OPEN ACCESS

Middle East Research Journal of Agriculture and Food Science
ISSN: 2789-7729 (Print) & ISSN: 2958-2105 (Online)
Frequency: Bi-Monthly
DOI: 10.36348/merjafs.2024.v04i02.003

KUWAIT SCHOLARS PUBLISHER
Website: http://www.kspublisher.com/
Email: office@kspublisher.com

Effects of Rhizobium Strains on Seed Yield and Yield Related Traits of Chickpea (*Cicer aritienum* L.) Varieties at Ambo, Ethiopia

Berhanu Soboka[1*], Wassu Mohammed[2], Chaluma Tujuba[3]
[1]Oromia Agricultural Input Regulatory Authority, Ciro Agricultural input Regulatory, Ethiopia
[2]College of Agriculture and Envinmental Science, Haramaya University, Haramaya, Ethiopia
[3]Ambo Agricultural Research Center, Ethiopian Institute of Agricultural Research, Ethiopia

Abstract: The chickpea (Cicer arietinum L.) is a significant legume food crop in West Showa that farmers exploit to generate revenue and sustenance. Nevertheless, two major obstacles to production are the scarcity of high-quality seed and the poor fertility of the soil. Thus, the purpose of this study was to evaluate how Rhizobium inoculation affected yield, growth, and its constituent parts. Four Rhizobium strains (Cp11, Cp17, Cp41, and control) x four varieties (Eshete, Dimtu, Teketay, and Local) organized in factorial combinations were assessed using a randomized complete block design with three replications. All phenology and growth parameters, yield components, seed yield, and productivity indices were significantly influenced by both variety and Rhizobium strain, with the exception of crop phenology and hundred seed weight, which were not significantly influenced by Rhizobium strain. Plant height and the number of pods per plant were significantly impacted by the interaction between the R strain and variety. Four types yielded seed with a range of 2013.89 to 2777.78 kg ha-1, whereas inoculation procedures produced seed with a range of 2152.78 to 2690.97 kg ha-1. The Teketay variety and seeds infected with the Cp17 Rhizobium strain produced the best seed yield. Higher grain yield index per day, Rhizobium sensitive or infection index, yield index, and seed production efficiency were also seen in Teketay variety and seeds infected with Cp17 Rhizobium strain. The largest seed yield was produced by the Teketay variety inoculated with the Cp17 Rhizobium strain, and in most cases, the enhanced varieties' seeds inoculated with the Cp17 strain also produced high yields.

Keywords: Growth, Productivity index and Seed Yield.

Research Paper

***Corresponding Author:**
Berhanu Soboka
Oromia Agricultural Input Regulatory Authority, Ciro Agricultural input Regulatory, Ethiopia

How to cite this paper:
Berhanu Soboka *et al* (2024). Effects of Rhizobium Strains on Seed Yield and Yield Related Traits of Chickpea (*Cicer aritienum* L.) Varieties at Ambo, Ethiopia. *Middle East Res J. Agri Food Sci.*, *4*(2): 61-70.

Article History:
| Submit: 26.01.2024 |
| Accepted: 28.02.2024 |
| Published: 02.03.2024 |

1. INTRODUCTION

Based on production level, chickpeas (Cicer arietinum L.) rank third among food legumes worldwide, after beans and peas. It is consumed in more than 120 countries and farmed in more than 50 countries worldwide. Only Turkey, India, Australia, and Myanmar produce more chickpeas globally than Ethiopia, which is among the top five producers (FAO, 2019). Ethiopia is the greatest chickpea grower in Africa and is regarded as the second center of origin for the bean (Anbessa and Bejiga *et al.*, 2002; ICARDA, 2010).

In the conventional farming system, the crop plays a variety of roles. According to Erman *et al.*, (2011), it is a major source of food for humans and animals, as well as a source of revenue for farmers in underdeveloped nations. Chickpea seeds are a good source of reasonably priced energy, protein, and possibly health-beneficial phytochemicals because they include 20.6% protein, 61.2% carbohydrates, and 2.2% fat (Togay *et al.*, 2008) (Wood and Grusakb *et al.*, 2007). Additionally, the crop is essential to maintaining soil fertility (Funga *et al.*, 2016).

Rhizobium strain inoculation enhanced the yield of both Stover and chickpea grains by 8 to 40% and 8 to 10%, respectively. To get the most out of grain legume crops in terms of soil improvement and maximum production, seed must be injected with a unique, suitable strain of Rhizobium before planting (Ayaz, *et al.*, 2010). Numerous Rhizobia strains that have been found and shown to be productive and competitive exist in Ethiopia (Wolde-Meskel *et al.*, 2012); up until 2019 (2011), 17 and 14 Desi and Kabuli type variations, respectively, have been made available. However, without the addition of suitable and efficient rhizobia strains, the utilization of high yielding varieties alone may not produce the necessary level of output (Mulongoy *et al.*, 1995; Shantharam *et al.*,) On 208,838 hectares of land, 779,033 farmers produced chickpea during the 2019–20 Meher Season. With an average yield of 2 t ha-1, 435193.21 tons of red and white chickpeas were produced. A significant portion of the Oromia Regional State's land—15.27 percent—was farmed for red chickpeas in the West Showa Administrative Zone (CSA, 2020). But compared to its potential to generate up to 5.5 t ha-1, the crop's production is poor (Belay *et al*., 2006). The low yield of chickpea in the nation is caused by a number of issues, including the use of indigenous cultivars and low-quality seeds, illnesses transmitted through seeds, and the low level of use of new technologies and agronomic methods (Melese *et al*., 2005). In order to increase crop productivity in the West Showa Zone of the Oromia Region state, it is crucial to identify enhanced varieties that contain a specific Rhizobial strain or strains associated with them. Thus, the purpose of this study is to assess how inoculating seeds with Rhizobium strains affects chickpea varieties' nodulation, phenology, growth, and seed output.

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The research was carried out in Ethiopia's Oromia Regional State at the Ambo Agricultural Research Centre. The Center is situated 2195 meters above sea level and is located in latitude 08°57'N and longitude 38°07' E. The region experiences mean annual maximum and lowest temperatures of 25.4 and 11.7 0C, respectively, with an average annual rainfall of 1036 mm (Am ARC, 2018).(Am ARC, 2018) Soil Type: Vertisol (Heavy Black Clay Soil).

2.2. Description of Experimental Materials

Three chickpea varieties—Eshete, Dimtu, and Teketay—produced during the 2021 cropping season were procured from the Ambo and Debre Zeit Agriculture Research Centers for their seeds. Debre Zeit Agriculture Research released the three varieties. Furthermore, the seeds of a single chickpea cultivar that was primarily grown by the research area's farmers were gathered from those who had planted the cultivar during the 2021 cropping season.

2.3. Treatments and Experimental Design

The treatments included inoculating four chickpea types (three improved and one farmer's cultivar) without inoculating them with any of the three Rhizobium strains (CP41 (commercial), CP11 (local), and CP17 (local). As a result, there were 16 treatments in total—4 (varieties) x 4 (inoculations) in a factorial combination. Three replications of the randomized complete block design (RCBD) were used to arrange the treatments. Every plot in the field was given a treatment at random. Each plot was 1.2 meters in width and 3 meters in length. The intra-row and inter-row spacings for the seed were 0.1 and 0.3 meters, respectively. Blocks and the plot will be separated by 1 and 0.5 meters, respectively.

2.4. Experimental Procedures and Management

2.4.1. *Rhizobium* Inoculant and Inoculation

The Holetta Agriculture Research Center's soil microbiology will provide the strains CP 11 and CP 17. The nodules of local chickpea genotype Ararti produced in greenhouses were used to isolate and purify the inoculant of the two strains of Rhizobium. Menagesha Biotech will procure strain CP 41 from the Damot Gale district of Southern Nations, Nationalities, and Peoples Regional State (Collee and Mackie *et al*., 1989The inoculant CP 41 Rhizobium strain was obtained and purified by Menagasha Biotech Institute from a local strain that was present in the Peoples Regional State, Southern Nations, Nationalities, and Damot Gale district. The process created by (Fatima *et al*., 2007) was used to inoculate the seeds prior to sowing. Before applying the peat-based inoculums, the seeds were moistened with a 48% sugar solution to ensure a thin, uniform coating of inoculums on the seeds just before sowing. In order to guarantee that the applied inoculant adhered to the seeds, the necessary amounts of seed was suspended in a 10% sugar solution at a 1:1 ratio. Ten grams of the inoculant per kilogram of dry seeds were carefully combined with the seeds. To preserve the viability of the cells, the inoculation was carried out in a little shade, and after letting the seeds air dry for a little while, they were seeded into the appropriate plots at the specified rate and spacing. Plots with uninoculated seeds were planted first, followed by infected ones, to prevent contamination.

2.5. Data Collection

2.5.1. Crop Phenology and Growth

Days to emergency (DE): The total number of days from planting to the point at which half of the plot's plants had emerged.

Days to flowering (DF): The amount of time measured from the time of seeding until 50% of the plants in the plot produced their first bloom.

Days to maturity (DM): The amount of time that passes between planting and the point at which 90% of the plants in a plot reach physiological maturity.

Plant height (cm): 10 randomly selected plants from the middle rows were measured with a ruler to determine the height of the plant from ground level to the tip of the main stem at 90% physiological maturity.

2.5.2. Seed Yield and Yield Components

Total number of pods on each plant at full maturity: This data was collected from ten randomly selected plants spread across the whole net plot area.

Total number of seeds per pod: This is the number of seeds per pod as a whole, and it will be derived from 20 randomly selected sample pods.

Weight of a hundred seeds (g): Weighed a sample of one hundred seeds from the plot using an electric sensitive balance.

Seed yield: This refers to the seed yield and it was determined by harvesting the crop from the entire net plot area (including that use for determination of yield attributes). Seed yield will be adjusted to 10% moisture content and yield was determined after sun drying for 1 to 2 weeks to attain maximum complete dry weight near complete drying of straw with minimum moisture content.

2.5.3. Production Efficiency

Seed production efficiency (SPE): Seed filling duration divided by duration of vegetative period and then multiplied by grain yield.

Grain yield per day (GYPD): Calculate as the ratio of gain yield (kg ha^{-1}) to days to physiological maturity and expressed as kg ha^{-1} day^{-1}.

***Rhizobium* strains sensitivity index (RSSI):** it will estimate for each variety with each *Rhizobium* strain inoculation in comparison the seed yield obtained from plot without inoculation as follow:

Rhizobium strains sensitivity index (RSSI)**:** $\frac{YR-YUI}{YUI}$

Where; YR = seed yield obtained from plot inoculated with each *Rhizobium* strain and YUI = seed yield obtained from plot without inoculation of four chickpea varieties in each replication.

Yield index: it will estimate for each variety as ratio of mean seed yield of variety obtained from plot inoculated with all *Rhizobium* strains to seed yield obtained from plot without inoculation in each replication as follow:

Yield index: µYs/µYUI

Where; µYR = mean seed yield of each variety obtained from plot inoculated with all *Rhizobium* strains and µYUI = mean seed yield of each variety obtained from plot without inoculation in each replication.

2.6. Data Analysis

The data that will be collected from field experiment will be subjected to analysis of variance (ANOVA) for RCBD factorial using Gen Stat 15th edition statistical software package. The mean values comparison will be performed following the significance test results from ANOVA using least significant difference (LSD) at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1. Seed Yield and Yield Related Traits of Chickpea Varieties

3.1.1. Phenology and Growth of Chickpea Varieties

3.1.1.1 Phenology of chickpea varieties

The chickpea types differed significantly in terms of days to emergency, days to blooming, and days to maturity, according to analysis of variance. The primary factor of Rhizobium strain inoculation and the combination of variety and Rhizobium strains had no discernible effects on chickpea phenology (Appendix Table 1). The Dimtu variety had the most days to emergence—13 days—while the Eshete variety had the shortest—11.66 days—with statistical parity with the Teketay and farmers cultivars of chickpea. Teketay variety matured later than Eshete variety (136.33 days) although the difference in days to maturity between the two varieties was not statistically significant. Eshete variety showed a delayed days to flowering of 64.33 days. The farmers' cultivar reached maturity (130 days) and flowering (53.25) in the lowest amount of time (Table 1). The variety registry also revealed the existence of variation, stating that the Teketay variety might take up to 145 days to mature (MoANR, 2013), whilst the Eshete and Dimtu varieties could take up to 138 and 122 days, respectively (MoANR, 2020 and 2016). Other authors also reported the presence of significant variations among Desi type chickpea genotypes in Ethiopia. Awol and Bulti (2018) reported significant variation among 202 Desi type chickpea landraces and two released varieties (*Fetenech* and *Minjar*) evaluated at Sirinka and Jari, North Wollo. Zerihun and Shiferaw (2019) also observed significant differences among 19 elite varieties for days to flowering and maturity. Sintayehu (2021) reported significant variations among 79 chickpea genotypes and two improved varieties for days to flowering and maturity evaluated at Debre Zeit for two consecutive years.

Table 1: Variation of chickpea varieties for days to emergence, flowering and maturity at Ambo in 2022/2023 cropping season

Variety	Days to emergence	Days to flowering	Days to maturity
Eshete	11.66^{b}	64.33^{a}	135.42^{a}
Dimtu	13.00^{a}	55.25^{b}	132.92^{b}
Teketay	12.75^{b}	55.50^{b}	136.33^{a}
Farmers cultivar Local	12.00^{b}	53.25^{c}	130.0^{c}
LSD (0.05)	0.47	1.39	1.94
CV (%)	4.62	2.93	1.74

Mean values within column designated with similar letters are not significant each other at p<0.05, LSD (5%) = Least significant difference at p≤0.05 and CV (%) = percentage of coefficient of variation.

3.1.1.2 Interaction effect of variety and *Rhizobium* strain on plant height of chickpea

The primary parameters of variety and Rhizobium strain inoculation, as well as the combination of the two, had a substantial impact on the height of the chickpea plant (Appendix Table 1). The tallest plants (52.26 cm) were established from the seeds of the Eshete variety inoculated with the CP17 Rhizobium strain; however, there was no statistically significant difference in height between the plants grown from the seeds of the Teketay and Eshete varieties inoculated with the CP11 and CP41 Rhizobium strains. Farmers' cultivar seeds that were sowed without inoculation and inoculated with Rhizobium strains CP11 and CP41 resulted in shorter plants with no discernible variation in plant height. The seeds of *Dimtu* variety without inoculation and innoculated with CP41 *Rhizobium* strain also had shorter plants and taller plants of this variety were observed at plots where the plants grown from seeds innoculated with CP17 *Rhizobium* strain but had nonsignificant difference with plants grown from seeds of *Teketay* variety innoculated with CP11 *Rhizobium* strain (Table 2).

The results showed that varieties were responded to different *Rhizobium* strains in terms of plant height and the compatibility of varieties to *Rhizobium* strains also varied. The seeds of *Teketay* and *Eshete* varieties inoculated with the three *Rhizobium* strains showed increased the height of plants ranged from 29.84 to 34.83% and 15.46 to 20.06%, respectively, as compared to plants grown from seeds of varieties without inoculation. On the other hand, seeds of farmers' cultivar and *Dimtu* variety innoculated only with CP17 *Rhizobium* strain had significantly taller plants by 14.09 and 13.91%, respectively, than plants grown seeds without inoculation (Table 2). The inoculations of chickpea seeds with Rhizobium strains help the plants to fix atmospheric nitrogen which contributes to the development of plant growth that increase height of plants (Rudresh, *et al.*, 2005; Elkoca, *et al.*, 2008). The presence of compatibility and differences of effective rhizobia strains among chickpea varieties was also reported by other authors (Mulongoy *et al.*, 1995; Shantharam *et al.*, 1997). Gemechu (2013) suggested the need to conduct specific tests for specific breeding materials, strain and environments to identify host genotype compatible to specific *Rhizobia* strain.

Table 2: Interaction effects of variety and *Rhizobium* strain on plant height of chickpea varieties at Ambo in 2022/2023 cropping season

Treatment	***Rhizobium* strain**			
Variety	**CP11**	**CP17**	**CP41**	**Control**
Eshete	50.26[ab]	52.26[a]	51.66[ab]	43.53[def]
Dimtu	44.00[cde]	47.73[bcd]	43.03[ef]	41.90[ef]
Teketay	47.60[bcd]	49.43[ab]	48.06[abc]	36.66[gh]
Farmers cultivar	36.26[gh]	39.36[fg]	35.36[gh]	34.50[h]
LSD (0.05)		4.36		
CV (%)		5.98		

3.1.2. Yield Components and Seed Yield of Chickpea

3.1.2.1 Influence of varieties and *Rhizobium* strains on yield components and biomass yield

The results of an analysis of variance showed that while varieties affected the weight of one hundred seeds, the number of seeds per pod and biomass production were significantly influenced by the inoculation of seeds with Rhizobium strains and chickpea varieties. The number of seeds per pod, weight of 100 seeds, and biomass production were not affected by the interaction between chickpea types and Rhizobium strains (Appendix Table 1). Farmers cultivar provided a lower biomass output of 1.68 kg per plot, while Teketay (2.49 kg) and Eshete (2.42 kg) cultivars produced higher biomass yields per plot. In comparison to Eshete, Dimtu, and Farmers cultivar, the Teketey variety yielded a higher biomass production by approximately 2.89, 14.75, and 48.21%, respectively (Table 3). Amare (2020) found that there were notable differences between the 100 advanced lines of Desi-type chickpea germplasms that were assessed at two different North Gondar locales. Farmers' cultivar, *Eshete* and *Teketey* varieties produced 1.64, 1.61 and 1.54 average number of seeds per pod, respectively, without significant difference each other,but significantly higher number of seeds per pod of *Dimtu* variety. *Dimtu* variety had significantly highest hundred seeds weight (34g) and *Teketey* variety had also heavier hundred seed weight (28.75g) next to the Farmers' cultivar whereas farmers cultivar followed by *Eshete* variety had lower hundred seed weight (Table 3). Amare (2020) reported 1 to 1.7 with 1.15 mean numbers of seeds per pod and 10.1 to 35.5g with 22.7g average hundred seeds weight of 100 advanced lines of *Desi*-type chickpea germplasms evaluated at two location of North Gondar. Yasin and Alamir (2023) reported 1.03 to 1.53 numbers of seeds per pod and 14.83 to 32.17g hundred seeds weight of eight chickpea varieties evaluated in two districts of South Gonder, northwestern Ethiopia. Ahmad (2003) and Jakhar (2014) reported significant variability in chickpea genotypes for seeds per pod and hundred seeds weight.

The chickpea types inoculated with CP17 Rhizobium strain yielded the maximum biomass (2.48 kg) when compared to those produced with CP 11 Rhizobium strain, while there was no statistically significant difference in biomass output. Although there was no discernible difference between the uninoculated and CP 41 Rhizobium-inoculated chickpea types, their respective biomass yields were lower. The largest number of seeds per pod (1.8) was produced by chickpea varieties inoculated with the CP17 Rhizobium strain. On the other hand, the number of seeds per pod produced by seeds inoculated with the CP 11 and CP 41 Rhizobium strains was significantly lower than that of the seeds inoculated with the CP17 strain, with no discernible difference between them. The fewest seeds per pod were generated by chickpea types whose seeds were sown without inoculation (Table 3). *Natoli* chickpea variety produced 1.6 number seeds per pod from plants grown from inoculated seeds by CP 41 *Mesorhizobium ciceri* strain but plants grown from uninoculated seeds produced 1.4 seeds per pod. Inoculation of seeds had also a positive and highly significant effect on total biomass of chickpea variety (Ibsa *et al.*, 2013).

This is due to the fact that higher nitrogen supplies brought about by biological nitrogen fixation contributed significantly to improved growth and assimilate accumulation, which in turn improved plant reproductive capacity and overall chickpea biomass. According to numerous authors (Ali *et al.,* 2004; Elkoca *et al.,* 2007; Togay *et al.,* 2008; Dutta and Bandyopadhyay *et al.,* 2009; Ahmed *et al.,* 2010 and Jakhar *et al.,* 2016), inoculating chickpea seeds increased the supply of nitrogen significantly and had positive effects on reproductive performance, vegetative growth, and assimilate accumulation of plants.

Table 3: Effects of Variety and Rhizobium strain on biomass yield, number seed per pod and hundred seed weight chickpeas at Ambo in 2022/2023 cropping season

Variety	Biomass yield (kg)	Number seed per pod	Hundred seed weight (g)
Eshete	2.42a	1.61a	20.41c
Dimtu	2.17b	1.45b	34a
Teketey	2.49a	1.56a	28.75b
Farmers cultivar	1.68c	1.64a	13.33d
LSD (0.05)	0.22	0.09	2.41
***Rhizobium* strains**			
CP 11	2.33a	1.59b	25.25
CP 17	2.48a	1.80a	25.25
CP 41	2.02b	1.57b	24.41
Control	1.93b	1.30c	22.02
LSD (0.05)	0.22	0.09	NS
CV (%)	12.46	7.55	11.99

Mean values within column designated with similar letters are not significant each other at p<0.05., NS = Nonsignificant, LSD (5%) = Least significant difference at p≤0.05 and CV (%) = percentage of coefficient of variation.

3.1.2.2 Interaction effect of variety and *Rhizobium* strain on number pods per plants of chickpea

Number of pods per plant was significantly influenced by varieties, *Rhizobium* strains and the interaction of the two factors (Appendix Table 1). Highest number pods per plant (114.66) were obtained from *Eshete* variety inoculated by CP17 *Rhizobium* strain which had statistical parity with *Dimtu, Teketay* and farmers' cultivar inoculated with the same CP17 strains. *Eshete* variety without inoculation had the lowest number of pods per plant (69) which had no statistical difference with seeds of same *Eshete* variety inoculated by CP11 and CP41, *Dimtu*, *Teketay* and farmers' cultivar without inoculation and farmers cultivar inoculated by CP11 and CP41 *Rhizobium* strains. *Eshete* variety was more responsive to the three *Rhizobium* strains to increased number of pods per plant. All other varieties increased number of pods per plant when inoculated with CP17 *Rhizobium* strain (Table 4). The results of Karadavut and Ozdemir's (2001) studies support the finding that chieck variety inoculation with a Rhizobium strain results in a higher number of pods per plant than in the control group. When compared to the uninoculated control, the number of pods per chickpea infected with Rhizobium was observed to be greater (Sharar *et al*., 2000; Khan *et al*., 2003). Tena (2016) also noted that by inoculating native CP-41 Rhizobial strain seeds instead of uninoculated ones, the number of pods per plant increased by 48%.

Table 4: Interaction effects of variety and *Rhizobium* strain on number of pod per plant of chickpea varieties at Ambo in 2022/2023 cropping season

Treatment	***Rhizobium* strain**			
Variety	CP11	CP17	CP41	Control
Eshete	80.66efg	114.66a	76.66fg	69.00g
Dimtu	96.33bcd	104.66abc	83.66def	81.33efg
Teketay	91.66cde	106.00ab	99.00bc	81.66efg
Farmers' cultivar	70.33fg	102.66abc	77.66fg	75.66fg
LSD (0.05)		13.82		
CV (%)		9.42		

Mean values in column and rows designated with similar letters are not significant each other at p<0.05, LSD (5%) = Least significant difference at p≤0.05 and CV (%) = percentage of coefficient of variation.

3.1.2.2 Seed yield

Rhizobium strain inoculation and variety had a considerable impact on chickpea yield, but their interaction had no discernible effect (Appendix Table 1). The Dimtu variety's output (2552.08 kg/ha) was not significantly different from the greatest yield (2777.78 kg/ha) generated by the Teketay variety. Different grain yields of the Dimtu variety were statistically not significantly affected by the Eshete variety. Farmers' cultivar yielded notably less than average. Table 5 shows that the Teketay variety outperformed the Dimtu, Eshete, and Farmers cultivars by 8.84, 17.65, and 37.93% in terms of yield. The difference of *Teketay*, *Dimtu* and *Eshete* varieties for yield potential at farmers field and research site were reported at the time of varieties release (MoA, 2020, 2016 and 2013). According to the variety register description, *Dimtu* variety released in 2016 had higher yield potential at farmers field (2300 to 3600 kg/ha) and research site (2500 to 4700 kg/ha) than the two varieties. However, the yield of varieties might not same at all environments die to effect of environment and genotype x environment interaction. *Dimtu* and *Teketay* varieties produced 3218.9 and 2296.3 kg/ha yield, respectively, at Kobo district, North Wollo under irrigation during 2018 and 2019 (Awol *et al*., 2020). *Dimtu* and *Teketay* varieties produced 1740 and 1970 kg/ha mean yield, respectively at five locations of Western Ethiopia, during the 2016/2017 main cropping season (Biru and Dagnachew, *et al*., 2018).

The seeds inoculated with the CP17 Rhizobium strain yielded the maximum yield (2690.97 kg/ha), which was statistically different from other treatments. The highest yield was achieved from uninoculated seeds, while the second highest yield was produced by seeds infected with the CP41 Rhizobium strain. However, this difference was not statistically significant from seeds inoculated with the CP11 Rhizobium strain. Chickpea seeds inoculated with the CP17 Rhizobium strain exhibited yield advantages of 25, 11.51, and 9.93% in comparison to uninoculated seeds and innoculated seeds with the CP11 and CP41 Rhizobium strains, respectively (Table 5).

Numerous investigations on Rhizobium inoculation have demonstrated its advantageous benefits in raising the performance of chickpea yield components. A significant increase in nodulation is produced by seed inoculation, which results in plants with great vigor. More dry matter accumulates as a result, increasing grain output in the end (Namwar *et al*., 2013; Uddin *et al*., 2014). Lack of nitrogen is one of the main problems preventing crops from being produced at a higher rate. The disadvantage of nitrogen deficiency can be significantly mitigated by using biofertilizers. When grown in conjunction with compatible and effective Rhizobium strains, chickpeas, being a legume, can obtain a significant portion of their N requirement through symbiotic N2 fixation. However, the amount of N2 fixation varies depending on biotic and abiotic factors that can affect the success of the legume-Rhizobium association (Fran *et al*., 2004). Depending on their ability to infect the host plant, different strains exhibit significantly different levels of nitrogen fixation (Anjali *et al*., 2020). The results of this study showed that the CP17 Rhizobium strain was superior to the other two Rhizobium strains (CP11 and CP41) when it came to the inoculation of chickpea seeds. Table 5 shows that the inoculation of seeds with CP17, CP41, and CP11 Rhizobium strains resulted in yield advantages of 25, 13.7, and 12.1%, respectively, over uninoculated seeds. The genotype of the legume, the Rhizobium strain, and their interactions with the biophysical environment and management techniques determine legume yields and nitrogen fixation (Giller *et al*., 1995). For this reason, it's critical to identify efficient Rhizobium strains that are compatible with the cultivar(s) and growing area(s).

Table 5: Effects of variety and Rhizobium strain on seed yield of chickpea at Ambo in 2022/2023 cropping season

Variety	Seed yield kg/ha.
Eshete	2361.11b
Dimtu	2552.08ab
Teketay	2777.78a
Farmers cultivar	2013.89c
LSD (0.05)	290.65
***Rhizobium* strains**	
CP 11	2413.19bc
CP 17	2690.97a
CP 41	2447.92b
Control	2152.78c
LSD (0.05)	290.65
CV (%)	14.38

Mean values within column designated with similar letters are not significant each other at $p<0.05$, LSD (5%) = Least significant difference at $p\leq0.05$ and CV (%) = percentage of coefficient of variation.

3.1.3. Production Efficiency

Analysis of variance revealed that chickpea varieties and *Rhizobium* strain had significant effect on seed production efficiency, grain yield per day, *Rhizobium* strains sensitivity index for varieties but effectiveness and compatibility for strains and yield index. However, the interaction of variety and *Rhizobium* strains had nonsignificant effect on production efficiency of chickpea (Appendix Table 1).

Teketay and *Dimtu* varieties were better for see d production efficiency, grain yield index per day *Rhizobium* sensitive index and yield index with nonsignificant difference between the two but significantly higher than *Eshete* variety and farmers' cultivar though *Eshete* variety showed statistically nonsignificant difference with the former two for yield index and with *Dimtu* variety for *Rhizobium* sensitive index. *Eshete* variety and farmers cultivar had nonsignificant difference for seed production efficiency and grain yield index per day but this variety was better than farmers' cultivar for *Rhizobium* sensitive index and yield index (Table 6). As another author pointed out, without the addition of suitable and productive Rhizobia strains, high yielding cultivars might not produce the necessary degree of production on their own. According to Mullongoy *et al*., (1995) and Shantharam *et al*., (1997), a specific legume cultivar nodulated by several strains of the same species of Rhizobium will fix varied amounts of nitrogen and hence yield. The findings of this study thus demonstrated *Teketay* followed by *Dimtu* varieties were better compatible to the *Rhizobium* strains used for seed inoculation.

Though there was a statistically insignificant difference between the CP17 Rhizobium strain and the other two strains for seed production efficiency, grain yield index per day, and yield index, and between the CP41 Rhizobium strain and the other strain for yield index, the CP17 Rhizobium strain was the best in all of these categories. With the exception of a nonsignificant difference in the yield index for the CP11 Rhizobium strain, the control plot had the considerably lowest values for all estimates (Table 6). According to Anjali *et al.*, (2020), the variation seen across Rhizobium strains and other authors' findings suggests that distinct strains exhibit significant diversity in the amount of nitrogen fixation and consequently yield, contingent upon their ability to infect the host plant. Most people agree that in nitrogen-limited environments, the symbiotic connection functions most efficiently when other potentially limiting elements are supplied in sufficient amounts (Abaidoo *et al*., 1990 and Abdiev *et al*., 2019).

In symbiosis with a variety of cultivars of the same plant species, a specific strain of Rhizobium wills nodulate and fix varying amounts of nitrogen (Mulongoy *et al*., 1995). Therefore, CP17 may be regarded as the top Rhizobium strain in the research region for raising chickpea productivity. However, chickpea may be less effective at fixing nitrogen dioxide (N2 fixation) than native strains (Smith *et al*., 1987), especially in areas with low or inefficient native Rhizobial populations (Beck *et al*., 1992). Native strains also have a wider host range, a higher tolerance to abiotic stress, better infective and stimulation capacity, and high nodulation efficiency (Anjali *et al*., 2020).

Thus, the lowest estimates of seed production e fficiency, grain yield index per day, *Rhizobium* sensitive index.

Table 6: Variation of chickpea varieties and *Rhizobium* strains for seed production efficiency, grain yield per day, *Rhizobium* strains sensitivity index and yield index

Variety	SPE	GYPD	RSSI	YI
Eshete	2412.67b	20.00b	1874.25b	1.17a
Dimtu	3235.00a	23.52a	2030.50ab	1.18a
Teketay	3535.46a	25.27a	2117.30a	1.12a
Farmers cultivar	2593.83b	18.89b	1527.10c	0.85b
LSD (0.05)	387.08	2.73	196.36	0.24
***Rhizobium* strains**				
Cp 11	2932.32ab	21.75ab	2412.19b	0.96c
CP 17	3286.03a	24.24a	2689.97a	1.29a
Cp 41	2950.91ab	22.16ab	2446.92b	1.15ab
Control	2607.70c	19.53c	0.07c	0.91c
LSD (0.05)	387.08	2.73	192.36	0.24
CV (%)	15.76	14.98	12.22	16.89

Mean values within column designated with similar letters are not significant each other at p<0.05, LSD (5%) = Least significant difference at p≤0.05 and CV (%) = percentage of coefficient of variation, SPE=Seed production efficiency; GYPD= Grain yield index per day; RSSI =*Rhizobium* sensitive index; YI=yield index

4. SUMMARY AND CONCLUSION

One of the most important food legumes, chickpeas are utilized to maintain soil fertility, provide food and feed for people, and generate cash for farmers. Chickpea in soils with no or little bacterial life requires seed inoculation with an effective and importunate Rhizobial strain in order to provide an appropriate rhizobial population in the rhizosphere. In this sense, rhizobium inoculation of the seed is a helpful method of attaining sustainable production and may replace expensive N-fertilizers. Thus, the purpose of this study was to evaluate how various Rhizobium strains affected the growth and yield of four distinct types of chickpeas. Four Rhizobium strains (Cp11, Cp17, Cp41, and control) x four varieties (Eshete, Dimtu, Teketay, and Farmers cultivar) were matched in a factorial arrangement to create the treatments. At the Ambo Agricultural Research Center experimental site, treatments were assessed using a randomized full block design with three replications over the 2022–2023 cropping season.

Under field conditions, the impact of two primary parameters (variety and Rhizobium strain) as well as any potential interactions between them on phenology, growth, yield components, and seed yield were assessed. The field experiment's findings showed that varietal differences had a considerable impact on all aspects of phenology, growth, and seed output. The major effect of Rhizobium strains had a substantial impact on plant height, biomass, pod per plant, seed per pod, seed yield, seed production efficiency, grain yield per day, sensitivity index of Rhizobium strains, and yield index. In addition, plant height and pod count per plant were significantly impacted by the interactions between Rhizobium strain and variety. While local varieties had a much lower seed yield (2013.89kg ha-1) when grown, Teketay and Dimtu types yielded greater seed yields (2777.78 and 2552.08 kg ha-1) when grown. When Cp17 strains are injected into chickpea types, seed yields rise by 538.19 kg ha-1 compared to control.

The tests' overall findings demonstrated that, following the growth of chickpea seeds of varying qualities influenced by variety, Rhizobium strain, and the combination of the two factors had a major impact on metrics related to yield-related features and seed yield. The majority of the time, enhanced variety seeds infected with the Cp17 bacterium yielded high yields. Therefore, it is advised to take into account strains of Rhizobium and types that provide a high yield in order to increase chickpea productivity.

REFERENCES

- Abaidoo, R. C., George, T., Bohlool, B. B., & Singleton, P. W. (1990). Influence of elevation and applied nitrogen on rhizosphere colonization and competition for nodule occupancy by different rhizobial strains on field-grown soybean and common bean.*Can. J. Microbiol,* 36, 92–96.
- Abdiev, A., Khaitov, B., Toderich, C., & Parc, K. W. (2019). Growth, nutrient uptake and yieldparameters of chickpea *(Cicer arietinum* L.*)* e nhanced by *Rhizobium* and *Azotobacter* inoculations in saline soil. *Journal of Plant Nutrition, 43,* 1-12.
- Ahmad, B., Wahid, M. A., Bugti, R. A., Zahid, M. A., & Shaukal, A. (2003). Evaluation of chickpea germplasm for semi arid zones of Balochistan. *International Journal of Agricultural Biology*, *5*, 113-116.
- Ahmed, A. G., Ahmed, M., Hassanein, M., & 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.
- Ali, H., Khan, M. A., & Randhawa, S. A. (2004). Interactive effect of seed inoculation and phosphorus application on growth and yield of chickpea (*Cicer arietinum* L.*). International Journal of Agriculture and Biology, 6*(1), 110-112.
- AmARC (Ambo Agricultural Research Center). (2 021). Annual Report Ambo Agricultural Research Center Agricultural Economics, Extension and Gender Research Process, unpublished.
- Amare, T., Asnake, F., & Muluken, B. (2020). Genetic variability and association analysis of Desi-type chickpea (*Cicer arietinum* L.) advanced lines under potential environment in North Gondar, Ethiopia. *Cogent Food & Agriculture*, *6*, 1806668. https://doi.org/10.1080/23311932.2020.180666.
- Anbessa, Y., & Bejiga. (2002). Evaluation of Ethiopian chickpea landraces for tolerance to M drought. *Genetic Resources and Crop Evolution*, *49*(6), 557-564.
- Anjali, P., & Saju, A. (2020). Biofertilizers Towards Sustainable Agriculture and Environment Development. *Agriculture and food, 2*(10).
- Awol, M., Sisay, B., Abebe, M., Abay, D., & Tadesse, A. (2020). Evaluation of desi type chickpea varieties for adapting under irrigation at Kobo *Agrotechnology, 9*, 200. doi: 10.35248/2168-9881.20.9.200.
- Ayaz, M., Ahmad, E., Sagoo, A. G., Ullah, I., Hussain, A., & Manzoor, M. (2010). Nod ulation, grain yield and grain protein contents as affected by rhizobium inoculation and fertilizer placement in chickpea cultivar bittle-98.
- Beck, D. P. (1992). Yield and nitrogen fixation of chickpea cultivars in response to inoculation with selected rhizobial strains. *Agron Journal, 84*, 510–516.
- Belay, G. (2006). PROTA. Plant Resources of Tropical Africa 1: Cereals and Pulses., Wageningen, PROTAFoundation-Backhuys–CTA.
- Biru, A., Dagnachew, L. (2018). Yield and agronomic performances of desi type chickpea genotypes against acidic soil of Western Ethiopia. *Journal of Agricultural Biotechnology and Sustainable Development, 10* (6):116-121.
- Collee, J. G., & Miles, R. S. (1989). Mackie & Mc. Cartney Practical Medical Microbio logy *Churchill Livingstone, Edinburgh,* 13th edn, pp-141-160.
- CSA. (2020). Agricultural sample survey report on area and production of crops private peasant holdings, meher season. Statistical Bulletin 587, Addis Ababa, Ethiopia.

- Dutta, D., & Bandyopadhyay, P. (2009). Performance of chickpea (*Cicer arietinum* L.) to application of phosphorus and bio-fertilizer in laterite soil. *Archives of Agronomy and Soil Science, 55*(2), 147-155.
- Elkoca, E., Kantar, F., & 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.
- Elkoca, E., Kantar, F., & Sahin, F. (2008). Influence of nitrogen fixing and phosphorus solubil izing bacteria on the nodulation, plant growth, and yield of chickpea. *Journal of Plant Nutrition, 31*, 157–171.
- Erman, M., Demir, S., Ocak, E., Tufenkci, S., Oguz , F., & Akkopru, A. (2011). Effects of *Rhizobium*, arbuscular mycorrhiza and whey applic ations on some properties in chickpea (*Cicer arietinum* L.) under irrigated and rain fed conditions: Yield, yield components, nodulation and AMF colonization. *Field Crops Res*, *122*(1), 14-24.
- FAO. (2019). FAOSTAT Statistical Database of the United Nation Food and Agriculture Organization (FAO) statistical division. Rome.
- Fatima, Z., Zia, M., & Chaudhary, M. F. (2007). Interactive effect of Rhizobium strains and P on soybean yield, nitrogen fixation and soil fertility. Pakistan journal of Botany, 39(1), 255-264.
- Fran, L.W., Steve, K., Garry, H., & Craig, S. (2004). Nitr ogen and phosphorus fertility management for desi and k abuli chickpea. *Canadian Journal of Plant Science*, 73-79.
- Funga, A. C., Ojiewo, O. O., Turoop, C. L., & Stephen Mwangi, S. G. (2016). Symbiotic effectiveness of rhizobia strains modulating desi type chickpea. (*Cicer arietinum* L.) Varieties.*Journal of Plant Sciences*, *4*(4), 88–94.
- Giller, K., & Cadisch, G. (1995). Future benefits from biological nitrogen fixation: an *ecological approach to agriculture. Plant and Soil*, *174*(1), 255-277.
- Ibsa, A. (2013). Agronomic and Symbiotic Characteristics of Chickpea, (*Cicer arietinum* L.), as Influenced by Rhizobium Inoculation and Phosphorus Fertilization under Farming Systems of Wolaita area, Ethiopia. MSc Thesis Plant Production Systems, Wageningen University, The Netherlands.
- ICRISAT. (2010). (International crops research Institutions for the semi-Arid tropics) cicer arietinum L.) Patancheru, Hyderabad India. pp. 31-35.
- Jakhar, D. S., Singh, R., & Kamble, M. S. (2016). Genetic diversity studies in chickpea (Cicer 70 arietinum L.) in Kolhapur region of Maharashtra. *Bangladesh Journal of Botany*, *45*(3), 459-464.
- Karadavut, U., & Ozdemir, S. (2001). Effect of Rhizobium inoculation and nitr ogen application on yield and yield characters of chickpea. *Anadolu*, *11*(1), 14-22.
- Keneni, G., Bekele, E., & Assefa, F. (2013). Evaluation of Ethiopian chickpea (Cicer arietinum L.) germplasm accessions for symbio-agronomic performance. *Renewable Agriculture and Food Systems, 28*(4), 338-349.
- Khan, M. A., Ali, A., & Tanveer, A. (2003). Effect of seed inoculation and different levels of phosphorus on the yield and yield components of chickpea. *Pakistan Journal of Life Soc. Sci*, *1*, 106-108.
- Namvar, A., Sharifi, R. S., Khandan, T., & Moghadam, M. J. (2013). Seed inoculation and inorganic nitrogen fertilizatio n effects on some physiological and agronomical tr aits of chickpea (*Cicer arietinum* L.) in irrigated condition. *Journal of Central European Agric*, 14, 28-40.
- Melese, D. (2005). Morphological and RAPD marker variation analysis in some droug ht tolerant and susceptible chickpea (Cicer arietinu m L.). Genotypes of Ethiopia. M.Sc. Thesis, Addis Ababa University Ethiopia.
- Mulongoy, K. (1995). Technical paper 2: Biological nitrogen fixation. *Food and Agriculture Organization of the United Nations (FAO)Corporate Document Repository, ILRI Training Manual*, *2*.N and P fertilizers and ino culation with *Rhizobium*.*African Crop Science Journal* 6.
- Rudresh, D. L., Shivaprakash, M. K., & Prasad, R. D. (2005). Effect of combined application of Rhizobium, phosphate solubilizing bacterium and *Trichoderma sp p*. On growth, nutient up take and yield of chickpea (*Cicer aritenium* L). *Applied Soil Ecology, 28*, 139-146.
- Shantharam, S., & Mattoo, A. K. (1997). Enhancing biological nitrogen fixation: An appraisal of current and alternative technologies for N input into plants. *Plant Soil*, 194, 205-216.
- Sharar, M. S., Ayub, M., Choudluy, A., & Nadeem, M. (2000). Effect of NP application and inoculation on the growth and yield of gram (*Cicer arietinum* L.). *Pak Journal of Agri Sci*, *37*, 155-157.
- Admas, S., Haileselassie, T., Tesfaye, K., Shiferaw, E., & FLYNN, K. C. (2021). Evaluation of Ethiopian chickpea (Cicer arietinum L.) genotypes for frost tolerance. *Acta agriculturae Slovenica*, *117*(2), 1-14.
- Smith, S. C., Bezdicek, D. F., Turco, R. F., & Cheng, H. H. (1987). Seasonal N_2 fixation by cool-season pulses based on several N methods. *Plant Soil*, *97*, 3-13.
- Tena, W., Endalkachew, W., & Fran, W. (2016). Response of chickpea (*Cicer arietinum* L.) to inoculation with native and exotic *Mesorhizobium* strains in Southern Ethiopia. *Academic journal*, *15*(35), 1920-1929.
- Togay, N., Togay, Y., Cimrin, K. M., & Turan, M. (2008). Effects of *Rhizobium* inoculation, sulfur and p hosphorus applications on yield, yield components an

d nutrient uptake in chickpea (*Cicer arietinum* L.). *African Journal of Biotechnology, 7*(6), 776-782.
- Uddin, M. Hussain, S., & Khan, M. M. A. (2014). Use of N and P bio fertilizers reduces inorganic phosphorus application and increases nutrient uptake, yield, and seed quality of chickpea. *Turkish Journal of Agriculture and Forestry*, 38, 47–54.
- Wolde-Meskel, E. (2012). Genetic and symbiotic diversity of rhizobia in Ethiopian soils: an untapped biological resource for enhancing N2-fixation. Presentation at ISFM Conference 2012. Nairobi, Kenya.
- Wood, J. A., & Grusak, M. A. (2007). Chickpea Breeding and Management, Yadav, S. S., Reddn, B., Chen, W., & Sharma, B. Eds., pp.101–142, CAB International, Walling fordm UK.
- Yasin, T., & Alamir, A. (2023). Performance evaluation of desi chickpea (*Cicer arietinum* L.) varieties through participatory variety selection South Gonder Zone, northwestern Ethiopia. *International Journal of Genetics and Genomics, 11*(2), 60-66. doi: 10.11648/j.ijgg.20231102.13.
- Zarihun, J., & Shifera, A. (2016). "Genetic Diversity Analysis of Ethiopia Elite Chickpea (Cicer arietinum L.) Varieties Based on Agronomic Character." *Journal of Plant Breeding and Crop Science 11*(3), 80-86.