus improve nodulation parameters when compare d with inoculation without phosphorous fertilizer. Likewise, Rift (2008) reported that inoculation along with phosphorus fertilizer had a significant effect on nodulation, %P and N on mung bean. Such positive effects of P and inoculant on legume nodulation also reported by other studies conducted on common bean in Ethiopia (Yoseph, 2011). Morad *et al*. (2013) also reported observed that the seed inoculation with proper *Rhizobium* together with minor amounts of P 13 kg ha-^{1} at early growth stage stimulated the root nodulation and improved grain weight. Number of total nodules per plant in chickpea was significantly influenced by the interaction effect of V, P application rate and *Rhizobium* inoculants.

Teketay variety supplied with 150 kg P ha^{-1} inoculated with Rhizobium produced the highest number (87.33) of total nodules per plant followed by Teketay variety supplied with 100 Kg P ha^{-1}(82.67) and same variety supplied with 100kg P per ha^{-1}without inoculants (83.00) (Table 21).

This suggests that differences in the performance of the cultivar genotype, introduction of inoculants that increase number of the *Rhizobium* bacteria which infect the roots to form nodules and the essentiality of fertilizer during nodulation for *Rhizobium* bacteria to convert atmospheric N_2 into an ammonium ($NH4^+$) form usable by crops that initiate and develop root nodule eventually resulted in higher total nodules (Birhanu and Pant, 2012)

Table 17. Total numbers of nodules per plant of chickpea as affected by interaction effect of variety and P rates

	Phosphorus levels (kg ha^{-1})			
Variety	0	50	100	150
Dubie	59.17e	60.50e	62.83de	65.33d
Teketay	75.33bc	79.00b	82.83a	84.50a
Ejere	73.67c	76.17bc	ʼ 8.17 b	78.83b
LSD (0.05)		4.08		
CV (%)		4.8		

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculants

Table.18. Total Numbers of Nodules per Plant of chickpea varieties influenced by the interaction effect of varieties and Rhizobium inoculants

Variety	Rhizobium	
	WI	WoI
Dubie	62.58c	61.33c
Teketay	81.00a	79.83ab
Ejere	76.58b	76.83b
LSD (0.05)	2.857	
CV (%)	4.8	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculants

Table 19. Total numbers of nodules per plant of chickpea as affected by interaction effect of P rates and Rhizobium inoculants.

P rate (kg ha^{-1})	Rhizobium	
	WI	WoI
0	69.44a	69.33a
50	71.56a	72.22a
100	75.00a	74.22a
150	77.56a	74.89a
LSD (0.05)	3.299	
CV (%)	4.8	

Means within a column followed by the same letter are not significantly different at 5% level of significance.Wi=with inoculants; WoI=without inoculants

Table 20. Total numbers of nodules per plantof chickpea as affected by interaction effect of varieties, P rates and *Rhizobium* inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	59.33e	59.00e
Dubie	50	61.00de	60.00e
Dubie	100	63.67de	62.00e
Dubie	150	66.33d	64.33e
Teketay	0	75.33c	75.33c
Teketay	50	78.67bc	79.33bc
Teketay	100	82.67ab	83.00ab
Teketay	150	87.33a	81.67ab
Ejere	0	73.67c	73.67c
Ejere	50	75.00c	77.33bc
Ejere	100	78.67bc	77.67bc
Ejere	150	79.00bc	78.67bc
LSD (0.05)		5.713	
CV (%)		4.8	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants;WoI=with inoculants

4.3.2. Numbers of effective nodules

The effect of varieties on effective numbers of nodules per plant showed significant difference ($P \leq 0.05$) in chickpea. Teketay variety produced the highest numbers (75.52) of effective nodules followed by Ejere variety (71.50), while Dubie variety produced significantly lowest number of effective nodules (57.50) (Table 17). Significant difference was observed among all tested varieties.

Phosphorus application rate indicated significant effect on effective numbers of nodules per plant in chickpea. The maximum numbers of effective nodules per plant was produced by kabuli and desi chickpea varieties treated with 150 Kg P ha^{-1} (71.22) followed by 100 kg P ha^{-1} (69.83) and 50Kg P ha^{-1} (67.06), whereas without phosphorus application produced lowest numbers (64.72) of effective nodules per plant (Table 17).

Seed inoculation with *Rhizobium* inoculant significantly influenced the effective number of nodules per plant in chickpea. Inoculation of chickpea seed with *Rhizobium* enhanced the numbers of effective nodules per plant from 67.94 to 68.47. (Table 17).

The interaction of variety and P application rate significantly affected the effective numbers of nodules per plant in chickpea (Table 22). The maximum numbers of effective nodules per plant was produced by Teketay variety treated with 150 Kg P ha^{-1} (79.50) followed by 100kg P ha^{-1} (77.83). The lowest numbers of effective nodules per plant was produced by Dubie variety (54.50) with no phosphorus produced (Table 22).

The study also indicated significant effect of variety and seed inoculation with *Rhizobium* inoculant on effective numbers of nodules per plant in chickpea (Table 23). Teketay variety inoculated with *Rhizobium* inoculants produced the maximum numbers (76.25) of effective nodules per plant followed by Ejere variety (71.17) inoculated with *Rhizobium* inoculants. The Dubie variety with and without inoculants produced significantly lowest numbers (58 and 57) of effective nodules per plant (Table 23).

The interaction of phosphorus fertilizer rate and seed inoculation with *Rhizobium* inoculant on the effective numbers of nodules per plant was also found significant on *Kabul and desi v*ariety (Table 24). The highest numbers of effective nodules per plant was recorded with the inoculation of rhizobium and from the application of 150 kg P ha^{-1} (72.33) followed by the inoculation of rhizobium and from the application of 100 kg P ha^{-1} (70.22) and with the application of 150 kg P ha^{-1} without bacteria (70.11) respectively (Table 24). This might be due to the availability of inorganic P in the soil solution already built from the frequent planting of leguminous plants in the experimental field. In line with this study (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 the effective root nodulation and increase biological nitrogen fixation eventually giving higher yields.

Number of effective nodules per plant in chickpea was significantly influenced by the interaction effect of V, P application rate and *Rhizobium* inoculants. Teketay variety inoculated with rhizobium supplied with 150 kg P ha^{-1}produced the highest numbers (82.00) of effective nodules per plant followed by Teketay variety inoculated with rhizobium and supplied with 100 Kg P ha^{-1} (77.67) and 50Kg P ha^{-1} (73.67) respectively.

The Dubie variety supplied with 0 kg P ha^{-1} with *rhizobium* inoculants yielded the lowest numbers (54.33) of effective nodules per plant (Table 25). This suggests that differences in the performance of chickpea varieties with *Rhizobium* inoculants compatibility and phosphorus fertilizer application that resulted in improved symbiotic relation between root bacteria and legume plant by providing energy duet increased rate of nitrogen fixation influence the effectiveness of nodules (Morad *et al*., 2013) .

Table 21. Numbers of effective nodules per plant of chickpea as affected by interaction effect of variety and P rates

Variety	Phosphorus levels (kg ha^{-1})			
	0	50	100	150
Dubie	54.5f	56.00ef	58.50de	61.00c
Teketay	71.17bc	74.00b	77.83a	79.50a
Ejere	68.50c	71.17bc	73.17b	73.17b
LSD (0.05)		3.889		
CV (%)		4.9		

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculants

Table 22.Numbers of effective nodules per plant of chickpea varieties influenced by the interaction effect of varieties and Rhizobium inoculants
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Variety	*Rhizobium* WI	WoI
Dubie	58.00d	57.00d
Teketay	76.25a	75.00ab
Ejere	71.17c	71.83bc
LSD (0.05)		2.75
CV (%)		4.9

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants; WoI=without inoculants.

Table 23. Numbers of effective nodules per plant of chickpea affected by interaction effect of P rates and Rhizobium inoculants.

P rate(kg ha^{-1})	*Rhizobium* WI	WoI
0	64.67a	64.78a
50	66.67a	57.44a
100	70.22a	69.44a
150	72.33a	70.11a
LSD (0.05)	3.175	
CV (%)	4.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance.. WI=with inoculants; WoI=without inoculants.

Table 24. Numbers of effective nodules per plantof chickpea affected by interaction effect of varieties, P rates and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Local	0	54.33i	54.67hi
Local	50	56.33hi	55.67hi
Local	100	59.33ghi	57.67ghi
Local	150	62.00g	60.00gh
Teketay	0	71.33 def	71.00ef
Teketay	50	73.60bcdef	74.33bcde
Teketay	100	77.67 abc	78.00ab
Teketay	150	82.00a	76.67bcd
Ejere	0	68.33f	68.67f
Ejere	50	70.00ef	72.33cdef
Ejere	100	73.67bcdef	72.67bcdef
Ejere	150	72.67bcdef	73.67bcdef
LSD (0.05)		5.5	
CV (%)		4. 9	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants, WoI=without inoculants

4.3.3. Dry weight of total nodules

The effect of varieties on dry weight of total nodules per plant showed significant difference (P≤0.05) among the chickpea varieties. Teketay variety produced the highest dry weight (0.26gm) of total nodules per plant whereas Dubie and Ejere varieties produced significantly lowest dry weight (0.1987gm and 0.15gm) of total nodules per plant, respectively (Table 17).

Phosphorus application rates significantly affected dry weight of total nodules per plant of chickpea varieties. The maximum dry weight of total nodules per plant was produced by Kabuli and desi chickpea variety that received 100Kg P ha^{-1} (0.25gm) followed by 50 kg P ha^{-1} treatment level (0.22 gm) and 150 Kg P ha^{-1} (0.19 gm) dry weight which was statistically different value with 100Kg P ha^{-1} (0.25gm). The chickpea variety without phosphorus produced significantly lowest dry weight (0.15 gm) of total nodules per plant (Table 17). The possible reason for lowest number of nodule dry weight might be due to either deficiency of phosphorus in soil or fixation of the available phosphorus in the soil. Contrary with this result, Tahir *et al*. (2009) reported that application of P alone significantly increased root length and root dry weight by 33 and 64% over the control.

The dry weight of total nodules per plant in kabuli and desi chickpea was significantly influenced by seed inoculation with *Rhizobium* inoculant. Inoculation of chickpea seed with *Rhizobium* enhanced the dry weight of total nodules per plant from 0.169 gm to 0.24 gm (Table 17). The increment of nodule dry weight by *Rhizobium* inoculation might be due to higher fixation activity in nodulated chickpea compared with inoculated. Similarly, increased nodule dry weight with inoculation has been reported by Vargas *et al.* (2000), Bhuiyan *et al.* (2008) and Ahmed (2013) on dry bean, chickpea and soybean, respectively.

The interaction effect of variety and P application rate on dry weight of total nodules per plant was found significant. Teketay variety treated with 100 Kg P ha^{-1} produced maximum dry weight (0.43 gm) of total nodules per plant followed by the same variety supplied with 50 Kg P ha^{-1} (0.4 gm) dry weight total nodule. (Table 26).This could be due to differences in Phosphorus use efficiency between varieties. Significant differences among dry weight of total nodules per plant were observed as a result of the interaction effect of variety and seed inoculation with *Rhizobium* inoculants. Teketay variety inoculated with *Rhizobium* inoculants produced the maximum (0.32 gm) dry weight of total nodules per plant followed by Dubie variety inoculated with *Rhizobium* inoculants that produced 0.25 gm dry weight. In the other way the Ejere variety without inoculants produced significantly lowest (0.15 gm) dry weight of total nodules per plant (Table 27). The possible reason for this result might be due to the fact that presences of variation in genetic make-up differently respondto the interaction effect of phosphorus rate and *rhizobium* inoculants that eventually led to higher dry weight of effective nodules through increased BNF availability.

Table 25. Dry weight of total nodules per plant of chickpea as affected by interaction effect variety and P rates

	Phosphorus levels (kg ha^{-1})			
Variety	0	50	100	150
Dubie	0.2bcd	0.25bc	0.28bc	0. 27bc
Teketay	0.2bcd	0.4a	0.43a	0.24ab
Ejere	0.13de	0.10d	0.21bc	0.15cd
LSD (0.05)		0.09		
CV (%)		27.9		

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Table 26.Dry weight of total nodules per plant of chickpea varieties influenced by the interaction effect of varieties and *Rhizobium* inoculants *WI=with inoculants;*

	Rhizobium		
Variety	WI		WoI
Dubie	0.25b		0.14c
Teketay	0.32a		0.19bc
Ejere	.0.15c		0.15c
LSD (0.05)		0.05	
CV (%)		27.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants; WoI=without inoculants.

Table 27. Dry weight of total nodules per plant of chickpea affected by interaction effect of P rates and Rhizobium inoculants.

	Rhizobium		
P rate (kg ha^{-1})	WI		WoI
0	0.178bcd		0.13d
50	0.25ab		0.17bcd
100	0.31a		0.18bcd
150	0.22bc		0.17cd
LSD (0.05)		0.05	
CV (%)		27.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculants.

Table 28. Dry weight of total nodules per plant of chickpea affected by interaction effect of varieties, P rates and Rhizobium inoculants

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	0.20bcde	0.13def
Dubie	50	0.25b	0.20bcde
Dubie	100	0.28b	0.12ef
Dubie	150	0.27b	0.13ef
Teketay	0	0.20bcde	0.11ef
Teketay	50	0.40a	0.23bc
Teketay	100	0.43a	0.22bcd
Teketay	150	0.24bc	0.23bc
Ejere	0	0.133	0.15cdef
Ejere	50	0.11ef	0.10f
Ejere	100	0. 22bcd	0.20bcde
Ejere	150	0.15def	0.13def
LSD (0.05)		0.09	
CV (%)		27.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance.

WI=with inoculants, WoI=with inoculants

4.3.4. Dry weight of effective nodules

The analysis on the effect of varieties on dry weight of effective nodules per plant revealed significant differences (P≤0.05) on chickpea varieties. Teketay Variety produced the highest (0.14 gm) dry weight of the effective nodulesfollowed by the Dubie (0.13) and Ejere (0.11) varieties (Table 30). Similarly. Phosphorous rates resulted in a significant differences (P≤0.05) on the dry weight of effective nodules per plant of the chickpea (Table 30). The maximum dry weight of effective nodules per plant was produced by both kabuli and desi chickpea that received 100 Kg P ha^{-1}(0.15 gm) followed by 50 kg P ha^{-1}(0.13 gm) and 0 Kg P ha^{-1}(0.11 gm) (Table 30).

Seed inoculation with *Rhizobium* inoculant significantly influenced the dry weight of effective nodules per plant in chickpea. Inoculation of chickpea seed increased the dry weight of effective nodules per plant from 0.12 to 0.14 gm (Table 30). The interaction effects of Rhizobium inoculation and Phosphorous rates resulted in a significant differences ($P \leq 0.05$) on dry weight of effective nodules per plant. The maximum effective dry weight nodule was recorded by 100kg P per ha (0.19gm) followed by 50kg per ha (0.138gm) without rhizobium bacteria and 50 kg of P per ha with Rhizobium bacteria inoculation (0.13gm) (Table 33).

Moreover, the interaction effect of variety and Rhizobium resulted in a significant differences ($P \leq 0.05$) on dry weight of effective nodules number per plant. The maximum number of effective dry weight of nodule per plant was recorded by Teketay variety inoculated with Rhizobium bacteria(0.14gm) and same variety without rhizobium bacteria (0.14gm) (Table 32).Similarly, the interaction effect of variety and P application rate on dry weight of effective nodules per plant on chickpea resulted in a statistical difference at $P \leq 0.05$. Teketay variety supplied with 100 Kg P ha^{-1}(0.19gm) produced the maximum dry weight of effective nodules per plant followed by Dubie variety supplied with 50 kg P per ha produced (0.16 gm) and Teketay (0.15 gm) respectively (Table 31). This could be due to differences in Phosphorus use efficiency between the three varieties. Results obtained in this study were in agreement with Mahamood *et al.* (2009). Mugendi *et al*. (2010) who reported significant differences between soybean varieties and observed significant positive responses to P application.

The dry weight of effective nodules per plant in chickpea was significantly influenced by the interaction effect of V, P application rate and *Rhizobium* inoculants. Teketay variety supplied with 150 kg P ha^{-1} inoculated with *Rhizobium* inoculants produced the highest (0.2 gm) dry weight of effective nodules per plant which was statistically at par with Dubie treated with 50 Kg P ha^{-1} (0.2 gm). (Table 34).This could be due to differences in the performance of the cultivar genotype with seed inoculation and phosphorus fertilizer supplied that increased rate of nitrogen fixation through its effects on growth and survival of *rhizobia*, nodule formation and functioning, and affecting uptake of nutrients and water on chickpea growth finally improved effectiveness of dry weight.

Table 29. Dry weight of effective nodules of chickpea varieties as influenced by the main effect of varieties, P rates and Rhizobium inoculants.

Treatments	DWEN/Plant
Variety	
Dubie	0.13ab
Teketay	0.14a
Ejere	0.11b
LSD (0.05)	0.01
P rates (kg ha^{-1})	
0	0.11b
50	0.13ab
100	0.15a
150	0.11b
LSD (0.05)	0.01
Rhizobium	
WI	0.14a
WoI	0.12ab
LSD (0.05)	0.008
CV (%)	13.6

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Table 30. Dry weight of effective nodules per plant of chickpea as affected by interaction effect variety and P rates.

	Phosphorus levels (kg ha^{-1})			
Variety	0	50	100	150
Dubie	0.11cd	0.16ab	0.14c	0.10cd
Teketay	0.11bcd	0.15abc	0.19a	0.10cd
Ejere	0.01de	0.09d	0.12bcd	0.12bcd
LSD (0.05)			0.016	
CV (%)		13.6		

Table 31.Dry weight of effective nodules per plant of chickpea varieties influenced by the interaction effect of varieties and Rhizobium inoculants

	Rhizobium	
Variety	WI	WoI
Dubie	0.16a	0.09c
Teketay	0.14ab	0.14ab
Ejere	0.1c	0.12bc
LSD (0.05)		0.014
CV (%)		14.0

Means within a column followed by the same letter are not significantly different at 5% level of significance.
WI=with inoculants; WoI=without inoculants.

Table 32.Dry weight of effective nodules per plant of chickpea affected by interaction effect of P rates and Rhizobium inoculants.

	Rhizobium	
P rate (kg ha^{-1})	WI	WoI
0	0.12bc	0.1bc
50	0.13b	0.14b
100	0.19a	0.11bc
150	0.1c	0.12bc
LSD (0.05)		0.02
CV (%)		14.0

Means within a column followed by the same letter are not significantly different at 5% level of significance.

WI=with inoculants; WoI=without inoculants

Table 33. Dry weight of effective nodules per plant of chickpea affected by interaction

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	0.14cd	0.08ij
Dubie	50	0.20 b	0 .12cdefgh
Dubie	100	0.09cdefg	0.06j
Dubie	150	0.12cdef	0.13cde
Teketay	0	0.13efghi	0.09i
Teketay	50	0.1ghi	0.2b
Teketay	100	0.1efghi	0.15c
Teketay	150	0.2a	0.1ghi
Ejere	0	0.1ghi	0.1hi
Ejere	50	0.09i	0.09cde
Ejere	100	0. 11hi	0.13cd
Ejere	150	0.09	0.13
LSD (0.05)		0.02	
CV (%)		4.0	

effect of varieties, P rates and Rhizobium inoculants. *inoculants*

Means within a column followed by the same letter are not significantly different at 5% level of significance. *WI=with inoculants; WoI=without inoculants*

4.3.5. Nodule volume

Nodule volume was not significantly (P>0.05) affected by application of treatments (Appendix Table 9, 10, 11 and 12). However, the highest nodule volume (0.07ml) was recorded by Teketay variety with the application of 100 kg P ha^{-1} followed by Teketay variety with 50 kg P ha^{-1} and Teketay variety with 150kg P ha^{-1}. Similarly, all other treatments resulted in a non-significant differences between treatments.

4.4. Yield components and yield of chickpea

4.4.1. Initial and final stand count

Analysis of variance indicated that the main effect of Rhizobium, Phosphorus fertilizer rates, and varieties resulted in a non- significant (P>0.05) differences on initial stand count. Similarly, all the interaction effects of V × P, V × R, P × R and V × P application rate × Rhizobium inoculant did not reveal significant effect on initial stand count. (Appendix Table 1.2 .3 4).

Simultaneously, the analysis of data resulted that the main effect of Rhizobium, Phosphorus fertilizer rates, and varieties resulted in a non- significant ($P>0.05$) differences on initial stand count. Similarly, all the interaction effects of V × P, V × R, P × R and V × P application rate × Rhizobium inoculant did not reveal significant effect on initial stand count. (Appendix Table 5, 6, 7, 8).

4.4.2. Number of total pods per plant

Analysis of variance showed a non- significant differences ($P>0.05$) among the main effects for Rhizobium. However, a significant differences ($P\leq0.05$) was recorded on Phosphorous rates (0, 50, 100 kg P per ha) and varieties of chickpea. The maximum number of pod per plant was recorded from Teketay variety (108.3) followed by Ejere variety (90.2) and the Dubie ()Shumbira dimtu variety (56.4). (Table 35).The differences in number of pods per plant might be due to varietal differences. The result was in line with, Tripathi *et al*. (2012) who reported significant differences among genotypes of chickpea on number of pods per plant. Similarly, a significant differences($P\leq0.05$) recorded between 150 kg P ha^{-1}, 100 kg P ha^{-1} and 50 kg ha^{-1} phosphorus rates which resulted 93.3, 89.4 and 82.6 pods per plant respectively. Simultaneously, the interaction effects of Rhizobium X P application rate also resulted in a non-significant differences at $P>0.05$ however, P × V interaction resulted in a significant ($P\leq0.05$) effect on the number of total pods per plant. Teketay variety supplied with 150 kg ha^{1}, 100 kg P per ha and 50 kg ha^{1}phosphorus rates resulted in 1 19.0, 111.5 and 107.2 pods per plant respectively (Table 36).

Seed inoculation with *Rhizobium* inoculant non significantly influenced total number of pods per plant in *kabuli and desi* chickpea verities. This result was contrary to Togay *et al*. (2008) who reported that inoculation with *Rhizobium* significantly increased pods per plant in chickpea. Saini *et al*. (2004) and Ogutcu *et al*. (2008) reported the same results in chickpea.

The result of this experiment revealed a significant differences ($P \leq 0.05$) on the interaction of variety and Rhizobium on total number of pods per plant. (Table 38). Teketay variety inoculated with Rhizobium bacteria produced the maximum number (108.8) of total pods per plant followed by same variety without inoculated with Rhizobium bacteria (107.9). The Dubie variety inoculated with and without bacteria produced lower number of total pods per plant (59.4 and 53.4) respectively. (Table38).In line with this study Singh et al (2008) who reported that the seeds and nutritional quality of legume is greatly influenced by the application of phosphorus and bio fertilizers. Likewise, Mena et al (2003) reported P fertilization increased the number of grains per pod of chickpea significantly.

Significant effect was observed between the interaction of varieties, phosphorus fertilizer rate and seed inoculation with *Rhizobium* inoculant on total number of pods per plant in Kabuli and desi chickpea variety (Table 39). The maximum number of total pods per plant was recorded from Teketay variety inoculated with *Rhizobium* inoculant and supplied with P fertilizer at the rate of 150 kg P ha^{-1} (120.7) which was statistically significantly different ($P \leq 0.05$) from the Dubie (54.3).

This may probably due to the supply of nitrogen through BNF as a result of seed inoculation and the cumulative effect of phosphorus in the processes of cell division, balanced nutrition and hydraulic conductibility of roots that play a vital role in enhanced growth and assimilate accumulation that eventually improved the reproductive performance of the plants.

The above results were in accordance with the findings of several other studies like (Kassa 2009; Ahmed *et al.* 2010; Yoseph 2011; Namvar and Sharifi 2011; Togay *et al*. 2008; Dutta and Bandyopadhyay 2009) who explained that the increased supply of nitrogen through BNF and the direct supplementation of phosphorus that in turn play important roles in enhanced growth and assimilate accumulation, thereby improving the reproductive performance of the plants.

Table 34. Number of pods per plant and number of seeds per pod of chickpea varieties as influenced by the main effect of varieties, P rates and Rhizobium inoculants

Treatments	TNP/plant	TNS/pod
Variety		
Dubie	56.4c	1.35b
Teketay	108.3a	2.71a
Ejere	90.2b	1.43b
LSD (0.05)	5.45	0.19
P rates (kg ha^{-1})		
0	74.7b	1.73a
50	82.6b	1.78ab
100	89.4b	1.82ab
150	93.3a	1.99a
LSD (0.05)	6.29	0.22
Rhizobium		
WI	87.0	1.93
WoI	82.9	1.73
LSD (0.05)	4.45	0.16
CV (%)	11.1	17.9

Means within a column followed by the same letter are not significantly different at 5% level of significance.

TNP = total number of pods; TNS = total number of seeds.

Table 35. Numbers of total pods per Plant of chickpea as affected by interaction effect variety and P rates

Variety	Phosphorus levels (kg ha^{-1}) 0	50	100	150
Dubie	52.5g	53.5g	57.2g	62.7g
Teketay	95.7de	107.2bc	111.51ab	119.0a
Ejere	75.8f	87.3e	99.5cd	98.2cde
LSD (0.05)		15.42		
CV (%)		9.4		

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Table 36. Numbers of total pods per Plant of chickpea as affected by interaction effect of P rates and Rhizobium inoculants.

P rate (kg ha^{-1})	*Rhizobium* WI	WoI
0	75.9b	73.4b
50	82.8ab	82.3ab
100	89.7ab	89.1ab
150	99.8a	86.8ab
LSD (0.05)	10.90	
CV (%)	11.1	

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants; WoI=without inoculants

Table 37. Number of total pods per plant as affected by interaction effect of Variety and Rhizobium inoculants.

Variety	*Rhizobium* WI	WoI
Ejere	93.0b	87.4b
Dubie	59.4c	53.4c
Teketay	108.8a	107.9a
LSD (0.05)	8.9	
CV (%)	11.1	

WI=with inoculants; WoI=without inoculants

Table 38. Numbers of total pods per Plant of chickpea as affected by interaction effect of P rate, Variety and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	54.3hi	56.7hi
Dubie	50	54.3hi	54.3i
Dubie	100	60.1ghi	52.0i
Dubie	150	68.7fgh	50.7ij
Teketay	0	95.0cd	96.3bcd
Teketay	50	107.7abc	106.7abc
Teketay	100	111.7ab	111.3ab
Teketay	150	120.7a	117.3a
Ejere	0	78.3ef	73.3efg
Ejere	50	86.3ef	88.3ed
Ejere	100	97.3bcd	101.7bcd
Ejere	150	110.0abc	86.3ed
LSD (0.05)		15.42	
CV (%)		11.1	

Means within a column followed by the same letter are not significantly different at 5% level of significance.

4.4.3. Number of seeds per pod

Analysis of variance revealed that the main effects Phosphorus application rate and Rhiz obium inoculation had shown a significant effect on the number of seeds per pod ($P \leq 0.05$). However the main effects of variety, the interaction effect of P× R and V × P × R resulted in a non-significant differences($P>0.05$) on the number of seeds per pod (Appendix Table).

Analysis of variance showed a non-significant difference between Ejere and Dubie variety on the number of seeds per pod however, there was a significant differences ($P \leq 0.05$) between Dubie and Teketay and Ejere and Teketay (Table 40).

The effect of Phosphorus application rate resulted in a significant differences on the number of seeds per pod in chickpea. The maximum number (1.986) of seeds per pod was produced by *kabuli and desi* chickpea variety that received 150 Kg P ha^{-1}rate followed by 100 Kg P ha^{-1} (1.819) which was statistically similar in value with 50kg and 0 kg P ha (Table 40).Seed inoculation with *Rhizobium* inoculant significantly influenced the number of seeds per pod in *kabuli* and desi chickpea varieties. Inoculation of chickpea seed with *Rhizobium* inoculants enhanced the number of seeds per pod from 1.733 to 1.926 (Table 35). The possible reason for maximum seeds per pod produced as a result of *Rhizobium* inoculation that has ability to initiate more N- fixation in the soil to be used by the plant for energy source. This result was in agreement with Togay *et al*. (2008) reported that inoculation with *Rhizobium* significantly increased seeds per plant in chickpea. Saini *et al*. (2004) and Ogutcu *et al*. (2008) reported the same results in chickpea.

A significant differences recorded on the interaction of Vx P (Table 40).The maximum number of seeds per pod recorded on Teketay varieties supplied with 0 kg P per ha (2.667), 50 kg P per ha(2.667) and 100 kg P per ha (2.5) respectively(Table 40).

The results of this study also indicated a non-significant effect between the interaction of phosphorus fertilizer rate and seed inoculation with *Rhizobium* inoculants on number of seeds per pod on the tested variety (Table 51). The maximum number (2.00) of seeds per pod was recorded from seeds inoculated with *Rhizobium* inoculants and fertilizer rate of 150 kg P ha^{-1} followed by 100 Kg P ha^{-1}(1.97). The lowest number (1.62) of seeds per pod was recorded from the chickpea supplied with 0 Kg P ha^{-1} without *Rhizobium* inoculants (Appendix Table 16).

The present result was in conformity with Singh *et al*. (2008) who reported that the seeds and nutritional quality of legumes is greatly influenced by application of phosphorus and bio fertilizers. Likewise, Mena *et al.* (2003) reported that P fertilization increased the number of grains per pod of chickpea significantly. A non-Significant differences were observed between the interaction of Varieties, phosphorus fertilizer rate and seed inoculation with *Rhizobium* inoculant on the number of seeds per pod per plant in Kabuli chickpea variety (Appendix Table 19).

Table 39. Number of seeds per pod of chickpea as affected by interaction effect variety and P rate

Variety	Phosphorus levels (kg ha^{-1})			
	0	50	100	150
Dubie	1.19c	1.26c	1.46c	1.51c
Teketay	2.67ab	2.67ab	2.50b	3.00a
Ejere	1.34c	1.42c	1.50c	1.45
LSD (0.05)		0.38		
CV (%)		17.9		

Means within a column followed by the same letter are not significantly different at 5% level of significance.

4.4.4. Hundred seed weight

Analysis of variance indicated that the hundred seed weight was significantly ($P \leq 0.05$) affected by the main effects of varieties, Rhizobium inoculation,interaction effect of Vx R However phosphorus application, the interaction effect of V x P, V × P × R did not show significant effect ($P > 0.05$) on the traits (Table 45).

Analysis of variance showed significant effect of varieties on hundred seed weight in chickpea (Table 45). The maximum hundred seed weight data was recorded under Teketay variety followed by Ejere variety (32.85).The lowest (25.66 g) 100 seed weight was recorded under Dubie variety (Table 46).Variation in seed weight among the chickpea varieties might be due to seed size. This result was in line with this study Shamsi (2009) and Tripathi *et al*. (2012) who reported significant differences among genotypes of chickpea on hundred seed weight. Tagore *et al.* (2013) also reported that the variation in test weight among the chickpea genotypes is likely to occur due to differences in seed size of the individual genotype which also results in increased grain yield.

Seed inoculation with *Rhizobium* inoculant significantly influenced hundred seed weight in *kabuli* and desi chickpea. Inoculation of chickpea seed with *Rhizobium* increased 100 seed weight from 30.16 g to 32.23 g as compared to uninoculated treatments (Table 45). This was related to the symbiotic relationship between *Rhizobium* and chickpea which results in fixation of atmospheric nitrogen into theroots and translocation of amino acids to the shoots, thus leading to increased yield. Such positive effects of bacterial inoculation on yield of various leguminous crops are well documented by (Lamptey *et al*., (2014), Albayrak*et al*., (2006), Tairo and N dakidemi (2013) and Aslam*et al*., (2010). Bambara and Ndakidemi (2010) further reported that the higher yields obtained with inoculation indicates that the *Rhizobium.*

The interaction effects of variety and Rhizobium resulted in a significant differences on hundred seed weight ($P \leq 0.05$). Maximum hundred seed weight recorded by Teketay variety inoculated with Rhizobium (36.04) followed by same variety without Rhizobium (34.12) and Ejere variety inoculated with Rhizobium (34.05) (Table 41).

Table 40. Hundred seed weight of chickpea as affected by interaction effect of Varities and Rhizobium inoculants.

	Rhizobium	
Variety	WI	WoI
Dubie	26.60c	24.72c
Teketay	36.04a	34.12ab
Ejere	34.05ab	31.65b
LSD (0.05)	2.245	
CV (%)	8.8	

Means within a column followed by the same letter are not significantly different at 5% level of significance.

WI=with inoculants; WoI=without inoculants

4.4.5. Above ground plant dry biomass yield

Analysis of variance for above ground plant dry biomass yield of chickpea revealed a non-significant ($P>0.05$) differences for main effects of Rhizobium, Phosphorus fertilizer rates, interaction effects of PxV, and RxVxP. However, a significant differences ($P\leq0.05$) recorded from main effects of variety and interaction effects of Rhizobium inoculation and varieties on above ground plant dry biomass yield of chickpea (Table 43and 44).

The study showed a significant difference ($P\leq0.05$) among the varieties tested on the above ground dry biomass yield in chickpea. The highest above ground dry biomass yield was recorded from the Ejere variety (5426Kg ha^{-1}) followed by Teketay variety (5101 Kg ha^{-1}) and the   variety (4069 kg per ha^{-1}) (Table 42).

In the same manner the analysis of variances indicated that the interaction effects of Rhizobium inoculation and varieties resulted in a significant differences ($P\leq 0.05$) on the above ground biomass of chickpea. Ejere variety (5445kg per ha^{-1})seed inoculated with rhizobium bacteria resulted in the highest above ground biomass followed same variety (5407kg per ha^{-1}) without Rhizobium bacteria and Teketay variety (5131 kg per ha^{-1}) respectively (Table 43).

Table 41. Above ground weight (kg per ha) of chickpea varieties influenced by the main effect of varieties

Variety	ABGW	
Dubie	4069c	
Teketay	5101b	
Ejere	5426a	
LSD (0.05)		317.4
CV (%)		11.2

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Table 42. Above ground weight per plant of chickpea varieties influenced by the interaction effect of varieties and Rhizobium inoculants

Variety	*Rhizobium*	
	WI	WoI
Dubie	4094b	4044ba
Teketay	5131a	5070a
Ejere	5445a	5407a
LSD (0.05)		448.9
CV (%)		11.2

Means within a column followed by the same letter are not significantly different at 5% level of significant.WI=with inoculants; WoI=without inoculant

Table 43. Above ground dry biomass yield of chickpea (kg per ha) as affected by interaction effect of P rates and Rhizobium inoculants

P rate (kg ha^{-1})	Rhizobium	
	With inoculants	Without inoculants
0	4736a	4787a
50	4772a	4723a
100	4874a	4843a
150	5177a	5009a
LSD (0.05)	518.4	
CV (%)	11.2	

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculant

4.4.6. Seed yield

Analysis of variance for seed yield revealed significant ($P \leq 0.05$) effect in chickpea as affected by the main effects of varieties, Phosphorus application rate and the two way interaction effect of P × R, V × R, V × P application rate and V × P × However, a non-significant differences recorded on rhizobium inoculation.The highest seed yield was recorded by Teketay variety (3237kg per ha) followed by Ejere variety (3169 Kg ha^{-1})

whereas lowest seed yield was recorded for the Dubie variety (2042 Kg ha^{-1}) (Table 45). The difference in seed yield might be due to variation in genetic make-up of the varieties.

The effect of Phosphorus application rate also indicated a significant effects ($P\leq0.05$) on seed yield of chickpea. The highest seed yield (2957Kg ha^{-1}) was produced by chickpea variety treated with 150 Kg P ha^{-1} followed 100 Kg P ha^{-1}(2848 Kg ha^{-1}). However, the application of phosphorus 0 and 50 kg P per ha $^{-1}$ resulted in a non-significant differences between them and produced lower seed yields (2717 kg ha^{-1} and 2741kg ha^{-1}) (Table 45 and 46).

Seed inoculation with *Rhizobium* inoculant none significantly influenced Seed yield in *Kabuli* and desi chickpea. This results was contrary with several other studies of Rokhzadi and Toashih 2011; Togay *et al*. 2008; Ahmed *et al*. 2010; Namvar and Sharif 2011; Verma *et al*. 2013) who reported Inoculation of chickpea seed improves grain yield.

The study also indicated significant differences on the interaction of phosphorus fertilizer rates and seed inoculation with *Rhizobium* inoculants on seed yield of *Kabuli* and desi chickpea (Table 47). The highest Seed yield (3006Kg ha^{-1}) recorded from the seeds inoculated with *Rhizobium* inoculants at fertilizer rate of 150 kg P ha^{-1} followed by 150 Kg P ha^{-1} without inoculated with *Rhizobium* inoculants (2860 Kg ha^{-1}). The lower seed yield was recorded from the chickpea treated with 0 Kg P ha^{-1} with *Rhizobium* inoculants (2701Kg ha^{-1}) and without inoculants (2734Kg ha^{-1}) (Table 46). The analysis of variances results indicated Teketay variety supplied with 150 kg P per ha^{-1}resulted in the highest seed yield (3509kg per ha) followed by same variety supplied with 100kg P per ha (3253kg per ha) and Ejere variety (3200kg per ha) (Table 47).

The above result was in agreement with that of Zai *et al*. (1999) who concluded that *Rhizobium* inoculation had significant effects on growth, N contents and uptake in shoots, yield and yield components of chickpea. Mena *et al.* (2003) reported P fertilization increased the number of grains per pod of chickpea significantly. Zafar *et al*. (2003) also reported a regulatory system through which it was possible to direct and concentrate available nutrients to permit development of more number of pods per plant and seeds per pod. They also further pointed out that phosphorus aids in transferring photosynthetic from the stalks, leaves and other growing parts to the economically important organs like seed making them plump and bold.

Table 44. Hundred seed weight (g) and seed yield (kg ha^{-1}) of chickpea varieties as influenced by the main effect of varieties, P rates and Rhizobium inoculants.

Treatments	100 seed weight (g)	Seed yield (kg ha^{-1})
Variety		
Dubie	25.66c	2042b
Teketay	35.08a	3237a
Ejere	32.85b	3169a
LSD (0.05)	1.58	72.4
P rates (kg ha^{-1})		
0	28.43b	2717a
50	30.74ab	2741a
100	32.36a	2848a
150	33.27a	2957a
LSD (0.05)	1.83	83.5
Rhizobium		
WI	32.23	2837a
WoI	30.16	2794b
LSD (0.05)	1.296	59.1
CV (%)	8.2	4.4

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculant

Table 45. Seed yield of chickpea as affected by the interaction effect of P rates and Rhizobium inoculants.

P rate (kg ha^{-1})	Rhizobium	
	With inoculants	Without inoculants
0	2701a	2734a
50	2782a	2700a
100	2860a	2837a
150	3006a	2908a
LSD (0.05)	118.1	
CV (%)	4.4	

Means within a column followed by the same letter are not significantly different at 5% level of significance.
WI=with inoculants; WoI=without inoculant

The interaction of Rhizobium inoculation, phosphorus fertilizer rates and varieties resulted in a significance differences (P≤0.05) on the seed yield of Chickpea (Table 48).The maximum seed yield was recorded with Teketay variety inoculated with rhizobium inoculants supplied with 150kg P per ha (3574kg per ha) followed by same variety supplied with 150 kg per ha without inoculants (3444kg per ha). The present result was in line with Singh *et al*. (2008) who reported that the seeds and nutritional quality of legumes is greatly influenced by application of phosphorus and bio fertilizers.

Table 46. Seed yield of chickpea as affected by interaction effect of P rates and Variety.

Variety	Phosphorus levels (kg ha^{-1})			
	0	50	100	150
Dubie	1955e	1962e	2088de	2162d
Teketay	3104c	3081c	3253b	3509a
Ejere	3092c	3178bc	3204bc	3200bc
LSD (0.05)		144.7		
CV (%)		4.4		

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Table 47. Seed yield of chickpea as affected by interaction effect of P rate, Variety and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	1923f	1987f
Dubie	50	1962f	1962f
Dubie	100	2123ef	2052ef
Dubie	150	2206e	2118ef
Teketay	0	3116cd	3092cd
Teketay	50	3147cd	3015d
Teketay	100	3254bc	3251bc
Teketay	150	3574a	3444ab
Ejere	0	3062cd	3123cd
Ejere	50	3236c	3121cd
Ejere	100	3201cd	3206cd
Ejere	150	3239c	3161cd
LSD (0.05)		204.6	
CV (%)		4.4	

Means within a column followed by the same letter are not significantly different at 5% level of significance.

WI=with inoculants; WoI=without inoculant

4.4.7. Harvest index

Analysis of variance revealed that the main effect of variety resulted in a significant ($P \leq 0.05$) difference among varieties tested on harvest index (Table 48). Teketay variety produced the highest harvest index (63.42 %) followed by Ejere variety (58.46%) and Dubie variety (40.88%)(Table 49). Moreover, the interaction effects VXP resulted in a significant differences ($P \leq 0.05$) on harvest index (Table 50). The maximum harvest index recorded by Teketay variety supplied with 100kg per ha (0.6683) followed by 150kg per ha (0.6483) and Teketay variety with 50kg per ha (0.625). However, there was a non-significant differences ($P > 0.05$) on the application of different rates of phosphorous fertilizers and interaction effects of RxP on harvest index (Appendix Table 14).

The interaction effects of V × P application rate × Rhizobium inoculant resulted in a non-significant effect (P>0.05) on harvest index (Appendix Table13).

Table 48. Harvest index of chickpea varieties as influenced by the main effect of varieties, and Rhizobium inoculants.

Treatments	HI
Variety	
Dubie	0.41c
Teketay	0.63a
Ejere	0.58b
LSD (0.05)	0.02
Rhizobium	
WI	0.54
WoI	0.54
LSD (0.05)	0.01
CV (%)	5.9

Means within a column followed by the same letter are not significantly different at 5% level of significance.

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Table 49. Harvest index of chickpea as affected by interaction effect variety and P rates

	Phosphorus levels (kg ha^{-1})			
Variety	0	50	100	150
Dubie	0.420e	0.42e	0.40e	0.39e
Teketay	0.59cd	0.63bc	0.67a	0.65ab
Ejere	0.58d	0.59cd	0.58d	0.59cd
LSD (0.05)		0.03		
CV (%)		5.9		

Means within a column followed by the same letter are not significantly different at 5% level of significance.

4.4.8. Partial budget analysis

Economic constraints and opportunities for improving chickpea production systems in Ethiopia must be understood as the basis for developing interventions. Considering the increasing needs for human consumption of plant products and the economic constraints of applying fertilizer in legumes, there is a greater role for grain legumes in cropping systems, especially in regions where affordability of fertilizer is difficult (Ndakidemi *et al*., 2006).,the agronomic data upon which the recommendations are based must be relevant to the farmers own agro ecological conditions and the evaluation of these data must be consistent with the farmers goal and socio economics circumstance (CIMMMYT, 1988).

The variable costs including inorganic P fertilizer and *Rhizobia* inoculants price at time of planting (September 10, 2018) and the price of the current (March 2019) chickpea grain data were taken from Office of Trade and Transportation marketing case team of Haramaya district. Labour cost per treatment was recorded and used for this analysis. The average yield was adjusted downward by 10 % to reflect the farmer's field yield as described by CIMMYT (1988). Net yield was multiplied by market price to obtain gross field benefit. Costs and benefits were calculated for each treatment. Variable costs were summed up and subtracted from gross benefits which were taken as net benefit. The partial budgeting procedure is the most useful in farming system research (Worman *et al.,* 1990). Data presented in Table 51 Revealed the partial budget analysis of chickpea varieties as affected by the effects of inorganic P fertilizer and *Rhizobia* inoculants.

It is clear from the budget summary of economic analysis that the highest total returns (64332 Birr ha^{-1}) was obtained from Teketay variety treated under 150.kg P ha^{-1} with seed inoculation followed by the same variety treated with 150 kg P ha^{-1} without seed inoculation resulted 61992 Birr ha^{-1}The lowest total return (31153 Birr ha^{-1}) was recorded from Dubie variety supplied with 0 kg P ha^{-1} with seed inoculation (Table 51). Based on this it can be inferred that application of P and seed inoculation is a means to increase the economic benefits of smallholder farmers growing chickpea in the study area.

Table 50. Summary of partial budget analysis of the effects of chickpea varieties, P rate application and Rhizobium inoculants.

Variety	P rates (kg ha-1)	Rhizobium WI	Gross yeld(Kg ha^{-1}	Adjusted yield(kg ha-1)	Total GR Birr ha-^{1}	Net R Birr ha-^{1}	Total VC Birr ha^{-1}	MRR
Dubie	0		1923	1730.7	31153	27833	3320	
Dubie	50		1962	1766.7	31801	28412	3389	839.1304
Dubie	100		2123	1910.7	34393	30728	3665	839.1304
Dubie	150		2206	1985.4	35251	31495	3756	839.9083
Teketay	0		3116	2804.4	56088	50110	5978	838.1114
Teketay	50		3147	2832.3	55116	49724	5922	841.3144
Teketay	100		3254	2928.6	58572	52339	6233	841.2633
Teketay	150		3574	3216.6	64332	57485	6847	840.7145
Ejere	0		3062	2755.8	55116	49249	5867	840.8324
Ejere	50		3236	2912.4	58248	52047	6201	840.4721
Ejere	100		3201	2880.9	57618	51484	6134	840.4762
Ejere	150		3236	2915.1	58302	52095	6207	840.4722
WOI								
Dubie	0		1987	1788.3	32189	30708	1481	-156.335
Dubie	50		1962	1765.8	31784	30322	1462	-133.961
Dubie	100		2052	1846.8	33242	31713	1529	-216.639
Dubie	150		2118	1906.2	34312	32734	1578	-281.343
Teketay	0		3092	2782.8	55656	53096	2560	-3324.08
Teketay	50		3015	2713.5	54270	51774	2496	-2905.46
Teketay	100		3251	2925.9	58518	55827	2691	-4450.56
Teketay	150		3444	3099.6	61992	59141	2851	-6675.48
Ejere	0		3123	2810.7	56214	53629	2585	-3509.66
Ejere	50		3121	2808.9	56178	53595	2583	-3495.52
Ejere	100		3206	2885.4	57708	55055	2653	-4081.26
Ejere	150		3161	2844.9	56898	54282	2616	-3756.96

WI=with inoculant; WoI=without inoculant; GR=Gross return; R= return and VC=Vari

5. Summary and conclusion

Though chemical fertilizers have amply proved their role in modern agriculture, the current increasing costs of fertilizers in our country have made them unaffordable for most of the farmers. Therefore invariably farmers are applying fertilizers below the recommended rates and hence, most of the time yields are lower than the potential. Thus, there is an urgent need to search for alternative and cheaper sources of nutrients particularly those of nitrogen and phosphorus.

Microbial processes such as biological nitrogen fixation, phosphate solubilization and cellulose degradation etc., could supplement the nutrient requirements of crops. The contributions of these microbial processes are enhanced by introducing efficient microbes in the rhizosphere. For instance, symbiotic nitrogen fixation rates could be markedly increased by introducing highly efficient, competitive and persistent strains of Rhizobia With this background, the study was conducted to assess the effect of phosphorus fertilizers and *Sinorhizobium ciceri* inoculation, on growth, nodulation, yield components and yield of chickpea varieties at Haramaya, East Ethiopia and to evaluate cost -benefit of inoculation and phosphorus fertilizer for chickpea production. Three chickpea varieties Dubie, Ejere and Teketay), four rates of phosphorus (0, 50, 100 and 150 kg of P ha^{-1}) with and without inoculation were tested in Randomized Complete Block Design (RCBD) in factorial arrangement with three replication. The effect of Phosphorus fertilizer rates indicated a significant differences ($P\leq0.05$) on days to 50% emergency, days to 50% flowering, physiological maturity, seed yield of chickpea. The shorter days to emergency was recorded by Teketay variety (8.29days) followed by Ejere (10.42 days) and Dubie (10.46 days). The interaction of variety, Phosphorous fertilizer rates and rhizobium also resulted in significant differences ($P\leq0.05$) over control. The shorter days to 50% emergence recorded by interaction of Teketay variety supplied with 100kg P rates with and without Rhizobium bacteria (7.33days) and (7.67 days) respectively. Shorter days to 50% flowering was recorded by Teketay (46.08days) followed by Ejere variety (52.62 days) respectively. Main effects of P rates with 100kg P per ha, 150 kg per ha and 50 kg per ha on days to 50% flowering resulted in 48.50days, 50.44 days and 52.56 days respectively. While interaction effects of 150kg P per ha with rhizobium bacteria resulted in 51.44 days. .Simultaneously, interaction effects of Teketay variety, 100kg P ha $^{-1}$, 150kg P and 50 kg P with rhizobium resulted shorter days to flowering (42.33 days, 47 days and 49.67 days) respectively. The results of this study also indicated that main effects of P rates with 100kg per ha, 150kg per ha and 50kg per ha resulted in longer days to maturity (119.44 days, 117.56 days and 115.,67 days) respectively. At same time Teketay variety inoculated with rhizobium with 100kg P per ha and 150kg P per ha resulted shorter days to physiological maturity (112days and 113.67 days) respectively. Similarly, the higher plant height recorded for the interaction of Teketay variety inoculated with rhizobium and with 150 kg per ha (60.67cm) and 100kg per ha (57.33cm) respectively. The plant height of chickpea as affected by main effects of varieties indicated a significant differences ($P \leq 0.05$) among tested varieties. Teketay variety was found higher in plant height (55.17cm) followed by Ejere variety (53.50cm) while Dubie variety height was 45.42cm.

As to the effect of varieties on number of primary branches. Ejere variety produced the highest number (4.625) of primary branches followed by the Dubie (4.429) and Teketay (4.45). Inoculation of chickpea seed with Rhizobium inoculants enhanced the number of primary branches per plant from 4.314 to 4.689. The interaction effects of variety and seed inoculation with Rhizobium inoculant on number of primary branches per plant were also found significant at $P \leq 0.05$. The highest number (4.792 and 4.767) of branches per plant was produced by Teketay inoculated with Rhizobium inoculants. The effect of varieties on number of secondary branches indicated that Teketay variety produced the highest number (15.80) of secondary branches followed by variety Ejere (15.08). The interaction effect of V, P application rate and Rhizobium inoculants indicated that Teketay variety supplied with 50kg P ha^{-1} with Rhizobium inoculants produced the highest number (18.20) of secondary branches per plant followed by Teketay variety supplied with 150 Kg P ha^{-1} (17.00).

Teketay variety resulted in higher number of total nodules (80.42), effective number of nodule (75.62), dry weight of total nodule (0.258 g) and dry weight of effective of nodule (0.14g). Similarly P rates of 150kg per ha resulted in higher number of total number of nodule (76.22), effective number of nodule (71.22). Moreover, the interaction of Teketay variety, 150kg P per ha and with rhizobium bacteria resulted in higher number of total nodule per plant (87.33) followed by same variety with 100kg P per ha inoculated with rhizobium bacteria (982.67).

The maximum number of pod per plant was recorded from Teketay variety (108.3) followed by Ejere variety (90.2) and Dubie variety (56.4). Seed inoculation with Rhizobium inoculant enhanced the number of seeds per pod from 1.733 to 1.926. Moreover, the maximum number (2.00) of seeds per pod was recorded from seeds inoculated with Rhizobium inoculants and fertilizer rate of 150 kg P ha^{-1} followed by 100 Kg P ha^{-1}(1.97). The maximum (35.06 g) hundred seed weight was recorded under Teketay variety followed by Ejere variety (32.85). Similarly, among the varieties tested on the above ground dry biomass yield of chickpea revealed that the highest above ground dry biomass yield (5426Kg ha^{-1}) was recorded from the Ejere variety followed by Teketay variety (5101 Kg ha^{-1}) and Dubie variety (4069 kg per ha^{-1}). The interaction effects of Rhizobium inoculation and varieties resulted in the highest above ground biomass of chickpea from Ejere variety (5445kg per ha^{-1}) inoculated with rhizobium bacteria followed by Teketay variety without inoculated with rhizobium bacteria (5101kg per ha^{-1}) and Dubie variety inoculated with rhizobium bacteria (5131 kg per ha^{-1}).

Seed yield of chickpea was also found the highest Seed yield under Teketay variety (3237kg per ha) followed by Ejere variety (3169 Kg ha^{-1}) whereas lowest s Analysis of variance showed significant effect of varieties on eed yield was that of the Dubie variety (2042 Kg ha^{-1}). Inoculation of chickpea seed with Rhizobium increased Seed yield from 2794 Kg $ha^{-1}$to 2827 Kg ha^{-1}. The effect of Phosphorus application rate indicated a significant effects ($P \leq 0.05$) on Seed yield of chickpea. The highest Seed yield (2957Kg ha^{-1}) was produced by chickpea variety treated with 150 Kg P ha^{-1} followed 100 Kg P ha^{-1}(2848 Kg ha^{-1}). The analysis of variances results indicated Teketay variety supplied with 150 kg P per ha^{-1} resulted in the highest seed yield (3509kg per ha) followed by same variety supplied with 100kg P per ha (3253kg per ha) and Dubie variety (3104kg per ha). The interaction of rhizobium inoculation, phosphorus fertilizer rates and Varieties also produced the maximum seed yield of

Teketay variety inoculated with rhizobium inoculants supplied with 150kg P per ha (3574kg per ha) followed by same variety supplied with 150 kg per ha without inoculants (3444kg per ha). The results indicated that the integrated use of chemical fertilizers and inoculants increase the growth, yield and yield parameters due to biological nitrogen fixation. Inoculation of *Sinorhizobium ciceri* and P rates of 150kg per ha could be recommended for Haramaya soils to maximize yield.

From the above summary one can conclude that the contributions of these microbial processes are enhanced by introducing efficient microbes in the rhizosphere that are helpful to farmers in reducing chemical fertilizer application on their farm. Therefore, the results of present study need to be further evaluated and re-confirmed by conducting extensive field trials under varying soil fertility conditions with different sources and rates of phosphorous fertilizer rates with Rhizobium. In addition promotional literature should be prepared in simple and Dubie languages and made available to the farmers and extension personnel to develop awareness of farmers about the benefits using inoculants, and some adaptive research demonstration and specific training programs should be done.

6. References

Abaidoo RCT, George T, Bohlool BB, Singleton PW .1990. Influence of elevation and a pplied nitrogenon rhizosphere colonization and competition for nodule occupancy by different *Rhizobia* strains on field-grown soybean and common bean. Can. J. Microbiol. 36:92-96.

Ahmed, A. G., Ahmed M., Hassanein M. and Zaki N. M. 2010. Effect of organic and Bio Fertilization on growth and yield of two chickpea cultivars in newly cultivated land. *Journal of Applied Sciences Research*, 6 (12): 2000-2009.

Alam, S.M., Naqvi, S.S.M. and Ansari, R. 1999. Impact of soil pH on nutrient uptake by crop plants.*In* Pessarakli, M. (ed.) *Handbook of Plant and Crop Stress*. New York: Marcel Dekker, 1999.pp. 51-60.

Ali A, Ishtiaq M, Jan NE (2004). Effect of *Rhizobium leguminosarum* inoculum on the growth and yield of different pea cultivars. Sarhad J. Agric.19 (1):55-59.

Ali H., Khan M. A., Randhawa Sh. A. 2004. Interactive effect of seed inoculation and phosp horus application on growth and yield of chickpea (*Cicer arietinum* L.). *International Journal of Agriculture & Biology*, 6(1): 110-112.

Ali, M.A., N.N. Nawab, G. Rasool and M. Saleem, 2008. Estimates of Variability and Correlations for Quantitative Traits in *Cicer arietinum. Journal of Agriculture and Social Sciences,* 4: 177–79.

Anbessa, Y., and G. Bejiga. 2002. Evaluation of Ethiopian chickpea landraces for tolerance to drought. *Genetic Resources and Crop Evolution,* 49 (6):557-564.

AsfawHailemariam. 1988. Studies on Interaction of *Rhizobiumjaponicum* and Phosphate Solubilizing Bacteria (PSB) on Soybean (*Glycine max* L.) Crop Yield, Ph.D. Dissertation, Indian Agricultural Research Institute, New Delhi.128P.

Asgelil Dibabe. 2000. Effect of fertilizer on the yield and nodulation pattern of faba bean on a Nitosol of Adet Northwestern Ethiopia. Ethiopian Journal of Natural Resources 2: 237-244.

Aslam MHKA, Ullah H, Ayaz M, Ahmad E, Sagoo AG, Ullah I, Hussain A, Manzoor M (2010). Nodulation grain yield and grain protein contents as affected by *Rhizobium*inoculation and fertilizer placement in chickpea cultivar bittle-98. Sarhad J. Agric. 26(4):467-474.

Asrat Asfaw, Abush Tesfaye, Sintayehu Alamire and Mulugeta Atnafu, 2003. Soybean Genetic Improvement in Ethiopia. Paper presented at the proceedings of second national workshop on food and forage legumes workshop organized by EARO, Addis Ababa, Ethiopia.

Bambara, S., and P.A., Ndakidemi. 2010. *Phaseolus vulgaris* response to *Rhizobium* Inoculation, lime and molybdenum in selected low pH soil in Western Cape, South Africa. *African Journal of Agricultural Research,* 5:1804-1811.

Bereke, W., and A. Hailemariam. 2012. Influence of inoculation methods and phosphorus levels on nitrogen fixation attributes and yield of soybean (*Glysine max* L.) at Haru

Western Ethiopia. *American Journal of Plant Nutrition and Fertilization Technology,* 2:44-45.

Ben Romdhane, S. M. Aouani, M. Trabelsi, P. De Lajudie and R. Mhamdi. 2008. Selection of high nitrogen-fixing rhizobia nodulating chickpea (*Cicer arietinum* L.) for semiarid Tunisia. *Journal of Agronomy and Crop Science,* 194 (6): 413-420.

Bejiga, G., & van der Maesen, L. J. G, 2006. Plant Resources of Tropical Africa, (*Cicer arietinum* L) 1, 42-46.

Birhanu M, Pant LM (2012). Effects of Inoculation of *Sinorhizobiumciceri* and Phosphate Solubilizing Bacteria on Nodulation, Yield and Nitrogen and Phosphorus Uptake of Chickpea (*Cicer arietinum* L.) in ShoaRobit Area. J. Biofertil. Biopestic. 3:129.

Bhuiyan, M.A.H., Khanam, D., Hossain, M.F., and M.S. Ahmed. 2008. Effect of *Rhizobium* Ino culation on nodulation and yield of chickpea in calcareous soil. *Bangladesh Journal of Agricultural Research*, 33:549-554.

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

CIMMYT (International Maize and Wheat Improvement Center). 1988. Farm Agronomic to farmer's recommendation. An Economic Training Manaual. Completely revised Edition, D.F. Mexico. 51p.

CSA (Central Statistical Agency). 2014. Agricultural sample survey report on area and Production of crops private peasant holdings, meher season. September–December 2014/2015, Statistical Bulletin 388. Addis Ababa, Ethiopia.

Catroux G., Hartmann A. and Revelin, C. (2001). Trends in *Rhizobial* inoculants production and use. Plant Soil 230: 21-30.Bulletin No. 10. Rome. 275pp.

Chapman, H. D. 1965. Cation exchange capacity by ammonium saturation. Pp. 891-901. In: C.

Chatel DL, Greenwood RM (1973). The location and distribution in soil of *rhizobia* under senesced annual legume pastures. Soil Biol. Biochem. 5:799-808.

CIMMTY (The International Maize and Wheat Improvement Center).1988. From Agronomic Data to Farmer Recommendations.

Coyne, 2001. Co-inoculation of a Pea Core-Collection with Diverse Rhizobial Strains Shows Competitiveness for Nodulation and Efficiency of Nitrogen Fixation Are Distinct traits in the Interaction

CSA (Central Statistical Agency).2014. Agricultural Sample Survey 2014: Area and Production of Crops (Private Peasant holdings, Meher Season).Statistical Bulletin 532, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency).2016. Agricultural Sample Survey 2016: Area and Production of Crops (Private Peasant holdings, Meher Season).Statistical Bulletin. Addis Ababa, Ethiopia.

Desta Beyene. 1988. Biological Nitrogen Fixation Research on Grain Legumes in Ethiopia: An Overview. Pp 73-78. In: Beck, D.P. and Materon, L.A. (Eds.). Proceedings of a Workshop on Biological Nitrogen Fixation on Mediterranean-Type Agriculture, April 14-17, 1986, ICARDA, Syria.

Dewis J. and Freitas P. 1975. Physical and chemical methods of soil and tissue analysis. FAO

Dorosinksy, L. M. and A.A. Kadyrov. 1975. Effect of Inoculation on Nitrogen Fixation by Chickpea, Its Crop and Content of Protein. Mikrobiologiya 44: 1103-1106.

Dubey, S.K. 1997. Co-Inoculation of Phosphorus Solubilizing Bacteria with *Bradyrhizobium japonicum* to Increase Phosphate Availability to Rainfed Soybean on Vertisol. Journal of the Indian Society of Soil Sciences 45(3): 506-509.

Dutta, D, Bandyopadhyay, P. 2009. Performance of chickpea to application of phosphorus and biofertilizer in laterite soil. *Archives of Agronomy and Soil Science*, 55:147-155.

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

Elkoca, E., Kantar, F. and Sahin F. 2007. Influence of nitrogen fixing and phosphorus Solubilizing bacteria on the nodulation, plant growth, and yield of chickpea. *Journal of Plant Nutrition,* 31 (1):157-171.

Erman M., Demir S., Ocak E., Tufenkci S., Oguz F., Akkopru A. 2011. Effects of *Rhizobium*, arbuscular mycorrhiza and whey applications on some properties inchickpea (*Cicer arietinum* L.) under irrigated and rainfed conditions 1-Yield, yield components, nodulation and AMF colonization. *Field Crops Research*, 122(1): 14-24.

Evans J .2005. An evaluation of potential *Rhizobium* inoculant strains used for pulse production in acidic soils of south-east Australia. Aust. J. Exp. Agric. 45:257-268

FAO (Food and Agriculture Organization of the United Nations). 2008. FAO fertilizer and Plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. FAO, Rome, Italy. 203pp. Accessed on June 12, 2016.

FAO (2014). Ethiopian highlands reclamation study (EHRS). Final report.Vol.1–2. Rome.

FAO (Food and Agriculture Organization of the United Nations). 2008. FAO fertilizer and plant

Foster, H. J. 1973. Fertilization recommendations for cereals grown on soils derived from Volcanic Rocks in Uganda. *East African Journal of Agriculture and Forestry,* 303-313.

Galal, Y.G., J.A. El-Grandeur and F.A.El-Akel. 2001. Stimulation of Wheat Growth and N Fixation through *Azospirillum* and *Rhizobium* Inoculation. A Field Trial with 15N Techniques. 666-667. In. (W.J. Horst.Eds.). Plant Nitrogen-Food Security and Sustainability of Agro Ecosystems.

Gan, Y.T., McDonald, C.L., Warkentin, T.D., Zentner, R.P. and Vandenberg, A. (2009). Seed yield and yield stability of chickpea in response to cropping systems and soil fertility in northern latitudes. Agron. J., 101: 1113-1122.

Gan, Y.T., Warkentin, T.D., Bing, D.J., Stevenson, F.C. and Mcdonald, C.L. (2010). Chickpea water use efficiency in relation to cropping system, cultivar, soil nitrogen and *Rhizobial* inoculation in semiarid environments. Agric. Water Manage. 97: 1375-1381.

Gaur, A.C., K.P. Ostwal and R.S. Mathur. 1980. Save Superphosphate by Using Phosphate Solubilizing Cultures and Rock Phosphate. Kheti 32: 23-25

Giller, K. E. 2001. *Nitrogen fixation in tropical cropping systems*: Cabi. Wallingford.

ICP. 2000. International Chickpea and Pigeonpea newsletter. Vol.No.7, Andhra Pradesh, India.Pp 45-49.P 5Jensen ES, Hauggaard-Nielsen H (2003). How can increased use of biological N2 fixation inagriculture benefit the environment? Plant Soil 252:177-186.

Jensen ES, Hauggaard-Nielsen H (2003). How can increased use of biological N2 fixation in agriculture benefit the environment? Plant Soil 252:177-186.

Keneni G, Bekele E, Assefa F, Imtiaz M, Debele T, Dagne K, Getu E. 2012. Phenotypic diversity for symbio-agronomic characters in Ethiopian chickpea (*Cicer arietinum* L.) germplasm accessions. Afr. J. Biotechnol. 11(63):12634-12651.

Kundu, B.S. and A.C. Gaur. 1980. Establishment of Nitrogen Fixing and Phosphate Solubilizing Bacteria in the Rhizosphere and Their Effect on Yield and Nutrient Uptake of Wheat Crop. Plant and Soil 57: 223-230.

Kupich FK (1977) The Delimitation of the Tribe *Viceae*(Leguminosae) and the Relationship of *Cicer arietinum* L. Botanical Journal of the Linnaean Society 74: 131-162

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

Landon, J.R, (1991). ’’Booker Tropical Soil Manual’’. A handbook for soil survey and agricultural land evaluation in the tropics and sub tropics, Longman Scientific and Technical manual, New York.

.López-Bellido, R.J., López-Bellido, L., Benítez-Vega, J., Muñoz-Romero, V., López-Bellido, F.J. and Redondo, R. (2011). Chickpea and faba bean nitrogen fixation in a Mediterranean rainfedVertisol: Effect of the tillage system. Eur. J. Agron., 34: 222-230.

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

Mahler, R. L., Saxena M. C., and Aeschllmann J. 1988. Soil fertility requirements of pea, Lentil, chickpea, and faba bean. Pp. 279-289. In: R. J., summer field, (ed.) World crops.Dordrecht, the Netherlands: Kluwer Academic Publishers.

Maleki A, Pournajaf M, Naseri R, Rashunavadi R, Heydari M (2014). The effect of supplemental irrigation, nitrogen levels and inoculation with *Rhizobium* bacteria on seed quality of chickpea (*Cicer arietinum* L.) under rainfed conditions. Int. J. Curr. Microbiol. Appl. Sci. 3(6):902-909.

Melese T. 2006. Seedbed Compaction effect on Soil erosion and yield of teff (*Eragrostic tef* L.) MSc Thesis submitted to School of Graduate Studies. Haramaya University, Ethiopia.

Melese T. 2006. Seedbed Compaction effect on Soil erosion and yield of teff (*Eragrostic tef* L.) MSc Thesis submitted to School of Graduate Studies. Haramaya University

Morad, M., Sara, S., Alireza, E., Reza, C.M. and Mohammad, D. 2013. Effects of seed inoculation by *Rhizobium* strains on yield and yield components in common bean cultivars (*Phaseolus vulgaris* L.). *International Journal of Biological Sciences,* 3:134-141.

Muhammad, A. 2010. Response of a promiscuous soybean cultivar to rhizobial inoculation and phosphorus in Nigeria's southern guinea savanna *alfisol*. *Nigerian Journal of Basic and Applied Science,* 18:79-82.

Mutch LA, Tamimi SM, Young JPW (2003). Genotypic characterization of rhizobia Nodulating*Viciafaba* from the soils of Jordon: a comparison with UK isolates. Soil Biol. Biochem. 35:709-714. nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. FAO, Ethiopia.

Mugendi, E., Gitonga, N., Cheruiyot, R and Maingi, J. 2010. Biological nitrogen fixation by promiscous soybean (*Glycine max* L.) in the central highlands of Kenya: Response to soil amendments. *World Journal of Agricultural Sciences,* 6:381-387.

Namvar, A., and Sharifi R. S. 2011. Phenological and morphological response of chickpea (*Cicer arietinum* L.) To symbiotic and mineral nitrogen fertilization. *Journal* of *Agriculture,* 98 (2): 121-130.

Namvar A., Seyed Sharifi R., Sedghi M., Asghari Zakaria R., Khandan T., Eskandarpour B.2011. Study on the effects of organic and inorganic nitrogen fertilizer on yield, yield components and nodulation state of chickpea (*Cicer arietinum* L.). *Communications in Soil Science and Plant Analysis,* 42(9): 1097-1109.

Namvar A., Seyed Sharifi R., Sedghi M., Khandan T., and M.J. Moghadam. 2013. Seed

Inoculation and inorganic nitrogen fertilization effects on some physiological and Agronomical traits of chickpea (*Cicer arietinum* L.) in irrigated condition. *Journal of Central European Agriculture*, 14:28-40.

Namvar, A, Sharif, R.S., Khanan, T, 2011. Growth analysis and yield of chickpea (*Cicer arietinum* L) in relation to organic and inorganic nitrogen fertilization.

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

Nicol, G.W., Leininger, S., Schleper, C. and Prosser, J.I. 2008. The influence of soil pH on the diversity, abundance and transcriptional activity of ammonia oxidizing archaea and bacteria. *Environmental Microbiology,* 10(11): 2966–2978

Ogutcu H., Algur O. F., Elkoca E., Kantar. 2008. The determination of symbiotic effectiveness of *Rhizobium* strains isolated from wild chickpea collected from high altitudes in Erzurum. *Turkish Journal of Agriculture and Forestry*, 32: 241-248.

Olsen, S. R., Cole, C. W Watanabe, F. S and Dean L. A. 1954. Estimation of available Phosphorous in soils by extraction with sodium bicarbonate. *Journal of Soil Science* 96: 308-312.

Olsen, S. R., Cole, C. W Watanabe, F. S and Dean L. A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. Journal of Soil Science.

Rashid E. Rafique S. Muhammed N. Bughio, 1993. Boron Deficiency in Rainfed Alkaline Soils of Pakistan

Rasul, F., M.A. Cheema, A. Sattar, M.F. Saleem and M.A. Wahid, 2012. Evaluating the Performance of Three Mungbean Varieties Grown under Varying Inter-row Spacing. *Journal of Animal & Plant Sciences*, 22(4): 1030-1035.

Raza, W., Akhtar, M.J., Arshad, M., and S. Yousaf. 2004. Growth, nodulation and yield of mungbean (*Vigna radiata* L.) as influenced by coinoculation with *Rhizobium* and plant growth promoting rhizobacteria. *Pakistan Journal of Agricultural Sciences* 41:125-130.

Rokhzadi, A., and V. Toashih. 2011. Nutrient uptake and yield of chickpea (*Cicer arietinum* L.) inoculated with plant growth-promoting rhizobacteria. Aust J Crop Sci 5 (1):44-48.

Rupela OP, Saxena MC (1987). Nodulation and Nitrogen Fixation in chickpea. In: M.C. Saxena and K.B. Singh, editors, The Chickpea. CAB International, Wallingford, Oxon. pp. 191-206.

Saini V. K., Bhandari S. C., Tarafdar J. C. 2004. Comparison of crop yield, soil microbial C, N and P, N-fixation, nodulation and mycorrhizal infection in inoculated and non-inoculated sorghum and chickpea crops. *Field Crops Research*, 89: 39-47.

Sajid, M., Rab, A., Wahid, F.I., Shah, S.N.M., Jan, I., Khan, M.A., Hussain, S.A., Khan, M.A., and Z. Iqbal. 2011. Influence of Rhizobium inoculation on growth and yield of groundnut cultivars. *Sarhad Journal of Agriculture,* 27:573-576.

Saxena MC, Singh KB (1987) The Chickpea CAB International, the International Center for Agricultural Research in the Dry Areas. Aleppo Syria.

Shamsi, K., 2009. Effect of Sowing Date and Row Spacing on Yield and Yield Components of Chickpea under Rain fed Conditions in Iran. Islamic Azad University, Kermanshah Branch, Iran.. *Journal of Applied Biosciences,* 17: 941 - 947.

Shukla, M., Patel, R.H., Verma, R., Deewan, P. and Dotaniya, M.L. (2013). Effect of bio- Organics and chemical fertilizers on growth and yield of chickpea (*Cicer arietinum* L.) Under Middle Gujarat Conditions. *Vegetos*, 26(1): 183-187

Singh R.P, Gupta, S.C. and Yadav, A.S. 2008. Effect of levels and sources of phosphorus and PSB on growth and yield of blackgram (*Vigna mungo* L. Hepper.). *Legume Research*, 31 (2): 139-141.

Stephen Kyei-Boahen E. Alfred Slinkard and L Fran. Walley. 2002. Evaluation of *Rhizobial*Inoculation Methods for Chickpea.Dep. Of Soil Sci., Univ. of Saskatchewan, 51 Campus Dr., Saskatoonsk, Canadas 7N, 5A.

Stoorvogel JJ, Smaling EMA (1993) Assessment of soil nutrient depletion in Sub-Saharan Africa: 1983–2000. Technical Report Winand Staring Centrum, Wageningen

Tagore, G.S., Namdeo, S.L., Sharma, S.K., and N. Kumar. 2013. Effect of *Rhizobium* and Phosphate solubilizing bacterial inoculants on symbiotic traits, nodule leghemoglobin, and yield of chickpea genotypes. *International Journal of Agronomy,* Volume? : 1-8. Tahir, M.M, Abbasi, M.K., Rahim, N., Khaliq, A. and Kazmi, M.H. 2009. Effect of *Rhizobium* inoculation and NP fertilization on growth, yield and nodulation of soybean *(Glycine max* L.) in the sub-humid hilly region of Rawalakot Azad, Jammu and Kashmir, Pakistan. *African Journal of Biotechnology,* 8 (22):6191-6200.

Trang, K.M. and J. Giddens. 1985. Shading and Temperature as Environmental Factors Affecting Growth, Nodulation and Symbiotic Nitrogen Fixation by Soybeans. Agronomy Journal, 72:305-308.

Tekalign Mamo, L. Haque and E. A. Aduayi. 1991. Working Document: Soil, Plant, Fertilizer, Animal Manure and Compost Analysis Manual, International Livestock center for Africa, No. B13, Addis Ababa, Ethiopia.

Togay N., Togay Y., Cimrin K. M., Turan M. 2008. Effect of *Rhizobium* inoculation, sulfur and phosphorus application on yield, yield components and nutrient uptake in chick pea Cicer aretinum L.). *African Journal of Biotechnology*, 7(6): 776-782.

Tripathi, S., V. Sridhar, A.K Jukanti, K. Suresh, BV Rao, CLL Gowda and P.M. Gaur, 2012. Genetic Variability and Inter-relationships of Phenological, Physicochemical and Cooking Quality Traits in Chickpea. ICRISAT, Patancheru, Hyderabad, Andhra Pradesh, India.

Unkovich M, Herridge D, Peoples M, Cadisch G, Boddey R, Giller K, Alves B, Chalk P (2008). Measuring plant-associated nitrogen fixation in agricultural systems. ACIAR Monograph No. 136, 258 p. SAS Institute, Inc. (2012). The SAS System for Windows. Release 9.3; SAS Institute, Inc.: Cary, NC, USA.

Vargas, M.A.T., Mendes, I.C., and M. Hungria. 2000. Response of field-grown bean (*Phaseolus vulgaris* L.) to *Rhizobium* inoculation and nitrogen fertilization in two Cerrados soils. *Biology and Fertility of Soils,* 32: 228-233.

Verma, J. P., Yadav, J. Tiwari, K. N. and Kumar A. 2013. Effect of indigenous *Mesorhizobium* pp. and plant growth promoting rhizobacteria on yields and nutrients uptake of chickpea (*Cicer arietinum* L.) under sustainable agriculture. *Ecological Engineering* 51: 282 - 286.

Walkley, A. J. and I. A. Black. 1934. Estimation of soil organic carbon by the chromic acid Titration method. *Soil Science,* 37: 29 - 38.

Walley F. L., Boahen S. K., Hnatowich G., Stevenson C. 2005. Nitrogen and phosphorus fer Tility management for desi and kabuli chickpea. *Canadian Journal of Plant Science*, 85:73 79.

Walley FL, George WC, Perry RM, Patrick MC, Guy PL (2006). Nitrogen Economy of Pulse Crop Production in the Northern Great Plains. Agron. J. 99(6):1710-1718.

Wassie Haile. 1999. Isolation and Characterization of Phosphate solublizing bacteria from Some Ethiopian Soils and their Effect on the Growth of Faba Bean. M.Sc Thesis, Addis Ababa University, A.A. 65P.

WondwosenTena, EndalkachewWolde-Meske and Fran Walley.2016.Response of chickpea (*Cicer arietinum* L.) to inoculation with native and exotic *Mesorhizobium*strains in Southern Ethiopia,African Journal of Biotechnology,Vol. 15(35), pp. 1920-1929

Worman, F., Norman, O. and Ware-Snyder, J. (eds). 1990. *Agricultural technology Improvement project: Farming Systems Research Handbook for Botswana.* Gaberone, Botswana: Department of Agricultural Research, Ministry of Agriculture

Yadav J, Verma JP, Rajak VK, Tiwari KN (2011). Selection of Effective Indigenous *Rhizobium* Strain for Seed Inoculation of Chickpea (*Cicer aritenium* L.) Production. Bacteriol. J. 1:24-30.

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

Zafar, M, Maqsood, M, Ramzan, M., Amzan, A., Zahid, A. 2003. Growth and yield of Lentil as affected by phosphorus. *Journal of Agriculture and Biology*, 1560-8530 (not clear?)

Zai, A.K.E., Solaiman, A.R.M. Karim, A. J. M. S. and Ahmed J. U. 1999. Performance of some chickpea varieties to *Rhizobium* inoculation in respect of growth, N uptake, yield and seed protein content. *Annals of Bangladesh Agriculture*, 9 (2):121 - 130

Zorawar Singh1 and Guriqbal Singh.2017. Role of *Rhizobium* in chickpea (*Cicer arietinum*) production - A review, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana-141 004, Punjab, India ,39(1) 2018 : 31-39

7. Appendices

Appendix Table 1. Initial plant stand count of chickpea varieties as influenced by the main effect of varieties, P rates and Rhizobium inoculants

Treatments	IPSC/Plant
Variety	
Dubie	69.29
Teketay	69.54
Ejere	69.50
LSD (0.05)	0.69
P rates (kg ha^{-1})	
0	69.44
50	69.11
100	69.50
150	69.72
LSD (0.05)	0.81
Rhizobium	
WI	69.50
WoI	69.39
LSD (0.05)	0.57
CV (%)	1.7

Means within a column followed by the same letter are not significantly different at 5% level of significance.

TNP = total number of pods; TNS = total number of seed

Appendix Table 2. Initial plant stand count of chickpea as affected by interaction effect variety and P rates

	Phosphorus levels (kg ha^{-1})			
Variety	0	50	100	150
Dubie	68.83	69.00	69.83	69.50
Teketay	69.83	69.17	69.00	70.17
Ejere	69.67	69.17	69.67 69.50	
LSD (0.05)		1.395		
CV (%)		1.7		

Appendix Table 3. Initial stand count of chickpea as affected by interaction effect of P rates and Rhizobium inoculants.

P rate (kg ha^{-1})	*Rhizobium* WI	WoI
0	69.67	69.22
50	69.11	69.11
100	69.11	69.89
150	70.11	69.33
LSD (0.05)	1.193	
CV (%)	1.7	

Means within a column followed by the same letter are not significantly different at 5% level of significance.
WI=with inoculants; WoI=without inoculants.

Appendix Table 4. Initial standcount of chickpea at harvest as affected by interaction effect of P rate, Variety and Rhizobium inoculants.

Variety	P rates (kg ha^{-1})	*Rhizobium* WI	WoI
Dubie	0	68.67	69.00
Dubie	50	68.67	69.33
Dubie	100	70.00	69.67
Dubie	150	70.33	68.67
Teketay	0	70.67	69.00
Teketay	50	69.33	69.00
Teketay	100	68.33	69.67
Teketay	150	70.33	70.00
Ejere	0	69.67	69.67
Ejere	50	69.33	69.00
Ejere	100	69.00	70.33
Ejere	150	69.67	69.33
LSD (0.05)		1.973	
CV (%)		1.7	

Appendix Table 5.Final plant standcount of chickpea varieties as influenced by the main effect of varieties, P rates and Rhizobium inoculants.

Treatments	FPSC/Plant
Variety	
Dubie	61.08
Teketay	61.17
Ejere	61.33
LSD (0.05)	0.73
P rates (kg ha^{-1})	
0	61.39
50	60.78
100	61.33
150	61.28
LSD (0.05)	0.84
Rhizobium	
WI	61.22
WoI	61.17
LSD (0.05)	0.596
CV (%)	2.1

Appenix Table 6. Final plant stand count of chickpea as affected by interaction effect variety and P rates

Variety	Phosphorus levels (kg ha^{-1})			
	0	50	100	150
Dubie	61.00	60.50	61.67	61.17
Teketay	61.67	60.83	61.17	61.00
Ejere	61.50	61.00	61.17	61.67
LSD (0.05)		1.461		
CV (%)		2.1		

Appendix Table 7. Final plant stand count of chickpea as affected by interaction effect of P rates and Rhizobium inoculants.

P rate (kg ha^{-1})	*Rhizobium*	
	WI	WoI
0	61.56	61.22
50	60.44	61.11
100	61.33	61.33
150	61.56	61.00
LSD (0.05)	1.193	
CV (%)	2.1	

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants; WoI=without inoculants.

Appendix Table 8. Final stand count ofchickpea at harvest as affected by interaction effect of P rate, Variety and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha-1)	WI	WoI
Dubie	0	0.03	0.03
Dubie	50	0.04	0.03
Dubie	100	0.04	0.03
Dubie	150	0.04	0.04
Teketay	0	0.05	0.06
Teketay	50	0.07	0.07
Teketay	100	0.07	0.07
Teketay	150	0.04	0.06
Ejere	0	0.04	0.04
Ejere	50	0.05	0.05
Ejere	100	0.06	0.05
Ejere	150	0.06	0.05
LSD (0.05)	0.0196		
CV (%)	23.9		

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants, WoI=without inoculants

Appendix Table 9. Days to flowering of chickpea as affected by interaction effect of P rates and *Rhizobium* inoculants

Phosphorubs rate (kg ha^{-1})	*Rhizobium*	
	WI	WoI
0	60.89a	52.89b
50	55.00b	50.11bc
100	51.89b	45.11c
150	51.44b	49.44bc
LSD (0.05)	3.163	
CV (%)	5.3	

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Appendix Table 10. Nodule volume per plant of chickpea as affected by interaction effect of variety and P rates

Variety	Phosphorus levels (kg ha^{-1})			
	0	50	100	150
Dubie	0.03	0.04	0.03	0.04
Teketay	0.05	0.07	0.07	0.07
Ejere	0.04	0.05	0.05	0.05
LSD (0.05)		0.0139		
CV (%)		23.9		

Means within a column followed by the same letter are not significantly different at 5% level of significance.

WI=with inoculants; WoI=without inoculants

Appendix Table 11. Nodule volume per plant of chickpea varieties influenced by the interaction effect of varieties and Rhizobium inoculants

Variety	*Rhizobium*		
	WI		WoI
Dubie	0.04		0.03
Teketay	0.07		0.07
Ejere	0.05		0.04
LSD (0.05)		0.009	
CV (%)		23.9	

.Means within a column followed by the same letter are not significantly different at 5% level of significance.

Appendix Table 12. Nodule volume per plant of chickpea affected by interaction effect of P rates and Rhizobium inoculants.

P rate(kg ha^{-1})	*Rhizobium*	
	WI	WoI
0	0.04	0.05
50	0.05	0.06
100	0,06	0.05
150	0.06	0.05
LSD (0.05)	0.01	
CV (%)	23.9	

Appendix Table 13. Nodule volume per plant of chickpea affected by interaction effect of varieties, P rates and Rhizobium inoculants.

WI=with inoculants, WoI=without inoculants

Variety	P rates (kg ha^{-1})	*Rhizobium*	
		WI	WoI
Dubie	0	0.03	0.03
Dubie	50	0.04	0.03
Dubie	100	0.04	0.03
Dubie	150	0.04	0.04
Teketay	0	0.05	0.06
Teketay	50	0.07	0.07
Teketay	100	0.08	0.07
Teketay	150	0.04	0.06
Ejere	0	0.04	0.04
Ejere	50	0.05	0.05
Ejere	100	0.06	0.05
Ejere	150	0.06	0.05
LSD (0.05)	0.0196		
CV (%)	23.9		

Means within a column followed by the same letter are not significantly different at 5% level of significance.

Appendix Table 14. Harvest index ofchickpea as affected by interaction effect variety and P rates

Variety	Phosphorus levels (kg ha^{-1})			
	0	50	100	150
Dubie	0.42e	0.42e	0.40e	0.39e
Teketay	0.59cd	0.63bc	0.67a	0.65ab
Ejere	0.58d	0.59cd	0.58d	0.59cd
LSD (0.05)		0.03		
CV (%)		5.9		

Appendix Table 15. Harvest index of chickpea as affected by interaction effect of P rates and Rhizobium inoculants.

P rate (kg ha^{-1})	*Rhizobium*	
	WI	WoI
0	0.53	0.54
50	0.55	0.53
100	0.54	0.56
150	0.55	0.54
LSD (0.05)	0.03	
CV (%)	5.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance. WI=with inoculants; WoI=without inoculants.

Appendix Table 16. Harvest index of chickpea as affected by interaction effect of P rate, Variety and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	0.39	0.44
Dubie	50	0.44	0.39
Dubie	100	0.38	0.42
Dubie	150	0.41	0.39
Teketay	0	0.60	0.59
Teketay	50	0.63	0.62
Teketay	100	0.67	0.67
Teketay	150	0.66	0.64
Ejere	0	0.59	0.58
Ejere	50	0.59	0.58
Ejere	100	0.57	0.58
Ejere	150	0.58	0.59
LSD (0.05)		0.053	
CV (%)		5.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance.
WI=with inoculants; WoI=without inoculants.

Appendix Table 17. The numbers of seeds per pod of chickpea as affected by interaction effect of P rate and *Rhizobium* inoculants

	Rhizobium	
P rate (kg ha^{-1})	WI	WoI
0	1.84	1.62
50	1.92	1.64
100	1.97	1.67
150	2.00	1.96
LSD (0.05)	0.31	
CV (%)	17.9	

Means within a column followed by the same letter are not significantly different at 5% level of significance.

WI=with inoculants; WoI=without inoculants

Appendix Table 18. Hundred seed weight of chickpea as affected by interaction effect of P rates and Rhizobium inoculants.

P rate (kg ha^{-1})	*Rhizobium*	
	WI	WoI
0	29.62	27.23
50	31.51	29.97
100	33.98	30.73
150	33.81	32.72
LSD (0.05)	2.41	
CV (%)	8.2	

Means within a column followed by the same letter are not significantly different at 5% level of significance.
WI=with inoculants; WoI=without inoculants

Appendix Table 19. Hundred seed weightof chickpea as affected by interaction effect of P rate, Variety and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	22.88	21.42
Dubie	50	26.44	22.42
Dubie	100	28.55	26.74
Dubie	150	28.54	28.29
Teketay	0	33.32	29.11
Teketay	50	35.07	36.20
Teketay	100	37.63	33.97
Teketay	150	38.13	37.20
Ejere	0	32.66	31.15
Ejere	50	33.03	31.29
Ejere	100	35.76	31.49
Ejere	150	34.76	32.68
LSD (0.05)	4.49		
CV (%)	8.8		

Means within a column followed by the same letter are not significantly different at 5% level of significance.WI=with inoculants; WoI=without inoculants

Appendix Table 20. Numbers of seeds per pod of chickpea as affected by interaction effect of P rate, Variety and Rhizobium inoculants.

		Rhizobium	
Variety	P rates (kg ha^{-1})	WI	WoI
Dubie	0	1.24c	1.15c
Dubie	50	1.31c	1.19c
Dubie	100	1.55c	1.36c
Dubie	150	1.38c	1.64c
Teketay	0	3.00a	2.33b
Teketay	50	3.00a	2.33b
Teketay	100	2.67ab	2.33b
Teketay	150	3.00a	3.00a
Ejere	0	1.29c	1.39c
Ejere	50	1.45c	1.39c
Ejere	100	1.68c	1.32c
Ejere	150	1.54c	1.36c
LSD (0.05)		0.54	
CV (%)		17.9	