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Effect of vesicular arbuscular mycorrhizae and phosphate-solubilizing bacteria on growth, yield and phosphorus uptake by wheat (*Triticum aestivum*) and chickpea (*Cicer arietinum*)

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ABSTRACT

A field experiment was conducted during 1997–98 and 1998–99 to study the effect of vesicular arbuscular mycorrhizae (VAM) and phosphate-solubilizing bacteria (PSB) on growth, yield and phosphorus uptake by wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and chickpea (*Cicer arietinum* L.). Application of phosphorus did exhibit perceptible influence on yield of the crops. Both biofertilizer and phosphorus nutrition interaction showed significant influence on growth and phosphorus uptake by wheat and chickpea compared with either of the components applied separately. Among the biofertilizers, *Pseudomonas striata* registered the highest grain yield in both crops at both levels of phosphorus, closely followed by *Glomus fasciculatum*. Among the VAM fungi, *Glomus fasciculatum* had positive influence on yield and phosphorus uptake whereas it was lacking in *Glomus macrocarpum*.

Key words : VAM, PSB, *Glomus fasciculatum, Glomus macrocarpum, Pseudomonas striata,* Wheat, Chickpea

The modern-day intensive crop cultivation requires the use of chemical fertilizer, but fertilizers are not only in short supply but also expensive. Therefore, the current trend is to explore the possibility of supplementing chemical fertilizer with the organic ones, more particularly biofertilizer of microbial origin. Favourable response of vesicular arbuscular mycorrhizae (VAM) and phosphate-solubilizing bacteria (PSB) have been noticed by many workers (Khalil *et al.*, 1992; Tilak and Singh, 1994). However, meagre attempts have been made to evaluate the response of these micro-organisms on plant growth and development. Unlike nitrogen and potassium, phosphorus possesses peculiar properties. In soil, soluble phosphorus characteristically undergoes fixation on reversion to relatively unavailable forms. Approximately 95–99% of soil phosphorus occurs in the form that are not directly available to plant root (Bieleski, 1973). Phosphorus is reported to be the limiting plant nutrient factor in soils and is considered to be the key to the crop productivity. Keeping these points in view, the present study was undertaken to study the effect of VAM and PSB on growth, yield and the availability of native and applied phosphorus in wheat and chickpea.

MATERIALS AND METHODS

The field experiment was conducted at Indian Agricultural Research Institute, New Delhi, during the winter season of 1997–98 and 1998–99. The experimental design was split plot with phosphorus levels (0 and 60 kg P_2O_5/ha) in main plots and crops, viz. wheat ('Kundan') and chickpea ('Pusa 372'), were in subplots. The subplots were further splited into smaller ultimate plots to be assigned to the biofertilizer, viz. *Glomus fasciculatum, Glomus macrocarpum* and *Pseudomonas striata.*

The soil was sandy loam, low in organic carbon (0.327%) and available nitrogen content (158.20 kg/ha). The available phosphorus (9.80 kg/ha) was low with high amount of exchangeable potassium (178.60 kg/ha). Crops were sown in rows with proper seed rate and spacing. A uniform dose of 40 kg K_2O/ha in the form of muriate of potash and variable dose of phosphorus (0 and 60 kg P_2O_2/ha) in the form of single superphosphate were placed. Nitrogen 100 kg/ha and 25 kg/ha were applied in wheat and chickpea respectively. A total of 15 VAM spores/plant were placed. The pure VAM culture was mixed thoroughly with slightly moistened soil and placed in the furrow below the seed.

RESULTS AND DISCUSSION

Dry-matter production

Interaction of biofertilizer and phosphorus nutrition significantly influenced the dry-matter production of wheat and chickpea (Table 1). The highest dry-matter production was noticed in the case of *Pseudomonas striata,* followed by *Glomus fasciculatum* at both levels of phosphorus and in both crops. The possible reason for such increase in dry matter in wheat could be correlated with the increased number of tillers. An increase in tiller production ultimately enhanced the dry-matter production. Such increase in tiller production could be the effect of increased root biomas through cell, division and multiplication which was influenced by the solubilization of native as well as added phosphorus by *Pseudomonas striata* and mobilization of native soil phosphorus.

Glomus fasciculatum

In chickpea significant increase of dry matter was noticed at later stage of crop growth. At early stage a low temperature restricted the vegetative growth which resulted in non-significant effect on dry-matter production at 50 days after sowing (Table 1). Effective solubilization of native and added phosphorus by *Pseudomonas striata* showed positive response on root biomass and biological nitrogen fixing ability by increasing nodule dry weight (Table 2). The cumulative development of root nodule and root biomass is a key factor on growth and yield of the crop.

Yield attributes

Biofertilizer alone or in combination

Table 1. Effect of biofertilizers on dry-matter production of wheat and chickpea at different stages of crop growth

Treatment	Dry-matter production of wheat (g/m^2)								Dry-matter production of chickpea (g/plant)							
	50 DAS		75 DAS		100 DAS		At harvest		50 DAS		75 DAS		100 DAS		At harvest	
	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}
Biofertilizer																
No inoculation	129.7	162.1	297.0	396.0	535.3	622.4	1,055.6	1,246.0	0.37	0.49	1.56	3.60	3.49	5.60	6.42	9.23
Glomus fasciculatum	153.1	173.5	353.0	437.0	593.0	645.4	1,186.0	1,312.5	0.42	0.53	2.46	4.63	4.67	6.70	7.82	10.56
Glomus macrocarpum	144.5	168.5	334.0	423.0	573.0	631.7	1,160.0	1,278.2	0.40	0.49	2.05	4.23	4.16	6.23	7.10	10.00
Pseudomonas striata	155.2	178.3	357.1	450.2	600.0	661.0	1,193.0	1,331.2	0.44	0.55	2.87	5.20	5.10	7.13	8.50	11.19
Mean	145.6	170.1	335.4	426.5	575.3	640.1	1,148.5	1,292.0	0.41	0.51	2.23	4.43	4.35	6.43	7.46	10.25
	P	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*
CD (P=0.05)	8.22	2.81	7.91	6.37	30.64	13.63	46.23	18.61	0.042	NS	0.924	0.238	0.901	0.206	1.514	0.193

P_0, Without phosphorus; P_{60}, 60 kg P_2O_5/ha; P, phosphorus; B, biofertilizer, NS, non-significant, DAS, days after sowing

Table 2. Effect of biofertilizers on yield attributes of wheat and chickpea and nodulation of chickpea

Treatment	Yield attributes of wheat						Yield attributes of chickpea						Nodule dry weight (mg/ plant)	
	Effective tillers/m^2		Grains/ ear		Test weight (g)		Sub-branches/ plant		Pods/ plant		Test weight (g)			
	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}
Biofertilizer														
No inoculation	261.0	271.3	33.7	35.6	45.9	46.9	6.3	8.5	21.7	26.3	132.0	137.0	33.1	81.0
Glomus fasciculatum	266.3	276.0	37.2	38.8	46.8	48.1	7.6	9.5	23.5	29.0	134.5	139.1	72.2	116.5
Glomus macrocarpum	264.0	273.4	36.1	38.5	46.5	47.5	7.2	9.0	22.7	27.6	133.1	138.2	65.4	97.0
Pseudomonas striata	267.0	278.0	36.0	39.5	47.3	47.9	7.9	10.1	24.2	30.3	135.0	140.0	77.0	118.0
Mean	264.6	274.6	35.7	38.1	46.6	47.6	7.2	9.3	23.0	28.3	133.6	138.6	62.0	103.1
	P	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*	*P*	*P×B*
CD (P = 0.05)	2.13	1.03	0.21	NS	NS	NS	0.71	0.25	1.86	0.37	2.54	NS	10.32	3.77

P_0, Without phosphorus; P_{60}, 60 kg P_2O_5/ha; P, phosphorus; NS, non-significant; B, biofertilizer with P increased the yield-attributing characters appreciably in both crops. In wheat the encouragement of early vegetative growth resulted in production of more tillers/m^2 which consequently increased the effective tillers/m^2 (Table 2). However, the trend was also similar in grains/ear and test weight but both were short of statistical significance. Stimulation of growth due to interaction of *Pseudomonas striata* and P nutrition resulted in more productive tillers (i.e. ear-bearing tillers)/m^2, grains/ear and test weight (Table 2).

In chickpea, sub-branches/plant and pods/plant differed significantly due to the interaction of biofertilizer and P nutrition. Among the biofertilizers, *Pseudomonas striata* registered highest yield attributes compared to VAM fungi at both levels of P (Table 2). *Pseudomonas striata* along with P nutrition improved the root biomass and nodule dry weight appreciably. The increased root biomass and nodule dry weight could be ascribed to a better vegetative growth and photosynthetic activity which might have resulted in better translocation and partitioning of assimilates towards the pod.

Yield

Growth, dry-matter production and different components of yield-attributing characters showed positive influence on grain yield of wheat and chickpea. Among the biofertilizers phosphate-solubilizing bacteria *Pseudomonas striata* resulted in significantly highest grain yield (Saraf *et al.*, 1996), while in VAM fungi *Glomus fasciculatum* was found to be significant over the *Glomus macrocarpum* at both

Table 3. Effect of biofertilizers on yield, net return and phosphorus uptake by wheat and chickpea

Treatment	Grain yield of wheat (q/ha)		Seed yield of chickpea (q/ha)		Phosphorus uptake by wheat (kg/ha)		Phosphorus uptake by chickpea (kg/ha)		Net return of wheat (Rs/ha)		Net return of chickpea (Rs/ha)		Benefit : cost ratio of wheat		Benefit : cost ratio of chickpea	
	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}
Biofertilizer																
Non inoculation	39.8	46.0	7.4	11.0	14.9	18.3	5.9	8.7	15,099	17,050	6,875	12,338	2.02	1.96	0.99	1.52
Glomus fasciculatum	43.3	47.5	9.2	12.2	15.9	19.1	7.1	10.1	16,444	17,308	9,760	14,095	2.07	1.89	1.32	1.64
Glomus macrocarpum	42.3	46.8	8.4	11.6	15.6	18.7	6.6	9.4	15,960	16,974	8,269	12,985	2.01	1.85	1.12	1.51
Pseudomonas striata	43.4	48.3	9.7	12.8	15.8	19.4	7.6	10.6	16,802	18,020	10,990	15,511	2.20	2.04	1.55	1.87
Mean	42.2	47.1	8.7	11.9	15.5	18.9	6.8	9.7								
	P	PxB	P	PxB	P	PxB	P	PxB								
CD (P=0.05)	1.24	0.42	0.48	0.24	0.39	0.25	0.36	0.32								

P_0, Without phosphorus; P_{60}, 60 kg P_2O_5/ha^{-1} P, phosphorus; B, biofertilizer

Cost of fertilizer (Rs/kg): Urea 4.00; SSP, 3.00; MOP, 3.70; Selling rate (Rs/q): wheat, 500; chickpea, 1,400; wheat straw, Rs 40/q; chickpea stalk, Rs 30/q; cost of labour: Rs 60/day levels of P and in both crops (Table 3).

An interaction effect of biofertilizer and phosphorus nutrition (60 kg P_2O_5/ha) increased the grain yield significantly over the application of P alone and the increment was 5, 3.2 and 1.74% in wheat, whereas in chickpea it was 16.4, 11.0 and 5.4% in *Pseudomonas striata, Glomus fasciculatum* and *Glomus macrocarpum* respectively.

Phosphorus uptake

Significant and positive influence of biofertilizer and P nutrition (60 kg P_2O_5/ha) interaction on P uptake was noted in both crops (Table 3). *Pseudomonas striata* registered maximum value of P uptake, followed by *Glomus fasciculatum. Pseudomonas striata* along with P increased the phosphorus uptake 6.0 and 21.8% more than only P and also 30.2 and 80.0% more than those under absolute control in wheat and chickpea respectively.

Economics

The monitory advantage indicated a positive gain under the biofertilizer treatments over the control treatments. *Pseudomonas striata* irrespective of P application proved beneficial to both the crops. Net returns/ha and benefit : cost ratio were maximum with *Pseudomonas striata* and correlated with 60 kg P_2O_5/ha where net returns obtained was were 17,050 and Rs 12,338 with benefit : cost ratio of 1.96 and 0.99 in wheat and chickpea respectively. *Pseudomonas striata* registered the net returns of Rs 16,802 and Rs 10,990 with benefit : cost ratio of 2.20 and 1.55 in wheat and chickpea respectively. It clearly indicates a great saving of phosphatic fertilizer.

Beneficial effect of *Pseudomonas striata* on growth, yield and P uptake was noticed which corroborates the fact that it effectively solubilizes the native and added P, while high phosphorus level has an inhibitory effect on VAM infection. These findings are in agreement with those of Li (1990) and Hetrick *et al.* (1996). Marschner and Dell (1994) also observed that with increasing levels of soluble P in soil the growth enhancement, effect of VAM declined and was either abolished or led to growth depression (shift from mutualism to parasitism), if carbon cost of symbiosis was not compensated by other beneficial effects.

Thus the effectiveness of *Glomus fasciculatum* can be increased by reducing the P level where mobilization of native and added P would be more pronounced due to satisfactory root colonization.

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