International Journal of Applied Agricultural Sciences
2019; 5(3): 62-70
http://www.sciencepublishinggroup.com/j/ijaas
doi: 10.11648/j.ijaas.20190503.11
ISSN: 2469-7877 (Print); ISSN: 2469-7885 (Online)

Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer Rates on Growth, Yield and Yield Components of Chickpea (*Cicer arietinum L.*) at Goro, Bale Zone, Oromia Regional State

Tamiru Meleta[1, *], Girma Abera[2]

[1]Sinana Agricultural Research Centre, Bale-Robe, Ethiopia
[2]College of Agriculture, Hawassa University, Hawassa, Ethiopia

Email address:
tamish09@gmail.com (T. Meleta)
[*]Corresponding author

To cite this article:
Tamiru Meleta, Girma Abera. Effects of *Rhizobium* Inoculation and Phosphorus Fertilizer Rates on Growth, Yield and Yield Components of Chickpea (*Cicer arietinum L.*) at Goro, Bale Zone, Oromia Regional State. *International Journal of Applied Agricultural Sciences*. Vol. 5, No. 3, 2019, pp. 62-70. doi: 10.11648/j.ijaas.20190503.11

Received: April 2, 2019; **Accepted:** May 17, 2019**; Published**: June 13, 2019

Abstract: Chickpea (*Cicer arietinum L.*) is an important legume crop in Ethiopia. However, the productivity of the crop is very low due to a number of constraints out of which soil nutrient depletions a serious problem. Field experiment was conducted in 2015/16 in Goro, Bale Zone, Oromia Regional State to determine the effectiveness of Rhizobium strains and phosphorus fertilizer application on two varieties of chickpea (Arerti and Habru). The thirty treatments included: two *Rhizobial* inoculants (EAL018andEAL029), five P_2O_5 rate (0, 15, 30, 45and 60 kg P_2O_5 ha^{-1}); and two varieties of chickpea (Arerti and Habru). The experiment was set up in split plot design with factorial arrangement of two varieties of chickpea on the main plots and five levels of P_2O_5 and two types of *Rhizobium* in the subplot. Flowering date and plant height (PH) were significantly affected due to varieties, application of P_2O_5 and *Rhizobium* inoculation. The shoot dry matter production, number of primary and secondary branch, maturity date, number of pod and seed per plant, above ground biomass (AGBM), grain yield, thousand grain weight, were significantly affected by variety, *rhizobium* inoculation and application of P_2O_5. Maximum response was obtained from EAL029 strain inoculation and application of 45kg P_2O_5 $ha^{-1}$for dry matter production, number of pod and seed per plant, AGBM and grain yield. However, increasing P_2O_5 applications from 45 to 60 kg ha^{-1} provide maximum thousand grain weight respectively. The current investigation indicated that Arerti variety inoculation with *Rhizobium* strain EAL029 along with application of P_2O_5 at rate of 45 kg ha^{-1} found to be appropriate for chickpea production in the study area. Since the experiment was conducted only for one year, we suggest the results to be verified with more varieties of chickpea and *rhizobium* strain under the same agro-climatic conditions.

Keywords: Chickpea, Phosphorus, Rhizobia Strain, Yield

1. Introduction

Chickpea (*Cicer arietinum* L.*)* is an important leguminous crop with high nutritive value and source of protein. It is originated in south eastern Turkey [1]. The crop is adapted to cool semi-arid areas of the tropics, sub-tropics as well as the temperate areas. In Africa, Ethiopia stands first in area and production but third in productivity after Egypt and Sudan [2]. It is the third most important crop in volume of production after faba bean and haricot bean, in Ethiopia. It occupies 239,755.25 ha of lands with estimated production of 4,586,822.55 quintals. In Bale Zone chickpea is produced on1, 296.46 ha of land annually with estimated production of 15,309.95 quintals [2].

Legume crops such as chickpea, faba bean and field pea were the potential crops which can be grown in rotation to break the mono-culture cropping practice in Bale area. However, application of P fertilizer and *rhizobium* inoculation was limited for chickpea production in the study areas. The productivity of chickpea in Ethiopia is far below its potential [3]. Even though 100k gha^{-1} of DAP (Di ammonium phosphate) is recommended in Ethiopia to increase production, the crop is mainly produced under marginal conditions without application of external inputs including fertilizer [3]. The amount of P_2O_5 rate and effective type of *rhizobium* strain were not identified for the Goro area. Most tropical soils are deficient in available phosphorus and in terms of appropriate and effective strains that are capable of fixing nitrogen. There is a need to identify appropriate *rhizobium* strain which will enhances nitrogen fixation attributes and yield of chickpea under different phosphorus levels. However, the recommended rate of fertilizer might vary according to crop type (variety), location, soil type, etc. Therefore; this research was initiated to study the effect of *rhizobium* inoculants and phosphorus fertlizer rateson, on, yield and yield component of chickpea varieties.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Goro mid altitude of Bale, Oromia Regional State, and South eastern Ethiopia during the main cropping season of 2015/16. Goro is located 30 km from Sinana Agricultural Research Center, 60km from Bale Robe and 490 km from Addis Ababa. The site is situated at6^{0}59'N latitude and 40^{0}29'E longitude and elevation of 1771meters above sea level. The area has bimodal rain fall patterns. Based on this there are two separate crop growing seasons locally called '*bona'* and '*gana'*. The main season *bona* extends from August to December and *gana* from March to May. The area receives a mean annual rain fall of 500 mm, with annual mean maximum and minimum temperatures of 20°C and 16°C, respectively. The soils are predominantly vertic in properties. The major crops grown widely in the area are cereals (wheat, maize *and t*eff), pulses (chickpea, field pea, faba bean, and lentil), spices (coriander, fenugreek) and vegetables (onion, potato, tomato and pepper) under rain fed and irrigation. Cereal mono cropping is the predominant crop grown in the study area.

2.2. Description of Experimental Materials

Source of rhizobium inoculants: Rhizobium inoculants EAL029 was obtained from Soil Microbiology Laboratory of National Soil Testing Center (NSTC), Addis Ababa, while Rhizobium inoculants, EAL018 from Menagesh Biotech PLC. The inoculants were brought with standard carrier and kept in the laboratory until treated to seed during planting. Triple super phosphate (TSP) was used as a source of P_2O_5 fertilizer.

Source of seed: The chickpea varieties used in the study are Arerti and Habru. The two varieties were Kabuli type and released by Debrezeyit Agricultural Research Center (DZARC).

2.3. Treatments and Experimental Design

The experiment was laid out as a split plot design where two chickpea varieties (Arerti and Habru) was allocated on the main plot, while factorial combined five phosphorus fertilizer rates (0, 15, 30, 45, and 60 kg P_2O_5 ha^{-1}) and two *Rhizobium* strains (No inoculation, EAL018, and EAL029) were assigned on the sub-plot in three replications. Treatments were assigned to each plot randomly. The total number of plots was 93 (90 for chickpea and 3 for wheat). The size of each plot was 4mx2.4m (9.6m^2) and the distance between the plots and blocks were 1m and 2m respectively. The distance between adjacent rows and plants was 0.3 m and 0.1m respectively. Each plot was consisted 8 rows. At physiological maturity, plants from the central four rows of net plot size of 1.2x4m (4.8m^2) were harvested and used for determining yield and yield components, while destructive sample were taken from the rest four rows for estimation of nodulation parameter. Reference crop wheat newly released variety Sanate was planted in the same area (4x2.4m) plots with 0.2m between rows and 0.05 m between plants and consists of a total of 12 rows.

2.4. Experimental Procedures

2.4.1. Treatment Application and Field Activities

Land preparation was done according to standard production practices. Before planting inoculation of the seeds was done using the dishes as a container and sugar as adhesive material to stick the inoculums on the seeds. Inoculation was done under the shade to avoid direct sunlight. The inoculated seeds were kept in the shade for a few minutes to let the main dry before planting. Plots receiving non inoculants were planted before the others followed by those receiving inoculants in order to reduce the possibility of cross contaminations. The seeds were sown at the recommended rate of 120 kg seed ha^{-1}. Planting was done in rows and 12 kg ha^{-1} of N fertilizer in the form of urea was applied to all plots as starter N in the chickpea treatments and the same amount was applied to wheat plots to keep the N balance. Hand weeding and hoeing were done according to the locally recommended practice. Reference crop wheat (non nitrogen-fixer) was sown at the recommended seed rate of 125 kg ha^{-1}and P_2O_5 fertilizer in the form of TSP (46 kg P_2O_5 ha^{-1}) was applied at planting. Harvesting was done when the leaves started shedding and pods turned yellow.

2.4.2. Soil Sampling, Preparation and Analysis

Before sowing the crop, one composite soil samples (0-30cm depth) was taken randomly in a W-shaped pattern from the representative fifteen spots of the experimental field using an augur. The samples were air dried at room temperature, thoroughly mixed and ground to pass through a 2 mm sieve. Finally the samples were analyzed for the following parameters: particle size distribution, pH, organic carbon, cation exchange capacity (CEC), K, total nitrogen and available P from the representative bulk soil sample before planting.

2.4.3. Agronomic Data Collection at Harvesting

Dry matter yield at 50% flowering: After nodules collected from the roots, the plant samples were placed in labeled perforated paper bags and oven-dried at 70°C to a constant weight to determine the dry matter yield. The average dry weight of five plants was measured to determine dry weight per plant.

Number of primary branches per plant: Number of primary branches per plant was determined by counting the number of branches that grow on the main stem of five randomly taken plants per plot at the time of maturity.

Number of secondary branches per plant: Number of secondary branches per plant was taken by counting the number of branches that grow on primary branches of five randomly taken plants at maturity.

Plant height: Plant height was measured from the ground to the tip off main stem of the plant using a ruler from randomly taken five plants per plot and the average was recorded as plant height (cm) at physiological maturity. The average height of five plants was recorded from each plot.

Number of pods per plant: Five plants were randomly selected from the central rows of each plot, the pods were collected separately from each plant and their average was taken and reported as number of pods per plant.

Number of seed per pod: After pod shad been counted from each of the five randomly selected non-border plants, seed were separated from pods to get the number of seed per plant. For each plant the number of seed per pod was calculated by dividing the total number of seed per plant to the number of pods per plant. Finally, the mean value of five plants was taken as number of seed per pod.

Biomass: At physiological maturity, plants from the central four rows of a net plot size of 1.6x4m (6.2m2) were manually harvested close to the ground surface using sickles. The harvested plants were sun dried in the open air, weighed to determine the above ground biomass yield.

Straw yield: Straw yield was determined by subtracting the grain yield from the above ground biomass production. From each treatment and then converted to kgha^{-1}.

Thousand grain weight: The weigh to random sample of thousand grains in gram was reported as thousand grain weight.

Grain yield: Grain yield was measured by using electronic balance from the harvested central four rows with areas of 4.8m^2 and then adjusted to15% moisture content.

Harvest index: Harvest index was calculated as the ratio of grain yield to total above ground biomass after adjusted to15% moisture base.

2.4.4. Data Analysis

Data was subjected to analysis of variance (ANOVA) using the General Linear Model of the SAS statistical package (SAS, 2002) version9.1. Finally the treatments mean significant differences were separated following Lsd at 5% level of significance.

3. Results and Discussion

3.1. Soil Physico-Chemical Properties of the Experimental Site

Table 1. *Major physical and chemical characteristics of the soil at the experimental site.*

Soil characteristics	Test result
pH (by1:2:5soilWater)	7.60
pH (Kcl)	6.89
Total N (N%)	0.17
CEC (cmol.(+) kgsoil^{-1})	49.46
Av.P (ppm), Olsen	8.43
OC (%)	1.19
OM (%)	2.05
K^+(cmol.(+) kgsoil^{-1})	2.83
Soiltexture	
Clay	46%
Sand	20%
Silt	34%
SoiltextureClass	Clay

3.2. Phenological and Growth Parameters of Chickpea

3.2.1. Days to 50% Flowering

Number of days to flowering date was significantly (P<0.05) affected by the main effects of varieties, inoculation and phosphorus application rates. However, interaction effect of two and three factors did not show any significant effect on days to 50% flowering. The application of phosphorus fertilizer rate from 0kg P_2O_5 ha^{-1} to 60 kg P_2O_5 ha^{-1} decreased number of days required to reach 50% flowering rate from 56.33 days to 53.11 days. This is due to the fact that phosphorus enhance reproductive phase through fasten flowering. This is consistent with the result of [4] who reported that phosphorus application to haricot bean significantly reduced days to flowering.

Days to 50 % flowering of chickpea was significantly influenced by variety and rhizobium inoculation. There was slight difference in days to 50 % flowering between the two chickpea varieties. Habru variety had shortest days (54.42) to reach days to 50 % flowering while Arerti variety had the longest day (55.13) to reach 50 % flowering date. This is due to their genetic difference in response to flowering.[5] reported that there were significant differences in the number of days required to reach 50 % flowering among 20 common bean genotypes. Inoculation of chickpea by EAL029 reduces days to flowering as compared to uninoculated ones. Similar results were found by [6] who reported early flowering with inoculated plants than uninoculated plants in chickpea.

3.2.2. Plant Height

The plant height was significantly affected by chickpea variety, while inoculation and Phosphorus fertilizer rate showed no significant effect on variety. The tallest plant height (60.8cm) was recorded from Habru variety, while the shortest height (53.2cm) was recorded from Arerti, this variation was due to genetic makeup of the plant. In agreement with this [7] reported that, plant height difference within common bean varieties could be due to differences among the genotype with respect to absorption of nutrients, nitrogen fixation and accumulation of other relevant nutrients. On the other hand, there were no significant difference in plant height between two and three way interaction effect of variety, phosphorus and inoculation.

3.2.3. Days to Physiological Maturity

Days to physiological maturity was significantly affected by rhizobium inoculation, variety and phosphorus fertilizer application. Increasing level of phosphorus fertilizer rates from 0 to 60 kg P_2O_5 ha^{-1} and inoculation of chickpea with *rhizobium* strains (EAL029 and EAL018) decreased days to physiological maturity as compared to the control treatments. The results are supported by earlier research findings that P_2O_5 application at 40, 50 and 60 kg P_2O_5 ha^{-1} significantly reduced days to physiological maturity as compared to the control in haricot bean [4]. There was a slight difference between the two chickpea varieties in terms of days to physiological maturity. The mean maximum day to physiological maturity (114.02) was recorded from Arerti when the lowest (110.07) days to physiological maturity was recorded from Habru variety. The difference might also suggest distinction in genetic makeup of the two cultivars. Two and three way interaction effect had not significantly influence days to physiological maturity.

Table 2. Effects of variety, Rhizobium and phosphorus rates on date of flowering, plant height, days to maturity and number of primary and secondary branch of chickpea.

Treatments	**Date to Flowering**	**Plant height (cm)**	**Day to Maturity**	**No of Primary branch plant-1**	**No of Secondary branch plant-1**
Variety					
Arerti	55.13^a	53.19^b	114.02^a	2.26	4.13^a
Habru	54.42^b	60.80^a	110.07^b	2.28	3.71^b
LSD (5%)	0.6895	3.7263	1.8167	Ns	0.2255
RhizobiumInoculation					
Uninoculated	55.00^a	56.73	112.67^a	2.26	3.92
EAL018	54.93^a	57.23	112.00^{ab}	2.28	3.89
EAL029	53.40^b	57.04	111.47^b	2.27	3.95
LSD (5%)	0.3816	ns	0.9476	Ns	ns
Phosphorusrateskgha^{-1}					
0	56.33^a	56.41	114.61^a	2.23^b	3.65^b
15	55.67^b	57.55	113.72^a	2.26^{ab}	3.61^b
30	54.83^c	57.43	112.06^b	2.27^{ab}	3.74^b
45	53.94^d	57.43	110.17^c	2.28^a	4.29^a
60	53.11^e	56.18	109.67^c	2.31^a	4.31^a
LSD (5%)	0.4927	ns	1.2233	0.0571	0.2044
CV (%)	1.35	3.18	1.64	3.71	7.81

3.2.4. Number of Primary and Secondary Branches per Plants

Number of primary branches per plant was increased with the increasing of phosphorus application rate. Increasing phosphorus from 0 to 60 kg ha^{-1} increased number of secondary branch per plant. Number of secondary branch was significantly ($P<0.001$) affected by main factor of chickpea varieties and P_2O_5 rate. However, primary and secondary branches were not influenced by rhizobium inoculation. Arerti produced more number of secondary branches than Habru. The application of P_2O_5 fertilizer rates significantly affected the number of secondary branch per plant. The maximum mean (4.31) number of branch per plant was recorded at rate 60 kg P_2O_5 ha^{-1} and the lowest mean (3.61) number of secondary branch per plant was recorded from the control treatment. The reason in increasing number of branches per plant might be because P_2O_5 involve in cell division activity, which is important for increasing plant height, number of branches and increased the plant dry weight [8]. Interaction effect had no significant effect on number of primary and secondary branch per plant.

3.3. Yield and Yield Components of Chickpea

3.3.1. Shoot Dry Matter Yield

The results showed that main effect of variety, phosphorus rate and *rhizobium* inoculation had significant effect ($P<0.05$) on shoot dry matter production at mid flowering stage. The application of P_2O_5 at 45 kg P_2O_5 ha^{-1} increased the shoot dry matter yield by 12.58 % as compared with control treatment. This may be due to stimulated biological activities in the presence of balanced nutrient supply [9]. Comparable investigation reported by [10] showed that increasing phosphorus levels from 0 to 60 kg P_2O_5 ha^{-1} increased the general biomass of lentil and pea plants.

Result of chickpea variety showed that there was significant difference ($P<0.05$) in shoot dry matter production. Arerti variety produced higher shoot dry matter yield (22.19 gm plant^{-1}) than Habru variety (20.36gmplant^{-1}). This is due to the inherent genetic difference among varieties and the result is inconformity with the finding [11] which showed the difference between two mungbean cultivar for dry matter production. Similarly, inoculation of chickpea showed significant difference ($P<0.05$) in dry matter production. The higher dry matter yield was recorded from inoculation with EAL0 29 strain while the lower was from control. The increased shoot dry matter yield due to inoculation of chickpea with effective rhizobium strain (EAL0 29) could be the result of increased nitrogen fixation and its supply to chickpea, which enhanced crop growth. This result was similar with the finding of [12], who reported that inoculation of chickpea with CpSK strain increased shoot dry matter over the uninoculated control. However, there was no interaction effect of variety and phosphorus rate, variety and rhizobium inoculation and variety, phosphorus and different rhizobium inoculation on dry matter yield on chickpea.

Table 3. *Number of pod per plant, number of seed per plant seed per pod and dry matter yield of chickpea as influenced by variety, rhizobium inoculation and phosphorus rate.*

Treatments	Drymatteryield (gmplant^{-1})	Numberofpodplant^{-1}	Numberofseedplant^{-1}	NumberofSeedpod^{-1}
Variety				
Arerti	22.19^{a}	60.46^{a}	68.92^{a}	1.14
Habru	20.36^{b}	52.86^{b}	59.95^{b}	1.14
LSD (5%)	1.290	3.458	6.846	ns
*Rhizobium*inoculation				
Uninoculated	20.64^{b}	55.49^{b}	63.35^{b}	1.14
EAL018	21.35^{a}	55.99^{ab}	63.94^{ab}	1.14
EAL029	21.84^{a}	58.51^{a}	66.01^{a}	1.15
LSD (5%)	0.883	3.098	2.958	ns
phosphoruskgha^{-1}				
0	19.79^{c}	48.04^{d}	54.80^{c}	1.14
15	20.97^{b}	51.76^{c}	57.72^{c}	1.13
30	21.61^{ab}	56.94^{b}	64.06^{b}	1.13
45	22.28^{a}	64.06^{a}	73.95^{a}	1.15
60	21.73^{ab}	62.51^{a}	71.64^{a}	1.15
LSD (5%)	1.140	3.098	2.958	ns
CV (%)	8.02	8.19	6.88	3.48

3.3.2. Number of Pod per Plant

Total number of pod per plant was significantly influenced by interaction effect of variety and phosphorus fertilize rate. Similarly the main effect of variety, phosphorus fertilizer rate and rhizobium inculcation affected the number of pod per plant. The highest number of total pods per plant (64.1) was recorded at 45 kg P_2O_5 ha^{-1} application, while the lowest number of pod per plant (48.04) was obtained from control. Phosphorus application at 60 and 45 kg P_2O_5 ha^{-1} increased pod number by30.1 and 33.4%, respectively over the control. This result was similar with [13] who reported that the highest pod number per plant of chickpea was obtained from application of 60 kg P_2O_5 ha^{-1}. Chickpea inoculated with EAL029 strain showed about 5.4% more pods per plant than non-inoculated plants. It might be due to effective *rhizobium* strain increase leaf area which was being associated with more reproductive nodes. Similar results indicated that number of pods per plant was significantly affected with *Rhizobium* inoculation in chickpea [13, 14]. These researchers noted that number of pod per plant was increased by 8.69 % more pods per plant than non-inoculated plants. There was also significant difference for the number of total pod per plant between Arerti and Habru varieties. Thus, Arerti produced 14.4% higher total number of pod per plant than Habru variety. Interaction between chickpea variety and phosphorus rate had highly significant (P<0.01) effect on the number of pod per plant. The highest number of pods per plant (70.0) was recorded from Arerti variety at 45 kg P_2O_5 ha^{-1} application, while the lowest (45.9) which was recorded in the Habru variety without P_2O_5 fertilization. On the other hand, interaction effects had no significant effect on total number of pod per plant.

3.3.3. Number of Seed per Plant

The number of seed per plant was significantly affected by phosphorus application, rhizobium inoculation and variety. The highest (74.0) seed per plant was recorded from 45 kg P_2O_5 ha^{-1} application, while the lowest (54.8) number of seed per plant was obtained from control. Similarly the highest (66.01) number of seed was recorded from plots inoculated with EAL029 strain, while the lowest numbers of seed per plant was obtained from the control. Arerti chickpea variety produced the higher (69.0) number of seed per plant than Habru variety (59.95). There was highly significant (P<0.01) interaction effects between chickpea variety and phosphorus rate on number of seed per plant. The highest mean number of seed per plant (81.0) was recorded when Arerti variety was supplied with 45 kg P_2O_5 ha^{-1} while the minimum (52.2) was recorded from Habru variety with control (0 kg P_2O_5 ha^{-1}). This result was in line with [15] who reported that application of P_2O_5 at 60 kg ha^{-1} increased the soybean seed number by 23.4% as compared to control treatment. This is due to the positive role of P_2O_5 in more photosynthetic materials production and allocation and its transfer to reproduction organs of the crop. The other interaction effects were found to be non-significant in affecting number of seed per plant.

3.3.4. Number of Seed per Pod

All the main effects (variety, inoculation with rhizobium and P_2O_5 fertilizer rates) and their interaction effects had no significant (P<0.05) influence on number of seed per pod. This result was in agreement with [16] who found that study on soya bean seed per pod was not influenced by *rhizobium* inoculation had no significant of grain per pod. Non significant effects of studied treatments on number of grain per pod may be due to more effects of genetic factors in control of this trait rather than environmental and management factor. Interaction effect of two and three way had no significant effect in chickpea for number of grain per pod.

Table 4. *Interaction effects of variety and phosphorus application rate on number of pod and seed per plant of chickpea variety.*

Variety	P_2O_5 (kgha^{-1})	Number of pod per plant	Number of seed per plant
	0	50.2de	57.4d
Arerti	15	52.1cd	59.2d
	30	61.2b	68.4b
	45	70.0a	81.0a
	60	68.9a	78.6a
Habru	0	45.9e	52.2e
	15	51.4d	56.3de
	30	52.7cd	59.7cd
	45	58.1b	66.8b
	60	56.1bc	64.7bc
LSD (5%)		5.09	5.02
CV (%)		9.58	8.31

Means in column followed by the same letter are not significantly different at 5% level of significance; LSD=Least Significant Difference; CV=Coefficient of Variation

3.3.5. Above Ground Biomass Yield

Total above ground biomass of chickpea was significantly (P<0.01) affected by the main effect of variety, rhizobium inoculation and phosphorus fertilizer application rate. Arertichickpea variety produced higher above ground biomass than Habru variety. Application of 45 kg of P_2O_5 ha^{-1} increased biomass yieldby11.7% as compared to the control. This increase in dry biomass yield in response to the increased phosphorus application may be ascribed to the phenomena on that sufficient supply of phosphorus is associated with increased root growth and leaf expansion that may lead to high dry matter accumulation through enhancing effective exploitation by the roots for the immobile nutrients such as phosphorus [17]. The current investigation was in line with the findings of [18] and [19] who reported that increasing P_2O_5 levels improved above ground biomass of fenugreek and Narvon vetch at harvest by as much as18.5%.

Similarly [16] reported that nitrogen fixation by *Rhizobium* hastened the vegetative grow than phosphorus application improved the yield components which are the possible reason for substantial increase for biological yield. The highest mean biomass (5620.97 kg ha^{-1}) was obtained due to inoculation of EAL029 strain, while the lowest mean (5314.81kgha^{-1}) of above ground biomass was recorded from uninoculated treatments. The increments of biomass yield could be due to sufficient nitrogen supply mainly from biological nitrogen fixation. In line with this result [20] also pointed out that above ground biomass yield of soybean were increased ranging from 39 to75% by the inoculation of different strains of rhizobia. Since nitrogen is a key factor in many biological compounds that plays a major role in photosynthetic activity and chlorophyll synthesis is which eventually resulted in vigorous vegetative growth and more biomass accumulation, its sufficient availability is essential. However, significant variation was not observed in above ground biomass due to interaction effect among the treatments.

3.3.6. Grain Yield

Significant variations ingrain yield were observed due to main effect of variety and rhizobium inoculation where as interaction effect did not significantly affect grain yield when compared with control plot. The higher grain yield (2963.1 and 2924.1 kg ha^{-1}) was obtained from Arerti variety and inoculation of chickpea with EAL 029 strain respectively. Arerti variety was higher (9.2 %) yielder than Habru variety. This increased grain yield might also due to effective nodulation which enhance the utilization of atmospheric nitrogen and availability of phosphorus towards higher yield. In line with this result [21] reported that the higher nodulation due to inoculation resulted in higher nitrogen fixation by rhizobium and eventually resulted in higher number of pods production per plant which brings about higher grain yields as whole. In other studies, [12] reported that yield and yield component of chickpea were increased after inoculating the seeds with specific strain of rhizobium [22], reported that *rhizobium* inoculated plants gave significantly higher seed yield compared with un-inoculated once.

Similarly significant variation was observed on grain yield of chickpea due to phosphorus application rates. The highest grain yield (3007.1 kg ha^{-1}) was obtained due to application of 45 kg P_2O_5 ha^{-1}, while the lowest grain yield (2626.9 kg ha^{-1}) was obtained with control (0 kg P_2O_5 ha^{-1}). Application of 45 kg P_2O_5 ha^{-1} and inoculation with EAL0 29 rhizobium strain increased grain yield by 14.5 and 8.0% as compared to the control treatment. This result may indicate that applying chemical fertilizer constituting phosphorus and small amount of nitrogen significantly increased economic yield of the crop [23, 13].

Table 51. *Effect of variety, rhizobium inoculation and phosphorus rate on biomass, grain yields thousand grain weight, harvest index and straw yield of chickpea.*

Treatments	Aboveground Biomass (kgha^{-1})	Grain Yield (kgha^{-1})	Thousand Grain weight (gm)	Harvest Index (%)	Straw Yield (kgha^{-1})
Variety					
Arerti	5652.69^{a}	2912.03^{a}	257.79^{b}	0.52	2689.543^{a}
Habru	5219.85^{b}	2667.67^{b}	308.51^{a}	0.52	2498.844^{b}
LSD (5%)	272.74	139.22	3.7047	ns	108.71
RhizobiumInoculation					
Uninoculated	5314.81^{b}	2707.15^{b}	280.31^{b}	0.51^{c}	2543.892

Treatments	Aboveground Biomass (kgha^{-1})	Grain Yield (kgha^{-1})	Thousand Grain weight (gm)	Harvest Index (%)	Straw Yield (kgha^{-1})
EAL018	5373.03^{b}	2738.35^{b}	282.77^{b}	0.52^{b}	2589.118
EAL029	5620.97^{a}	2924.05^{a}	286.36^{a}	0.53^{a}	2650.253
LSD (5%)	100.46	117.31	2.846	0.006	ns
Phosphoruskgha^{-1}					
0	5148.75^{d}	2626.90^{d}	280.27^{ab}	0.52	2499.114^{bc}
15	5209.35^{cd}	2652.92^{cd}	282.63^{ab}	0.52	2456.944^{c}
30	5478.24^{bc}	2781.33^{bc}	282.83^{ab}	0.52	2619.134^{b}
45	5817.87^{a}	3007.09^{a}	286.21^{a}	0.52	2771.893^{a}
60	5527.13^{b}	2881.03^{ab}	285.81^{a}	0.53	2623.881^{b}
LSD (5%)	284.34	151.44	3.6748	ns	129.69
CV (%)	7.83	8.13	1.94	2.04	7.49

3.3.7. Thousand Grain Weight

Thousand grain weights was significantly (P<0.01) affected by main effect of variety, inoculation and P_2O_5 fertilizer application. Increasing of phosphorus fertilizer level from 0 to 45 kg ha^{-1} increase thousand grain weight of chickpea, similarly inoculation of chickpea by EAL0 29 increased thousand grain weights as compared to other treatment. The results suggest that P_2O_5 fertilizer application and *rhizobium* inoculation could contribute to increase the efficiency of major nutrient use and thus led to the higher grain weight and yield. [24] also observed that seed inoculation with proper rhizobium together with P_2O_5 application at early growth stage stimulated the root nodulation and improved grain weight. Inconformity with this result, [25] found 91% increase in hundred seed weight by inoculation and application of P_2O_5 over the control treatment. Increasing P_2O_5 levels increased thousand seed weight, perhaps through improving photosynthetic activity and source sink relationship. The other most important reason for variation in thousand seed weight might be due to genetic characteristics of the varieties for this trait. Interaction effects of treatments had no significant effect.

3.3.8. Harvest Index

Harvest index is very useful in measuring nutrient partitioning in crop plants, which provides an indication of how efficiently the plant acquired nutrients are partitioned for grain production. Harvest index was observed to be non-significantly affected by the main effects of variety, phosphorus and their interaction effects. However, rhizobium inoculation showed significant (P<0.05) influence on harvest index. The highest harvest index (HI) (0.53) was obtained due to inoculation of EAL0 29 strain where as the lowest (0.51) HI was recorded from uninoculated treatment. The higher mean HI also implies higher partitioning of dry matter into grain. Similar results reported by [26], stated that there were no significant differences (P<0.05) in harvest index between the inoculated and the fertilized soybean varieties.

3.3.9. Straw Yield

Straw yield was significantly affected by P rates and chickpea varieties. Statistical analysis revealed that both variety and P_2O_5 application had significant (P<0.01) effect on straw yield. Chickpea that received 45 kg P_2O_5 ha^{-1} gave maximum (2771.89 kg ha^{-1}) straw yield, while minimum (2499.11kgha^{-1}) obtained from control (0 kg P_2O_5 ha^{-1}). This may be due to adequate supply of P_2O_5 played a vital role in physiological and developmental processes of chickpea. Furthermore, the favorable effect of this important nutrient might have accelerated the growth processes that in result increased straw yield of the crop. This result was in line with the result of [27] who stated that significant effect of P_2O_5 on straw yield of mungbean; the highest yield (3.29 gm plant^{-1}) was recorded from phosphorus applied at rate of 40 kg P_2O_5 ha^{-1}. Chickpea variety Arerti produced higher (2770.38 kg ha^{-1}) straw yieldha^{-1}, than Habru variety. This is similar with the result of [28] who reported that three garden pea varieties significantly differ in biomass yield by 20% more among genotypes that they have tested. Straw yield was not significantly influenced by rhizobium inoculation and interaction between two and three factors.

3.4. Economic Analysis

Partial budget analysis was employed for economic analysis of inoculation and fertilizer application and it was carried out for grain yield data. The potential response of crop towards the added fertilizer and price of fertilizers during planting ultimately determine the economic feasibility of fertilizer application [29]. The average yield was adjusted downward by15% to reflect the farmer's field yield as described by CIMMYT [29]. Chickpea seeds were valued at an average open market price of 17.00 birr/kg. To estimate the total costs, mean current prices of rhizobium strain (40 birr/packet) and DAP (16.56birr/kg) were used at the time of planting. Though, TSP was used as a source of P, the price of DAP was considered for the calculation by equating the amount of Ps in recurrent price of TSP is unknown. All cost and benefits were calculated on hectares basis in Ethiopian Birr (ETBha^{-1}). For a treatment to be considered as a worthwhile option to farmers, the minimum acceptable rate of return (MARR) needs to be at least between 50 and 100% [29], So to draw farmers' recommendations from marginal analysis in thisstudy, 100% return to the investment is reasonable minimum acceptable rate of return since farmers 'in the study area usually not apply P_2O_5 and *rhizobium* inoculants for chickpea production. The economic analysis was based on formula developed by CIMMYT [29] and given as follows:

Gross average yield (GAY) (kgha^{-1}): is the average yield of each treatment.

Adjusted (AJY) = is the average yield adjusted downward by 15% to reflect the difference between the experimental yield and yield of the farmers.

$$AJY= GAY-(GAY*0.15)$$

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. GFB= AJY*field/farm get price of a crop.

Total cost (TC): Mean current prices of rhizobium Strain (15birr/pack), DAP (16 birr/kg), phosphorus application and rhizobium Strain application were considered P_2O_5 per hectare.

Net benefit (NB): was calculated by subtracting the total costs from the gross field benefit for each treatment (NB= GFB-TC).

Marginal Cost (MC) = change in cost between treatments

Marginal benefit (MB) = change in benefit between treatments

$$\text{Marginal rate of return } \{MRR (\%)\} = (MB/MC*100)$$

Table 6. *Marginal analysis of Rhizobium inoculation and phosphorus rates on chickpea.*

Treatment	Total Cost	Marginal Cost	Net Benefit	Marginal Benefit	Marginal ret of Return
V1*R0*P0	0	0	41572.31	0	0
V1*R0*P1	273.4	273.4	43987.63	2415.32	883.44
V1*R0*P2	546.8	273.4	48263.77	4276.14	1564.06
V1*R0*P3	795.2	248.4	49233.14	969.3667	390.24
V1*R0*P4	1068.6	273.4	50888.22	1655.08	605.37
V1*R1*P3	980.2	248.4	52025.35	1137.13	457.78
V1*R2*P3	980.2	223.4	60685.88	8660.537	3876.70
V2*R0*P0	0	0	43323.99	0	0.00
V2*R0*P2	546.8	273.4	45017.28	1693.29	619.35
V2*R0*P3	770.2	223.4	45356.86	339.5833	152.01
V2*R2*P3	980.2	248.4	47650.57	2293.703	923.39

V1=Arerti, V2=Habru, R0=Noinoculation, R1=EAL018, R2=EAL029, P0=0kg P_2O_5, P1=15kg P_2O_5, P2=30kg P_2O_5, P3=45kg P_2O_5 and P4=60kg P_2O_5

4. Summary and Conclusion

Days to50% flowering was highly significantly affected by variety, inoculation and phosphorus application. Inoculation with EAL0 29 shortened daystar flower than other treatments. Similarly, the highest P_2O_5 fertilizer (60 kg P_2O_5 ha^{-1}) application shortened daysto50% flowering. Habru variety had shorter daysto50% flowering than Arerti variety. Days to physiological maturity decreased with increased P_2O_5 application rates and under inoculated condition than uninoculated ones. The results showed that *Rhizobium* inoculation significantly affected flowering date, dry matter yield, number of pod and seed per plant, maturity date, aboveground biomass, harvest index, grain yield, and thousand grain weights. The highest mean values of most of agronomic parameters were recorded when chickpea was inoculated with EAL0 29 *rhizobium* strain while correspondingly the lowest mean values were recorded from the control (uninoculated plots).

The results displayed that phosphorus fertilizer had significantly affected flowering date, number of pod and seed per plant, aboveground biomass, grain yield, and thousand grain weights. The highest and lowest mean values of most of the chickpea agronomic parameters we rerecorded at 45 kg P_2O_5 ha^{-1} and control, respectively. The interaction effects of variety and P_2O_5 rates had significantly ($P<0.05$) affected number of pod and seed per plant were recorded from Arerti variety and application of 45 kg P_2O_5 ha^{-1}. The best combination of Arerti variety inoculated with EAL0 29 at 45 kg P_2O_5 ha^{-1} application gave profitable yield response with positive MRR of 3876.70 %. Finally, application of this treatment is recommended as the best with an attractive acceptable return. However, this result needs to be confirmed by repeating similar experiments under the same agro-climatic conditions and growing season's in the area. Based on the results of this study, chickpea production was new in the area where this activity was conducted so it is possible to improve production and productivity of this crop by selection of variety and appropriate *rhizobium* strain with optimum P_2O_5 application.

References

[1] Redden B, Furman BJ, Upadhyaya HD, Pundir RPS, Gowda CLL, Coyne C, Enne king D. 2007. Biodiversity Management in Chickpea. In: Yadav SS, Redden R, Chen W, Sharma B, editors. Chickpea Breeding & Management. CABI, Walling ford, UK. Pp 355-368

[2] CSA (Central Statistics Authority). 2015. Agricultural Sample Survey. Reports on area under cultivation, yield and production of major crops for main (Maher) season, Ethiopia.

[3] Bejiga, G. and Dab K. 2006. Breeding chickpea for wide adaptation. In: Food and Forage Legumes of Ethiopia: Progress and Prospects, pp. 59-66.

[4] Gidago Gifole, Sheleme Beyene, Walelign Worku and Ethiopia Sodo. Response of Haricot Bean (*Phaseolus vulgaris L.*) to Phosphorus Application on Ultisols atAreka, Southern Ethiopia. Journal of Biology Agric. and Healthcare1, no. 3 (2011): 38-49.

[5] Nchimbi-M solla S. and Try phone G. M. 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.

[6] ZamanS. Mazid M. A. and Kabir G. 2011. Effect of *Rhizobium* inoculants on nodulation, yield and yield traits of chickpea (*Cicer arietinum L.*) in four different soils of greater Rajshahi. Journal of Life and Earth Sciences 6: 45-50.

[7] Chabot R. Antoun H. And Cescas M. C. 1996. Growth promotion of maize and lettuce by phosphate-solubilizing. Plant and Soil, 184: 311–321.

[8] Tesfaye M. J. Liu D. L. Allan and Vance C. P. 2007, Genomic and genetic control of phosphate stress in legumes. Plant Physiol. 144. 594-603.

[9] ZafarM. Maqsood M. Ramzan M. Amzan A. and Zahid A. 2003. Growth and yield of lentil as affected by phosphorus. Journal of Agriculture and Biology, 1560-8530.

[10] Erman, M. B. Yildirim, N. Togay and F. Cig, 2009. Effect of phosphorus application and Rhizobium inoculation on the yield, nodulation and nutrient uptake in field pea (*Pisum sativumsp. arvense L.*). J. of Anim. andVeter. Adva. 8 (2): 301-304.

[11] Elahi, N. S. Musta F. and Mirza J. I. 2004. Growth and nodulation of mungbean (*Vignardiat L.)* as affected by sodium chloride. JRes. Sci. 15: 39-143.

[12] Tena W. Wolde-Meskel E. Walley F. 2016. Symbiotic Efficiency of Native and Exotic Rhizobium Strains Nodulating Lentil (*Lens culinaris medik.*) in Soils of Southern Ethiopia. Agronomy6 (11): 1-10.

[13] Togay N. Togay Y. Cimrin K. M. Turan M. 2008. Effectof Rhizobium inoculation, sulfur and phosphorus application on yield, yield components and nutrient uptake in *Trigonella foenum- graecum L*. J. Environment and Ecology, 9: 281-287.

[14] Namvar A. Seyed Sharifi R KhandanT. Jafari Moghadam M. 2013 Seed Inoculation and Inorganic Nitrogen Fertilization Effects on Some Physiological and Agronomical Traits of Chickpea (*Cicer arietinum L.)* in Irrigated Condition and Appl. Scie. 5 (7): 793–799.

[15] Behzad Mahmoodi, Amir Abbas Mosavi, Morteza Sam Daliri and Namdari M. 2013. The evaluation of different values of phosphorus and sulphur application in yield components and seed quality characteristics of soy bean (*Glycinmax L.*) Advances in Environmental Biology, 7 (1): 170-176.

[16] Malik M. A. Mumtaz A. C. Haroon Z. K. and Wahid M. A. 2006. Growth and yield response of soybean (Glycinmax L.) to seed inoculation and varying P levels. J. Agric. Res. 44 (1): 155-161.

[17] Gustfson A. A. 2010. Hand book of fertilizers, their source, makeup, effect and use (3rd). Agro bios, India. Pp. 78-88.

[18] Yilmaz S. 2008. Effects of increased phosphorus rates and plant densities on yield and yield related traits of Narvon vetch lines. TurkJAgric. 32: 49-56.

[19] Alemu Desa. 2009. Effect of phosphorus application and rhizobium inoculation on nodulation, yield and yield related traits of fenugreek (*Trigonella foenum-graecum L.*) in sinana, south eastern Ethiopia. Thesis, Haramaya University, Haramaya, Ethiopia.

[20] Abbasid K. M. Manor, Mandy Tapir M. M. 2010. Efficiency of Rhizobium inoculation and P fertilization in enhancing nodulation, seed yield, and phosphorus use efficiency by field grown soybean under hilly region of Rawalakot Azad Jammu and Kashmir, Pakistan. Journal of Plant Nutrition, 33: 1080–1102.

[21] SinghA. Baoule A. Ahmed HG. Dikko AU. Aliyu U. Sokoto MB. Hassan J. Musa M. Haliru B. 2011. Influence of phosphorus on the performance of cowpea (*Vigna unguiculata L. Walp*.) varieties in the Sudan savanna of Nigeria. Agri. Science. 2 (3): 313-317.

[22] Bhuiyan M. Khanam D. Hossain M. Ahmed M. 2009. Effect of rhizobium inoculation on nodulation and yield of chickpea in Calcareous soil. Bangladesh J. of Agri. Research 33: 549-554.

[23] Getchew A. and Rezone F. 2006. Response of Faber Bean to Phosphate Fertilizer and Weed Control on Nit sols of Ethiopian Highlands. Holeta Agricu. Resea. Cent. EARO.

[24] Morad M. SaraS. Alireza E. Reza CM. 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 Biosciences, Vol. 3, p. 134-141, 2013.

[25] Tairo E. V. and Ndakidemi P. A. 2013. Bradyrhizobium japonicum Inoculation and phosphorus supplementation on growth and chlorophyll accumulation in soybean (*Glycinemax L.*). Am. J. Plant Sci. 4: 2281.

[26] Kamara A. Y. Abaidoo R. Kwari J. and Omoigui L. 2007. Influence of phosphorus application on growth and yield of soybean genotypes in the tropical savannas of northeast Nigeria, *Archives of Agronomy and Soil Science* 53: 5, 539-552.

[27] Bhuiyan M. M. H, Rahman M. M. Afroze F. Sutradhar G. N. C. and Bhuiyan M. S. I. 2008**.** Effect of phosphorus, molybdenum and Rhizobium inoculation on growth and nodulation of mungbean Scientific Officer, RARS, Hathazari, Chittagong. J. Soil Nature. 2 (2): 25-30.

[28] AliM. E. Khanam D. M. Bhuiya H. A. Khatun M. R. and Talukder M. R. 2008. Effect of *Rhizobium* inoculation on different varieties of garden pea (*Pisumsativum L.*). *J. Soi. Nature* 2: 30-33.

[29] CIMMYT. 1998. From agronomic data to farmer recommendations: Economics training manual completely revised. CIMMYT, Mexico, D. F.