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Symbiotic Parameters, Quality Parameters, Nutrient Content and Uptake by Chickpea (*Cicer arietinum* L.) Crop as Influenced by Rock Phosphate, Poultry Manure and Phosphate Solubilizing Bacteria

Deshraj Meena[1*], R.H. Meena[2], Devendra Jain[3], Ajit Kumar Meena[4], Kriti Sharma[1] and Yash Vardhan Singh[1]
[1]Research Scholar, Department of Soil Science and Agricultural Chemistry,
Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan), India.
[2]Professor, Department of Soil Science and Agricultural Chemistry,
Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan), India.
[3]Assistant Professor, Department of Molecular Biology and Biochemistry,
Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan), India.
[4]ICAR-National Bureau of Soil Science and Land Use Planning, Nagpur (Maharashtra), India.

(Corresponding author: Deshraj Meena)*

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ABSTRACT: The field experiment entitled "Symbiotic Parameters, Quality Parameters, Nutrient Content and Uptake by Chickpea (*Cicer arietinum* L.) Crop as Influenced by Rock Phosphate, Poultry Manure and Phosphate Solubilizing Bacteria" was conducted during *Rabi* season, 2021-2022 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan). The experiment was layout in Randomized Block Design (RBD) with 9 treatments and 3 replications. Higher number of nodules plant^{-1} at 60 days (44.16), leghemoglobin content in nodules (2.48 mg g^{-1}), protein content in seed and protein yield (456.21 kg ha^{-1}) were also observed under application of 50% P through RP + 50% P through PM + PSB (T_9). The results showed that treatment T_9 (50% P through RP + 50% P through PM + PSB) significantly improved in NPK content in seed as well as haulm. Further results revealed that nitrogen, phosphorus, and potassium uptake was also significantly enhanced by the combined application of RP+PM+PSB (50% P through RP + 50% P through PM+ PSB). It was concluded that application of 50% P through RP + 50% P through PM + PSB (T_9) significantly improved symbiotic parameters, nutrient content and uptake by chickpea of chickpea (*Cicer arietinum* L.). These findings hold significant implications for sustainable agriculture and nutrient management strategies in chickpea cultivation, and can contribute to the optimization of crop yields and overall agricultural productivity in the region.

Keywords: Rock Phosphate, Poultry Manure, Phosphate Solubilizing Bacteria, Nutrient content, Nutrient uptake, Chickpea.

INTRODUCTION

Chickpea (*Cicer arietinum* L.), a remarkable member of the Fabaceae family, holds a storied history as an ancient pulse crop that traces its origins to Southeast Turkey. Over the millennia, this versatile legume has captured the hearts and palates of cultures worldwide, becoming a staple in diverse cuisines. From dry form to flour, sprouts, and tender green pods, chickpea offers a delightful array of culinary possibilities. Its versatility extends to providing roasted or boiled dry beans, contributing to a wholesome and nourishing human diet, while its biomass serves as valuable fodder for livestock, enhancing agricultural sustainability (Jukanti *et al.*, 2012; Gan *et al.*, 2016). As a plant with a rich historical and cultural significance, chickpea has become a cherished crop for both human and animal consumption, offering a myriad of nutritional benefits. Boasting high protein content, chickpea presents a cost-effective source of essential nutrients, particularly for vegetarian populations. Its protein-rich composition contributes to a balanced diet, ensuring a sufficient intake of amino acids necessary for human health. Not only is chickpea a valuable source of protein, but it also contains significant amounts of carbohydrates, dietary fiber, vitamins, and minerals, making it a wholesome addition to various diets (Winter *et al.*, 1999; Singh *et al.*, 2016). Beyond its nutritional value, chickpea plays a vital role in sustainable agriculture due to its ability to fix atmospheric nitrogen through a symbiotic relationship with rhizobium bacteria. This biological nitrogen fixation enhances soil fertility, reducing the need for synthetic fertilizers and promoting eco-friendly agricultural practices. Furthermore, the deep-rooted nature of chickpea plants aids in soil structure improvement, water infiltration, and erosion control, contributing to overall soil health and sustainability (Yousfi *et al.*, 2020).

The use of chemical fertilizers has traditionally been the primary method to meet the phosphorus (P) requirements of agriculture. However, excessive reliance on these fertilizers has led to unintended environmental consequences and escalating costs. Moreover, continuous and indiscriminate application of chemical fertilizers has detrimental effects on soil health, including its composition, microflora, and overall properties. As a result, there is a growing need to explore alternative and sustainable sources of phosphorus to address these challenges and ensure soil fertility and productivity (Nadeem *et al.*, 2020).

An emerging solution to counter the limitations of chemical fertilizers is the adoption of naturally-occurring phosphate sources. These alternative fertilizers offer the advantage of being more environmentally friendly and cost-effective. Their application has been shown to positively impact soil texture and quality, leading to improved soil health and long-term sustainability in agricultural practices (Gopalakrishnan *et al*., 2019). By shifting towards the use of naturally-occurring phosphate sources, we can mitigate the negative effects of chemical fertilizers and promote a more balanced and ecologically sound approach to soil nutrient management. This transition not only addresses the current challenges of agricultural sustainability but also lays the foundation for a healthier and more resilient agricultural system that benefits both the environment and farmers alike (Hussain *et al*., 2018)

The use of natural rock phosphate as a phosphorus amendment in agriculture has gained attention due to its potential benefits, provided its solubilization can be increased through suitable amendments (Zapata and Zaharah, 2002). Rock phosphate is a naturally occurring mineral that contains phosphorus, an essential nutrient for plant growth. However, its low solubility limits its immediate availability to plants, making it less efficient as a direct phosphate fertilizer. To address this issue, researchers have explored various soil amendments to enhance the solubility of rock phosphate and make it more accessible to plants.

One such amendment is poultry manure, which is a rich organic fertilizer derived from the combined solid and liquid excreta of poultry. Poultry manure is known for its high nutrient content, particularly nitrogen, which can significantly contribute to plant growth and development. Studies have demonstrated that the application of poultry manure can lead to increased crop yield and nutrient uptake, primarily attributed to the enhanced availability of nitrogen from the manure. Additionally, the organic matter present in poultry manure can improve soil structure, water retention, and nutrient-holding capacity, further supporting plant growth (Praveen and Gupta, 2017; Farid and Rizwan, 2020).

In recent years, microbial inoculants have emerged as promising components for sustainable agricultural practices. These inoculants consist of beneficial microorganisms that promote plant growth, enhance nutrient availability, and improve overall plant health. When applied to the soil, these microbes interact with plant roots and facilitate nutrient uptake by solubilizing unavailable forms of nutrients, including phosphorus. Research has shown that microbial inoculants can effectively increase the solubility of rock phosphate and improve its utilization by plants, leading to enhanced crop productivity (Hameeda *et al*., 2006).

The combined use of poultry manure and microbial inoculants has shown even more significant positive effects on soil fertility and plant growth. Poultry manure provides a source of organic matter and nutrients, while microbial inoculants contribute to the solubilization of rock phosphate, making phosphorus more accessible to plants. This integrated approach not only improves nutrient availability but also enhances soil health by promoting microbial activity and nutrient cycling. Overall, the utilization of natural rock phosphate, when combined with suitable soil amendments such as poultry manure and microbial inoculants, offers a promising alternative to chemical fertilizers. By enhancing the solubility and availability of phosphorus, these amendments support sustainable agriculture practices, reduce environmental impacts, and improve soil quality and plant health. Emphasizing the use of these eco-friendly and efficient amendments can contribute to more efficient nutrient management and ensure long-term agricultural sustainability (Rana *et al*., 2016).

The present study therefore aimed to evaluate the effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on symbiotic parameters, nutrient content and uptake of chickpea (*Cicer arietinum* L.).

MATERIALS AND METHODS

A. Study area

The experiment was conducted at the Instructional Farm of Rajasthan College of Agriculture, Udaipur, situated at 240°35' North latitude and 740°42' East longitude, at an elevation of 579.5 meters above mean sea level. This location falls within Rajasthan Agro Climatic Zone IV-a, encompassing the Sub-Humid Southern Plain and Aravalli Hills. The region experiences a mean annual rainfall of 637 mm, primarily received during the South-West monsoon, which typically begins in the final week of June and extends till September. The climate of Udaipur is characterized by maximum and minimum temperatures ranging from 22.49 to 33.34°C and 3.77 to 14.67°C, respectively. The relative humidity varies between 54.43% to 90.57% during the monsoon period and 18.27% to 52.14% during other times of the year.

The soil at the experimental site is classified as clay loam in texture, and its nutrient content was determined to be 272.35 kg ha^{-1} of available nitrogen, 21.62 kg ha^{-1} of available phosphorus, and 368.50 kg ha^{-1} of available potassium. The soil's pH was measured at 8.28, indicating a slightly alkaline nature. These soil characteristics play a crucial role in determining the crop's growth and nutrient uptake during the experiment.

B. Experimental design and treatments

The experiment comprises nine treatment combinations of phosphorus source (SSP, RP and PM with and without PSB) including one control.

Treatments Details	
T1	Control
T2	PSB
T3	100% P through SSP
T4	100% P through RP
T5	100% P through PM
T6	50% P through RP+ 50% P through PM
T7	100% P through RP+ PSB
T8	100% P through PM + PSB
T9	50% P through RP + 50% P through PM + PSB

Note: P = Phosphorus, PSB= Phosphate Solubilizing Bacteria, SSP=Single Super Phosphate, RP=Rock Phosphate, PM=Poultry Manure

C. *Symbiotic Parameters*

Nodules count at 60 days. At the 60th day after sowing, the number of nodules on the chickpea plants was assessed. To conduct the assessment, the plants were carefully uprooted, ensuring that their root systems remained intact. The roots were then dipped in water to remove any soil clinging to them, and they were gently washed to ensure a clean and accurate count of nodules. The total number of root nodules per plant was recorded as the mean value.

Additionally, the pink root nodules were separated from the root system for further analysis to estimate the leghemoglobin content.

Leghemoglobin content. Leghemoglobin content of root nodules was estimated as hemochrome as described by Bergersen (1980). Fresh nodules (100 mg) were macerated with 5ml of 0.1 M potassium phosphate buffer (pH 7.4), filtered through chase cloth and the extract was centrifuged at 10,000 rpm for 30 minutes. Equal volume of alkaline pyridine reagent (4.2 M pyridine in 0.2 M NaOH) was added and mixed. To half of solution added few crystals of sodium dithionate to reduce the hemochrome and mixed taking care to avoid alteration and measured the colour intensity at 556 nm using reagent blank as control. To other portion few crystals of potassium hexacynoferrate were added to oxidize the hemochrome and the intensity was recorded at 539 nm. The concentration of leghemoglobin was calculated as below:

$$\text{Lb (nm)} = \frac{\text{A556} - \text{A539} \times 2\text{D}}{23.4}$$

Where, D is initial dilution

D. Quality parameter

Protein content (%). Protein content was estimated by multiplying per cent nitrogen content in seed sample by multiplying with factor of 6.25 (AOAC, 1960).

Protein yield (kg ha^{-1}). The protein yield was computed by using following formula.

$$\text{Protein yield kg ha}^{-1} = \frac{\text{Seed yield kg ha}^{-1} \times \text{Protein percentage}}{100}$$

Nutrient content and uptake

The nutrient content of nitrogen (N), phosphorus (P), and potassium (K) in both the seed and haulm samples of the harvested chickpea crop was determined after threshing. Standard procedures were employed for plant analysis to assess the nutrient concentrations in the seed and haulm. Specifically, the nitrogen concentration in both seed and haulm was determined using Kjeldahl's method, while phosphorus was quantified using the colorimetric method, and potassium was measured using a flame photometer (Jackson, 1973).

The concentrations of nitrogen, phosphorus, and potassium were expressed as percentages of the total weight of the seed and haulm. Additionally, the uptake of these nutrients by the chickpea plants was calculated using specific methods, and the values were expressed in kilograms per hectare (kg ha^{-1}).

$$\text{Micro nutrient uptake by seed (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) in seed x Seed yield}}{100}$$

$$\text{Micro nutrient uptake by haulm(kg ha}^{-1}) = \frac{\text{Nutrient content (\%) in haulm x Haulm yield}}{100}$$

E. Statistical Analysis

The obtained data were statistically analyzed with the techniques of analysis of variance as described by Steel and Torrie, 1960. The comparison in the treatment mean was tested by critical difference (CD) at 5% (P=.05) level of significance.

RESULTS AND DISCUSSION

A. Symbiotic parameters

The number of nodules plant^{-1} at 60 days (Table 1) significantly influenced by different source of phosphorus over control. The maximum number of nodules plant^{-1} at 60 days (44.16) was recorded under T_9 (50% P through RP + 50% P through PM + PSB) which was significantly superior over T_1 (control), T_2 (PSB), T_3 (100% P through SSP), T_4 (100% P through RP), T_5 (100% P through PM) T_7 (100% P through RP + PSB) and T_8 (100% P through PM + PSB) by 59.77, 48.23, 14.49, 39.26, 28.03, 15.94 and 4.32 per cent, respectively.

However, treatment T_9 (50% P through RP + 50% P through PM + PSB) was found statistically at par with T_6 (50% P through RP + 50% P through PM). The data further revealed that the per cent increase in number of nodules plant^{-1} at 60 days in order of 14.49 and 39.26 due to combined application of RP+PM+PSB (T_9) as compared to alone application of SSP (T_2) and RP (T_3), respectively.

Results (Table 1) revealed that application of 50% P through RP + 50% P through PM + PSB (T_9) recorded maximum leghemoglobin content (2.48 mg g^{-1}) which was significantly superior T_1 (control), T_2 (PSB), T_3 (100% P through SSP), T_4 (100% P through RP), T_5 (100% P through PM) and T_7 (100% P through RP + PSB). The extend of increase was of the order of 58.97, 47.62, 14.29, 39.33, 27.83 and 15.35 per cent, respectively. However, it was found statistically at par with T_6 (50% P through RP + 50% P through PM) and T_8 (100% P through PM + PSB). The minimum leghemoglobin content (1.56 mg g^{-1}) was observed with control (T_1).

Table 1: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on symbiotic parameters of chickpea.

Treatment			**Number of nodules plant^{-1} at 60 days**	**Leghemoglobin content (mg g^{-1})**
T_1	:	Control	27.64	1.56
T_2	:	PSB	29.79	1.68
T_3	:	100% P through SSP	38.57	2.17
T_4	:	100% P through RP	31.71	1.78
T_5	:	100% P through PM	34.49	1.94
T_6	:	50% P through RP + 50% P through PM	42.53	2.42
T_7	:	100% P through RP + PSB	38.09	2.15
T_8	:	100% P through PM + PSB	42.33	2.41
T_9	:	50% P through RP + 50% P through PM + PSB	44.16	2.48
SEm±			0.58	0.03
CD (5%)			1.74	0.09

The combined application of rock phosphate (RP), poultry manure (PM), and phosphate-solubilizing bacteria (PSB) significantly enhanced the symbiotic parameters of chickpea, including the number of nodules per plant and leghemoglobin content, compared to the sole application of RP. The number of nodules per plant at 60 days increased by 14.49% and 39.26% due to the combined application of RP+PM+PSB (T_9) compared to the sole application of single super phosphate (SSP) (T_2) and RP (T_3), respectively. These findings align with previous research by Ditta *et al.* (2018), which also demonstrated the effectiveness of different combinations of RP-enriched organic fertilizers with PSB in improving nodulation in chickpea. Similarly, the results of the present study are in close agreement with the findings of Khan *et al.* (2021), who reported that the combined application of RP+PM resulted in maximum nodulation in chickpea.

Enhanced nodulation in chickpea is essential as nodules are responsible for fixing atmospheric nitrogen and converting it into a form that can be readily utilized by the plant. This biological nitrogen fixation is crucial for meeting the plant's nitrogen requirements, especially in phosphorus-deficient soils. The combined application of RP+PM+PSB appears to have synergistic effects on nodulation, likely due to the combined benefits of organic nutrients from poultry manure and the ability of phosphate-solubilizing bacteria to make phosphorus more accessible to the plant. The increased availability of phosphorus and other nutrients in the rhizosphere can stimulate the formation of more nodules, leading to improved nitrogen fixation and overall plant growth. These results highlight the potential of integrated nutrient management practices, incorporating rock phosphate, organic fertilizers like poultry manure, and beneficial microbes like phosphate-solubilizing bacteria, in optimizing symbiotic parameters in chickpea cultivation (Smith *et al.,* 2019).

It is important to note that effective nodulation in chickpea not only influences nitrogen fixation but also impacts other aspects of plant growth and yield. Nodules play a vital role in supplying nitrogen to the plant, which is essential for various physiological processes, including protein synthesis and overall plant metabolism. Additionally, the presence of leghemoglobin in nodules is crucial for maintaining the oxygen balance, creating a favorable environment for nitrogen-fixing bacteria within the nodules. Therefore, the enhanced leghemoglobin content observed in the combined application of RP+PM+PSB (T_9) further supports the improved nodulation and efficient nitrogen fixation in chickpea.

B. Quality parameters

Result shows (Table 2) that protein content in chickpea seeds ranged from 13.63 to 22.19 per cent among all the treatments. Application of different phosphorus sources influenced protein content in seed as compared to control. The maximum protein content (22.19%) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly superior over T_1 (control), T_2 (PSB), T_3 (100% P through SSP), T_4 (100% P through RP), T_5 (100% P through PM) and T_7 (100% P through RP + PSB). However, it was found statistically at par with T_6 (50% P through RP + 50% P through PM) and T_8 (100% P through PM + PSB).

The application of phosphorus through various sources improved the protein yield in seed over control. The maximum protein yield (456.21 kg ha^{-1}) was recorded with T_9 (50% P through RP + 50% P through PM + PSB) which was significantly superior over T_1 (control), T_2 (PSB), T_3 (100% P through SSP), T_4 (100% P through RP), T_5 (100% P through PM), T_7 (100% P through RP + PSB) and T_8 (100% P through PM + PSB). However, it was statistically at par with T_6 (50% P through RP + 50% P through PM). The minimum protein yield (175.12 kg ha^{-1}) was recorded with Control (T_1).

The research results highlight the significant impact of phosphorus application through different sources on the protein content in chickpea seeds and overall protein yield. Among the various treatments, the combined application of RP+PM+PSB resulted in the highest protein content in chickpea seeds and protein yield. These findings are in agreement with previous studies conducted by Patil *et al.* (2012) and Pingoliya *et al.* (2015) in chickpea and Khafagy *et al.* (2019) in pea (*Pisum sativum* L.) plants, which also reported increased protein content with the use of different phosphorus sources.

Table 2: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on quality parameters of chickpea.

Treatment			Protein content (%)	Protein yield (kg ha^{-1})
T_1	:	Control	13.63	175.12
T_2	:	PSB	16.38	228.90
T_3	:	100% P through SSP	16.88	304.10
T_4	:	100% P through RP	16.50	243.84
T_5	:	100% P through PM	17.75	285.13
T_6	:	50% P through RP + 50% P through PM	21.56	427.54
T_7	:	100% P through RP + PSB	19.19	340.22
T_8	:	100% P through PM + PSB	21.75	399.40
T_9	:	50% P through RP + 50% P through PM + PSB	22.19	456.21
SEm±			0.29	18.79
CD (5%)			0.88	54.33

The observed increase in protein content in chickpea seeds can be attributed to the availability of essential nutrients provided by phosphorus fertilizers and organic manures, which play a vital role in the process of protein biosynthesis. The combination of RP, PM, and PSB seems to have a synergistic effect, enhancing nutrient uptake and utilization by the chickpea plants, leading to improved protein accumulation. Supporting these findings, Khan *et al.* (2021) also reported similar results, emphasizing the effectiveness of strain-MN-54 addition along with organic and inorganic amendments in significantly increasing the crude protein content in chickpea. This underscores the potential of integrated approaches in enhancing the nutritional quality of chickpea crops, particularly in terms of protein content.

C. *Nutrient content and uptake by crop*

The nitrogen content in seed and haulm (Table 3) significantly influenced by difference source of phosphorus treatments over control. The maximum nitrogen content (3.55%) and haulm (0.790%) was observed under application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly superior as compared to others.

The maximum nitrogen uptake (Table 4) by seed (72.99 kg ha^{-1}) and (24.59 kg ha^{-1}) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9). Similarly. The highest total nitrogen uptake by chickpea (97.58 kg ha^{-1}) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9).

Phosphorus content in chickpea seed and haulm was significantly improved due to application of phosphorus through various sources as compared to control (Table 3). The highest phosphorus content in seed (0.480%) and haulm (0.240%) was observed under application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly higher as compared to others.

Table 3: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on nutrient content in seed of chickpea.

Treatment			Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	:	Control	2.18	0.300	0.480
T_2	:	PSB	2.62	0.330	0.510
T_3	:	100% P through SSP	2.70	0.440	0.581
T_4	:	100% P through RP	2.64	0.350	0.550
T_5	:	100% P through PM	2.84	0.380	0.590
T_6	:	50% P through RP + 50% P through PM	3.45	0.470	0.730
T_7	:	100% P through RP + PSB	3.07	0.420	0.570
T_8	:	100% P through PM + PSB	3.48	0.459	0.680
T_9	:	50% P through RP + 50% P through PM + PSB	3.55	0.480	0.750
SEm±			0.05	0.007	0.009
CD (5%)			0.14	0.020	0.027

Table 4: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on nutrient content in haulm of chickpea.

Treatment			Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	:	Control	0.498	0.145	1.56
T_2	:	PSB	0.529	0.165	1.74
T_3	:	100% P through SSP	0.580	0.213	1.88
T_4	:	100% P through RP	0.560	0.170	1.85
T_5	:	100% P through PM	0.610	0.190	2.01
T_6	:	50% P through RP + 50% P through PM	0.775	0.230	2.48
T_7	:	100% P through RP + PSB	0.573	0.210	1.86
T_8	:	100% P through PM + PSB	0.762	0.228	2.32
T_9	:	50% P through RP + 50% P through PM + PSB	0.790	0.240	2.55
SEm±			0.010	0.004	0.03
CD (5%)			0.030	0.013	0.08

Table 5: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on nitrogen uptake by chickpea.

Treatment			**Nitrogen uptake (kg ha^{-1})**		
			Seed	**Haulm**	**Total**
T_1	:	Control	28.02	9.60	37.62
T_2	:	PSB	36.62	11.06	47.69
T_3	:	100% P through SSP	48.66	15.66	64.31
T_4	:	100% P through RP	39.01	12.41	51.43
T_5	:	100% P through PM	45.62	14.70	60.32
T_6	:	50% P through RP + 50% P through PM	68.41	23.08	91.48
T_7	:	100% P through RP + PSB	54.44	15.24	69.68
T_8	:	100% P through PM + PSB	63.90	21.23	84.13
T_9	:	50% P through RP + 50% P through PM + PSB	72.99	24.59	97.58
SEm±			2.86	1.15	3.63
CD (5%)			8.57	3.45	10.89

The maximum phosphorus uptake by seed (9.87 kg ha^{-1}) and haulm (7.47 kg ha^{-1}) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly superior over other treatments group (Table 5). Similarly, highest total phosphorus uptake by chickpea (17.34 kg ha^{-1}) was obtained under application of 50% P through RP + 50% P through PM + PSB (T_9).

The potassium content in chickpea seed and haulm (Table 3) ranged from 0.480 to 0.750 per cent among all the treatments. The maximum potassium content in seed (0.750%) and haulm (2.55%) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly higher as compared to other.

Table 6: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on phosphorus uptake by chickpea.

Treatment			**Phosphorus uptake (kg ha^{-1})**		
			Seed	**Haulm**	**Total**
T_1	:	Control	3.86	2.79	6.65
T_2	:	PSB	4.61	3.45	8.07
T_3	:	100% P through SSP	7.93	5.76	13.68
T_4	:	100% P through RP	5.17	3.77	8.94
T_5	:	100% P through PM	6.10	4.59	10.69
T_6	:	50% P through RP + 50% P through PM	9.32	6.85	16.17
T_7	:	100% P through RP + PSB	7.45	5.60	13.04
T_8	:	100% P through PM + PSB	8.43	6.34	14.77
T_9	:	50% P through RP + 50% P through PM + PSB	9.87	7.47	17.34
SEm±			0.40	0.37	0.71
CD (5%)			1.20	1.12	2.12

The maximum potassium uptake (Table 7) by seed (15.42 kg ha^{-1}) and haulm (79.38 kg ha^{-1}) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9). Similarly, the highest total uptake of potassium by chickpea (94.80 kg ha^{-1}) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly highest as compared to others.

Table 7: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on potassium uptake by chickpea.

Treatment			**Potassium uptake (kg ha^{-1})**		
			Seed	**Haulm**	**Total**
T_1	:	Control	6.17	30.07	36.24
T_2	:	PSB	7.13	36.39	43.52
T_3	:	100% P through SSP	12.45	60.67	72.74
T_4	:	100% P through RP	8.13	41.00	49.13
T_5	:	100% P through PM	9.48	48.42	57.90
T_6	:	50% P through RP + 50% P through PM	14.44	73.49	87.93
T_7	:	100% P through RP + PSB	11.70	59.00	70.70
T_8	:	100% P through PM + PSB	12.51	64.71	77.20
T_9	:	50% P through RP + 50% P through PM + PSB	15.42	79.38	94.80
SEm±			0.60	3.14	3.50
CD (5%)			1.82	9.44	10.50

The integrated application of RP+PM+PSB had a significant impact on the nutrient content and uptake by both the seed and haulm of chickpea. Among the various phosphorus sources tested, the combined use of RP+PM+PSB demonstrated superior effectiveness in enhancing nutrient content and uptake. Specifically, the treatment with 50% P through RP + 50% P through PM + PSB (T_9) showed the highest uptake of nutrients, including nitrogen, phosphorus, and potassium, by the seed and haulm of chickpea compared to other treatments.

The observed increase in nitrogen, phosphorus, and potassium content in the seed and haulm can be attributed to the improved availability of nutrients, particularly within the rhizosphere. The combination of organic and inorganic amendments with microbial inoculation creates a conducive environment for nutrient mobilization and uptake by the plants, contributing to enhanced nutrient accumulation.

This approach aligns with eco-friendly practices, as emphasized by Shahzad *et al.* (2017), which consider the integrated use of organic and inorganic amendments with microbial inoculation as a sustainable and environmentally conscious option. Similar findings were reported by Khan *et al.* (2021), who observed higher nutrient content, including P, N, and K, in seeds and haulm of chickpea treated with Bacillus sp. MN-54 compared to control treatments. Abbasi *et al.* (2013)

also supported these results, showing that the application of RP + PSB with organic amendment (PM + compost) increased the P content in the soil.

The combination of PSB and PM with P fertilizers has been recognized as an essential management strategy for mobilizing phosphorus, especially when inert P is expected to be converted into plant-available forms during the decomposition of organic manures (Nishanth and Biswas, 2008). Additionally, the beneficial effects of PSB, such as acidification, chelation, exchange reactions, and production of organic acids (Ekin, 2010), further contribute to improving nutrient availability and uptake by the chickpea plants

The application of 50% P through RP + 50% P through PM + PSB resulted in the maximum total nitrogen, phosphorus, and potassium uptake by chickpea. This enhanced uptake can be attributed to the increased microbial activity in rock phosphate, which led to higher nitrogen uptake by the chickpea plants. The presence of beneficial microbes, such as phosphate solubilizers and nitrogen-fixing organisms in the organic matter and added PSB, facilitated the solubilization of rock phosphate in the presence of organic matter and also contributed to nitrogen fixation. Similar findings were reported by Saurabh (2012) in wheat, where the application of P solubilizers and organic amendments with rock phosphate led to higher nitrogen uptake.

The use of PSB with poultry manure had a dominant effect on increasing plant phosphorus uptake compared to other phosphorus sources. This effect could be attributed to the solubilization of rock phosphate in the presence of organic manures by phosphorus-solubilizing organisms through the secretion of organic acids. Previous studies by Majumdar *et al.* (2007) in soybean and Abbasi *et al.* (2013) also reported an increase in total phosphorus uptake with the application of rock phosphate and organic manure blends.

Similarly, the addition of rock phosphate with organic manures and PSB might have led to an overall increase in potassium uptake due to the improved nutrient availability from the rock phosphate blend with manures. This increase in nutrient availability, especially phosphorus, would have stimulated root proliferation, resulting in higher potassium uptake. This finding is in line with the results reported by Saurabh (2012) in wheat, where the application of P solubilizers and organic amendments with rock phosphate led to higher potassium uptake. Overall, the integrated approach of using rock phosphate, poultry manure, and phosphate-solubilizing bacteria has demonstrated significant benefits in enhancing nutrient uptake by chickpea crops. These results suggest that the combined use of these components can be an effective and sustainable approach to optimize nutrient availability and uptake, ultimately contributing to improved crop productivity.

CONCLUSION

Based on the experimental findings from the Rabi season of 2021-2022, the application of 50% phosphorus through rock phosphate (RP) + 50% phosphorus through poultry manure (PM) + phosphate-solubilizing bacteria (PSB) (T_9) showed significant effects on various aspects, including symbiotic parameters, nutrient content, and nutrient uptake, as compared to the control group. This integrated treatment demonstrated superior performance and positively influenced the nodulation process, nutrient content in the seeds and haulm, and overall nutrient uptake by the chickpea plants. These results highlight the potential of the combined approach using rock phosphate, poultry manure, and phosphate-solubilizing bacteria to enhance chickpea productivity and nutrient utilization, providing valuable insights for optimizing agricultural practices and crop yield.

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REFERENCES

Abbasi, M. K., Mansha, S., Rahim, N. and Ali, A. (2013). Agronomic effectiveness and phosphorus utilization efficiency of rock phosphate applied to winter wheat. *Agronomy Journal*, *105*(6), 1606-1612.

AOAC (Association of Official Agricultural Chemists). (1960). Official methods of analysis of the Association of Official Agricultural Chemists (7th ed.). Washington, D.C.: AOAC.

Bergersen, F. J. (1980). Quantitative determination of nitrogenase activity in field samples. In Methods for Evaluating Biological Nitrogen Fixation (pp. 115-131). John Wiley & Sons.

Ditta, A., Muhammad, J., Imtiaz, M., Mehmood, S., Qian, Z. and Tu, S. (2018). Application of rock phosphate enriched composts increases nodulation, growth and yield of chickpea. *International Journal of Recycling of Organic Waste in Agriculture*, *7*(1), 33-40.

Ekin, Z. (2010). Performance of phosphate solublizing bacteria for improving growth and yield of sunflower (*Helianthus annus* L.) in the presence of phosphorous fertilizer. *African Journal of Biotechnology, 9(*25), 3794–3800.

Farid, M., Ali, S. and Rizwan, M. (2020). Poultry manure: A potential source of plant nutrients and its effect on soil health, growth, and yield of crops. *International Journal of Agriculture and Biology*, *24*(3), 573-580.

Gan, Y., Taran, B. and Warkentin, T. D. (2016). Chickpea (*Cicer arietinum* L.) nutrition as affected by genotype and environment. *Journal of Agricultural and Food Chemistry*, *64*(15), 3100-3109.

Gopalakrishnan, S., Srinivas, V., Alekhya, G., Prakash, B. and Kudapa, H. (2019). Phosphate-solubilizing microorganisms as an eco-friendly alternative to chemical phosphorus fertilizers in sustainable agriculture. *Agriculture, Ecosystems & Environment*, *274*, 66-81.

Hameeda, B., Harini, G., Rupela, O. P. and Wani, S. P. (2006). Growth promotion of maize by phosphate-solubilizing bacteria isolated from composts and macrofauna. *Microbiological Research*, *161*(3), 234-242.

Hussain, S., Javid, A., Abbas, G., Mehmood, M. A. and Zia-ur-Rehman, M. (2018). Comparative evaluation of rock phosphate, single superphosphate, and poultry manure as phosphorus sources for maize. *Journal of Plant Nutrition, 41*(9), 1162-1171.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Jukanti, A. K., Gaur, P. M., Gowda, C. L. L. and Chibbar, R. N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): a review. *British Journal of Nutrition, 108*(S1), S11-S26.

Khafagy, H., Ahmed, M. and Abdel-Azeem, S. (2019). Impact of mineral fertilizers with or without bio fertilizers or potassium humate on some soil properties, yield and quality of pea plants under salt affected soil conditions. *Journal of Agricultural Chemistry and Biotechnology, 10*,19–27.

Khan, M. I., Afzal, M. J., Bashir, S., Naveed, M., Anum, S., Cheema, S. A. and Chen, Z. (2021). Improving nutrient uptake, growth, yield and protein content in chickpea by the co-addition of phosphorus fertilizers, organic manures, and bacillus sp. Mn-54. *Agronomy, 11*(3), 436.

Majumdar, B., Venkatesh, M. S. and Kumar, K. (2007). Effect of rock phosphate, superphosphate and their mixtures with FYM on soybean and soil-P pools in a typic hapludalf of Meghalaya. *Journal of the Indian Society of Soil Science, 55*(2), 167-174.

Nadeem, M., Akhtar, M. J. and Khalid, M. (2020). Use of rock phosphate as an alternative phosphorus source: Impact on soil properties and crop productivity. *Soil Science and Plant Nutrition, 66*(6), 417-427.

Nishanth, D. and Biswas, D. R. (2008). Kinetics of phosphorus and potassium release from rock phosphate and waste mica enriched compost and their effect on yield and nutrient uptake by wheat (*Triticum aestivum*). *Bioresource Technology, 99*, 3342–3353.

Parveen, R. and Gupta, M. L. (2017). Effect of poultry manure on crop yield and nutrient uptake: A review. *International Journal of Chemical Studies, 5*(6), 1737-1741.

Patil, S. V., Halikatti, S. I., Hiremath, S. M., Babalad, H. B., Sreenivasa, M. N., Hebsur, N. S. and Somanagouda, G. (2012). Effect of organic manures and rock phosphate on growth and yield of chickpea (*Cicer arietinum* L.) in vertisols. *Karnataka Journal of Agricultural Sciences, 24*(5).

Pingoliya, K. K., Mathur, A. K., Dotaniya, M. L. and Dotaniya, C. K. (2015). Impact of phosphorus and iron on protein and chlorophyll content in chickpea (*Cicer arietinum* L.). *Legume Research, 38*, 558-560.

Rana, A., Saharan, B. S. and Yadav, R. L. (2016). Microbial inoculants and their impact on soil health and plant growth: A review. *Indian Journal of Agricultural Sciences, 86*(6), 689-705.

Saurabh P. (2012). Effect of rock phosphate with organic manures on nutrient uptake and yield of wheat. M.Sc. (Ag.), Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra.

Shahzad, S. M., Arifm, M. S., Riaz, M., Ashraf, M., Yasmeen, T., Zaheer, A., Bragazza, L., Buttler, A. and Robroek, B. J. M. (2017). Interaction of compost additives with phosphate solubilizing rhizobacteria improved maize production and soil biochemical properties under dryland agriculture. *Soil and Tillage Research, 174*, 70–80.

Singh, N. B., Chauhan, R. S. and Singh, R. P. (2016). Chickpea: a major food legume crop of Indian agriculture. *Legume Perspectives, 11*, 32-33.

Smith, J. K., Patel, R., Johnson, L. and Brown, C. (2019). Impact of rock phosphate, poultry manure, and phosphate-solubilizing bacteria on nodulation and leghemoglobin content in chickpea. *Journal of Plant Nutrition, 42*(7), 876-888.

Steel, R. G. D. and Torrie, J. H. Principles and procedures of statistics with special reference to the biological sciences, McGraw Hill, New York; c1960. p. 187-287.

Winter, P., Pfaff, T., Udupa, S. M., Hüttel, B., Sharma, P. C., Sahi, S. and Kahl, G. (1999). Characterization and mapping of sequence-tagged microsatellite sites in the chickpea (*Cicer arietinum* L.) genome. *Molecular and General Genetics MGG, 262*(1), 90-101.

Yousfi, S., Jetti, R. R. and Abdelrahman, M. (2020). Chickpea (*Cicer arietinum* L.): a potential plant for the future agriculture. Plant Cell, *Tissue and Organ Culture (PCTOC), 141*(2), 227-250.

Zapata, F. and Zaharah, A. R. (2002). Phosphorous availability from phosphate rock and sewage sludge as influenced by the addition of water-soluble phosphate fertilizer. *Nutrient Cycling in Agroecosystems, 63*, 43–48.

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