Effect of Different Phosphorus Sources on Soil Physico-Chemical Property Dynamics under Chickpea Crop

ABSTRACT

A field experiment was conducted during Rabi season of 2021-2022 to study the effect of rock phosphate (RP), poultry manure (PM) and phosphate solubilizing bacteria (PSB) on soil properties. The experiment was laid out in three replications with 9 treatments in Randomized Block design (RBD). Results revealed that the combined application of 50% P through RP + 50% P through PM + PSB (T_9) significantly decrease the bulk density but, higher soil porosity was observed with application of 100% P through PM (T_5) and 100% P through PM + PSB (T_8) were at par. Whereas, improved in soil pH and organic carbon were reported with the application of T_8. Also, the maximum available nitrogen (294.95 kg ha^{-1}) was acquired under T_8. However, the highest available phosphorus, potassium and available Fe, Mn, Cu and Zn content in soil were observed with T_9. Similarly, higher PSB population and acid phosphatase activity was recorded with application of T_9. Dehydrogenase activity was observed to be higher underT_8 at harvest of chickpea crop. It was concluded that application of phosphate, poultry manure and phosphate solubilizing bacteria improve the soil properties.

Keywords: Poultry manure, Phosphorus, Enzyme activity, Rock phosphate.

Introduction

Phosphorus (P) is an important nutrient for plant growth and development which plays a vital role in its metabolic activities and various functions (Malhotra *et al*., 2018). Increasing demands for higher yields has put pressure on land resources which eventually increased demand for phosphate fertilizers (Mala, 2013). However, overuse of fertilizers can not only cause harmful environmental impacts but also they are expensive (Sharma and Subehia, 2003), and have harmful impacts on the soil quality (Cheraghi *et al*., 2012), composition (Lwin *et al*., 2018), microflora (Kafle *et al*., 2019) and other properties of soil (Jiao *et al*., 2012). Increasingly high cost of chemical fertilizers has been the major stimulus to search for an alternative, naturally-occurring phosphate source (Langemeier, 2022).

The ability of soil microorganisms and organic manures to convert insoluble phosphorus (P) to an accessible form offers a biological rescue system for improving P solubilization and utilization in soil-plant systems. Phosphate-solubilizing bacteria could be utilized as an effective and economic alternative to expensive synthetic P fertilizers with a documented potential to improve crop yields and soil properties (Billah *et al.*, 2019). *Bacillus*, *Pseudomonas*, *Rhizobium*, *Aspergillus* and *Penicillium* are the potential P-solubilzers commonly present in the soil (Zineb *et al*., 2020; Emami *et al*., 2020). Among these the *Bacillus megaterium* is the most effective phosphate solubilizer (Wang *et al*., 2022). Use of RP as alternative P source has been increased in recent times due to the relative low cost and its utilization potential. In India phosphate rock deposits and this material will provide a cheap source of phosphate fertilizer for crop production (Soumare *et al*., 2021). Application of poultry manures with phosphatic source is considered another possible means of mobilizing P because of the acidic environment generated during decomposition of the manures (Kaleem and Manzoor, 2018). These organic manures increase the density of beneficial microbes, release acids in the root rhizosphere and may help to solubilize P and to increase P availability to the plants. In addition, combined use of RP, organic manures and bacterial inoculation is also considered an option that may increase the yield as well as soil properties. This research was thus aimed at establishing a clear linkage between the use and application of RP, PM, and PSB on nutrient dynamics and other related soil properties.

Materials and methods

1. Experimental site and treatments:

The experiment conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur which is located at 24° 35’ N latitude and 74° 42’ Elongitude at an elevation of 579.5 meters above mean sea level. It is located in region of Rajasthan Agro Climatic Zone IV-a (Sub-humid southern plains and Aravalli hills). The mean annual rainfall of Udaipur is 637 mm. The maximum and minimum temperatures, according to statistics, were 22.49 and 33.34°C, and 3.77 and 14.67°C, respectively. The maximum and minimum relative humidity readings were 54.43 and 90.57 percent, respectively, and 18.27 and 52.14 percent. The soil of the experimental site was clay loam in texture with 272.35 kg ha^{-1}, 21.62 kg ha^{-1} and 368.50 kg ha^{-1} available nitrogen, phosphorus and potassium, respectively with 8.28 pH.

The experiment was laid out in Randomized Block Design with three replications. The experiment comprises nine treatment combinations of phosphorus source (single super phoshphate (SSP), RP and PM with and without PSB) including one control (Table 1).

Table 1: Treatments details

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

2. Soil Properties

(1) Initial soil properties

A composite soil sample of experimental field was analyzed for bulk density, particle density, porosity, pH, EC, organic carbon, available macronutrients (N, P, and K) and micronutrients (Fe, Mn, Zn, and Cu) by standard methods.

(2) Soil properties after harvest of crop

Physico-Chemical and biological Properties

Soil samples were drawn from each plot up to 15 cm depth after harvest of crop. These were dried, ground to pass through 2 mm sieve and analyzed for organic carbon, pH, EC, BD, PD, available N and P_2O_5, K_2O, and DTPA extractable micronutrients (Fe, Mn, Cu, Zn) by standard methods presented in Table 2.

The data collected during worked out, whereas the F test was found significant at 5 per cent level of significance.

Table 2: Methods employed for soil analysis

S. No.	Properties	Procedure	Reference
1.	Bulk density	Method No. 38 of USDA Hand Book No. 60	Richards (1954)
2.	Particle density	Method No. 39 of USDA Hand Book No. 60	Richards (1954)
3.	Porosity	Method No. 40 of USDA Hand Book No. 60	Richards (1954)

4.	pH (1:2 soil water suspension)	Potentiometeric method using pH meter	Richards (1954)
5.	EC (dSm^{-1})	EC of 1:2 soil-water suspension with the help of "solubridge"	Richards (1954)
6.	Organic Carbon (%)	Determination by rapid titration method	Walkley and Black (1934)
7.	Available N (kg ha^{-1})	Estimation by alkaline potassium permanganate method	Subbiah and Asija (1956)
8.	Available P (kg ha^{-1})	Olsen's P, 0.5 M $NaHCO_3$ method, pH 8.5	Olsen *et al*. (1954)
9.	Available K (kg ha^{-1})	Neutral ammonium acetate extraction and Flame photometry	Richards (1954)
10.	Available Fe, Zn, Cu and Mn (mg kg^{-1})	Extraction by 0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M triethanolamine at pH 7.3	Lindsay and Norvell (1978)
11.	PSB population ($x10^{-6}$ cfu g^{-1})	Standard serial dilution and plate count method	Vance *et al.* (1987)
12.	Acid and alkaline phosphatase activity (µg PNP g^{-1} soil h^{-1})	P-nitrophenol estimation method	Tabatabai and Bremner (1969)
13.	Dehydrogenase activity (µg TPF g^{-1} soil h^{-1})	Colorimetric determination of TPF (Triphenyl formazon)	Casida *et al.* (1964)

Results and Discussion

Soil properties at harvest of chickpea crop

1. **Bulk density, particle density and porosity of soil**

The bulk density (Table 3) of soil ranged from 1.39 to 1.46 Mgm^{-3} among all the treatments. The lowest bulk density (1.39 Mg m^{-3}) was observed under the treatment of T_9 (50% P through RP + 50% P through PM + PSB) and highest value of bulk density (1.46 Mg m^{-3}) was recorded with control (T_1).

Particle density of soil (Table 3) ranged from 2.57 to 2.65 Mg m^{-3} among all the treatments. The effect of rock phosphate, poultry manure and PSB on particle density of soil was found statistically non-significant. However, lowest particle density of soil was observed with the application of 50% P through RP + 50% P through PM + PSB (2.57 Mg m^{-3}) and highest particle density of soil (2.65 Mg m^{-3}) was reported in control (T_1).

The results (Table 3) revealed that significantly higher porosity obtained with T_5 (100% P through PM) and T_8 (100% P through PM + PSB) followed by T_9 (50% P through RP + 50% P through PM + PSB) and T_6 (50% P through RP + 50% P through PM). The minimum porosity (44.19%) was observed under T_4 (100% P through RP).

Table 3: Effect of different treatments on BD, PD, porosity, pH, Electric Conductivity and Organic carbon of soil at harvest of chickpea crop

Treatment			Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Porosity (%)	pH	EC (dS m^{-1})	OC (%)
T_1	:	Control	1.46	2.65	44.9	8.28	0.63	0.46
T_2	:	PSB	1.46	2.62	44.27	8.23	0.61	0.49
T_3	:	100% P through SSP	1.45	2.6	44.23	8.15	0.62	0.52
T_4	:	100% P through RP	1.44	2.58	44.19	8.19	0.61	0.5
T_5	:	100% P through PM	1.4	2.59	45.95	8.18	0.61	0.59
T_6	:	50% P through RP + 50% P through PM	1.4	2.58	45.73	8.17	0.59	0.53
T_7	:	100% P through RP + PSB	1.42	2.59	45.17	8.18	0.6	0.51
T_8	:	100% P through PM + PSB	1.4	2.58	45.95	8.12	0.6	0.62
T_9	:	50% P through RP + 50% P through PM + PSB	1.39	2.57	45.91	8.15	0.59	0.6
SEm±			0.015	0.05	0.527	0.03	0.01	0.011
CD (5%)			0.045	NS	1.579	0.09	NS	0.032

The application of RP+PM+PSB significantly decreased the bulk density and soil pH and improves the porosity and organic carbon content in soil over the control after harvest of chickpea. This reduction in soil bulk density might be attributed to the presence of high organic matter content in the poultry manure. This might be due to improving soil physical properties through decrease in the volume of micropores while increasing macropores, increased soil aggregation, improved aggregate stability, by organic manure applications (Brar *et al.*, 2015). The decrease in bulk density with increase in porosity of the soil may also be mainly due to action of gum compounds, polysaccharides and fulvic acid compound of organic matter on the soil structure (Manickam, 1993).

2. Soil pH, electrical conductivity and organic carbon

The results (Table 3) revealed that pH was significantly decreased due to different treatments of phosphorus source as compared control. Minimum value of pH (8.12) observed under treatment of 100% P through PM + PSB (T_8) and maximum value of pH was observed with the control (T_1). The EC was not significantly influence by different treatments of phosphorus source. However, the EC of soil was affected with application of 50% P through RP + 50% P through PM + PSB (T_9) had lowest EC value of 0.592 dSm^{-1} which was superior in reducing the amounts of salts in the soil. The EC ranged from 0.592 to 0.631 dSm^{-1} among different treatments. The organic carbon content varied from 0.46 to 0.62 per cent among all treatments in the experiment. The highest organic carbon content after harvest of crop (0.62%) was recorded under application of 100% P through PM + PSB (T_8) which was significantly highest as compared to other.

The highest available organic carbon after harvest of crop was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly superior rest of treatments. The organic carbon content in soil was increased significantly with the application of rock phosphate with organic manures and PSB, which might be due to direct addition of organic carbon through organic amendments. They also stated that due to increase in soil available P resulted in better root growth consequently leading to accumulation of organic matter content in rhizosphere. Similar results were observed by Dalvi, (2011) using rock phosphate with organic manures in chickpea and Abbasi *et al.*, (2013) in wheat. The present findings were in accordance with the observations of Aria *et al.*, (2010) and Khan and Sharif (2012) who reported a significant decrease in soil pH after applying PSB.

3. Available macronutrient and micronutrient in soil at harvest of crop

Application of various source of phosphorus significantly influenced the available nitrogen status of soil after harvest of chickpea crop. The maximum available nitrogen (294.95 kg ha^{-1}) was acquired under treatment T_8 (100% P through PM + PSB) which was significantly superior over other treatments (Table 4). Results (Table 4) showed that different sources of phosphorus significantly influenced the available phosphorus content in soil after harvest of crop. The highest available phosphorus content in soil (28.84 kg ha^{-1}) was observed with the application of 50% P through RP + 50% P through PM + PSB (T_9) which was significantly highest as compared to others. Smillarly, the results (Table 4) showed that application of 50% P through RP + 50% P through PM + PSB (T_9) was recorded highest available potassium (373.62 kg ha^{-1}) status in soil after harvest of chickpea crop.

Application of various sources of phosphorus significantly increased iron content in soil after harvest of chickpea crop over control (T_1). The highest available Fe content (5.59 mg kg^{-1}) in soil was obtained under application of 100% P through PM + PSB (T_8) followed by 50% P through RP + 50% P through PM + PSB (T_9). Whereas, the maximum available manganese (4.41 mg kg^{-1}), Cu (2.47 mg kg^{-1}), zinc (0.63 mg kg^{-1}) status (Table 4) in the soil was recorded under treatment T_8 (100% P through PM + PSB).

Table 4: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on available macro and micro nutrients in soil at harvest of chickpea crop

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Fe	Mn	Cu	Zn
				(mg kg^{-1})			
Control	258.53	16.25	337.86	5.11	4.04	2.47	0.54
PSB	262.27	21.3	359	5.38	4.21	2.77	0.56
100% P through SSP	275.56	23.52	363.85	5.55	4.24	2.94	0.6
100% P through RP	271.09	23.22	362.78	5.42	4.21	2.82	0.58
100% P through PM	292.33	22.44	367.63	5.45	4.32	2.9	0.62
50% P through RP + 50% P through PM	281.22	24.5	369.52	5.47	4.29	2.87	0.61
100% P through RP + PSB	272.52	25.52	360.76	5.5	4.35	2.85	0.6
100% P through PM + PSB	294.95	24.2	369.42	5.59	4.41	2.97	0.63
50% P through RP + 50% P through PM + PSB	285.85	28.84	373.62	5.56	4.38	2.93	0.62
SEm±	5.65	0.53	4.07	0.06	0.61	0.054	0.009
CD (5%)	16.95	1.58	12.19	0.18	0.182	0.162	0.026

The integrated application of rock phosphate, poultry manure and phosphate solubilizing bacteria significantly increased the available nutrients in soil after harvest of chickpea crop. The higher available nitrogen was observed with PM+PSB whereas available phosphorus, potassium and micronutrients were obtained with RP+PM+PSB. The higher availability of nutrients may also be attributed to its inherent capacity to add good amount of organic manure to the soil, which hastens the process of mineralization of organically bound macro and micronutrients present in the native soil. The availability of nutrients was increased due to formation of organics chelates of higher stability with organics ligands, which have lower susceptibility to adsorption, fixation and precipitation in soil. Increase in available N, P and K might be due to the direct addition of N through organic manure, PSB and increased multification of soil microbes, which might have converted organical bound N to inorganic form. The beneficial effect of combined application of RP+PM+PSB on root growth and development of chickpea which led to more N_2 fixation, P solubilization and potassium mobilization so that absorbed more soil nutrients from subsurface layers to meet their requirement and part of which was left in surface soil with the root residues after harvest of the crop decomposed and improved the soil fertility (Jangir *et al.* 2017). It was reported that higher availability of Fe, Zn, Mn and Cu in soil under integrated use of RP+PM+PSB was mainly due to its functions in mobilizing the native micro nutrients and chelation. Soil iron has a strong tendency to form mobile organic complexes and chelates thus contributing to increased availability of iron in soil. The higher level of micronutrient content in soil samples after harvesting may be attributed to role of organic matter and microbial activity also played a significant role toward increasing the concentration of micronutrient in the post-harvest soil. The role of organic matter in complexing micronutrient is important because organic matter can affect the redox status of soils. The microbial decomposition of added organic matter in continuous crops creates reducing conditions that favor micronutrient solubilization. The results of the present investigation are similar to Abbasi *et al.,* (2013).

4. Biological properties

The PSB population in soil at harvest of chickpea was significantly influenced by various treatments of phosphorus source over control. The maximum PSB population (55.83 x 10^7 cfu g^{-1} of soil) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9). Acid phosphatase activity in soil at harvest is ranged from 14.75 to 21.98 µg PNP g^{-1} soil h^{-1}. The maximum acid phosphatase activity in soil (21.98 µg PNP g^{-1} soil h^{-1}) was observed under application of 50% P through RP + 50% P through PM + PSB (T_9). Simillarly, the maximum alkaline phosphatase activity (15.90 µg PNP g^{-1} soil h^{-1}) was observed under application of 50% P through RP + 50% P through PM + PSB (T_9). Whereas, the Dehydrogenase activity in soil at harvest ranged from 6.23 to 14.65 µg TPF g^{-1} soil h^{-1}. The highest dehydrogenase activity (14.65 µg TPF g^{-1} soil h^{-1}) was recorded under application of 100% P through PM + PSB (T_8).

Table 5: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on biological properties of soil at harvest of chickpea crop

Treatment			PSB population (1 x 10^7 cfu g^{-1})	Acidphosphatase activity (µg PNP g^{-1} soil h^{-1})	Alkaline phosphatase activity (µg PNP g^{-1} soil h^{-1})	Dehydrogenase activity (µg TPF g^{-1} soil h^{-1})
T_1	:	Control	41.57	14.75	8.91	6.23
T_2	:	PSB	49.38	17.82	12.32	9.17
T_3	:	100% P through SSP	47.56	19.68	13.50	8. 72
T_4	:	100% P through RP	45.30	16.77	11.07	8. 22
T_5	:	100% P through PM	50.76	19.07	12.69	13.74
T_6	:	50% P through RP + 50% P through PM	50.84	21.54	14.97	11.77
T_7	:	100% P through RP + PSB	53.92	19.36	13.55	11.29
T_8	:	100% P through PM + PSB	54.48	21.04	15.27	14.65
T_9	:	50% P through RP + 50% P through PM + PSB	55.83	21.98	15.90	13.68
SEm±			0.805	0.471	0.488	0.245
CD (5%)			2.414	1.411	1.463	0.733

The result showed that application of phosphorus through different sources significantly influence the PSB population and enzymic activities in soil over control. The maximum PSB population, acid phosphatase activities, alkaline phosphatase activities and dehydrogenase activity was recorded under application of 50% P through RP + 50% P through PM + PSB (T9). The increased in PSB population might be due to the combined application of PSB, rock phosphate and poultry manure increase supply of organic carbon, macro nutrients and micro nutrients which serves as a food for microbes. Organic amendments can encourage the growth of microorganisms, which could potentially increase the soil's supply of enzymes (Chang *et al.*, 2007). An essential part of the biological oxidation of soil organic materials is played by the respiratory enzyme dehydrogenase. The highest dehydrogenase activity found may be the result of enhanced respiratory activity brought on by bacteria growing more quickly in the presence of easily available nutrients and carbon (Chatterjee *et al.*, 2021). In order to make fixed soil phosphorus available to plants, soil enzymes (alkaline phosphatase and acid phosphatase) are essential. The availability of organic carbon may have increased the soil phosphatase activity, which in turn increased the alkaline phosphatase activities with the application of RP withpoultry manure in the current study additionally, the poultry manure may have provided a significant amount of carbon and nitrogen for the microbes' maximum growth (Billah *et al.,* 2020). Similar results were in agreement with Shrivastava *et al.,* 2011 who concluded that the availability of metabolizable carbon plays a significant role in increasing soil phosphatase activity with the application of P enriched manure on mungbean crop.

5. Periodically Availability of Phosphorus in soil

The results (Table 6) revealed that application of different sources of phosphorus treatments significantly increased available phosphorus in soil at 20 days over control. The maximum available phosphorus in soil at 20 days (25.26 kg ha^{-1}) and 40 days (25.05 kg ha^{-1}) was recorded under application of 100% P through SSP (T_3). A critical analysis of data revealed that availability of phosphorus in soil at 40 days improved in all the treatments except control (T_1) and 100% P through SSP (T_3) where it was slightly decrease as compared to availability of phosphorus in soil at 20 days. The lowest available phosphorus at 40 days (17.06 kg ha^{-1}) was observed under control (T_1). The highest available phosphorus at 60 days (25.35 kg ha^{-1}) and 90 days (26.25 kg ha^{-1}) was recorded under application of 50% P through RP + 50% P through PM + PSB (T_9). The results shows that integrated treatments RP+PM, RP+PSB, PM+PSB and RP+PM+PSB improved availability of phosphorus in soil at 90 days as compared to alone application of RP, PM and PSB.

Table 6: Effect of rock phosphate, poultry manure and phosphate solubilizing bacteria on periodically available phosphorus in soil

Treatment			Soil available phosphorus (kg ha^{-1})			
			20 days	**40 days**	**60 days**	**90 days**
T_1	:	Control	19.18	17.06	15.57	16.25
T_2	:	PSB	20.34	20.58	20.75	21.00
T_3	:	100% P through SSP	25.26	25.00	24.50	23.80
T_4	:	100% P through RP	22.32	22.58	22.88	23.00
T_5	:	100% P through PM	20.95	21.56	21.90	22.30

T_6	:	50% P through RP + 50% P through PM	23.42	23.75	24.27	24.30
T_7	:	100% P through RP + PSB	24.42	24.88	25.12	25.38
T_8	:	100% P through PM + PSB	23.05	23.25	23.70	24.51
T_9	:	50% P through RP + 50% P through PM + PSB	24.84	25.00	25.40	26.25
SEm±			0.26	0.37	0.38	0.78
CD (5%)			0.78	1.12	1.14	2.33

Application of PM+PSB and RP+PM+PSB significantly increased phosphorus at different days during crop growth. The maximum available phosphorus in soil (25.26 kg ha^{-1}) at 20 and 40 days was recorded with the application of 100% P through SSP whereas, at 60 as well as 90 days, maximum availability of phosphorus was observed with the application of 50% P through RP + 50% P through PM + PSB. This might be because of addition of organic manures enhanced the activity of PSB by providing source of energy as carbon, which may reflected in increased solubilization of phosphorus added through rock phosphate. The chickpea roots released the organic acids like succinic and malic acid during growth period. These organic reduced the soil pH and $CaCO_3$ content in soil, which in turn reduced the conversion of soluble phosphorus to insoluble phosphorus (Ca $(PO_4)_3$) or $CaHPO_4$ (Panneerselvam *et al.,* 2000). The addition of organic manures might change the adsorption desorption phenomenon in soil. These results of present finding are in line with Dalvi, (2011) in chickpea and Saurabh, (2012) in wheat. The PSB increased P solubilization of added P fertilizers either from soluble or insoluble sources and moreover, the relative efficiency of PSB for releasing P is higher when PSB applied with PM (Abbasi *et al.*, (2015). Toor (2009) found a substantial increase in soil solution P following the application of PM with P fertilizers because of the release of organic acids during decomposition of the manure and production of carbon dioxide during organic matter decomposition that may increase the solubility of Ca^{2+} and Mg^{2+} phosphates. Poultry manure acidify soil by releasing H^+ ions into the soil (Alvarez *et al*. 2004) as a result P solubility/mineralization of both exogenously applied and soil indigenous P increases (Qin *et al*. 2019).

Conclusion

Based on the above findings it can be concluded that Chickpea with the application of 50% P through RP + 50% P through PM + PSB recorded higher periodically availability of nutrients and improved soil properties.

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