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Productivity enhancement in chickpea through integrated use of phosphorus, vermicompost and PSB

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Abstract
A field experiment was conducted during the rabi season of 2022–23 at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, to evaluate the effect of integrated use of phosphorus, vermicompost and phosphorus-solubilizing bacteria (PSB) on growth, nodulation, yield attributes, productivity and economics of chickpea (*Cicer arietinum* L.). The experiment was laid out in a factorial randomized block design with four replications comprising three levels of phosphorus (20, 30 and 40 kg P_2O_5 ha^{-1}), two levels of vermicompost (1 and 2 t ha^{-1}) and two levels of PSB inoculation (without and with PSB @ 5 ml kg^{-1} seed). The results revealed that application of 40 kg P_2O_5 ha^{-1} significantly improved nodulation, yield attributes and yield of chickpea. The treatment recorded the highest number of nodules per plant (21.58), fresh nodule weight (126.55 mg plant^{-1}), dry nodule weight (38.64 mg plant^{-1}), branches per plant (4.24), pods per plant (40.54), seed yield per plant (9.14 g), seed yield (1683 kg ha^{-1}) and stover yield (2427 kg ha^{-1}). Vermicompost application at 2 t ha^{-1} significantly enhanced nodulation, yield attributes and productivity over 1 t ha^{-1}. Similarly, seed inoculation with PSB significantly increased nodulation, yield components and seed yield compared with uninoculated treatment. Harvest index and seed index remained unaffected by the treatments. Economic analysis indicated that application of 40 kg P_2O_5 ha^{-1} recorded the highest gross return (₹101,334 ha^{-1}), net return (₹58,184 ha^{-1}) and benefit-cost ratio (2.35). The improvement in productivity under integrated nutrient management was attributed to enhanced phosphorus availability, improved root development, greater nodulation and efficient nutrient utilization. The study concluded that application of 40 kg P_2O_5 ha^{-1} along with vermicompost at 2 t ha^{-1} and PSB inoculation can be recommended for achieving higher productivity and profitability of chickpea under North Gujarat conditions.

Keywords: Chickpea, phosphorus, vermicompost, phosphorus-solubilizing bacteria, nodulation, yield attributes, seed yield, economics, integrated nutrient management

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops cultivated in India and several other semi-arid regions of the world. It occupies a prominent place in the farming systems owing to its ability to fix atmospheric nitrogen, improve soil fertility and provide protein-rich food for human consumption. Chickpea seeds contain about 20–22 per cent protein and serve as an inexpensive source of dietary protein, particularly for the vegetarian population. In addition to its nutritional significance, chickpea contributes substantially to sustainable agriculture through biological nitrogen fixation and improvement of soil health.

Despite being the largest producer of chickpea, India continues to face a substantial gap between the potential and realized productivity of the crop. Low soil fertility, inadequate nutrient management, imbalanced fertilizer use and poor adoption of integrated nutrient management practices are among the major factors responsible for low productivity. Phosphorus is one of the most important nutrients limiting chickpea production, particularly in light-textured soils where phosphorus availability is often restricted due to fixation and low native reserves.

Phosphorus plays a vital role in several physiological and biochemical processes, including energy transfer, photosynthesis, root development, nodulation, nitrogen fixation and seed formation. Adequate phosphorus nutrition promotes vigorous root growth, enhances the activity of Rhizobium, increases the number and effectiveness of nodules and ultimately improves crop productivity. However, the efficiency of applied phosphorus fertilizers remains low because a considerable proportion becomes unavailable to plants soon after application.

The integrated use of inorganic fertilizers with organic and biological sources of nutrients has emerged as a sustainable strategy for improving nutrient-use efficiency and maintaining soil productivity. Vermicompost is a nutrient-rich organic amendment that supplies essential macro- and micronutrients, improves soil physical properties and stimulates microbial activity. It also contains plant growth-promoting substances that enhance root development and crop growth. Application of vermicompost has been reported to improve nutrient availability, water-holding capacity and overall soil health, thereby contributing to higher crop yields.

Phosphorus-solubilizing bacteria (PSB) represent an important group of beneficial microorganisms capable of converting insoluble forms of phosphorus into plant-available forms through the secretion of organic acids and other metabolites. Seed inoculation with PSB enhances phosphorus availability, nutrient uptake, root growth and biological nitrogen fixation. The combined application of phosphorus fertilizer, vermicompost and PSB may therefore create a synergistic effect that improves nutrient availability, promotes plant growth and increases productivity of chickpea.

Considering the importance of integrated nutrient management in enhancing crop productivity and sustaining soil fertility, the present investigation was undertaken to evaluate the effect of phosphorus levels, vermicompost and phosphorus-solubilizing bacteria on growth, nodulation, yield attributes and productivity of chickpea under North Gujarat conditions.

Materials and Methods

A field experiment was conducted during the rabi season of 2022–23 at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India. Geographically, the experimental site is located at 24°19′ N latitude and 72°19′ E longitude with an elevation of 154.52 m above mean sea level and falls under the North Gujarat Agro-climatic Zone characterized by a semi-arid climate. The soil of the experimental field was loamy sand in texture, slightly alkaline in reaction (pH 7.5) and non-saline (EC 0.15 dS m^{-1}). The soil was low in organic carbon (0.24%) and available nitrogen (160.9 kg ha^{-1}), medium in available phosphorus (32.75 kg ha^{-1}) and high in available potassium (286.2 kg ha^{-1}).

The experiment was laid out in a factorial randomized block design with four replications comprising twelve treatment combinations. The treatments consisted of three levels of phosphorus viz., 20, 30 and 40 kg P_2O_5 ha^{-1}, two levels of vermicompost viz., 1 and 2 t ha^{-1} and two levels of phosphorus-solubilizing bacteria (PSB), namely without PSB and seed inoculation with PSB @ 5 ml kg^{-1} seed. Thus, twelve treatment combinations were evaluated under factorial arrangement.

Chickpea variety GJG 3 was used as the test crop. The crop was sown manually on 14 November 2022 using a seed rate of 60 kg ha^{-1} with row spacing of 45 cm. The recommended dose of nitrogen (20 kg N ha^{-1}) was applied uniformly to all treatments through urea, whereas phosphorus was applied as basal dose through single super phosphate according to the treatment specifications. Vermicompost was incorporated in furrows at the time of sowing as per the treatments. Seeds assigned to PSB treatments were inoculated with liquid PSB culture @ 5 ml kg^{-1} seed before sowing and shade dried prior to planting. The crop was raised following the recommended agronomic practices of the region. Irrigation was applied immediately after sowing and subsequently at critical crop growth stages. Interculturing and hand weeding were carried out to maintain weed-free conditions throughout the crop growth period.

Five plants were randomly selected and tagged from each net plot for recording biometric observations. Plant height was recorded at 30 and 60 days after sowing (DAS) and at harvest. The number of root nodules per plant and fresh and dry weight of nodules were recorded at 45 DAS. At harvest, observations on number of branches per plant, number of pods per plant, seed yield per plant and seed index were recorded. The crop was harvested manually at maturity and seed yield and stover yield were recorded from the net plot area and converted into kilogram per hectare. Harvest index was calculated as the ratio of economic yield to biological yield and expressed as percentage.

The data obtained from various observations were subjected to analysis of variance appropriate to the factorial randomized block design. The significance of treatment effects was tested using the F-test and treatment means were compared using the critical difference (CD) at the 5 per cent level of significance as described by Panse and Sukhatme (1985).

Results and Discussion

Nodulation

The nodulation characteristics of chickpea were significantly influenced by phosphorus levels, vermicompost application and PSB inoculation. Application of 40 kg P_2O_5 ha^{-1} recorded the highest number of nodules per plant (21.58), fresh weight of nodules (126.55 mg $plant^{-1}$) and dry weight of nodules (38.64 mg $plant^{-1}$), which remained statistically at par with 30 kg P_2O_5 ha^{-1} but significantly superior to 20 kg P_2O_5 ha^{-1}. The increase in nodulation under higher phosphorus application may be attributed to enhanced root growth and increased energy availability for Rhizobium activity and nitrogen fixation. Phosphorus is a key component of ATP and plays a vital role in cell division, root proliferation and development of effective nodules. Adequate phosphorus availability promotes symbiotic nitrogen fixation and increases both the number and biomass of nodules. Similar findings were reported by Bhatt *et al*. (2012), Jat *et al*. (2012) and Dubey *et al*. (2017) [1, 3, 4].

Application of vermicompost at 2 t ha^{-1} significantly improved nodulation over 1 t ha^{-1}. The treatment produced 20.94 nodules $plant^{-1}$ compared with 18.44 nodules $plant^{-1}$ under the lower dose. Fresh and dry weights of nodules also increased significantly with vermicompost application. This improvement may be attributed to enhanced microbial activity, improved soil aeration and continuous nutrient supply resulting from vermicompost decomposition. Vermicompost is known to contain plant growth regulators, enzymes and beneficial microorganisms that stimulate root development and create favourable conditions for Rhizobium multiplication. Similar observations were reported by Singh and Chauhan (2011) and Singh *et al*. (2015) [8, 9].

PSB inoculation significantly enhanced nodulation characteristics. Seed inoculation with PSB recorded 20.44 nodules $plant^{-1}$ compared with 18.94 nodules $plant^{-1}$ under uninoculated treatment. The beneficial effect of PSB may be attributed to increased solubilization of native and applied phosphorus, thereby improving phosphorus availability in the rhizosphere. Enhanced phosphorus nutrition stimulates root growth and nodule formation, resulting in greater biological nitrogen fixation. These findings corroborate those reported by Kumar *et al*. (2016) and Dubey *et al*. (2017) [3, 5].

Yield Attributes

Yield attributes exhibited significant improvement under integrated phosphorus management practices. Application of 40 kg P_2O_5 ha^{-1} recorded the highest number of branches per plant (4.24), pods per plant (40.54) and seed yield per plant (9.14 g), remaining statistically at par with 30 kg P_2O_5 ha^{-1}. The increase in yield attributes may be attributed to enhanced photosynthetic activity, improved nutrient uptake and efficient translocation of assimilates towards reproductive organs. Phosphorus plays a critical role in flowering, pod formation and seed development through its involvement in energy transfer reactions and metabolic processes. Similar results have been reported by Jat *et al*. (2012), Kumar *et al*. (2016) and Yadav *et al*. (2020) [4, 5, 10].

Application of vermicompost at 2 t ha^{-1} significantly increased branches per plant (4.08), pods per plant (38.10) and seed yield per plant (8.94 g) compared with 1 t ha^{-1}. The favourable effect of vermicompost may be attributed to improved soil fertility, balanced nutrient supply and enhanced microbial activity. Improved soil physical properties and moisture retention under vermicompost application further facilitate better crop growth and reproductive development. Similar findings were reported by Das *et al*. (2014) and Singh *et al*. (2015) [2, 8].

Seed inoculation with PSB significantly improved yield attributes, producing 4.02 branches $plant^{-1}$, 38.02 pods $plant^{-1}$ and 8.87 g seed yield $plant^{-1}$. The enhanced availability of phosphorus resulting from microbial solubilization likely improved reproductive growth and seed development. Increased nutrient-use efficiency under PSB inoculation contributes to better flowering, pod setting and grain filling. Similar observations were reported by Dubey *et al*. (2017) and Sharma *et al*. (2019) [3, 7].

Seed index remained unaffected by phosphorus, vermicompost and PSB treatments. The non-significant response of seed index suggests that seed size is largely governed by genetic factors and is less influenced by nutrient management practices under the prevailing experimental conditions.

Seed yield, stover yield and harvest index

Integrated phosphorus management significantly enhanced seed and stover yields of chickpea. Application of 40 kg P_2O_5 ha^{-1} recorded the highest seed yield (1683 kg ha^{-1}) and stover yield (2427 kg ha^{-1}), which remained statistically comparable with 30 kg P_2O_5 ha^{-1} and significantly superior to 20 kg P_2O_5 ha^{-1}. The increase in seed yield under higher phosphorus levels may be attributed to improved nodulation, enhanced nutrient uptake and superior yield attributes. Phosphorus promotes root development, biological nitrogen fixation and energy transfer, thereby increasing photosynthate production and translocation to developing grains. The yield advantage obtained under higher phosphorus application is in agreement with the findings of Bhatt *et al*. (2012), Jat *et al*. (2012) and Kumar *et al*. (2016) [1, 4, 5].

Application of vermicompost at 2 t ha^{-1} significantly increased seed yield (1629 kg ha^{-1}) and stover yield (2419 kg ha^{-1}) over 1 t ha^{-1} vermicompost. Improved nutrient availability, enhanced microbial activity and better soil moisture retention under vermicompost application may have contributed to greater biomass production and grain yield. Vermicompost not only supplies nutrients but also improves nutrient-use efficiency and soil health, leading to sustained crop productivity. Similar results were reported by Das *et al*. (2014) and Singh *et al*. (2015) [2, 8].

PSB inoculation significantly improved seed yield (1604 kg ha^{-1}) and stover yield (2384 kg ha^{-1}) compared with uninoculated treatment. The increased yield under PSB inoculation may be attributed to enhanced phosphorus availability, improved root growth and greater nutrient absorption. Enhanced phosphorus nutrition improves metabolic activity and reproductive development, ultimately resulting in higher grain yield. Similar findings were reported by Dubey *et al*. (2017) and Sharma *et al.* (2019) [3, 7].

Harvest index was not significantly affected by phosphorus levels, vermicompost application or PSB inoculation. Although numerical differences were observed among treatments, the proportionate increase in both grain yield and biological yield resulted in non-significant variation in harvest index.

Economics

Economic analysis revealed that integrated phosphorus management significantly influenced profitability of chickpea cultivation. Application of 40 kg P_2O_5 ha^{-1} recorded the highest gross return (₹101,334 ha^{-1}), net return (₹58,184 ha^{-1}) and benefit-cost ratio (2.35). The higher profitability was mainly associated with increased seed and stover yields obtained under adequate phosphorus nutrition. Although the cost of cultivation increased with phosphorus application, the additional expenditure was compensated by substantially higher returns from increased productivity. Similar economic advantages of phosphorus fertilization in chickpea have been reported by Jat *et al*. (2012) and Yadav *et al.* (2020) [4, 10].

Application of vermicompost at 2 t ha^{-1} generated higher gross and net returns owing to increased crop productivity. The beneficial effect of vermicompost on profitability may be attributed to improved nutrient availability, enhanced crop growth and greater yield realization. Similar observations were reported by Das *et al*. (2014) and Meena *et al*. (2018) [2, 6].

PSB inoculation proved to be an economically viable practice due to its low cost and significant yield enhancement. Inoculated plots recorded higher gross returns, net returns and benefit-cost ratio than uninoculated plots. Enhanced phosphorus solubilization and nutrient uptake under PSB inoculation resulted in greater productivity and profitability. Similar findings have been reported by Kumar *et al.* (2016) and Sharma *et al.* (2019) [5, 7].

Table 1: Effect of phosphorus, vermicompost and PSB on number and weight of root nodules of chickpea

Treatments	Number of root nodules per plant	Fresh weight (mg/plant)	Dry weight (mg/plant)
A. Levels of phosphorus			
P_1 : 20 kg/ha	17.68	110.21	28.20
P_2 : 30 kg/ha	19.82	118.02	35.83
P_3 : 40 kg/ha	21.58	126.55	38.64
S.Em.±	0.64	3.19	1.06

C.D. at 5%	1.84	9.17	3.06
B. Levels of vermicompost			
V_1 : 1 t/ha	18.44	113.29	32.50
V_2 : 2 t/ha	20.94	123.23	35.94
S.Em.±	0.52	2.60	0.87
C.D. at 5%	1.50	7.49	2.50
C. PSB application			
B_0 : Without PSB	18.94	114.43	32.95
B_1 : With PSB @ 5 ml/kg seed	20.44	122.09	35.49
S.Em.±	0.52	2.60	0.87
C.D. at 5%	1.50	7.49	2.50
Interactions			
P × V	NS	NS	NS
P × B	NS	NS	NS
V × B	NS	NS	NS
P × V × B	NS	NS	NS
C.V.%	13.01	10.78	12.45

Table 2: Effect of phosphorus, vermicompost and PSB on number of branches and number of pods per plant of chickpea

Treatments	Number of branches per plant	Number of pods per plant
A. Levels of phosphorus		
P_1 : 20 kg/ha	2.96	31.48
P_2 : 30 kg/ha	3.98	37.74
P_3 : 40 kg/ha	4.24	40.54
S.Em.±	0.10	1.09
C.D. at 5%	0.30	3.15
B. Levels of vermicompost		
V_1 : 1 t/ha	3.38	35.06
V_2 : 2 t/ha	4.08	38.10
S.Em.±	0.08	0.89
C.D. at 5%	0.24	2.57
C. PSB application		
B_0 : Without PSB	3.44	35.14
B_1 : With PSB @ 5 ml/kg seed	4.02	38.02
S.Em.±	0.08	0.89
C.D. at 5%	0.24	2.57
Interactions		
P × V	NS	NS
P × B	NS	NS
V × B	NS	NS
P × V × B	NS	NS
C.V.%	11.10	11.97

Table 3: Effect of phosphorus, vermicompost and PSB on seed yield per plant and seed index of chickpea

Treatments	Seed yield per plant (g)	Seed index (g)
A. Levels of phosphorus		
P_1 : 20 kg/ha	7.43	19.44
P_2 : 30 kg/ha	8.79	20.46
P_3 : 40 kg/ha	9.14	21.04
S.Em.±	0.28	0.56
C.D. at 5%	0.81	NS
B. Levels of vermicompost		
V_1 : 1 t/ha	7.95	19.66
V_2 : 2 t/ha	8.94	20.97
S.Em.±	0.23	0.45
C.D. at 5%	0.66	NS
C. PSB application		
B_0 : Without PSB	8.04	20.08
B_1 : With PSB @ 5 ml/kg seed	8.87	20.55
S.Em.±	0.23	0.45
C.D. at 5%	0.66	NS
Interactions		
P × V	NS	NS
P × B	NS	NS

V × B	NS	NS
P × V × B	NS	NS
C.V.%	13.30	10.97

Table 4: Effect of phosphorus, vermicompost and PSB on seed yield, stover yield and harvest index of chickpea

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
A. Levels of phosphorus			
P_1 : 20 kg/ha	1364	2128	39.07
P_2 : 30 kg/ha	1596	2346	40.50
P_3 : 40 kg/ha	1683	2427	41.00
S.Em.±	47.41	70.16	0.95
C.D. at 5%	136	202	NS
B. Levels of vermicompost			
V_1 : 1 t/ha	1466	2182	40.18
V_2 : 2 t/ha	1629	2419	40.21
S.Em.±	38.71	57.28	0.78
C.D. at 5%	111	165	NS
C. PSB application			
B_0 : Without PSB	1491	2217	40.17
B_1 : With PSB @ 5 ml/kg seed	1604	2384	40.22
S.Em.±	38.71	57.28	0.78
C.D. at 5%	111	165	NS
Interactions			
P × V	NS	NS	NS
P × B	NS	NS	NS
V × B	NS	NS	NS
P × V × B	NS	NS	NS
C.V.%	12.25	12.20	9.50

Table 5: Economics of chickpea as influenced by different levels of phosphorus, vermicompost and PSB

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	BCR
Levels of phosphorus (kg/ha)						
P_1	1364	2128	42025	82932	40907	1.97
P_2	1596	2346	42592	96318	53726	2.26
P_3	1683	2427	43150	101334	58184	2.35
Levels of vermicompost (t/ha)						
V_1	1466	2182	39419	88608	49189	2.25
V_2	1629	2419	45759	98432	52673	2.15
PSB application						
B_0	1491	2217	42566	90108	47542	2.12
B_1	1604	2384	42611	96932	54321	2.27

Selling price of chickpea seed @ 53 ₹/kg, Selling price of chickpea stover @ 5 ₹/kg

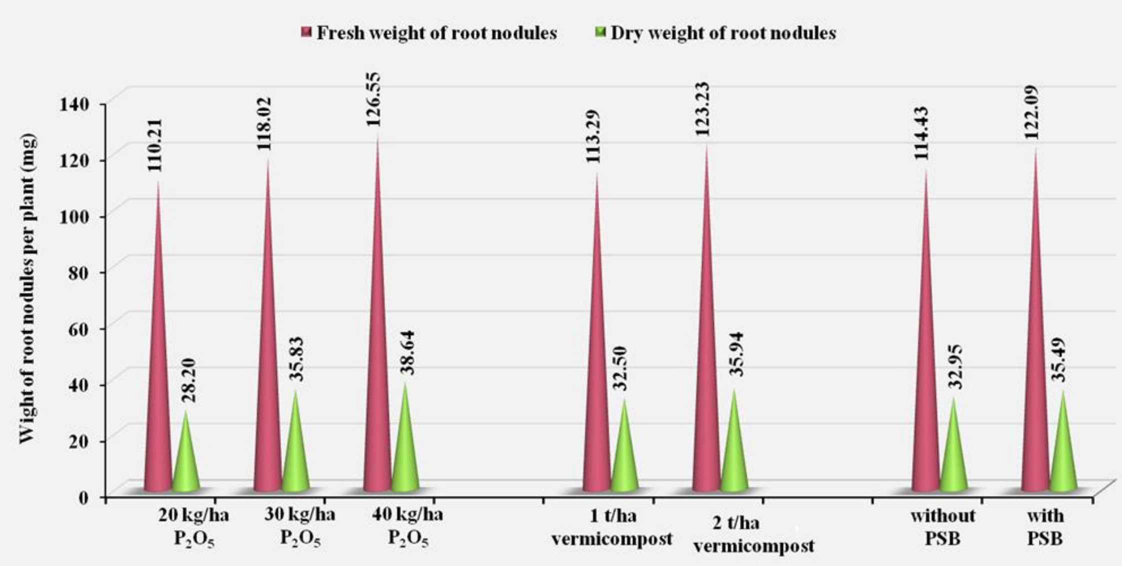

Figure 4.3: Effect of phosphorus, vermicompost and PSB on weight of root nodules of chickpea

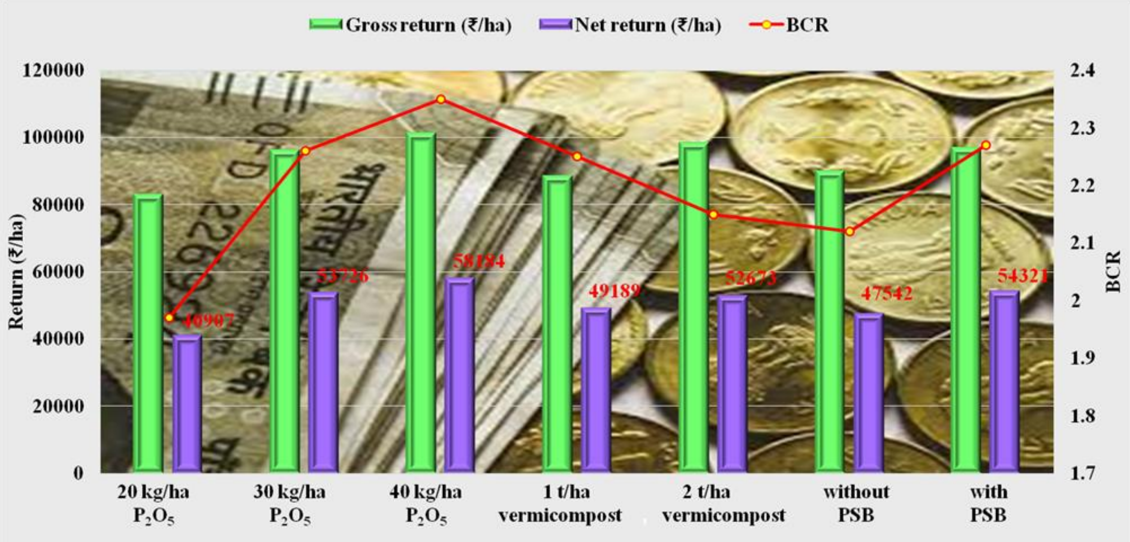

Figure 4.14: Economics of chickpea as influenced by different levels of phosphorus, vermicompost and PSB

Conclusion

The results clearly demonstrated that integrated application of phosphorus, vermicompost and PSB substantially improved nodulation, yield attributes, seed yield, stover yield and profitability of chickpea. Application of 40 kg P_2O_5 ha^{-1} along with vermicompost at 2 t ha^{-1} and PSB inoculation proved most effective in enhancing crop productivity through improved phosphorus availability, better root development, enhanced biological nitrogen fixation and efficient nutrient utilization.

References

1. Bhatt PK, Patel PT, Patel BT, Raval CH. Effect of phosphorus, FYM and biofertilizers on growth and yield of chickpea (*Cicer arietinum* L.). Legume Research – An International Journal,2012:35(4):339–343.
2. Das A, Patel DP, Munda GC, Ghosh PK. Effect of organic and inorganic sources of nutrients on yield, nutrient uptake and economics of chickpea. Indian Journal of Agronomy,2014:59(1):131–136.
3. Dubey SK, Tripathi SK, Singh B. Influence of phosphorus and phosphorus-solubilizing bacteria on growth, nodulation and yield of chickpea. International Journal of Current Microbiology and Applied Sciences,2017:6(5):2308–2315.
4. Jat RA, Ahlawat IPS, Gangaiah B. Effect of phosphorus and biofertilizers on productivity, nutrient uptake and economics of chickpea. Indian Journal of Agronomy,2012:57(4):370–374.
5. Kumar R, Singh R, Yadav L. Response of chickpea to phosphorus and biofertilizer application under irrigated conditions. Legume Research – An International Journal,2016:39(5):803–807.
6. Meena BL, Fageria VD, Prajapat K. Effect of integrated nutrient management on productivity and profitability of chickpea. International Journal of Chemical Studies,2018:6(3):2215–2219.
7. Sharma A, Singh H, Kumar P. Integrated use of phosphorus and biofertilizers for enhancing productivity of chickpea. International Journal of Chemical Studies,2019:7(5):1876–1880.
8. Singh G, Sekhon HS, Sharma P. Effect of phosphorus and organic manures on growth, nodulation and productivity of chickpea. Legume Research – An International Journal,2015:38(4):535–540.
9. Singh R, Chauhan SVS. Effect of phosphorus, vermicompost and biofertilizers on growth and yield of chickpea. Annals of Agricultural Research,2011:32(3):145–149.
10. Yadav V, Sharma SK, Meena RS. Influence of integrated nutrient management on yield attributes, productivity and economics of chickpea. International Journal of Current Microbiology and Applied Sciences,2020:9(7):1250–1258.