

Effect of Nitrogen and Phosphorus Based Liquid Bio-Fertilizers on Chickpea (*Cicer arietinum* L.)

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Abstract:

A field experiment was conducted during the Rabi season at the Agriculture Instructional farm, School of Agricultural Sciences, Career Point University, Kota (Rajasthan), to evaluate the effects of nitrogen and phosphorus-based liquid bio-fertilizers on chickpea (*Cicer arietinum* L.). The objective was to assess crop performance under varying fertility levels and identify economically viable nutrient management practices. The study employed four fertility levels (Control, 10 kg N + 30 kg P₂O₅ ha⁻¹, 15 kg N + 40 kg P₂O₅ ha⁻¹, and 20 kg N + 50 kg P₂O₅ ha⁻¹) and four bio-fertilizer treatments (Control, Liquid Rhizobium, Liquid PSB, and Rhizobium + PSB combination). The treatment comprising 20 kg N + 50 kg P₂O₅ ha⁻¹ with dual inoculation of Rhizobium and PSB recorded the highest seed yield (2035 kg ha⁻¹), net return (₹76,641 ha⁻¹), and benefit-cost ratio (2.5). Enhanced growth parameters, yield attributes, nutrient uptake, and quality traits were observed with increased fertility levels and bio-fertilizer application.

Keywords: Chickpea, Bio-fertilizers and Nitrogen

I Introduction:

Chickpea (*Cicer arietinum* L.) is mainly a cool season crop belonging to family Leguminaceae sub family Papilionaceae. It contributes highest area and production i.e. 9.44 million ha and 10.13 million tonnes, respectively among pulses with a productivity of 1073 kg per ha at national level. More than 90 per cent production in the country has been cultivated in states like Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka, Chattisgarh, Andhra Pradesh, Gujarat, Jharkhand, Tamil Nadu and Telangana. In Rajasthan, chickpea is cultivated in 1.60 million ha area with a production of 1.76 million tonnes and productivity 1103 kg ha⁻¹ (Govt. of India, 2018-19).

Chickpea has deep root system, which make it to withstand in drought and low moisture condition. Because of this property, it is very suitable for dryland and irrigated farming. It is widely grown as rainfed crop in tropical and subtropical climate. Under the pulses, chickpea has important place so it is known as ‘king of pulses’.

Chickpea is grown primarily for its nutritive value. Pulses are rich source of protein (20-25%) which is almost double the protein content of wheat and thrice that of rice. Pulses are main source of protein, essential amino acids, vitamins and minerals (Pingoliya *et al.* 2013). They also provide nutrition, health benefits and reduce non-communicable diseases like colon cancer and cardiovascular diseases (Jukanti *et al.* 2012). It provides 358 calorie energy in 100 grains. Chickpea contains protein (20%), carbohydrate (52-70%), fat (4-10%), phosphorus (49-53 mg 100⁻¹ g), crude fiber (6%), iron (7 mg 100⁻¹ g) (Deppe, 2010), vitamin A (316 IU), vitamin C (3 mg 100⁻¹ g), thiamine, riboflavin, nicotinic acid and biotin etc. It is consumed as whole seed (boiled, roasted, spouted), dal flour and as a dal (decorticated cotyledons boiled or meshed to make a soup). Chickpea has many medicinal properties. Its germinated seeds are used for curing scurvy disease because of sufficient amount of vitamin C. It is also used for blood purification.

Nitrogen is a primary nutrient. It is constituent of protein, nucleic acid and nucleotides chlorophyll, phospholipids, enzymes, hormones, vitamins etc. Legume crops fix the atmospheric nitrogen with the help of symbiotic association with *Rhizobium*. Nitrogen has an important role in the physiological processes in plants. It's starter dose at the time of sowing leads to rapid leaf area development and increase in overall assimilation rate. Thus, it contributes in increasing the seed yield.

Phosphorus is an integral nutrient element in the plant system. Phosphorus participates in photosynthesis, transfer of sugar and energy. It is a constituent of energy rich compounds viz. adenosine triphosphate (ATP) and adenosine diphosphate (ADP), nucleic acid, phytin, phospholipids, nicotinamide adenine dinucleotide phosphate (NADP). It stimulates early root growth, enhances the activity of rhizobia and root nodules, root length, root dry weight, pods per plants, leaf size, flowering, grain yield, test weight (Shahzad *et al.* 2014). It plays an important role in cell division, seed and fruit development. It improves biological nitrogen fixation and grain quality (Kumar *et al.* 2009). Phosphorus also helps in enhancing the uptake of nutrients and water which results in higher dry matter production in chickpea (Islam *et al.* 2013). Phosphorus level is low to medium in soils of most of the states in India (Pathak, 2010).

Organic matter is deficient in Indian soils. Because of this, rapid fixation of phosphorus occurs and available soluble phosphorus is very low (Sarawgi *et al.* 2012). Bio-fertilizers especially phosphorus solubilising bacteria is used to get rid of this problem. During and after the Green revolution, due to indiscriminate use of chemical inputs, the sustainability of soil in terms of macro and micro nutrients is decreasing day by day. Excessive use of chemical fertilizers are destroying physical, chemical and biological composition of soil and also imparting a negative impact on the environment. Hence, the sustainability of agriculture has become a major global concern (Laranjo *et al.* 2014, Verma *et al.* 2014). The use of chemical fertilizers is quite expensive, so it is also necessary to know about their adequate dosage of application which would be both economically and ecologically beneficial. Soil is a complex system, where several micro-organisms survive together with affecting growth of plant. The rhizosphere of plants is harbour of several fungi, bacteria and most important being nitrogen fixation organism.

Bio-fertilizers are widely used for sustainable results and good physical condition of soils in agriculture. Bio-fertilizer is a microbial inoculant, which contains live and latent cells of efficient strain of nitrogen fixing bacteria, phosphorus solubilizing bacteria or cellulytic micro-organism. Thus, it plays vital role in supply the essential plant nutrients. It is very important for eco-friendly environment and sustainable agriculture. Leguminous crops can fix nitrogen with the symbiotic micro-organisms present in their root nodules. Use of bio-fertilizers (*Rhizobium* with phosphobacteria) enhance crop yield by fixing the atmospheric nitrogen and making phosphorus available to leguminous crops (Selvakumar *et al.*, 2012).

Rhizobium is a symbiotic micro-organism which is associated with leguminous plants. *Rhizobium* improves the nutrient availability. It increases nodulation with better root development and helps in increasing grain yield (Das *et al.* 2013). It is mainly used as a seed inoculant. In chickpea, *Rhizobium* improves nodulation, dry weight, plant height, pods per plant, test weight, root length and grain yield. Phosphorus solubilizing micro-organisms have specific role in solubilizing the phosphorus, converting the insoluble phosphorus to soluble phosphorus, which is easily available to plants.

Liquid bio-fertilizers are inoculants especially in liquid formulation which not only contain desired micro-organisms and their nutrients but also contain special protectants and amendments which promote cell survival in a package and after application to seed or soil. Additives used in liquid inoculants, improve quality of inoculants increasing the population density and shelf life (Tittabutr *et al.*, 2007). Liquid bio-fertilizers have greater shelf life than carrier based bio-fertilizers. The shelf life of carrier based fertilizers is only up to 6 months but of liquid bio-fertilizers may be one year or more. Carrier based fertilizers have many constraints like poor survival rate, low shelf life, low water activity of inoculums and high degree of contamination. The liquid bio-fertilizers minimize the cost of cultivation by avoiding processing and sterilization of carrier-based material. They require minimum labour, energy, and space for handling and also less quantity of inoculum than carrier-based formulation. The liquid inoculants have efficient amount of population of *Rhizobium* sp., *Azotobacter* sp., *Azospirillum* sp and phosphorus solubilizing bacteria up to the level of 10^8 cells per ml (Dayamani, 2010, Velineni and Brahmaaprakash *et al.*, 2011). Liquid bio-fertilizers are capable of fixing, solubilizing or mobilizing plant nutrients and retain their biological activity. The appropriate application of liquid bio-fertilizer improves the soil quality and yield as compared to carrier based bio-fertilizers. Liquid formulation of bio-fertilizers plays a vital role in increasing the shelf life of micro-organisms (Verma *et al.*, 2018).

II Methodology:

A field experiment entitled “Effect of nitrogen and phosphorus based liquid bio-fertilizers on chickpea (*Cicer arietinum* L.)” was conducted at agriculture instructional farm, School of Agricultural Sciences, Career Point University, Kota (Rajasthan) India. The site is situated in Kota Region, which falls in south eastern part of Rajasthan and covers geographical area of 24.43 lakh ha and represents 7.71 per cent of the total geographical area of the state. The zone is located between 23045′ and 26033′ North latitudes and 75027′ and 77026′ East

longitudes. The area under cultivation is 18.0 lakh hectares, out of which approximately 26% is irrigated and remaining is under rainfed and dry land conditions.

Climate and weather condition

The Humid Southern Eastern Plain agro-climatic zone has typical subtropical weather conditions characterized by mild winters and moderate summers coupled with high relative humidity during the months of July to September. This region has mean annual rainfall 800-1000 mm, much of which is contributed from July to September by south-west monsoon.

These measurements showed that the maximum and minimum temperatures ranged from 21.0 to 30.2 °C and from 4.4 to 17.5 °C. Total rainfall is 15.40 mm recorded during cropping season.

EXPERIMENTAL DETAILS

Details of treatments used in experimentation

Fertility	Levels
Control	F ₀
10 kg N + 30 kg P ₂ O ₅ ha ⁻¹	F ₁
15 kg N + 40 kg P ₂ O ₅ ha ⁻¹	F ₂
20 kg N + 50 kg P ₂ O ₅ ha ⁻¹	F ₃
Liquid bio-fertilizers	Level
Control	LB ₀
Liquid <i>Rhizobium</i> inoculation alone	
(10 ml kg ⁻¹)	LB ₁
Liquid PSB inoculation alone	
(10 ml kg ⁻¹)	LB ₂
Liquid <i>Rhizobium</i> + liquid PSB inoculation	LB ₃

STATISTICAL ANALYSIS

Analysis of variance

The data recorded during the experiment were subjected to statistical analysis by applying appropriate techniques of analysis of variance for “Factorial RBD”. The test of significance of the experimental results was found significant at 5 percent level of significance. The CD (critical difference) for the treatment means was calculated. In “Experimental results” summary tables along with $SEm \pm$ and CD at 5 percent were embodied. Their analysis of variance is given in the Appendices at the end.

III RESULTS AND DISCUSSION:

PLANT POPULATION

Fertility levels: The data indicates that plant population recorded at 15 DAS and harvest were non-significant due to different fertility levels.

Liquid bio-fertilizers: The results revealed that plant population at 15 DAS and harvest were not significant effect due to different levels of liquid bio-fertilizers.

GROWTH PARAMETERS

The growth parameters data under the influence of different treatments are furnished and analysis of variance for respective parameters.

Plant height

30 DAS

Fertility levels: The maximum plant height (19.89 cm) was obtained with F_3 (20 kg N + 50 kg P_2O_5 ha⁻¹) fertility level. The minimum plant height (18.35 cm) was recorded with the treatment F_0 (control). All the fertility levels failed to show any significant effect on plant height at 30 DAS.

Liquid bio-fertilizers: All bio-fertilizers failed to show any significant effect on plant height at 30 DAS.

60 DAS

Fertility levels: Data reported that maximum plant height (43.56 cm) was recorded with the treatment F_3 (20 kg N + 50 kg P_2O_5 ha⁻¹), which was significantly higher over F_2 (15 kg N + 40 kg P_2O_5 ha⁻¹), F_1 (10 kg N + 30 kg P_2O_5 ha⁻¹) and F_0 (control) and minimum (37.02 cm) was recorded with F_0 (control).

Liquid bio-fertilizers: A perusal of data show that maximum plant height (41.46 cm) was recorded with the treatment LB₃ (liquid *Rhizobium* + liquid PSB co-inoculation), which was at par with LB₂ (liquid PSB inoculation alone) and LB₁ (liquid *Rhizobium* inoculation) and significantly higher over LB₀ (control). The treatment LB₃ (liquid *Rhizobium* + liquid PSB inoculation) recorded 2.31 and 1.31 per cent higher plant height over LB₁ (liquid *Rhizobium* inoculation) and LB₂ (liquid PSB inoculation alone), respectively.

Harvest

Fertility levels: A perusal of data show that maximum plant height (54.85 cm) with the treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) and minimum (47.08 cm) was recorded with the treatment F₀ (control). The F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) fertility level was significantly higher by 7.44, 10.16 and 16.50 per cent over the F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹), F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and F₀ (control), respectively.

Liquid bio-fertilizer: The maximum plant height (53.50 cm) was recorded with the treatment LB₃ (liquid *Rhizobium* + liquid PSB co-inoculation) and minimum (48.96 cm) was recorded with LB₀ (control). The application of LB₃ (liquid *Rhizobium* + liquid PSB co-inoculation) resulted significant hike in plant height by 5.83, 7.51 and 9.27 per cent over LB₁ (liquid *Rhizobium* inoculation), LB₂ (liquid PSB inoculation alone) and LB₀ (control), respectively.

YIELD ATTRIBUTES AND YIELD

Number of pods plant⁻¹

Fertility levels: The maximum numbers of pods plant⁻¹ (91.25) was with the treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) and minimum number of pods plant⁻¹ (55.17) was with F₀ (control). The number of pods plant⁻¹ at F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) was significantly superior by 7.05, 22.97 and 65.45 per cent over F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹), F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and F₀ (control), respectively.

Liquid bio-fertilizers: The maximum number of pods plant⁻¹ (91.08) was recorded with the treatment of LB₃ (liquid *Rhizobium* + liquid PSB inoculation), which was significantly superior 12.55, 19.71 and 57.93 per cent over LB₁ (liquid *Rhizobium* inoculation alone) and LB₂ (PSB inoculation alone) and LB₀ (control), respectively.

Interaction effect of fertilizers and bio-fertilizers: The combined effect of treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) + LB₃ (Liquid *Rhizobium* + liquid PSB inoculation) recorded

maximum number of pods plant⁻¹ (101), which was statistically at par with F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) + LB₁ (liquid *Rhizobium* inoculation alone) and F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹) + LB₃ (Liquid *Rhizobium* + liquid PSB inoculation). The next best treatment in this regard were F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) + LB₁ (liquid *Rhizobium* inoculation alone) and F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹) + LB₃ (Liquid *Rhizobium* + liquid PSB inoculation).

Number of seeds pod⁻¹

Fertility levels: The maximum number of seeds pod⁻¹ (2.51) was recorded with treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹) fertility level, which was statistically at par with F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹) and significantly higher over F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and F₀ (control), respectively. The minimum number of seeds pod⁻¹ (2.15) was recorded with F₀ (control).

Liquid bio-fertilizers: The maximum number of seeds pod⁻¹ (2.43) was recorded with LB₃ (Liquid *Rhizobium* + liquid PSB inoculation), which was statistically at par with LB₁ (*Rhizobium* inoculation alone) and LB₂ (PSB inoculation alone) and significantly higher by 24.61 per cent over LB₀ (control).

Seed yield

Fertility levels: The reveal that maximum seed yield (1912 kg ha⁻¹) was obtained with the treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹). It was recorded significantly higher by 122 kg ha⁻¹, 199 kg ha⁻¹ and 422 kg ha⁻¹ over F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹), F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and control (F₀).

Liquid bio-fertilizers: The maximum seed yield (1856 kg ha⁻¹) was obtained with the treatment LB₃ (liquid *Rhizobium* + liquid PSB inoculation), which was statistically at par with LB₁ (*Rhizobium* inoculation alone) significantly higher by 138 kg ha⁻¹ and 306 kg ha⁻¹ over LB₂ (liquid PSB inoculation alone) and LB₀ (control). However, LB₃ (liquid *Rhizobium* + liquid PSB inoculation) recorded 4.21 per cent higher seed yield over LB₁ (*Rhizobium* inoculation alone).

Haulm yield

Fertility levels: The data (Table 4.4) indicate that maximum haulm yield (2577 kg ha⁻¹) was obtained with the treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹), which was significantly higher by 146 kg ha⁻¹, 168 kg ha⁻¹ and 313 kg ha⁻¹ over F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹), F₁ (10

kg N + 30 kg P₂O₅ ha⁻¹) and F₀ (control), respectively. These represented that 6.05, 6.97 and 13.82 per cent higher haulm yield recorded by F₃ fertility level.

Liquid bio-fertilizers: The liquid bio-fertilizers failed to show any significant effect on haulm yield.

NUTRIENT CONTENT AND UPTAKE

Nitrogen content

Seed:

Fertility levels: Fertility levels did not show any significant effect on nitrogen content in seed.

Liquid bio-fertilizers: Liquid bio-fertilizers failed to show any significant effect on nitrogen content in seed.

Phosphorus content

Seed

Fertility levels: Fertility levels did not show any significant effect on phosphorus content in seed.

Liquid bio-fertilizers: Liquid bio-fertilizers failed to show any significant effect on phosphorus content in seed.

Haulm

Fertility levels: Fertility levels did not show any significant effect on phosphorus content in haulm.

Liquid bio-fertilizers: Liquid bio-fertilizers failed to show any significant effect on phosphorus content in haulm.

Nitrogen uptake

Seed:

Fertility levels: The maximum nitrogen uptake (59.42 kg ha⁻¹) in seed was recorded with the treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹), which was significantly superior by 6.79, 13.48 and 30.59 per cent over F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹), F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and F₀ (control).

Liquid bio-fertilizers: The maximum nitrogen uptake (58.66 kg ha^{-1}) was recorded with LB₃ (liquid *Rhizobium* + liquid PSB inoculation), which was statistically at par with LB₁ (liquid *Rhizobium* inoculation alone) and significantly higher by 12.76 and 26.18 per cent over LB₂ (PSB inoculation alone) and LB₀ (control), respectively.

Haulm:

Fertility levels: The maximum nitrogen uptake (27.59 kg ha^{-1}) was recorded with treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹), which was significantly higher by 7.52, 10.84 and 19.02 per cent over F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹), F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and control.

Liquid bio-fertilizers: Liquid bio-fertilizers failed to show any significant effect on nitrogen uptake in haulm.

Phosphorus uptake

Seed:

Fertility levels: The higher phosphorus uptake (16.07 kg ha^{-1}) was recorded with the treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹), which was significantly higher by 7.63, 18.07 and 35.49 per cent over F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹), F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and F₀ (control) respectively.

Liquid bio-fertilizers: The higher phosphorus uptake (15.53 kg ha^{-1}) in seed was recorded with LB₃ (liquid *Rhizobium* + liquid PSB inoculation), which was statistically at par LB₁ (liquid *Rhizobium* inoculation alone) and significantly higher by 10.06 and 26.56 per cent over LB₂ (PSB inoculation alone) and LB₀ (control), respectively.

Haulm:

Fertility levels: The maximum phosphorus uptake (6.61 kg ha^{-1}) was recorded with the treatment F₃ (20 kg N + 50 kg P₂O₅ ha⁻¹), which was significantly higher by 7.13, 10.90 and 18.45 per cent over F₂ (15 kg N + 40 kg P₂O₅ ha⁻¹) and F₁ (10 kg N + 30 kg P₂O₅ ha⁻¹) and control, respectively.

Liquid bio-fertilizers: The higher phosphorus uptake (6.13 kg ha^{-1}) was recorded with LB₃ (liquid *Rhizobium* + liquid PSB inoculation), which was statistically at par LB₁ (liquid *Rhizobium* inoculation alone) and LB₂ (PSB inoculation alone) and significantly higher by 6.79 per cent over LB₀ (control).

IV Discussion:

The superior performance of the F₃ + LB₃ combination can be attributed to improved nutrient availability from both fertilizers and microbial action. Nitrogen and phosphorus supported vegetative growth and reproductive development, while Rhizobium and PSB enhanced nutrient uptake and soil health through biological nitrogen fixation and phosphorus solubilization. These findings highlight the potential of integrated nutrient management in improving chickpea productivity and profitability.

Table 1.1: Effect of fertility levels and liquid bio-fertilizers inoculation on yield attributes and yield of chickpea

Treatments	Num ber of pods plant ⁻¹	Num ber of seeds pod ⁻¹	Weig ht of seeds plant ⁻¹ (g)	Seed inde x (100 seeds weig ht)	Yield (kg ha ⁻¹)			HI (%)
					Se ed	Haul m	Biologi cal	
Fertility levels								
Control	55.17	2.15	23.9 8	20.00	14 90	2264	3754	39.6 2
10 kg N + 30 kg P ₂ O ₅ ha ⁻¹	74.26	2.16	34.9 9	20.13	17 13	2409	4129	41.5 0
15 kg N + 40 kg P ₂ O ₅ ha ⁻¹	85.08	2.30	36.3 4	21.22	17 90	2431	4222	42.3 8
20 kg N + 50 kg P ₂ O ₅ ha ⁻¹	91.25	2.51	39.6 5	21.16	19 12	2577	4489	42.5 8

SEm±	1.03	0.08	1.07	0.43	26	32	35	0.58
CD (P= 0.05)	2.97	0.22	3.10	NS	76	94	102	1.69
Liquid bio-fertilizers								
Control	57.67	1.95	26.9	19.95	15	2375	3925	39.4
			0		50			2
Liquid <i>Rhizobium</i> inoculation alone	80.92	2.42	34.4	20.72	17	2441	4221	42.1
			1		81			1
Liquid PSB inoculation alone	76.08	2.32	33.3	20.65	17	2413	4130	41.5
			7		18			1
Liquid <i>Rhizobium</i> + liquid PSB inoculation	91.08	2.43	40.2	21.20	18	2454	4310	43.0
			8		56			3
SEm±	1.03	0.08	1.07	0.43	26	32	35	0.58
CD (P= 0.05)	2.97	0.22	3.10	NS	76	NS	102	1.69

Table 1.2: Effect of fertility levels and liquid bio-fertilizers inoculation on nutrient content of chickpea

Treatments	N content (%)		P content (%)	
	Seed	Haulm	Haulm	
			Seed	
Fertility levels				
Control	3.047	1.024	0.790	0.246
10 kg N + 30 kg P ₂ O ₅ ha ⁻¹	3.050	1.032	0.793	0.247

15 kg N + 40 kg P ₂ O ₅ ha ⁻¹	3.100	1.055	0.834	0.254
20 kg N + 50 kg P ₂ O ₅ ha ⁻¹	3.106	1.072	0.839	0.256
SEm±	0.045	0.014	0.017	0.005
CD (P= 0.05)	NS	NS	NS	NS

Liquid bio-fertilizers

Control	2.999	1.027	0.788	0.242
Liquid <i>Rhizobium</i> inoculation alone	3.122	1.056	0.813	0.252
Liquid PSB inoculation alone	3.026	1.036	0.819	0.253
Liquid <i>Rhizobium</i> + liquid PSB inoculation	3.156	1.064	0.836	0.256
SEm±	0.045	0.014	0.017	0.005
CD (P= 0.05)	NS	NS	NS	NS

V Conclusion:

The application of 20 kg N + 50 kg P₂O₅ ha⁻¹ combined with *Rhizobium* and PSB liquid bio-fertilizers significantly improved chickpea growth, yield, nutrient uptake, and economic returns. This treatment achieved the highest seed yield (2035 kg ha⁻¹), net return (₹76,641 ha⁻¹), and benefit-cost ratio (2.5). These results underscore the value of integrating chemical and biological inputs for sustainable chickpea production. Further studies across varied agro-climatic zones are recommended to validate these findings.

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