



Response of Mungbean (*Vigna radiata* L.) to Integrated Nitrogen and Phosphorus Nutrition with *Rhizobium* and PSB Inoculation

Deepak ^{a++}, Pradeep Kumar ^{a#*}, J. S. Ranawat ^{a#}, Ekta Singh ^{a#},
G. M. Mathur ^{b†}, Dropati Saran ^{c#} and U. S. Shwkhawat ^{d†}

^a Department of Agronomy, FoAG, Tanta University, Sri Ganganagar, India.

^b Department of Soil Science, FoAG, Tanta University, Sri Ganganagar, India.

^c Department of Agricultural Economics, FoAG, Tanta University, Sri Ganganagar, India.

^d Department of Genetics and Plant Breeding, FoAG, Tanta University, Sri Ganganagar, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/ijps/2026/v38i106384>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://pr.sdiarticle5.com/review-history/168050>

Original Research Article

Received: 25/07/2026

Accepted: 15/10/2026

Published: 23/10/2026

Abstract

This field study assessed the effects of integrated nitrogen and phosphorus nutrition with *Rhizobium* and phosphate-solubilising bacteria (PSB) inoculation on the growth, yield and economic returns of mung bean (*Vigna radiata* L.) in Sri Ganganagar, Rajasthan. The experiment was conducted during the Kharif season of 2025 at the Agricultural Research Farm, Tanta University. Seven nutrient treatments were evaluated in a randomised block design with three replications, using the MH-1142 variety. The experimental soil was alkaline (pH 8.65) and contained 0.17% organic carbon. Plant growth, nodulation, yield attributes, yield and treatment economics were recorded. Among the evaluated treatments, the combination of $N_{30} + P_{60}$ kg ha⁻¹ with *Rhizobium* and PSB inoculation (T₇) produced the highest recorded number of pods (22.27 per plant), grains per pod (11.53) and test weight (35.3 g). It

⁺⁺ M.Sc. Student; [#] Assistant Professor; [†] Professor;

*Corresponding author: E-mail: pradeepsevtal1@gmail.com;

also gave the highest reported grain yield ($1,276.67 \text{ kg ha}^{-1}$), compared with $860.00 \text{ kg ha}^{-1}$ in the control, together with the highest gross returns ($\text{₹}116,211.93 \text{ ha}^{-1}$) and net returns ($\text{₹}78,620.62 \text{ ha}^{-1}$). The reported benefit–cost ratio was 2.09 under T₇. These findings suggest that the evaluated combination of mineral nutrients and microbial inoculation may improve mung bean performance under the study conditions. Further field evaluations would be needed to assess its applicability across seasons and locations.

Keywords: *Mung bean; Vigna radiata; nitrogen; phosphorus; Rhizobium inoculation; phosphate-solubilising bacteria; integrated nutrient management; nodulation; grain yield; economic returns.*

1. Introduction

Mung bean (*Vigna radiata* L.), commonly known as green gram, is an important short-duration pulse crop widely cultivated in tropical and subtropical regions. Pulses play a vital role in human nutrition and sustainable agriculture, as they are rich sources of protein, carbohydrates, dietary fibre, vitamins, and minerals. Mung bean contains approximately 22–25% protein (Mohanty & Satyasai, 2015) and is valued for its nutritional quality and its ability to improve soil fertility through biological nitrogen fixation (Mubarak, 2005). India is a major producer of mung bean, with Rajasthan being one of the leading producing states (Indian Institute of Pulses Research [IIPR], n.d.). However, crop productivity is often affected by low soil fertility and inadequate nutrient availability. Therefore, efficient nutrient management is essential for achieving higher and more sustainable mung bean production. A field study on green gram reported differences in seed nitrogen and phosphorus contents among integrated nutrient-management treatments (Kamal et al., 2026).

Nitrogen and phosphorus are essential nutrients for the growth and development of mung bean. Nitrogen plays an important role in protein synthesis, chlorophyll formation, and vegetative growth, while phosphorus promotes root development, nodulation, energy transfer, flowering, and seed formation (Marschner, 2012; Taiz et al., 2015). Although mung bean can fix atmospheric nitrogen through its symbiotic association with *Rhizobium*, effective nitrogen fixation depends on suitable soil conditions and efficient bacterial strains (Dakora & Keya, 1997; Graham & Vance, 2003). Adequate phosphorus availability further promotes nodulation and improves biological nitrogen fixation. Recent research on mung bean has examined how nitrogen and phosphorus fertilisation influence biological nitrogen fixation and crop yield (Ge et al., 2025a). Another study reported that combined nitrogen–phosphorus management was associated with changes in photosynthetic performance and grain formation in mung bean (Ge et al., 2025b). A two-year field study reported differences in mung bean nodulation and yield following the application of microbial biofertilisers (Yousefi et al., 2025). Research conducted in Rajasthan also evaluated the influence of mineral fertilisers combined with *Rhizobium* and PSB inoculation on mung bean yield and economic returns (Verma et al., 2026).

In recent years, the use of biofertilisers such as *Rhizobium* and phosphate-solubilising bacteria (PSB) has gained importance as a sustainable approach to nutrient management. *Rhizobium* enhances biological nitrogen fixation, whereas PSB increases phosphorus availability in the soil. Their combined application with suitable nitrogen and phosphorus levels can improve nutrient uptake, nodulation, plant growth, yield attributes, and mung bean productivity. The integrated application of chemical fertilisers and biofertilisers may therefore improve crop productivity, profitability, and resource-use efficiency. However, limited information is available on the combined effects of nitrogen, phosphorus, *Rhizobium*, and PSB under the agro-climatic conditions of Sri Ganganagar, Rajasthan. Therefore, the present investigation was undertaken to evaluate the effects of nitrogen and phosphorus levels, in combination with *Rhizobium* and PSB, on the growth, yield, and economics of mung bean.

2. Materials and Methods

2.1 Experimental Design and Treatments

The field experiment was laid out in a randomised block design (RBD) comprising seven treatments with three replications. Each experimental plot measured $4.0\text{m} \times 3.0\text{m}$, with a net plot area of $2.8\text{m} \times 2.2\text{m}$. The mung bean variety MH-1142 was used in the study.

The treatments were formulated to evaluate the effects of different nitrogen and phosphorus levels in combination with *Rhizobium* and phosphate-solubilising bacteria (PSB) on the growth, yield, and economics of mung bean. The treatments consisted of T₁: Control (no fertiliser), T₂: N₁₀ + P₂₀ kg /ha, T₃: N₂₀ + P₄₀ kg /ha, T₄: N₃₀ + P₆₀ kg /ha, T₅: N₁₀ + P₂₀ kg /ha + *Rhizobium* + PSB, T₆: N₂₀ + P₄₀ kg /ha + *Rhizobium* + PSB, and T₇: N₃₀ + P₆₀ kg /ha + *Rhizobium* + PSB. Recommended agronomic practices for mung bean were followed uniformly across all treatments throughout the crop growth period. *Rhizobium* and PSB cultures were applied by seed inoculation according to the respective treatments. Nitrogen and phosphorus were applied at the specified rates through suitable fertiliser sources. Uniform irrigation, weed management, and plant protection practices were maintained to minimise experimental variation.

The field experiment was conducted at the Agricultural Research Farm, Faculty of Agriculture, Tanta University, Sri Ganganagar, Rajasthan, India (29.8°N, 73.9°E; altitude 178 m above mean sea level), during the Kharif season of 2025 to study the effects of nitrogen and phosphorus levels in combination with *Rhizobium* and PSB on the growth, yield, and economics of mung bean (*Vigna radiata* L.). The experimental site falls within Agro-climatic Zone I-b of Rajasthan, commonly known as the Irrigated North Western Plain Zone, and is characterised by a semi-arid climate. During the crop growth period, the maximum temperature reached 36.84°C , while the minimum temperature ranged from approximately 25.84 to 28.78°C . Rainfall occurred at different intervals during the experimental period, with relative humidity ranging from 54.43% to 92.43%.

Before sowing, composite soil samples were collected from five representative locations in the experimental field at a depth of 0–15 cm. The samples were air-dried, passed through a 2 mm sieve, and analysed using standard analytical procedures. The experimental

soil, sampled at a depth of 0–15 cm, had a pH of 8.65, indicating alkaline conditions. The organic carbon content was 0.17%, indicating a relatively low level of organic matter. The soil contained 125.44 kg /ha of available nitrogen, 16.9 kg /ha of available phosphorus (P₂O₅), and 147.84 kg /ha of available potassium (K₂O), which were described as being in the medium range in the study. Soil pH was determined using a pH meter (Piper, 1966); organic carbon was determined using the Walkley and Black (1934) wet oxidation method; available nitrogen was measured using the alkaline permanganate method (Subbiah & Asija, 1956); available phosphorus was measured using Olsen's method (Olsen et al., 1954); and available potassium was measured using the flame photometer method (Jackson, 1967). Overall, these observations indicated that the experimental soil was alkaline, low in organic carbon, and had medium available N, P, and K status.

Table 1. Meteorological data during the experimental period (July 2025-September 2025, Sri Ganganagar, Rajasthan)

Month	Max. Temp. (°C)	Min. Temp. (°C)	Mean RH Max. (%)	Mean RH Min. (%)	Total Rainfall (mm)	Rainy Days	Mean Pan Evaporation (mm day ⁻¹)
July 2025	34.69	26.67	71.48	56.97	343.30	6	2.14
August 2025	33.48	27.57	75.09	65.75	38.30	3	1.46
September 2025*	32.75	27.02	84.58	65.15	9.00	1	2.17

2.2 Observations Recorded

Growth observations of mung bean were recorded at 30 DAS, 45 DAS, and harvest from randomly selected plants in each plot. Plant height, number of branches plant⁻¹ (at harvest), number of nodules plant⁻¹, and pod length (cm) were recorded at the appropriate growth stages.

Yield attributes included the number of pods per plant, number of grains per pod, and test weight of 1000 seeds (g). Grain and straw yields were also recorded. Biological yield was calculated as: (BY= grain yield + the straw yield). Harvest index was calculated as:

$$HI (\%) = (\text{grain yield} / \text{biological yield}) \times 100.$$

The economic performance of each treatment was evaluated in terms of the cost of cultivation, gross returns, net returns, and benefit:cost (B:C) ratio, calculated as B:C ratio = gross returns / cost of cultivation.

2.3 Statistical Analysis

The analysis was carried out using MS Excel software. The significance of treatment effects was tested using an F-test based on the null hypothesis. The standard error of the mean [S.E.m. (±)] was calculated for each parameter, and the critical difference (CD) at the 5% significance level was determined for comparisons of treatment means wherever treatment effects were significant. The statistical procedures followed those described by Panse and Sukhatme (1967).

3. Results and Discussion

3.1 Growth Parameters

Plant height, number of branches, nodules per plant, and pod length of mung bean were significantly influenced by different nitrogen and phosphorus levels, either alone or in combination with *Rhizobium* and PSB. Among all treatments, T₇ (N₃₀ + P₆₀ kg /ha + *Rhizobium* + PSB) recorded the highest plant height at 30 DAS, 45 DAS, and harvest (20.35, 47.12 and 52.07 cm), number of branches per plant (6.87), number of nodules plant⁻¹ at 45 DAS (19.70), and pod length (8.10 cm), remaining statistically at par with T₆ and T₄ for most parameters. The lowest values were recorded under T₁ (control), with plant heights of 11.79, 32.20 and 36.64 cm, 4.00 branches plant⁻¹, 12.00 nodules plant⁻¹, and a pod length of 5.90 cm. The improved growth and yield attributes under T₇ may be attributed to better nutrient availability, enhanced nodulation, and improved nutrient uptake following the combined application of N, P, *Rhizobium*, and PSB. Similar improvements in growth parameters following combined nutrient and biofertiliser application have been reported by Gavhane *et al.* (2024), Naushad *et al.* (2023), Harish *et al.* (2023), Kapat *et al.* (2024), Reddy *et al.* (2023), Tadewos *et al.* (2022), Kalal *et al.* (2021), and Amruta *et al.* (2015).

Table 2. Effect of Various Treatments on growth attributes of moong bean

Treatment	Plant height			Number of branches at harvest	Number of nodules per plant at 45 DAS	Pod length(cm)
	30 DAS	45 days	At harvest			
T1	11.79	32.20	36.64	4	12.00	5.9
T2	13.32	34.69	39.11	4.27	13.00	6.1
T3	15.91	39.07	43.93	5.33	15.00	6.8
T4	17.83	42.20	47.47	6.13	16.00	7.2
T5	14.61	36.26	41.00	4.93	14.00	6.6
T6	19.57	46.54	51.04	6.53	17.00	7.6
T7	20.35	47.12	51.40	6.87	19.67	8.1

3.2 Yield Attributes and Yield

The data presented in Table 3 revealed that different levels of nitrogen and phosphorus, applied alone or in combination with *Rhizobium* and PSB, significantly influenced the yield attributes and yield of mung bean. Among all treatments, T₇ (N₃₀ + P₆₀ kg/ha + *Rhizobium* + PSB) recorded the highest number of pods per plant (22.27), grains per pod (11.53), and test weight (35.3 g), followed by T₆ and T₄. Grain yield per plant was also highest under T₇ (6.63 g), which was statistically at par with T₆ (6.03 g) and T₄ (5.39 g). Similarly, T₇ recorded the highest grain yield (1276.67 kg /ha), followed by T₆ (1183.33 kg /ha) and T₄ (1096.67 kg /ha), whereas the lowest grain yield (860.00 kg /ha) was observed under the control (T₁).

A similar trend was observed for straw and biological yields. T₇ recorded the highest straw yield per plant (8.68 g) and straw yield (2374.33 kg /ha), followed by T₆ and T₄. Biological yield was also highest under T₇, at 15.03 g plant⁻¹ and 4257.36 kg /ha, respectively, while the lowest values were recorded under T₁. The higher yield under T₇ may be attributed to the combined effects of adequate nitrogen and phosphorus supply with *Rhizobium* and PSB, which may have enhanced nutrient availability, nodulation, plant growth, and translocation of photosynthates towards reproductive organs. However, the harvest index followed a different trend, with the highest value (30.06%) recorded under T₁ (control) and the lowest (28.90%) under T₅. Overall, the combined application of N₃₀ + P₆₀ kg /ha with *Rhizobium* and PSB improved the yield attributes, grain yield, straw yield, and biological yield of mung bean. Similar findings have been reported by Bajiyya *et al.* (2025), Mohit and Kumar (2022), Naushad *et al.* (2023), Tadewos *et al.* (2022), Singh *et al.* (2019), and Reddy *et al.* (2023).

Table 3. Effect of Various treatments on yield attributes and yield of moong bean

Treatment	Number of pods/ plant	Number of grains/ pod	Test weight at harvest	Yield (kg/ha)			Harvest index (%)
				Grain	Straw	Biological	
T1	18.20	8.80	32.2	860	1803	2864	30.06
T2	18.93	9.40	32.5	907	1851	3040	29.91
T3	19.87	10.00	33.2	1010	2011	3370	30.02
T4	20.87	10.40	33.8	1096	2125	3653	30.06
T5	19.67	9.73	32.9	966	1955	3349	28.90
T6	21.67	10.87	34.4	1183	2238	3946	30.03
T7	22.27	11.53	35.3	1276	2374	4257	29.99

3.3 Economic Analysis

The data presented in Table 4 revealed that different nutrient-management treatments significantly influenced the economics of mung bean. The highest cost of cultivation was recorded under T₇ (N₃₀ + P₆₀ kg /ha + *Rhizobium* + PSB) at ₹37,591.30 /ha, followed by T₆ (₹35,960.87 /ha), mainly because of the additional costs of fertilisers and biofertilisers; the lowest cost was recorded under T₁ (control) at ₹31,000.00 /ha. T₇ recorded the highest gross returns (₹116,211.93 /ha) and net returns (₹78,620.62 /ha), followed by T₆ (₹107,783.66 and ₹71,822.79 /ha) and T₄ (₹99,980.73 and ₹64,089.42 /ha), respectively. The lowest gross and net returns were recorded under T₁ (₹78,651.80 and ₹47,651.80 /ha). Similarly, the highest B:C ratio (2.09) was obtained under T₇, followed by T₆ (2.00) and T₄ (1.79), whereas the lowest B:C ratio (1.54) was recorded under T₁ and T₂. Overall, T₇ was the most economically favourable treatment for mung bean production. Similar findings have been reported by Bajiyya *et al.* (2025), Kishor *et al.* (2021), and Naushad *et al.* (2023).

Table 4. Effect of various treatments on economics of moong bean

Treatment	Cost of Cultivation	Gross Return	Net Return	B:C Ratio
T1	31000.00	78651.80	47651.80	1.54
T2	32630.43	82886.98	50256.55	1.54
T3	34260.87	92177.80	57916.93	1.69
T4	35891.30	99980.73	64089.42	1.79
T5	34330.43	88276.33	53945.89	1.57
T6	35960.87	107783.66	71822.79	2.00
T7	37591.30	116211.93	78620.62	2.09

4. Conclusion

The field experiment demonstrated differences in the growth, yield attributes and economic performance of mung bean across the seven nitrogen- and phosphorus-based treatments. The treatment comprising N₃₀ + P₆₀ kg ha⁻¹ with *Rhizobium* and PSB inoculation (T₇) produced the highest recorded number of pods per plant (22.27), grains per pod (11.53), test weight (35.3 g) and grain yield (1,276.67 kg ha⁻¹). The control yielded 860.00 kg ha⁻¹, indicating a favourable response to the integrated treatment under the conditions examined. The same treatment was associated with the highest reported gross returns of ₹116,211.93 ha⁻¹ and net returns of ₹78,620.62 ha⁻¹, with a reported benefit–cost ratio of 2.09. Although the harvest index did not follow the same pattern, the combined nutrient and inoculant treatment performed most favourably for the principal yield and economic indicators assessed. These findings support the potential usefulness of integrated nitrogen and phosphorus nutrition with microbial inoculation for mung bean cultivation in the experimental area. Because the study was conducted during one growing season at a single site, broader recommendations should await confirmation under additional agro-climatic and soil conditions.

5. Limitations

The experiment was conducted at a single location during one Kharif season and evaluated only one mung bean variety. Consequently, the findings may not represent responses under different soil conditions, seasonal environments or genotypes. The seven treatments examined selected combinations of nitrogen, phosphorus and microbial inoculation rather than every possible combination of these inputs. Accordingly, the conclusions are limited to the treatment levels and conditions investigated. Further field studies across multiple seasons, locations and varieties would help establish the consistency and wider applicability of these responses.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

- Amruta, N., Maruthi, J. B., Sarika, G., & Deepika, C. (2015). Effect of integrated nutrient management and spacing on growth and yield parameters of black gram cv. LBG-625 (Rashmi). *The Bioscan*, 10(1), 193–198. <https://thebioscan.com/index.php/pub/article/view/1195>
- Bajjiya, R., Lakhra, H., Ram, M., Meena, S. S., Sodani, R., Kumari, M., Mundiara, R., & Kumar, A. (2025). Optimizing productivity and profitability of mungbean (*Vigna radiata* L.) with strategic foliar application of nutrients under hot arid condition of Rajasthan. *Asian Journal of Soil Science and Plant Nutrition*, 11(3), 13–21. <https://doi.org/10.9734/ajsspn/2025/v11i3547>
- Dakora, F. D., & Keya, S. O. (1997). Contribution of legume nitrogen fixation to sustainable agriculture in sub-Saharan Africa. *Soil Biology and Biochemistry*, 29(5–6), 809–817. [https://doi.org/10.1016/S0038-0717\(96\)00225-8](https://doi.org/10.1016/S0038-0717(96)00225-8)
- Gavhane, P., Rajput, P., Kanaujiya, P. K., Gautam, S. K., & Suryawanshi, D. (2024). Maximizing productivity and profitability of green gram (*Vigna radiata* L.) through fertility levels and bio fertilizers. *International Journal of Plant & Soil Science*, 36(7), 399–403. <https://doi.org/10.9734/ijps/2024/v36i74745>
- Ge, J., Han, X., Wang, Q., Zhong, R., Li, S., Wang, Q., Li, E., Wang, Q., Gao, F., Feng, B., & Gao, J. (2025b). From photosynthesis to grain formation: A comprehensive evaluation of nitrogen-phosphorus co-optimization strategies in mung bean (*Vigna radiata* L.) cultivation. *Field Crops Research*, 333, Article 110112. <https://doi.org/10.1016/j.fcr.2025.110112>
- Ge, J., Wang, Q., Li, E., Zhang, S., Han, X., Li, S., Wang, Q., Wang, Q., Wu, P., Gao, F., Feng, B., & Gao, J. (2025a). Breaking the legume intensification paradox: Precision nitrogen-phosphorus fertilization for optimizing biological nitrogen fixation, yield, and soil physicochemical properties in mung bean. *Applied Soil Ecology*, 214, Article 106374. <https://doi.org/10.1016/j.apsoil.2025.106374>
- Graham, P. H., & Vance, C. P. (2003). Legumes: Importance and constraints to greater use. *Plant Physiology*, 131(3), 872–877. <https://doi.org/10.1104/pp.017004>
- Harish, A., Singh, P. K., Sharma, Y. K., & Singh, A. P. (2023). Effect of different sources of nutrients on growth, yield and quality of mung bean (*Vigna radiata* L.). *International Journal of Environment and Climate Change*, 13(10), 1390–1401. <https://doi.org/10.9734/ijec/2023/v13i102791>
- Indian Institute of Pulses Research. (n.d.). *Mungbean*. ICAR–Indian Institute of Pulses Research. <https://www.icar-iipr.org.in/mungbean/>
- Jackson, M. L. (1967). *Soil chemical analysis*. Prentice-Hall of India.
- Kalal, P. H., Virdia, H. M., & Patel, K. R. (2021). Effect of integrated nutrient management on growth, yield and economics of summer green gram (*Vigna radiata* L.) under South Gujarat condition. *The Pharma Innovation Journal*, 10(12), 499–501. <https://www.thepharmajournal.com/archives/2021/vol10issue12/PartG/10-10-575-434.pdf>
- Kamal, Ramesh Kumar, Anil Kumar, Dhaka, A. K., Kavinder, Ravi, & Monika. (2026). Effect of integrated nutrient management on NPK content in green gram (*Vigna radiata* L.). *Journal of Biology and Nature*, 18(1), 127–133. <https://doi.org/10.56557/joban/2026/v18i110224>
- Kapat, T., David, A. A., Dawson, J., Thomas, T., Toppo, N., Chowdhury, B., Sen, P., & Kushwaha, R. K. (2024). Influence of N, P, K, *Rhizobium* and vermicompost on soil health parameters and yield of green gram (*Vigna radiata* L.) var. Samrat. *International Journal of Plant & Soil Science*, 36(7), 282–289. <https://doi.org/10.9734/ijps/2024/v36i74731>
- Kishor, K., Kumar, V., Upadhya, B., & Borpatragohain, B. (2021). Effect of integrated nutrient management on growth, yield and economics of summer mungbean (*Vigna radiata*). *The Pharma Innovation Journal*, 10(8), 978–983. <https://www.thepharmajournal.com/archives/?ArticleId=7349&issue=8&vol=10&year=2021>
- Marschner, P. (Ed.). (2012). *Marschner's mineral nutrition of higher plants* (3rd ed.). Academic Press. <https://doi.org/10.1016/C2009-0-63043-9>
- Mohanty, S., & Satyasai, K. J. (2015). Feeling the pulse: Indian pulses sector. *NABARD Rural Pulse*, (10), 1–4. <https://www.nabard.org/auth/writereaddata/tender/2009164501Rural-Pulse-July-August-2015.pdf>
- Mohit, & Kumar, V. (2022). Integrated nutrient management in green gram (*Vigna radiata* L.). *Journal of Eco-friendly Agriculture*, 17(1), 52–55. <https://doi.org/10.5958/2582-2683.2022.00011.9>

- Mubarak, A. E. (2005). Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. *Food Chemistry*, 89(4), 489–495. <https://doi.org/10.1016/j.foodchem.2004.01.007>
- Naushad, M., Sanodiya, L. K., Rehan, M., Prajapati, A., Singh, R., & Kumar, R. (2023). Influence of INM on growth and yield of green gram (*Vigna radiata* L.) NEPZ. *International Journal of Environment and Climate Change*, 13(10), 1898–1903. <https://doi.org/10.9734/ijec/2023/v13i102846>
- Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (USDA Circular No. 939). United States Department of Agriculture. <https://agris.fao.org/search/en/providers/122535/records/65dded244c5aef494fd7641c>
- Panse, V. G., & Sukhatme, P. V. (1967). *Statistical methods for agricultural workers* (2nd ed.). Indian Council of Agricultural Research. <https://library.nehu.ac.in/bib/21661>
- Piper, C. S. (1966). *Soil and plant analysis: A laboratory manual of methods for the examination of soils and the determination of the inorganic constituents of plants*. Hans Publishers. <https://spices.res.in/opac/cgi-bin/koha/opac-detail.pl?biblionumber=780>
- Reddy, B. J., Fayaz, S., Menon, S., Bhat, T. A., Sharma, S., Jamsheed, B., Rana, N., Kumar, S., Khan, S., & Chijina, K. (2023). Comparative analysis of NPK with *Rhizobium* and PSB on the growth and yield of field pea under the sub-tropical regions of Punjab, India. *Ecology, Environment and Conservation*, 29(October Special Issue), S325–S330. <https://doi.org/10.53550/EEC.2023.v29i05s.058>
- Singh, P. K., Anees, M., Kumar, M., Yadav, K. G., Kumar, A., Kumar, M., Sharma, R., Singh, R. B., & Kumar, S. (2019). Effect of integrated nutrient management on growth, yield and quality of moongbean (*Vigna radiata* L.). *Journal of Pharmacognosy and Phytochemistry*, 8(2S), 1003–1006. <https://www.phytojournal.com/archives/2019.v8.i2S.7817/effect-of-integrated-nutrient-management-on-growth-yield-and-quality-of-moongbean-Itemgtvigna-radiataltemgt-l>
- Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science*, 25, 259–260.
- Tadewos, T., Ayalew, T., & Yoseph, T. (2022). Growth, nodulation and yield of mung bean (*Vigna radiata* (L.) Wilczek) as affected by bio-chemical fertilizers integration at Southern Ethiopia. *Ukrainian Journal of Ecology*, 12(11), 39–49. https://doi.org/10.15421/2022_412
- Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2015). *Plant physiology and development* (6th ed.). Sinauer Associates. <https://pure.au.dk/portal/en/publications/plant-physiology-and-development/>
- Verma, A. K., Mehriya, M. L., & Vishnawat, A. (2026). Effect of biofertilizers and growth promoting microorganisms on productivity and profitability of mungbean [*Vigna radiata* (L.) Wilczek] under mungbean-wheat cropping system. *International Journal of Plant & Soil Science*, 38(9), 109–115. <https://doi.org/10.9734/ijpss/2026/v38i96271>
- Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1), 29–38. <https://doi.org/10.1097/00010694-193401000-00003>
- Yousefi, A., Nabati, J., Mirzaeetalarposhti, R., & Malakshahi Kurdestani, A. (2025). Optimizing mung bean productivity and root morphology with biofertilizers for sustainable farming. *Scientific Reports*, 15, Article 40333. <https://doi.org/10.1038/s41598-025-28815-8>

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2026): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here: <https://pr.sdiarticle5.com/review-history/168050>