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Effect of levels and mode of phosphorus and biofertilizers on chickpea (*Cicer arietinum*) under dryland conditions

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ABSTRACT

A field experiment was conducted during the winter seasons of 2000–2001 and 2001–2002, to study the effect of levels and mode of phosphorus, and biofertilizers [vesicular arbuscular mycorrhiza (VAM) and phosphate-solubilizing bacteria (PSB)] on yield attributes and yield of chickpea (*Cicer arietinum* L.). Inoculation of biofertilizers significantly increased yield attributes of pods/plant and seeds/plant and yield of chickpea. Among biofertilizers, dual inoculation of PSB+VAM markedly enhanced these yield attributes and yield compared with PSB or VAM alone. Application of phosphorus from 0 to 60 kg P_2O_5/ha resulted in linear increase in yield attributes and yield. Aqua placement of phosphorus significantly increased grain yield in first year only.

Key words **:** PSB, VAM, Aqua placement, Dry placement, Phosphorus, Chickpea, Dryland

Chickpea is a major winter (*rabi*) pulse crop grown in India. The average productivity (832 kg/ha) is far below the potential especially in dryland areas. The primary limitation of crop production in these regions is the lack of available moisture and nutrients especially phosphorus. Among the important nutrients, phosphorus is considered to be most important (Saraf, 1983). Amelioration of phosphorus deficiency by application of costly phosphorus fertilizer is also not a viable option to many resource poor farmers of these regions. The use of phosphate-solubilizing bacteria (PSB) and vesicular arbuscular mycorrhiza (VAM) have opened the new vistas of phosphorus nutrition. Favourable response of these micro-organisms has been noticed by Mukherjee and Rai (2000). Hence an experiment was conducted to study the effect of levels and mode of phosphorus application with and without biofertilizers on yield attributes and yield of chickpea.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2000–2001 and 2001–2002 at the Indian Agricultural Research Institute, New Delhi. The experiment was laid out in balanced confounded asymmetrical factorial design with 3 replications, in which 4 levels of biofertilizers inoculation [no inoculation, phosphate-solubilizing bacteria (PSB), vesicular arbuscular mycorrhizae (VAM) and PSB + VAM], 3 levels of phosphorus (0, 30 and 60 kg P_2O_5/ha) and 2 modes of phosphorus application (dry placement and aqua placement with 20,000 litres water/ha). There were 2 blocks/replication and 12 plots/block.

The soil was alluvial sandy loam with slightly alkaline in reaction (pH 7.4), low in organic carbon (0.42%), available nitrogen (251.7 kg/ha), phosphorus (9.1 kg/ha) and medium in available potassium (269.6 kg K_2O/ha). Chickpea ('BG 256') was treated with PSB culture before sowing and dried under shade. A total of 3 VAM spores/plant were placed. The pure VAM culture was mixed thoroughly with sand and placed in the furrow below the seed. Five tagged plants were taken from each treatment and yield attributes were recorded. The data recorded on yield attributes and yield were analysed using the Statistical Analysis System (SAS) General Linear Model Procedure (GLM PROC).

The environmental conditions prevailed in the 2 years during the period of crop growth were not identical in terms of precipitation and temperature. In first year, precipitation was 41.14 mm during entire growth period but during second year only 26.61 mm precipitation was recorded. In second year, temperature was high at grain filling stage compared to the first year.

RESULTS AND DISCUSSION

Yield attributes

Pods/plant and seeds/plant were significantly influenced by biofertilizers inoculation (Table 1). In the first year, dual inoculation of PSB+VAM recorded significantly higher pods/plant and seeds/plant than PSB and VAM inoculation alone, whereas in the second year, dual inoculation of PSB+VAM was on a par with VAM. This

Table 1. Yield-attributing characters as influenced by biofertilizers inoculation, levels and mode of phosphorus application

Treatment	Pods/plant		Seeds/plant		1,000-seed weight (g)	
	2000–2001	2001–2002	2000-2001	2001–2002	2000–2001	2001–2002
Biofertilizer						
No inoculation	30.2	23.2	35.7	23.5	220.9	213.5
PSB	33.2	26.3	37.8	27.1	222.5	214.2
VAM	33.9	28.1	40.0	28.4	222.6	214.4
PSB+VAM	37.4	28.2	45.4	28.6	224.9	218.4
CD (P=0.05)	1.94	1.49	2.06	1.38	NS	NS
P (kg P_2O_5/ha)						
0	29.5	24.5	34.9	25.0	219.3	212.7
30	34.7	27.2	39.9	27.8	223.6	213.6
60	36.8	27.6	44.3	28.4	225.2	217.6
CD (P=0.05)	1.68	1.29	1.79	1.13	3.44	4.76
Mode of P application						
Dry placement	33.0	26.2	39.1	26.6	220.7	213.6
Aqua placement	34.3	26.8	40.4	27.2	224.7	215.6
CD (P=0.05)	NS	NS	NS	NS	2.80	NS

Table 2. Seed and stover yield, and total P uptake as influenced by biofertilizer inoculation, levels and mode of phosphorus application

Treatment	Seeds yield (q/ha)			Stover yield (q/ha)		Total P uptake (kg/ha)	
	2000–2001	2001–2002	Pooled	2000–2001	2001–2002	2000–2001	2001–2002
Biofertilizer							
No inoculation	23.16	18.05	20.60	29.59	19.92	8.84	4.75
PSB	24.94	19.71	22.33	31.46	22.64	9.68	5.35
VAM	25.66	20.39	23.03	31.00	22.09	9.98	5.81
PSB + VAM	27.28	20.89	24.08	31.95	22.73	11.08	6.21
CD (P=0.05)	1.14	1.12	0.76	NS	1.59	0.93	0.48
P (kg P_2O_5/ha)							
0	23.61	18.63	21.12	29.79	20.63	8.77	4.62
30	25.78	20.21	23.00	31.40	21.82	10.06	5.56
60	26.35	20.43	23.41	31.80	23.08	10.91	6.54
CD (P=0.05)	0.98	0.97	0.66	NS	1.37	0.80	0.41
Mode of P application							
Dry placement	24.52	19.38	21.95	30.95	21.16	9.56	5.24
Aqua placement	26.00	20.14	23.07	31.05	22.52	10.27	5.90
CD (P=0.05)	0.80	NS	0.54	NS	0.12	0.66	0.34

increase in yield attributes by PSB+VAM inoculation might be owing to increased roots, relative leaf water content, root biomass and nodule number and dry weight that could be ascribed to a better vegetative growth and photosynthetic activity. This might have resulted in better translocation and partitioning of assimilates towards the yield attributes. Pods/plant, seeds/pod and 1000-seed weight were significantly influenced by phosphorus application. These yield attributes increased with increasing levels of phosphorus up to the highest level, i.e., 60 kg P_2O_5/ha. However, the difference between 30 and 60 kg P_2O_5/ha was at par in the second year. This might be due to less moisture in soil during crop growth period. The increase in yield attributes with phosphorus application might be owing to low initial phosphorus status in the soil. Saraf *et al.* (1997) also reported such increase in yield-attributing characters owing to increasing levels of phosphorus. The mode of phosphorus application had no significant influence on yield-attributing characters except 1,000-grain weight in the first year.

Yield

Inoculation of biofertilizers showed significant effect on grain yield (Table 2). In first year and pooled data, PSB + VAM inoculation recorded significantly higher grain yield than PSB or VAM inoculation, whereas in the second year, PSB + VAM inoculation separately recorded higher grain yield than PSB inoculation. The higher seed yield owing to PSB and VAM might be due to better growth and yield attributes. The PSB is known to produce vitamins (Baya *et al.*, 1981), indole acetic acid and gibberellin like substances (Sattar and Gaur, 1987). These growth factors in combination with better nutritional condition due to increase in availability of phosphorus in soil might have played a role in increasing the seed yield of chickpea. On the other hand, VAM helped in supply of essential nutrients and water to plants, resulted in better yield attributes that led to increase in seed yield. The dual inoculation recorded grian yield, which might be due to synergistic effect between PSB and VAM. The increase in seed yield by PSB and VAM was also reported by Mukherjee and Rai (2000). Inoculation of biofertilizers showed significant effect on stover yield in the second year only.

Phosphorus application increased seed yield up to 60 kg P_2O_5/ha. The difference between 0 and 30 kg P_2O_5/ha was significant in both the years as well as in pooled data. However, the increase between 30 and 60 kg P_2O_5/ha was significant in the first year and pooled data. The increase with 30 and 60 kg P_2O_5/ha over no phosphorus application was 9.19 and 11.60% in the first year, 8.48 and 9.66% in the second year and 8.9 and 10.8% in pooled data, respectively. This improvement in yield with increased supply of phosphorus might be due to profuse nodulation leading to increase in nitrogen fixation which in turn had positive effect on photosynthesis. Saraf *et al.* (1997) also noted such increase in seed yield with increasing levels of phosphorus. Stover yield was also increased significantly with increasing levels of phosphorus in the second year only.

Among modes of phosphorus application, aqua placement of phosphorus significantly increased the seed yield in the first year and pooled data. The increase by aqua placement over dry placement was 6.03, 3.92, and 5.10% in the first year, second year and pooled data respectively. In the second year, aqua placement significantly increased the stover yield.

Phosphorus uptake

Inoculation of biofertilizers increased the total phosphorus uptake in both years. In the first year, PSB + VAM inoculation recorded significantly higher phosphorus uptake than PSB and VAM inoculation separately. In the second year, inoculation of PSB + VAM was at par with VAM but was significantly higher than PSB inoculation alone. The increase with PSB, VAM and PSB + VAM over no inoculation was 9.5, 12.9 and 25.3% in the first year and 12.6, 22.3 and 30.7% in the second year respectively. Higher uptake of phosphorus with PSB and VAM inoculation may be possible as PSB produce vitamins (Baya *et al.*, 1981) and IAA and GA like growth substances (Sattar and Gaur, 1987), resulting in the increased availability of phosphorus in soil and plants. The VAM not only help in supply essential nutrients but also in supply of water to plants, especially in stressed conditions by connecting the gaps between root cells and soil particles, resulting in better growth and yields in chickpea.

Application of phosphorus significantly increased the phosphorus uptake up to 60 kg P_2O_5/ha in the first year and up to 30 kg/ha in the second year. The increase with 30 and 60 kg P_2O_5/ha over no phosphorus application was 11.4 and 24.4% in the first and 20.3 and 41.5% in the second year respectively. Aqua placement of phosphorus resulted significant higher uptake of phosphorus compared to traditionally dry placement. The percentage increase with aqua placement over dry placement was 7.4 and 12.5 in the first and second year respectively. Higher uptake of phosphorus with aqua fertilization in stress situation may be due to quick solubilization and utilization of P resulting in higher biomass accumulation. Similar results were also reported by Gutierrez-Boem and Thomson (1999).

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