



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(6): 1230-1235
Received: 04-04-2026
Accepted: 06-05-2026

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Effect of bio-fertilizer combinations on growth and yield of chickpea (*cicer arietinum* L.) under gwalior conditions

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i6p.5853>

Abstract

A field experiment was conducted during the *rabi* season of 2024-25 at the Agriculture Research and Development Centre, Sakatpura, Vikrant University, Gwalior, Madhya Pradesh, to evaluate the effect of bio-fertilizer combinations on growth, nodulation, yield and economics of chickpea. The experiment was laid out in a randomized block design with six treatments and three replications using chickpea variety G-517. Treatments consisted of 100% recommended dose of fertilizers (RDF) alone and its combinations with *Rhizobium*, *Trichoderma* and phosphate-solubilizing bacteria (PSB). The crop responded clearly to integrated microbial inoculation. The treatment T₆, comprising 100% RDF + *Rhizobium* @ 20 g kg⁻¹ seed + *Trichoderma* @ 20 g kg⁻¹ seed + PSB @ 20 g kg⁻¹ seed, recorded maximum plant height (59.0 cm), leaves plant⁻¹ (52.0), branches plant⁻¹ (8.9), dry matter accumulation (25.85 g plant⁻¹), nodules plant⁻¹ at 45 DAS (47.1), pods plant⁻¹ (64.1), seeds pod⁻¹ (1.73), test weight (25.0 g), biological yield (5670 kg ha⁻¹), seed yield (2280 kg ha⁻¹) and straw yield (3390 kg ha⁻¹). The same treatment also produced the highest gross return (₹132,180 ha⁻¹), net return (₹91,380 ha⁻¹) and B:C ratio (3.24). The results indicated that combined inoculation of *Rhizobium*, *Trichoderma* and PSB with RDF was the most effective and profitable option for chickpea production under the sandy loam soils of the Gwalior region.

Keywords: Chickpea, bio-fertilizers, *Rhizobium*, *Trichoderma*, PSB, nodulation, seed yield, economics

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important *rabi* pulse crops of India and has a key role in nutritional security, soil fertility improvement and crop diversification. The crop is valued for its protein-rich seed, good digestibility, wide adaptability and ability to fix atmospheric nitrogen through symbiosis. In vegetarian diets, chickpea serves as an affordable source of protein, minerals and dietary fibre. Its inclusion in cropping systems also improves soil biological activity and reduces the need for external nitrogen inputs (Jukanti *et al.*, 2012; Directorate of Pulses Development, 2024) [12, 4].

In India, chickpea productivity is often lower than its genetic potential because of imbalanced nutrient management, poor soil organic matter, low phosphorus availability, weak nodulation and limited microbial activity in the rhizosphere. The problem is more common in semi-arid regions where soil moisture and nutrient availability frequently limit crop growth. Continuous dependence on inorganic fertilizers alone may not sustain soil health in the long term; therefore, integrated and biological approaches are needed to improve nutrient-use efficiency and crop productivity (Jat and Ahlawat, 2006; Vessey, 2003) [11, 29].

Bio-fertilizers are living microbial inoculants that improve nutrient availability and plant growth through biological nitrogen fixation, phosphorus solubilization, root stimulation and better rhizosphere activity. *Rhizobium* is especially important in chickpea because it forms root nodules and fixes atmospheric nitrogen. Phosphate-solubilizing bacteria convert insoluble phosphorus into plant-available forms, whereas *Trichoderma* improves root growth and plant vigour and can also suppress soil-borne pathogens (Richardson and Simpson, 2011; Rudresh *et al.*, 2005; Harman *et al.*, 2004) [20, 21, 10].

Several studies have reported that the combined application of *Rhizobium*, PSB and other growth-

promoting microorganisms improves plant height, branching, dry matter production, nodulation, yield attributes and seed yield in chickpea (Bahr, 2007; Tanwar *et al.*, 2014; Langade *et al.*, 2020; Kumawat *et al.*, 2021) [2, 26, 16, 15]. However, the efficiency of microbial inoculants varies with soil type, crop variety, native microbial population and local climate. Therefore, the present investigation was undertaken to assess the effect of different bio-fertilizer combinations on growth, yield and economics of chickpea under the agro-climatic conditions of Gwalior, Madhya Pradesh.

Materials and Methods Experimental site and soil

The field experiment was conducted during the *rabi* season of 2024-25 at the Agriculture Research and Development Centre, Sakatpura, Vikrant University, Gwalior, Madhya Pradesh. The experimental site represents semiarid subtropical conditions with cool winter, hot summer and moderate rainfall mainly during the south-west monsoon. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium. Initial soil properties are presented in Table 1.

Table 1: Initial physico-chemical properties of the experimental soil

Property	Value	Status/remark
Texture	Sandy loam	65.7% sand, 13.2% silt and 21.1% clay
pH	7.5	Slightly alkaline
Electrical conductivity	0.33 dS m ⁻¹	Non-saline
Organic carbon	0.45%	Medium to low
Available N	184 kg ha ⁻¹	Low
Available P	16.7 kg ha ⁻¹	Medium
Available K	347 kg ha ⁻¹	High/adequate

Note: Soil samples were collected from 0-15 cm depth before sowing. Experimental design, treatments and crop management

The experiment was arranged in randomized block design with six treatments and three replications. Chickpea variety G-517 was sown manually at 30 cm × 10 cm spacing. Recommended dose of fertilizers was applied uniformly, and seed treatment with bio-

fertilizers was done according to treatment details. The crop was raised using standard agronomic practices including timely thinning, hand weeding, irrigation and need-based plant protection measures.

Table 2: Treatment details used in the experiment.

Treatment	Treatment details
T ₁	Control + 100% RDF
T ₂	100% RDF + <i>Rhizobium</i> @ 20 g kg ⁻¹ seed
T ₃	100% RDF + <i>Trichoderma</i> @ 20 g kg ⁻¹ seed
T ₄	100% RDF + <i>Rhizobium</i> @ 20 g kg ⁻¹ seed + PSB @ 20 g kg ⁻¹ seed
T ₅	100% RDF + <i>Trichoderma</i> @ 20 g kg ⁻¹ seed + <i>Rhizobium</i> @ 20 g kg ⁻¹ seed
T ₆	100% RDF + <i>Rhizobium</i> @ 20 g kg ⁻¹ seed + <i>Trichoderma</i> @ 20 g kg ⁻¹ seed + PSB @ 20 g kg ⁻¹ seed

Observations and statistical analysis

Five plants were randomly selected and tagged from each plot for recording growth and yield attributes. Plant population was recorded at 15 DAS and at harvest. Plant height, leaves plant⁻¹, branches plant⁻¹, fresh weight and dry matter accumulation were recorded at different crop growth stages. Number of nodules plant⁻¹ was recorded at 30, 45 and 60 DAS. Yield attributes including pods plant⁻¹, seeds pod⁻¹ and test weight were recorded at harvest. Seed yield and straw yield were obtained from net plot harvest and converted into kg ha⁻¹. Harvest index was calculated using biological yield and seed yield. Economics was worked out using prevailing input and output prices. The data were analyzed statistically as per the standard procedure for randomized block design (Gomez and Gomez, 1984) [9], and treatment means were compared using critical difference at 5% level of significance wherever the F-test was significant.

Results and Discussion Effect on growth attributes and flowering

Growth attributes improved consistently with the combined use of bio-fertilizers. Plant population did not differ significantly among treatments, which indicated uniform germination and

establishment across the plots. However, at harvest, T₆ recorded the highest plant height (59.0 cm), leaves plant⁻¹ (52.0), branches plant⁻¹ (8.9), fresh weight (55.8 g plant⁻¹) and dry matter accumulation (25.85 g plant⁻¹). The lowest values were recorded under T₁, where only RDF without microbial integration was applied. The improvement under T₆ may be attributed to better root activity, nitrogen fixation, phosphorus solubilization and greater nutrient uptake. Similar improvement in vegetative growth of chickpea due to bio-fertilizer inoculation and balanced nutrient supply was reported by Bahr (2007) [2], Tanwar *et al.* (2014) [26], Ganga *et al.* (2014) [7], Langade *et al.* (2020) [16] and Kumawat *et al.* (2021) [15].

Days to 50% flowering were reduced with combined bio-fertilizer application. The earliest flowering was recorded under T₆ (52.4 days), followed by T₅ (53.1 days) and T₄ (53.9 days), whereas T₁ recorded delayed flowering (57.1 days). Early flowering under integrated inoculation may be associated with better crop vigour, improved nutrient availability and early transition from vegetative to reproductive growth. The beneficial role of phosphorus and microbial inoculation in reproductive development has also been reported by Singh *et al.* (2014) [23], Deepak Kumar (2015) [3] and Langade *et al.* (2020) [16].

Table 3: Effect of bio-fertilizers on growth attributes and flowering of chickpea.

Treatment	Plant population at harvest (plants m ⁻²)	Plant height at harvest (cm)	Leaves plant ⁻¹ at harvest	Branches plant ⁻¹ at harvest	Fresh weight at harvest (g plant ⁻¹)	Dry matter at harvest (g plant ⁻¹)	Days to 50% flowering
T ₁	30.2	46.0	38.4	6.2	39.8	18.10	57.1
T ₂	30.7	50.4	43.8	7.0	45.2	20.75	55.0
T ₃	30.5	48.8	41.9	6.7	43.7	19.95	55.6
T ₄	31.0	54.0	47.2	7.8	50.1	23.20	53.9
T ₅	31.3	56.4	49.7	8.5	53.4	24.65	53.1
T ₆	31.6	59.0	52.0	8.9	55.8	25.85	52.4
S.E.m. ±	1.56	2.54	2.23	0.36	2.14	1.06	0.86
CD (P = 0.05)	N.S.	8.00	7.03	1.14	6.74	3.34	2.71
CV (%)	8.7	8.3	8.5	8.2	8.4	8.4	2.7

DAS = days after sowing; N.S. = non-significant

Effect on nodulation

Nodulation showed a strong response to microbial inoculation. T₆ recorded the maximum number of nodules plant⁻¹ at 30 DAS (34.4), 45 DAS (47.1) and 60 DAS (41.4), followed by T₅ and T₄. The lowest nodulation was observed under T₁ at all stages. The peak nodule number at 45 DAS and the decline at 60 DAS may be due to active symbiotic growth during vegetative phase followed by natural ageing of nodules during reproductive development. The superior nodulation under T₆ confirms the synergistic effect of *Rhizobium*, PSB and *Trichoderma*. *Rhizobium* promotes nodule formation and nitrogen fixation, PSB improves phosphorus availability required for nodular energy metabolism, and *Trichoderma* supports root growth and rhizosphere health. These results agree with Dubey *et al.* (2012) [6], Meena *et al.* (2013) [19], Sharma *et al.* (2014) [22], Singh *et al.* (2016) [24], Verma *et al.* (2017) [28], Langade *et al.* (2020) [16] and Kumawat *et al.* (2021) [15].

Table 4: Effect of bio-fertilizers on number of nodules plant⁻¹ of chickpea

Treatment	30 DAS	45 DAS	60 DAS
T ₁	19.0	26.4	22.3
T ₂	25.6	36.2	31.5
T ₃	21.8	31.5	27.3
T ₄	30.2	41.8	36.6
T ₅	32.5	44.6	39.2
T ₆	34.4	47.1	41.4
S.E.m. ±	1.46	2.01	1.72
CD (P = 0.05)	4.59	6.34	5.42
CV (%)	8.6	8.6	8.6

Effect on yield attributes and yield

Yield attributes improved markedly with integrated bio-fertilizer application. T₆ recorded the highest pods plant⁻¹ (64.1), seeds pod⁻¹ (1.73) and test weight (25.0 g), followed by T₅ and T₄. The improvement in yield attributes may be due to better vegetative development, more branches, higher dry matter accumulation and efficient translocation of assimilates to reproductive organs. Better nitrogen and phosphorus nutrition under microbial inoculation may have enhanced flowering, pod setting and seed filling.

Similar improvement in chickpea yield attributes with *Rhizobium* and PSB inoculation has been reported by Gaur and Tripathi (2011), Meena *et al.* (2012) [18], Singh *et al.* (2014) [23], Verma *et al.* (2016) [27], Yadav *et al.* (2018) [30] and Langade *et al.* (2020) [16]. Seed yield followed the same trend as the yield attributes. T₆ produced the highest seed yield (2280 kg ha⁻¹), straw yield (3390 kg ha⁻¹) and biological yield (5670 kg ha⁻¹), whereas T₁ recorded the lowest seed yield (1545 kg ha⁻¹). The increase in seed yield under T₆ was mainly due to higher nodulation, better plant growth, more pods plant⁻¹, higher seeds pod⁻¹ and improved test weight.

The harvest index varied only slightly among treatments, indicating that the increase in seed yield was accompanied by a proportional increase in straw yield and total biomass. These findings are in close agreement with Singh *et al.* (2014) [23], Verma *et al.* (2016) [27], Yadav *et al.* (2018) [30], Langade *et al.* (2020) [16] and Kumawat *et al.* (2021) [15], who reported higher chickpea productivity under integrated nutrient and bio-fertilizer management.

Table 5: Effect of bio-fertilizers on yield attributes and yield of chickpea.

Treatment	Pods plant ⁻¹	Seeds pod ⁻¹	Test weight (g)	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest index (%)
T ₁	39.6	1.29	19.8	1545	2425	3970	38.9
T ₂	47.8	1.42	21.3	1795	2760	4555	39.4
T ₃	45.2	1.38	20.8	1715	2635	4350	39.4
T ₄	56.8	1.58	23.4	2010	3010	5020	40.0
T ₅	60.7	1.66	24.2	2140	3190	5330	40.2
T ₆	64.1	1.73	25.0	2280	3390	5670	40.2
S.E.m. ±	2.83	0.07	1.01	92.10	140.30	232.50	-
CD (P = 0.05)	8.92	0.22	3.18	290.30	442.10	732.50	N.S.
CV (%)	8.5	8.4	8.0	8.4	8.4	8.4	-

Harvest index was statistically non-significant.

Effect on economics

Economic analysis showed that the small additional cost of microbial inoculants was compensated by higher seed and straw yield. The highest cost of cultivation was recorded under T₆ (₹40,800 ha⁻¹), but the same treatment also produced the highest gross return (₹132,180 ha⁻¹), net return (₹91,380 ha⁻¹) and B:C ratio (3.24). T₅ and T₄ were the next best treatments with B:C

ratios of 3.10 and 2.93, respectively. The higher profitability under T₆ was directly associated with better crop growth, higher yield attributes and increased seed yield. Similar economic advantages of bio-fertilizer-based nutrient management have been reported by Ali (2014) [1], Mallesha (2013) [17], Verma *et al.* (2016) [27], Yadav *et al.* (2018) [30] and Langade *et al.* (2020) [16].

Table 6: Effect of bio-fertilizers on economics of chickpea.

Treatment	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio
T ₁	38,000	89,825	51,825	2.36
T ₂	38,800	104,245	65,445	2.69
T ₃	39,000	99,595	60,595	2.55
T ₄	39,800	116,570	76,770	2.93
T ₅	40,000	124,080	84,080	3.10
T ₆	40,800	132,180	91,380	3.24

Conclusion

The present study confirmed that integrated use of bio-fertilizers with the recommended dose of fertilizers improved growth, nodulation, yield attributes, yield and economic returns of chickpea under the sandy loam soil conditions of Gwalior. Among the treatments, T₆, comprising 100% RDF + *Rhizobium* @ 20 g kg⁻¹ seed + *Trichoderma* @ 20 g kg⁻¹ seed + PSB @ 20 g kg⁻¹ seed, proved superior for most of the growth and yield parameters. This treatment recorded the highest seed yield (2280 kg ha⁻¹), net return (₹91,380 ha⁻¹) and B:C ratio (3.24).

On the basis of one-season field results, combined inoculation of *Rhizobium*, *Trichoderma* and PSB with 100% RDF may be recommended as an effective and economical nutrient management practice for improving chickpea productivity under similar agro-climatic conditions. Multi-season testing may further strengthen the recommendation for wider adoption.

Acknowledgement

The authors acknowledge the School of Agriculture Science, Vikrant University, Gwalior, Madhya Pradesh, for providing field and laboratory facilities to conduct the experiment.

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