



Response of Chickpea (*Cicer arietinum* L.) to Farm Yard Manure Application and Rhizobium Inoculation

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ABSTRACT

Chickpea (*Cicer arietinum* L.), an important source of protein, is well adapted to soils of low fertility which can be improved by the application of farm yard manure (FYM) and effective rhizobium strains which are cost-effective fertilizers for poor resources farmers. To determine the optimum level of FYM and select compatible rhizobia strains for maximum yield of chickpeas, a field experiment was conducted at Goladjo Research Center, Fafan, Ethiopia during the main rainy season of 2022. The experiment consisted of four rhizobia strains (CP0 (control), CP1, CP2, and CP3) and three FYM levels (0, 5, and 10 t ha^{-1}) which were laid out in randomized complete block design with three replications. Results indicated that rhizobia strains did not affect nodule formation which could be due to the chickpea genotype, used in this experiment, failure to produce nodules or failure of the strains to adapt experimental environment and soil, thus they had no significant effect on all parameters except on pod bearing branches. FYM significantly affected days to flowering, pod-bearing branches per plant, pod per plant, seed per pod, grain yield, total biomass, and harvest index. The 5 t FYM ha^{-1} treatment shortened the days to flowering as compared with the control and 10FYM t ha^{-1} . The highest branches per plant (7.13), pod per plant (20.96), seed per pod (1.21), grain yield (2090.6 kg ha^{-1}), biomass (3670.8 kg ha^{-1}), and harvest index (0.58) were recorded with the level of 5t FYM ha^{-1} . The 5t FYM ha^{-1} treatment increased the grain yield by 31.88% as compared with the control. Based on the economic analysis, the maximum net benefit (75,522 ETB ha^{-1}) and the highest marginal rate of return (23.66 %) were also found with a level of 5 t FYM ha^{-1} . Therefore, a level of 5t FYM ha^{-1} is recommended for chickpea production in a test area.

Key Words: Farm yard manure, Grain yield, the marginal rate of return, Rhizobia strain

1. Introduction

Chickpea is the most important pulse crop and well adapted to environmental stresses such as high temperatures and soils of low fertility. Due to its proliferating rooting habits, the crop extracts water from deep layers of soil profiles, and thus it is moderately drought tolerant (Tripathi et al., 2015). The crop is an important source of protein for human nutrition and a source of cash income for farmers (Erman et al., 2011). Chickpea seeds contain 20.6% protein, 61.2% carbohydrate, and 2.2% fat (Togay et al., 2008), which implies it is an important source of protein in cereal-based diets. Moreover, it is also widely used as fodder and green manure (Togay et al., 2008; Erman et al., 2011).

In Ethiopia, the average yield of chickpeas is 1.7 t ha^{-1} (Agency, 2013), which is far below the potential yield of 4.5 t ha^{-1} . Due to inappropriate water use, and fertilizer application, the average yield falls even below the national average (Werner and Newton, 2005). Application of the optimum amount of inorganic and organic fertilizer is vital to maximize crop productivity (Naruka et al., 2000).

Nitrogen is the most essential macronutrient needed for grain legumes like chickpeas and has significant effects on growth and yield performance. The use of chemical fertilizers may disturb the normal functioning of soil and water bodies. The use of a high rate of N fertilizer can cause water pollution and eutrophication of lakes and rivers (Kremser and Schnug, 2002). Moreover, mineral N is too expensive to afford for poor farmers. Therefore, biological nitrogen fixation (BNF) is an appropriate alternative that provides N to achieve the N needs of both legumes and the subsequent crops (Courty et al., 2015). It is the biochemical process in which rhizobia bacterial symbionts of legumes fix atmospheric nitrogen into plant-available form (Mohammadi et al., 2012). Compared to mineral N fertilizer, BNF is a cost-effective, eco-friendly, and renewable source of plant nutrition (Oldroyd and Dixon, 2014).

Chickpea rhizobium inoculation is the process of applying rhizobium inoculants to the chickpea seed before planting to increase the nitrogen fixation and nodulation of the chickpea roots. Tropical soil rhizobia strains were

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not effective in fixing enough biological nitrogen to sustain legume growth and thus, the a need for a search for more effective rhizobial strains (Okogun and Sanginga, 2003). It is possible to select strains of chickpeas to fix biological nitrogen efficiently for the environmental conditions in a given production area. Chickpea can obtain a significant fraction (4–85%) of its N requirement through its highly specific symbiotic association with effective and compatible rhizobium strains (Walley et al., 2005), which is vital for the formation of nodules and nitrogen fixation. A study showed that inoculated chickpeas gave significantly higher nodule number and weight, root length and weight, shoot length, and weight, seed, and biological yields compared with uninoculated ones (Giri and Joshi, 2010).

Application of manure increases organic matter concentrations which have been proved to enhance the yield and yield components of crops as well as soil aeration, moderate extremes of soil temperatures, and maximizing water holding capacity of soil for seed germination and plant root development (Zia et al., 1998). This led to an increase in microbial population and resulted in a positive correlation between the population of symbiotic bacteria and nitrogen fixation (Giller, 2001). Application of FYM @ 5t ha^{-1} is the recommended practice for better yield of chickpeas (Singh et al., 2012). Organic manures are also preferred by poor farmers because they are easily available and affordable than chemical fertilizers (Alam et al., 2007). FYM resources are abundant in the Somali region. However, these resources are not being utilized properly by the community as fertilizer or soil amendment.

Selecting compatible rhizobia strains and identifying the optimum rate of farm yard manure are some of the important steps to developing agronomic packages for chickpea production in the region. To do so, testing the response of the chickpea variety to rhizobia strain and farm yard manure is very crucial. Therefore, the objective of the present study was to determine the optimum rates of FYM and to select compatible rhizobia strains for maximum yield of chickpeas.

2. Material and Methods

2.1. Site description

The experiment was conducted at Golajo, Fafan Zone, Somali Region, Ethiopia. Fafan is situated in the northern part of the Somali Region. The landscape in the zone is characterized as 52.6% flat to gentle slopes, 31% hills, and 7% steep slopes. The farming systems in the zone are pastoralism, agro-pastoralism, and sedentary production systems. Of which, agropastoralism (95%) is the dominant production system (IPS, 2002). The community mostly produces cereal, vegetable, and fruit crops through traditional agronomic practices. The zone geographically lies between 8° 44' N to 11° 00' N latitude and 40° 22' E to 44° 00' E longitude. The altitude of the zone ranges from 500 to 1650 m above sea level. The mean minimum and maximum temperature ranges from 16 to 20 °C and 28–38 °C, respectively (Agency and of Water Resources, 2004). The rainfall distribution in the

zone is very erratic with a mean annual rainfall of 600 to 700 mm (Milkessa and Kurtu, 1997).

2.2. Chickpea Variety

Due to its market values, taste, seed size, resistance to disease, and productivity, the Kabuli chickpea type is preferred by producers (Shiferaw and Teklewold, 2007) as compared to the desi type. Therefore, in this experiment, the Koka chickpea variety, which is the Kabuli type, was used. The variety was released by ICRISAT in 2019 (Fikre and Bekele, 2019).

2.3. Treatment and Experimental Design

A field experiment was conducted on-site in the 2022 growing season. The experiment consists of three FYM levels (0, 5, and 10 t ha^{-1}) in combination with three different rhizobium inoculants (CP_1 , CP_2 , CP_3) and a non-inoculated control (CP_0). The treatments were arranged in a randomized complete block design with three replications. The chickpea seeds were sown on the plots with a spacing of 10 cm between plants and 40 cm between rows. Each experimental plot will have a 4m length and 1.6 m width having an area of 6.4 m^2 . The distance between plots and blocks will be 1m, and 1.5m, respectively.

2.4. Agronomic management

The land was selected, plowed, harrowed, and ridged with a tractor. The plots were kept 1.0 m apart with 1.5 m spacing between blocks. Carrier-based inoculants were applied at the rate of 125 g inoculant for 15 kg seed. To ensure that all the applied inoculum sticks to the seed, the required quantity of inoculants was suspended in a 1:1 ratio in a 10% sugar solution. The thick slurry of the inoculant was mixed gently with dry seed so that all the seeds received a thin coating of the inoculant. All inoculations were applied just before planting under shade to maintain the viability of bacterial cells. Phosphorus and nitrogen fertilizers were applied in the form of Diammonium phosphate (DAP) at 100 kg ha^{-1} to give 18kg N and 46 kg P_2O_5 ha^{-1} as a basal for all plots. Then, the inoculated and un-inoculated seeds were planted. Seeds were covered immediately with soil after sowing to avoid the death of cells due to the sun's radiation (sunlight makes the inoculant ineffective). To avoid direct sunlight the inoculated seeds were sown in the morning. All other cultural practices were performed uniformly for all treatments.

2.5. Soil Sampling and Analysis

Soil samples (0 to 20 cm) were randomly collected using a soil auger from the soil surface of the experimental fields to form a composite before sowing and were analyzed for the following soil physicochemical parameters: The determination of particle size distribution was carried out by the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil pH was measured in the supernatant suspension of 1:2.5 soil and water mixture by using a pH meter. Soil organic carbon was determined by using the Walkley and Black method (Walkley and Black, 1934). The Total N of the soils

was determined through digestion, distillation, and titration procedures of the Micro-Kjeldahl method as described by (Nelson and Sommers, 1983). Plant-available P in the soil was measured according to Olsen et al. (1954), with soil extracted with 0.5 M $NaHCO_3$ and the P in the extract determined colorimetrically using the molybdenum blue method (Murphy and Riley, 1962).

2.6. Data Collection

Days to 50% flowering were recorded as the number of days from sowing until the date on which 50% flowered per plot. Days to 90% physiological maturity were taken when 90% of the pods turned golden yellow. The height of the plants was measured at the flowering stage as the distance from the base to the tip of the plant of five randomly selected plants in each plot and were averaged. The pod number per plant was determined by taking pods of the five randomly selected plants. Seeds from ten randomly selected pods were counted and converted into several seeds per pod. A hundred seeds were counted at random from a sample of each plot and were weighed. For recording grain yield data, two central rows were harvested in each plot with the help of a sickle. Samples were sun-dried, and threshed by hand and seeds were weighed with the help of an electronic balance the data were converted into $kg\ ha^{-1}$ by using the following formula:

$$Grain\ yield\ (Kg\ ha^{-1}) = \frac{Seed\ weight\ of\ central\ rows}{Row\ length \times R - R\ distance \times No\ of\ rows} \times 10000 \quad (1)$$

Biomass yield was determined by harvesting two representative rows from each plot at their maturity, then they were tied into bundles separately. The bundles were sun dried and weighed by spring balance to calculate biomass yield. The data were converted into $kg\ ha^{-1}$ by using the following formula:

$$Grain\ yield\ (Kg\ ha^{-1}) = \frac{Biomass\ yield\ in\ central\ rows}{Row\ length \times R - R\ distance \times No\ of\ rows} \times 10000 \quad (2)$$

Harvest index is the ratio of grain yield to the biomass yield. It was calculated after collecting the data on grain yield and biomass yield:

$$HI = \frac{Grain\ yield}{Above\ ground\ biomass} \times 100 \quad (3)$$

2.7. Economic analysis

Economic analysis was carried out to evaluate the economic feasibility of the treatments used. Accordingly, the partial budget, dominance, and marginal rate return were done. The average yield was adjusted downwards by 10%, assuming that farmers could get a 10% less yield. The following input's prices were taken during planting. The mean market price for chickpea seed (Birr 50.0 kg^{-1}) and grain (Birr 40.0 kg^{-1}) were used in the analysis. The market prices of rhizobium strain (Birr 180.0 kg^{-1}) and FYM (Birr 1.25 kg^{-1}) were used for analysis. The nitrogen content of the FYM was converted into the equivalent price of nitrogen fertilizer. The exchange rate of 1 US dollar was 50.01 Eth birr. The number of laborers involved in manure application and strain application was considered per hectare. The wage rate of 200 ETH birr per laborer per day was also considered. The cost of protection, storage, planting material, postharvest, and others were not included in the calculation.

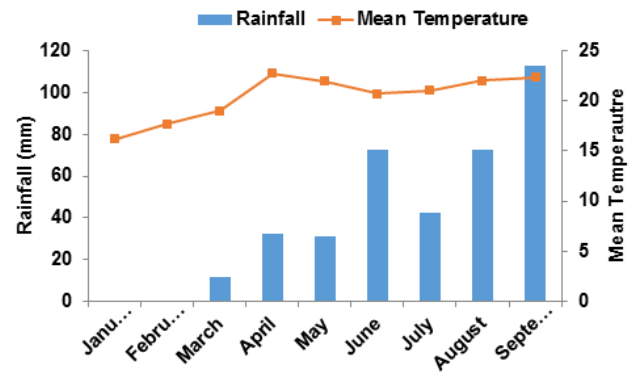


Figure 1: Monthly rainfall and Mean temperature at Golajo, Fafan, in 2022

2.8. Statistical Analysis

The data collected were subjected to statistical analysis of variance (ANOVA) procedures using SAS (version 9) software and the significant differences were determined using Fisher's LSD test at P0.05 level.

3. Results and Discussions

3.1. Weather and Physiochemical properties of the experiment

The experiment was conducted during the main cropping season (June to September 2022) under rain-fed conditions, the amount of rainfall for the crop growth duration was 207.6 mm and the annual rainfall was 375.3mm (Fig 1). Although the chickpea requires approximately 436.7mm of precipitation per growing season for maximum productivity (Desta et al., 2015), it can survive with rainfall amounts range 152-254 mm (Arif et al., 2021). It shows that the amount of rainfall in the study area was enough for chickpea growth and development. However, supplementary irrigation was applied for better yield. During the cropping period, the mean temperature was 21.55 with the mean minimum and maximum temperature of 15.82 C and 27.27 C, respectively. Chickpea is sensitive to high temperatures >35°C as well as low temperatures <15°C (Gaur et al., 2010). It indicates that the temperature of the study area during the growing period was suitable for chickpea growth.

Soil analysis result indicates a soil pH value of 7.9 which is moderately alkaline (Table 1). Chickpea grows best in soils with pH values between 5.7 and 7.2 (Mahler et al., 1988), therefore the soil pH of the study area was a bit out of the required range. The soil textural class was clay loam and contains a total N of 0.11% which falls low range (0.05-0.15%), available P of 7.6 $mg\ kg^{-1}$ which also falls in the low range (5-10 $mg\ kg^{-1}$), and organic carbon of 0.90% which is low (0.5-1.5%) (Table 1). It indicates that the experimental soil is deficient in total N, available P, and organic C.

Table 1: Properties of soil sample of experiment site composition of applied FYM

Parameters	Value	Interpretation
Soil		
Soil pH	7.9	moderately alkaline
Organic carbon (%)	0.90	low
Total N (%)	0.11	low
C: N	8.34	-
Available P (mg kg ⁻¹)	7.26	low
CEC (col(+)/kg)	43.60	Very high
Electrical conductivity (EC) ds m ⁻¹	0.11	Nonsaline
Bulk density (g cm ⁻³)	1.12	low
Texture (%)		
Sand	53	
Silt	16	
Clay	31	
Class	Clay loam	
FYM		
Organic carbon (%)	5.98	
Total N (%)	1.81	
Total P (%)	0.42	

3.2. Response of chickpea to rhizobium strains and FYM

The results of this study indicated that the rhizobium strain had no significant effect on all parameters except on pod-bearing branches per plant (Tables 2 and 3). This was because the strains failed to form nodules on the root of the *Koka* chickpea variety. In other words, this variety could not be compatible with the strains; thus no nodulation was observed. Similarly, Gul et al. (2014) also reported that forty-seven chickpea germplasm were evaluated for seed inoculation with rhizobium and the result showed that 43 genotypes showed nodulation and 4 genotypes failed to produce nodules. The introduced chickpea germplasm could be high in genetic diversity for symbiotic characters. Therefore, the other reason for the failures of nodulation in this study could be a lack of adaptation of the strains to the local environment and soil conditions. To obtain the maximum benefits of BNF, the rhizobia strain must be compatible with the specific crop variety in a growing agroecology. It indicates that in selecting a rhizobial strain, the effectiveness in nitrogen fixation, adaptation of the prevailing soil environment, and competitiveness of the strain are the important attributes to be considered (Beltayef et al., 2018). This is because the rhizobium strain efficiency depends on the interaction among plant genotype, rhizobium strain, and the environment (Avelar Ferreira et al., 2012). To optimize effective nodulation, the host-specific rhizobial strain must adapt to the local environment and soil conditions (Stajkovic et al., 2011). Thus, in selecting a rhizobia strain in dryland areas, the strain should be efficient, compatible with specific crop varieties, and adapted to the local environment (tolerant to drought, heat, and/or saline). Therefore, suppliers of rhizobia strain, as biofertilizers, must consider the specific agricultural environment (soil, climate) of the customer (farmer, crop producer), type of crop, and variety. FYM fertilizers had no significant effect on days to maturity and plant height (Table 2). However, FYM significantly affected days to 50%

Table 2: Effects of rhizobium strain & FYM on phenology & plant height of chickpea

Treatment	Days to	Days to	Plant
	Flowering	Maturity	height (cm)
<i>CP</i> ₀	48.88a	96.22a	39.24a
<i>CP</i> ₁	49.11a	95.55a	39.66a
<i>CP</i> ₂	48.77a	96.44a	38.73a
<i>CP</i> ₃	49.55a	96.11a	39.24a
<i>LSD</i> _{0.05}	NS	NS	NS
<i>F</i> ₀	49.58a	96.41a	38.98a
<i>F</i> ₅	47.83b	96.33a	38.90a
<i>F</i> ₁₀	49.83a	95.50a	39.78a
<i>LSD</i> _{0.05}	1.43	NS	NS

NS, non-significant

flowering. The 5 t FYM ha^{-1} treatment shortened the days to flowering as compared with the control and 10 t ha^{-1} .

FYM fertilizer positively influenced several pod-bearing branches (Table 3). The highest branches per plant (7.13) were recorded with the level of 5t FYM ha^{-1} and the lowest (5.15) in control. FYM releases nutrient that enhances above-ground plant growth. The FYM fertilizer had a significant effect on pod per plant and seed per pod (Table 3). The highest pod per plant (20.96) and seed per pod (1.21) were recorded with the level of 5 t FYM ha^{-1} . Farmyard manure had no significant effect on 100-seed weight. However, grain yield, biomass, and harvest index were significantly affected by farm yard manure. The highest grain yield (2090.6 kg ha^{-1}) was recorded with the level of 5 t FYM ha^{-1} . It shows that the 5t FYM ha^{-1} treatment increased the grain yield by 31.88% as compared with the control. Our results are in line with the findings of Basir et al., (2008) and (Singh et al., 2012) who reported the positive effect of FYM application on the yield of chickpeas. The release of nutrients from FYM might be the possible reason for increasing seed yield. The maximum biomass (3670.8 kg ha^{-1}) was also registered with the level of 5t FYM ha^{-1} . Hussain et al (2017) also reported that higher biomass was recorded in mung bean with plots treated with FYM at a level of 5t ha^{-1} as compared with 10t ha^{-1} . Application of 5t FYM ha^{-1} improved the plant growth and yield attributes of chickpeas over no application of FYM (Singh et al., 2012).

3.3. Profitability of FYM application on chickpea production

The economic analysis of net benefit, total variable cost, and marginal rate of return is shown in Table 4. The result of the economic analysis showed that the highest net benefit of 72,522 ETB was achieved with a level of 5 t FYM ha^{-1} . The highest marginal rate of return (23.66%) was also achieved with a level of 5 t FYM ha^{-1} . Therefore, the application of 5 t FYM ha^{-1} would be best and most economical for the production of chickpea production in the test area and other areas with similar agroecology.

Table 3: Effects of rhizobium strain and FYM on yield and yield components of chickpea

Treatment	Pod bearing branch	Pod per plant	Seed per pod	100-seed weight(g)	Yield (kg ha ⁻¹)	Biomass (kg ha ⁻¹)	Harvest Index
CP ₀	5.95b	14.55a	1.04a	34.73a	1750.0a	3207.3a	0.53a
CP ₁	6.33a	15.40a	1.15a	35.27a	1650.9a	3253.9a	0.51a
CP ₂	6.01b	15.02a	1.17a	36.55a	1890.8a	3511.1a	0.54a
CP ₃	6.01b	15.53a	1.13a	35.11a	1872.7a	3284.9a	0.57a
LSD _{0.05}	0.13	NS	NS	NS	NS	NS	NS
F ₀	5.15c	12.36b	1.08b	36.00a	1585.2b	2836.5b	0.54ab
F ₅	7.13a	20.96a	1.21a	35.09a	2090.6a	3670.8a	0.58a
F ₁₀	5.95b	12.05b	1.08b	35.16a	1697.5b	3435.6ab	0.49b
LSD _{0.05}	0.12	4.22	0.12	NS	336.86	609.98	0.06

NS = not significant. Means in a column followed by the same letters are not significantly different at P < 0.05.

Table 4: The economic (Dominance and MRR) advantages of different rates of FYM on chickpea production

Treatment	Av Yield (kg ha ⁻¹)	Adj yield (kg ha ⁻¹)	Gross Benefit (ETB ha ⁻¹)	Total Cost (ETB ha ⁻¹)	Net Benefit (ETB ha ⁻¹)	Marginal Rate of Return (%)
0	1423.6	1281.2	51248.00	0	51248	-
5	2232.6	2009.3	80372.00	7850	72522	23.66
10	1593.8	1434.4	57376.00	14,900	42476	D

4. Conclusion

Rhizobium strain had no significant effect on all parameters. This could be the chickpea genotype (Koka variety) failure to form nodules. The other reason, for the failure of nodulation, could be a lack of adaptation of the strains to the local environment and soil conditions. Thus, in selecting a rhizobia strain in dryland areas, the strain should be efficient, compatible with specific crop varieties, and adapted to the local environment (tolerant to drought, heat, and/or saline). Therefore, suppliers of rhizobia strain, as biofertilizers, must consider the specific agricultural environment (soil, climate) of the customer (farmer, crop producer), type of crop, and variety. Farmyard manure (FYM) had a significant effect on yields; the highest grain yield (2090.6 kg ha⁻¹) and biomass (3670.8 kg ha⁻¹) were recorded with the level of 5 t FYM ha⁻¹. The result of the economic analysis showed that the highest net benefit of 72,522 ETB and marginal rate of return (23.66%) was achieved with the level of 5 t FYM ha⁻¹. Therefore, the application of 5 t FYM ha⁻¹ would be best and most economical for the production of chickpeas production on a test area.

Conflict of Interest

The authors declare that they don't have conflict of interest.

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