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Effect of sources of phosphorus and microbial inoculation on productivity, nutrient availability in soil and uptake of nutrients by chickpea (*Cicer arietinum*) grown on sandy loam soil

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ABSTRACT

A field experiment was conducted for two consecutive, winter (*rabi*) seasons of 2004–05 and 2005–06 to study the response to different sources of phosphorus, viz. fertilizer (DAP), P-enriched organic manures (vermicompost and compost), and *Rhizobium* and phosphorus-solubilizing microorganisms (PSM) inoculation on growth, yield, crude protein content, uptake of nutrients by chickpea and availability of N, P, K and S at harvest in sandy loam soil of old alluvial plains of Rajasthan. The results revealed that the application of P through organic manures (P-enriched vermicompost and compost) and fertilizer alone or in combination with *Rhizobium* and PSM inoculation significantly improved the growth, yield, crude protein content, N, P, K and S uptake by chickpea. Maximum grain (2 639 kg/ha) and stover yield (2 978 kg/ha) of chickpea was recorded with addition of recommended dose of P through P-enriched vermicompost along with *Rhizobium* and PSM inoculation, followed by 2 575 kg grain/ha and 2 916 kg stover/ha yields with recommended dose of P through P-enriched vermicompost and *Rhizobium* inoculation. Available N and P after harvest of chickpea crop was significantly higher with the application only or combination of organic manure and fertilizer sources of P, *Rhizobium* and PSM inoculation over control. Maximum gain was 97 kg available N/ha and 0.69 kg available P/ha over initial (152 kg/ha available N and 9.73 kg/ha available P) with application of P through P-enriched vermicompost along with *Rhizobium* and PSM inoculation. Available S in soil significantly decreased with application of P through fertilizer and increased with application of P through organic manures as compared to control.

Key words: Available nutrients, Chickpea, Crude protein, Fertilizer, Organic manure, P-sources, Uptake, Yield

Chickpea (*Cicer arietinum* L.) is one of the predominant *rabi* crops in pulse-growing areas in India. Being a legume it responds well to phosphorus added through both organic manure and fertilizer. In India, the price of commonly used phosphatic fertilizer has increased considerably since the early seventies. The price rise has dampened the use of phosphatic fertilizers by Indian farmers (Pareek *et al.* 2004). There is an urgent need to substitute the high cost water-soluble phosphatic fertilizers with indigenous sources of phosphorus such as rock phosphate for increased crop production. Phosphorus rich organic manures like compost and vermicompost are able to overcome the problems of phosphatic fertilizers, as these are equally or sometimes more effective than the conventional chemical fertilizer (Shaktawat *et al.* 2004). Keeping the above aspect in view, a study was undertaken to determine the effectiveness of doses of organic and fertilizer sources of P alone and in combination with microbial inoculation on growth, yield, crude protein, uptake of nutrients and available N, P, K and S status in soil after the harvest of chickpea crop.

MATERIALS AND METHODS

A field experiment was carried out on instructional farm, Banasthali University, Banasthali, Rajasthan during winter (*rabi*) seasons of 2004–05 to 2005–06. The experimental soil had *p*H 7.9, electrical conductivity 0.35 dS/m, organic carbon content 2.95 gm/kg, available N, P, K, S contents were 152 kg/ha, 9.73 kg/ha, 305 kg/ha and 10.5 kg/ha respectively. The experiment was laid out in a randomized block design with 10 treatments and three replications. The treatment details were as follows: T_1 - control, T_2 - recommended dose of P as DAP, T_3 - recommended dose of P as DAP with *Rhizobium* inoculation, T_4 - recommended dose of P as DAP along with *Rhizobium* and PSM inoculation, T_5 - recommended dose of P as P-enriched compost, T_6 - recommended dose of P as P-compost with *Rhizobium*

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inoculation, T_7 - recommended dose of P as P-enriched compost along with *Rhizobium* and PSM inoculation, T_8 - recommended dose of P as P-enriched vermicompost, T9 - recommended dose of P as P-enriched vermicompost with *Rhizobium* inoculation, T_{10} - recommended dose of P as P-enriched vermicompost along with *Rhizobium* and PSM inoculation. The recommended doses of nutrients for chickpea crop were 20 kg N/ha and 40 kg P_2O_5/ha and the same were applied as per treatment through 1.27 tonnes/ha P-enriched vermicompost and 1.39 tonnes/ha P-enriched compost and remaining N was applied through urea. The inoculation of seed was followed as per treatment with *Rhizobium* spp and PSM (*Aspergillus awamari*) at the time of sowing of chickpea crop. The chickpea variety RSG 888 was sown in third week of October in both the years. Two irrigations were applied at flowering and pod-formation stage. The packages of practices were adopted as per AICRP on chickpea, Durgapura, Jaipur (RAU, Bikaner). The rainfall during cropping season was 17 and 31 mm during first and second year of experimentation. The rainfall received during 2004–05 and 2005–06 was 460 and 556 mm respectively. At harvest, growth and yield data of crop was recorded from the net plot (5 m × 5 m). The plant samples were analyzed for N, P, K and S content (Piper 1966) and nutrient uptake was calculated by multiplying grain and stover yield of the crop with respective contents. Crude protein in grain was calculated by multiplying 6.25 with percentage of N in grain. Soil samples (0–15 cm) were drawn after the harvest of chickpea and analyzed organic carbon (Walkley and Black 1934), available N (Kjeltec-II auto analyzer), Olsen P, NH4 OAc K and S (Jackson 1973).

For preparation of P-enriched vermicompost and compost, raw material (mustard straw) and fresh dung on dry weight basis in the ratio of 1:1 were mixed with 2.5% P_2O_5 through rock phosphate (34% P_2O_5, 74 micron size particles). Total 1.8 tonnes raw material and 0.118 tonnes rockphosphate were used for preparing P-enriched compost and the same amount of material used for P-enriched vermicompost. For composting, the material was saturated with water and decomposed in pit 3 m × 1.8 m × 0.9 m and for vermicomposting two pits 3 m × 0.9 m × 0.5 m each were used. The temperature rose from 28 to 32°C after 35 days when 1 000 earthworms (*Eisenia foetida*)/m^3 for vermicomposting were applied. Also, two turnings after 30 days each were given, and watering on alternative days for maintaining 35 to 40% moisture content was done. The decomposition periods for P-enriched vermicompost and compost were 90 and 150 days, respectively. From decomposed material, nitrogen content was determined by Kjeltec-II auto analyzer. Phosphorus, potassium and micronutrients (Cu, Fe, Zn and Mn) were estimated by taking 1g dry sample in a digestion flask with 10 ml tri-acid mixture (9:3:1 HNO_3 : $HClO_4$: H_2SO_4) and digestion was carried out on a hot plate at 180 - 200°C until dense white fumes of H_2SO_4 and $HClO_4$ were evolved. The digested material was used for estimation of phosphorus as given by Jackson (1973). The determination of potassium was done using flame photometer and Cu, Fe, Zn and Mn using atomic absorption spectrophotometer (Lindsay and Norvell 1978). The nutrient content of P-enriched compost was 0.76% N, 2.87% P_2O_5, 0.80% K_2O, 47 mg/kg Cu, 9640 mg/kg Fe, 87 mg/kg Zn and 306 mg/kg Mg, while P-enriched vermicompost contained 1.15% N, 3.16% P_2O_5, 0.85% K_2O, 49 mg/kg Cu, 10285 mg/kg Fe, 98 mg/kg Zn and 325 mg/kg Mg.

RESULTS AND DISCUSSION

Growth attributes

Pooled data revealed that the use of recommended doses of phosphorus through P-enriched compost and vermicompost alone or in combination with *Rhizobium* and PSM significantly increased the growth (plant height, branching, nodulation, nodule dry weight and shedded leaf fall) over control (Table 1). Among the treatments, highest increased plant height (56.9 cm/plant), branching (19.4/plant),

Table 1 Growth and yield of chickpea affected by fertilizer and organic manure sources of P and inoculation (two years mean)

Treatment	Plant height (cm)	Branching	Nodule/ plant	Nodule dry weight (mg/plant)	Days of maturity (no.)	Shaded residue through leaf fall (kg/ha)	100-seed weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)
T_1	40.1	9.3	8.2	75	132	142	15.6	1470	1785
T_2	51.3	15.8	10.6	93	130	191	16.92	2109	2525
T_3	53.5	16.7	11.4	100	130	223	17.16	2212	2702
T_4	54.2	16.9	11.6	102	130	215	17.23	2293	2814
T_5	52	15.7	11	96	130	220	17.1	2319	2778
T_6	55.7	17.5	12	105	129	237	17.21	2386	2855
T_7	55.9	18.5	12.6	111	129	239	17.26	2498	2966
T_8	54.8	17.2	11.2	99	129	241	17.2	2464	2909
T_9	56.6	18.8	12.6	113	129	245	17.31	2575	2916
T_{10}	56.9	19.4	12.8	115	129	249	17.45	2639	2978
CD (*P*=0.05)	1.11	0.48	0.23	4.3	1.42	8	0.22	33	41

nodulation (12.8/plant) and nodule dry weight (115 mg/plant) were obtained by addition of recommended dose of P through P-enriched vermicompost with *Rhizobium* and PSM inoculation, followed by P-enriched vermicompost with *Rhizobium* and P-enriched compost along with *Rhizobium* and PSM inoculation. Singh and Ganguly (2005) reported that P-enriched vermicompost was superior in terms of all quality parameters and nutrient status than the P-enriched compost. Days of maturity were significantly reduced with addition of P through combination of organic manure and fertilizer along with *Rhizobium* and PSM inoculation. Soni and Arey (2004) observed similar trend in cowpea crop.

Grain and stover yield

The test weight, grain and stover yield of chickpea significantly improved with application of P through fertilizer, P-enriched compost and vermicompost alone or in combination with *Rhizobium* and PSM inoculation as compared to control (Table 1). Maximum grain 2 639 kg/ha and stover 2 978 kg/ha was recorded with addition of recommended dose of P as P-enriched vermicompost with *Rhizobium* and PSM inoculation, followed by 2 575 kg grain/ha and 2 916 kg stover/ha with recommended doses of P as P-enriched vermicompost with *Rhizobium* inoculation and 2 498 kg grain/ha and 2 966 kg stover/ha with recommended doses of P through P-enriched compost with *Rhizobium* and PSM inoculation. Minimum yield 1 470 kg grain and 1 785 kg stover/ha was recorded in control plot. Similar trend in cowpea observed crop on application of P-enriched organic manure has been reported by Kumari *et al.* (2002). Gupta (2006) has also reported better nodulation and grain yield due to increased P availability through PSM and *Rhizobium* inoculation.

Crude protein content and uptake of N, P, K and S.

Addition of P through fertilizer and organic manure sources and inoculation significantly increased the crude protein content and uptake of N, P, K and S by grain and stover of chickpea over control (Table 2). Application of recommended dose of P through P-enriched vermicompost along with *Rhizobium* and PSM inoculation recorded the maximum value of crude protein content (22.02%), uptake values of N (92.89 kg/ha), P (12.03 kg/ha), K (7.36 kg/ha) and S (7.39 kg/ha) in grain, followed by recommended dose of P through P-enriched vermicompost with *Rhizobium* inoculation (crude protein 21.93%, uptake value of N - 90.13 kg/ha, P - 11.59 kg/ha, K - 6.98 kg/ha and S - 7.18 kg/ha in grain) as against 19.17% content of crude protein, uptake of 47.73 kg N/ha, 6.39 kg P/ha, 4.05 kg K/ha and 3.99 kg S/ha under control. Similar trend for crude protein and uptake of N, P, K and S was followed in stover of chickpea. Both the organic manure and fertilizer sources of P along with *Rhizobium* and PSM inoculation increased the nodulation and nitrogen fixation led to better growth of chickpea crop which might have resulted in increased N, P, K and S uptake and crude protein content. Similar trend in cowpea crop were reported by Soni and Aery (2004).

Table 2 Crude protein content in grain and uptake of N, P, K and S by grain and stover of chickpea affected by fertilizer, organic manure sources of P and inoculation (Two years mean)

Treatment	Crude protein in grain (%)	Uptake (kg/ha)			
		N	P	K	S
T_1	19.17	47.73 (12.08)	6.39 (3.15)	4.05 (19.07)	3.99 (2.83)
T_2	19.81	69.99 (20.19)	10.07 (5.28)	5.72 (32.47)	5.76 (4.25)
T_3	20.53	75.83 (23.05)	10.4 (5.72)	6.22 (34.09)	6.12 (4.66)
T_4	20.67	78.49 (23.31)	11.18 (5.91)	6.41 (36.16)	6.49 (4.9)
T_5	20.59	76.3 (21.24)	10.46 (5.64)	6.19 (36.18)	6.24 (4.5)
T_6	20.92	79.69 (26.52)	10.71 (5.78)	6.44 (38.39)	6.54 (4.83)
T_7	20.84	82.54 (25.57)	11.29 (6.03)	6.77 (39.54)	6.83 (5.18)
T_8	21.05	83.66 (24.97)	11.25 (6.01)	6.72 (40.88)	6.77 (4.94)
T_9	21.93	90.13 (27.22)	11.59 (6.11)	6.98 (42.14)	7.18 (5.43)
T_{10}	22.02	92.89 (28.54)	12.03 (6.46)	7.36 (43.33)	7.39 (5.67)
CD (P=0.05)	0.69	2.27 (1.08)	0.49 (0.31)	0.3 (2.17)	0.58 (0.43)

Figure in parentheses indicate uptake by stover of chickpea

Residual fertility status

Available N and P in soil after harvest of chickpea crop (Table 3) was significantly increased in all the treatments compared with control, whereas available S significantly decreased on application of P through fertilizer, but increased with application of P through P-enriched compost and vermicompost. Organic carbon and available K status showed non-significant differences. Maximum available N (249 kg/ha) and P (10.42 kg/ha) were recorded with application of P through P-enriched vermicompost along with *Rhizobium* and PSM inoculation. P-enriched vermicompost along with *Rhizobium* and PSM inoculation increased the root growth and nodulation thereby increasing the available N and P to the plant (Soni and Aery 2004). These results are also concurrent with the findings of Pareek *et al.* (2004).

It can be concluded that application of organic sources of P through P-enriched vermicompost or P-enriched compost in chickpea crop significantly increased yield, crude protein content of grain, uptake of N, P, K, S and available N and P in soil compared with recommended does of P through fertilizer. In the present study *Rhizobium* and PSM

Table 3 Residual fertility status after harvest of chickpea as affected by fertilizer, organic manure sources of P and inoculation (two years mean)

Treatment	OC (g/kg)	Available nutrients (kg/ha)			
		N	P	K	S
T_1	2.82	177 (+25)	7.26 (–2.47)	303 (–2)	9.86 (–0.64)
T_2	2.97	195 (+43)	9.69 (–0.04)	302 (–3)	9.41 (–1.09)
T_3	2.95	208 (+56)	9.35 (–0.38)	299 (–6)	9.28 (–1.22)
T_4	3.28	217 (+65)	10.25 (+0.52)	297 (–8)	8.97 (–1.53)
T_5	3.41	225 (+73)	10.08 (+0.35)	313 (+8)	11.16 (+0.66)
T_6	3.56	232 (+80)	9.92 (+0.19)	312 (+7)	10.77 (+0.27)
T_7	3.42	241 (+89)	10.27 (+0.54)	308 (+3)	10.6 (+0.10)
T_8	3.47	234 (+82)	10.29 –0.56	315 (+10)	11.28 (+0.78)
T_9	3.52	243 (+91)	10.15 (+0.42)	313 (+8)	11.04 (+0.54)
T_{10}	3.51	249 (+97)	10.42 (+0.69)	311 (+6)	10.93 (+0.43)
CD (P=0.05)	NS	5.11	0.31	N.S.	0.38
Initial	2.95	152	9.73	305	10.5

Figure in parentheses + gain or –loss over initial.

inoculation along with organic manure and fertilizer sources showed significant positive response.

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