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Response of pea (*Pisum sativum*) to phosphorus, molybdenum and biofertilizers

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 1991—92 and 1992—93 to study the effect of P, Mo and biofertilizers [*Rhizobium* and phosphate-solubilizing bacteria (PSB)] on growth and yield attributes, yield and nutrient uptake by pea (*Pisum sativum* L. sensu lato) in a sandy-loam soil under semi-arid and subtropical climatic conditions. Application of P up to 25.8 kg/ha significantly improved nodulation, plant height, dry-matter accumulation, number of pods/plant, seeds/pod, seed yield, and N and P uptake by the crop. Moreover, response of seed yield to P was linear in nature. Similarly, addition of 0.5 kg Mo/ha marked enhanced growth, yield attributes and yield of the crop. Seed inoculation with *Rhizobium* or PSB and the combined inoculation resulted in conspicuous increase in nodulation, nitrogenase activity, growth, yield and nutrient uptake by the crop over no inoculation. However, the increase was more pronounced with the combined inoculation than with the single ones.

Pea (*Pisum sativum* L. sensu lato), the highest-yielding pulse crop of India, holds great promise for bridging the gap between the present per capita availability of pulses (35 g) in the country and the standard set by WHO (85 g). However, this is possible only when balanced and adequate supply of major and micronutrients is provided to the crop.

Being a legume, pea crop after seed inoculation with *Rhizobium leguminosarum* fixes 55—70 kg N/ha. Thus the major portion of N requirement of the crop is met through biological nitrogen fixation (BNF). The requirement for P which is essential for root growth and nodulation, on the other hand, has to be fulfilled largely through inorganic fertilizers. Enhancing P availability to crop through phosphate-solubilizing bacteria holds promise in the present scenario of escalating prices of phosphatic fertilizers in the country and a general deficiency of P in Indian soils. Alagawadi and Gaur (1988) observed positive response of phosphate-solubilizing bacteria inoculation in gram and pigeonpea yields.

Adequate availability of Mo, in addition to N and P, is pivotal for proper nodulation and higher yield of pea, as it plays an important role for the activity of enzymes, viz. nitrogenase and nitrate reductase. The present experiment was therefore carried out to study the response of pea to P and Mo, and to single and combined inoculations of *Rhizobium* and phosphate-solubilizing bacteria.

MATERIALS AND METHODS

A field experiment was conducted during

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Table 1. Nodulation and nitrogenase activity as affected by P, Mo and biofertilizers

Treatment	Nodules/plant at				Dry weight of nodules (mg)/plant at				Nitrogenase activity (μ mole C_2H_4/plant/hr) at flowering	
	Flowering stage		Pod-filling stage		Flowering stage		Pod-filling stage			
	1991–92	1992–93	1991–92	1992–93	1991–92	1992–93	1991–92	1992–93	1991–92	1992–93
P (kg/ha)										
0	19.66	16.8	14.6	11.9	20.1	17.2	15.5	11.9	3.4	3.1
12.9	24.25	20.4	19.1	16.6	26.3	19.7	22.1	16.6	3.8	3.6
25.8	27.96	24.4	23.8	19.3	34.5	23.6	24.7	19.3	5.1	4.3
CD (P = 0.05)	1.39	0.9	0.8	1.4	1.4	1.2	1.5	1.4	0.1	0.2
Mo (kg/ha)										
0	23.23	20.2	18.4	18.3	26.2	19.6	19.7	15.3	3.8	3.5
0.5	24.69	20.9	20.0	16.6	27.7	20.7	21.8	16.6	4.4	3.8
CD (P = 0.05)	1.13	0.7	0.6	1.1	1.1	1.0	1.2	1.1	0.1	0.2
Biofertilizer										
None	20.98	18.1	16.5	14.4	23.8	18.4	18.6	14.4	3.4	3.3
Rhizobium	24.06	20.1	18.1	15.0	26.7	20.3	20.5	15.0	3.9	3.6
PSB	23.85	20.3	18.1	15.1	27.2	20.2	21.9	15.1	4.0	3.4
Rhizobium + PSB	26.94	23.7	24.0	19.3	30.1	21.7	22.0	19.3	5.0	4.4
CD (P = 0.05)	1.31	1.1	1.2	1.4	1.5	1.1	1.5	1.4	0.2	0.3

PSB, Phosphate-slubilizing bacteria

Table 2. Growth of pea as affected by P, Mo and biofertilizers

Treatment	Plant height (cm) at				Dry-matter accumulation/plant (g)			
	Flowering		Pod-filling		Flowering		Pod-filling	
	1991—92	1992—93	1991—92	1992—93	1991—92	1992—93	1991—92	1992—93
P (kg/ha)								
0	41.1	35.1	49.9	45.1	2.0	1.1	19.2	15.5
12.9	43.8	40.1	53.8	49.3	3.3	1.8	23.9	18.2
25.8	48.8	43.5	57.6	51.6	5.2	1.9	27.2	21.8
CD (P = 0.05)	0.6	1.3	1.0	0.9	0.1	0.1	0.5	0.9
Mo (kg/ha)								
0	43.8	39.4	53.2	48.2	3.2	1.6	23.0	18.0
0.5	45.3	39.7	54.3	49.1	3.8	1.6	23.9	18.9
CD (P = 0.05)	0.5	NS	0.8	0.7	0.1	NS	0.4	0.7
Biofertilizer								
None	42.0	38.5	52.1	47.1	2.7	1.6	22.5	17.2
Rhizobium	44.8	39.4	53.8	48.6	3.4	1.6	23.4	18.3
Phosphate-solubilizing bacteria (PSB)	44.6	39.8	53.1	48.1	3.5	1.6	23.6	17.6
Rhizobium + PSB	46.8	40.5	56.1	50.9	4.5	1.6	24.3	20.8
CD (P = 0.05)	0.9	0.9	0.9	1.2	0.1	NS	0.8	0.7

the winter season of 1991—92 and 1992—93 at the Indian Agricultural Research Institute, New Delhi (28° 35' N and 71° 12' E). It has semi-arid and subtropical climate with an average rainfall of about 630 mm. Soil of the experimental field belongs to the order Inceptisols Typic Ustocrept and sandy loam in texture. The soil had pH 8.1, organic carbon 0.54%, available nitrogen 144.2 kg/ha, available phosphorus 8.55 kg/ha, available potash 260 kg/ha and molybdenum 0.06 ppm.

The experiment was laid out in split-plot design replicated thrice, with 6 main-plot treatments comprising 3 levels of P (0, 12.9 and 25.8 kg/ha) and 2 levels of Mo (0 and 0.5 kg/ha) and 4 subplots treatments comprising no biofertilizer, seed inoculation with *Rhizobium*, seed inoculation with phosphate-solubilizing bacteria (PSB) and dual inoculation with *Rhizobium* and PSB. Seeds were treated with Rhizobial inoculant (*Rhizobium leguminosarum*) and PSB (*Bacillus polymixa*) before sowing as per the treatments. The crop (cv. 'Arkel') was sown on 24 and 10 September in 1991 and 1992 respectively. A basal dose of 20 kg N/ha was applied at sowing. Crop was irrigated at branching, flowering and pod-development stages.

RESULTS AND DISCUSSION

The yield was higher during 1991—92 because of conducive climatic conditions for growth and development of the crop. During 1992—93 a sudden rise in temperature at pod-filling stage of the crop might have caused the loss in the yield.

Nodulation

In all the treatments, number as well as dry weight of nodules/plant were found

Table 3. Yield attributes and yield of pea as influenced by different treatments

Treatment	Pods/ plant		Seeds/ pod		1,000-grain weight (g)		Seed yield (tonnes/ha)		
	1991–92	1992–93	1991–92	1992–93	1991–92	1992–93	1991–92	1992–93	Pooled
P (kg/ha)									
0	11.0	7.3	4.12	3.41	188.7	181.7	1.47	1.26	1.37
12.9	14.2	9.4	4.39	3.80	188.7	186.2	1.70	1.48	1.59
25.8	16.0	10.5	4.77	4.13	190.2	187.1	1.89	1.81	1.75
CD (P = 0.05)	0.4	0.8	0.20	0.20	NS	2.9	0.08	0.11	0.08
Mo (kg/ha)									
0	13.1	8.7	4.41	3.70	187.7	184.4	1.64	1.42	1.53
0.5	14.3	9.5	4.44	3.86	190.9	187.6	1.73	1.48	1.61
CD (P = 0.05)	0.3	0.6	NS	NS	2.2	2.4	0.06	NS	0.06
Biofertilizer									
None	12.5	8.7	3.86	3.61	184.8	182.5	1.54	1.36	1.45
Rhizobium	13.7	9.0	4.43	3.84	189.3	185.6	1.69	1.48	1.59
PSB	13.8	8.8	4.40	3.83	192.0	185.5	1.67	1.45	1.56
Rhizobium + PSB	15.0	9.8	5.03	3.85	191.1	186.6	1.81	1.63	1.72
CD (P = 0.05)	0.6	0.9	0.26	NS	2.9	NS	0.12	0.11	0.08

PSB, Phosphate-solubilizing bacteria

higher at flowering than at pod-filling stage (Table 1). There was decline in nodulation after flowering because the nitrogenase activity in the nodules reaches its maximum at flowering stage and declined well before maturity, possibly due to assimilates being unavailable for continued nodule activity, as the photosynthates were directed to reproductive parts for grain development.

Dry weight and number of nodules/plant recorded a significant increase with increasing levels of P up to 25.8 kg/ha both at flowering and pod-filling stages (Table 1). This could be attributed to the association of P with several vital functions such as utilization of sugar and starch, nucleus formation, cell-division, photosynthesis and root growth (Arnon, 1956). Corresponding increase in nitrogenase activity by P application also supports the finding. Similar behaviour of applied P on nodulation was also noticed by Singh *et al.* (1981). Molybdenum application at 0.5 kg/ha also significantly increased number of nodules and nodule dry weight/plant. It may be ascribed to the significant increase in nitrogenase activity by Mo application.

Crop growth

Crop growth in terms of plant height and dry-matter accumulation improved significantly by application of P and Mo and inoculation with *Rhizobium* and PSB (Table 2). Crop receiving 25.8 kg P/ha produced the tallest plants at both flowering and pod-filling stages. The difference between 12.9 and 25.8 kg P/ha was also significant. Similar effect of P was observed on dry-matter accumulation. Application of 0.5 kg Mo/ha significantly increased plant height and dry-matter accumulation at pod-filling stage in both the seasons and at flowering in

Table 4. Nitrogen and P uptake as influenced by different treatments in pea

Treatment	N uptake (kg/ha)		P uptake (kg/ha)	
	1991–92	1992–93	1991–92	1992–93
P (kg/ha)				
0	129.5	122.8	10.3	9.1
12.9	131.2	124.2	11.4	10.0
25.8	135.1	128.8	12.2	10.7
CD (P = 0.05)	1.9	1.6	0.9	1.0
Mo (kg/ha)				
0	131.5	125.1	11.2	9.9
0.5	133.1	126.2	11.3	9.9
CD (P = 0.05)	1.5	NS	NS	NS
Biofertilizer				
None	130.3	124.5	10.7	9.8
Rhizobium	132.8	126.6	11.2	9.8
Phosphate-solubilizing bacteria (PSB)	132.7	126.0	11.4	9.9
Rhizobium + PSB	134.8	128.3	11.9	10.1
CD (P = 0.05)	1.4	1.1	0.26	NS

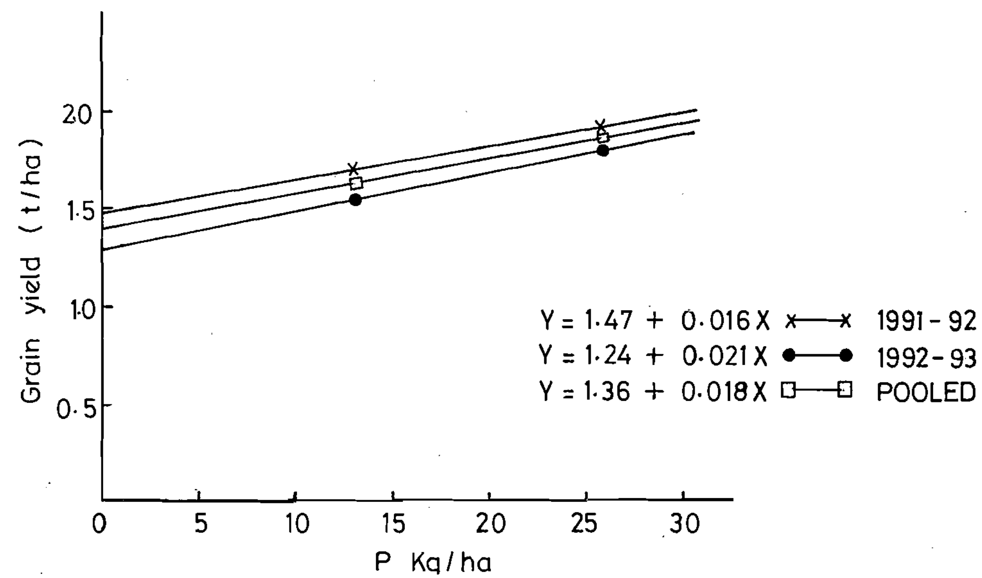

Fig. 1. Response of pea to phosphorus

1991–92 only. Single inoculation either with *Rhizobium* or PSB and dual inoculation with both of them had significant effect on plant height at both the stages in both the seasons and on dry-matter accumulation at pod-filling stage in both the years and at flowering in 1991–92 only. Single inoculations were distinctly inferior to the combined inoculation. This could be ascribed to enhanced availability of N in *Rhizobium* inoculation, P in PSB inoculation and both N and P in dual-inoculation plots. Bhandal *et al.* (1989) and Alagawadi and Gaur (1988) reported similar responses of these inoculations.

Yield attributes and yield

Application of P increased the number of pods/plant, seeds/pod and 1,000-seed weight which culminated into significant increase in yield (Table 3). The grain yield markedly increased with increasing levels of P up to 25.8 kg/ha. The relationship of grain yield and applied P was linear in nature (Fig. 1) and the equation derived based on pooled data was:

$$Y = 1.36 + 0.018\,X$$

The improvement in yield attributes and yield by P application may be attributed to profuse nodulation leading to increased N fixation, which in turn had positive effect on photosynthetic organs and rate. This is in close agreement with the findings of Sharma and Ahlawat (1989). Application of 0.5 kg Mo/ha resulted in great increase in yield in 1991–92 and pooled data. The improvement in yield by Mo could be attributed to greater nitrogenase activity which led to development of more yield attributes.

Single and dual inoculations with *Rhizobium* and PSB improved the yield attributes and yield (Table 3). Associative effect of *Rhizobium* and the PSB in dual, inoculation resulted in significant increase in yield attributes compared to their single inoculations. This could be owing to increased and balanced availability of both N and P in dual-inoculation plots. More pronounced effect of combined inoculation over single inoculation was also observed by Alagawadi and Gaur (1988) in gram or chickpea.

Nutrient uptake

Uptake of both N and P markedly increased by P application up to 25.8 kg/ha. Application of Mo increased N uptake in 1991–92 only, whereas P uptake remained unaffected in both the seasons (Table 4).

Increased N and P uptake by the crop was observed due to dual and single inoculations with *Rhizobium* and PSB. Dual inoculation of *Rhizobium* and PSB had relatively greater increase in N and P uptake than their individual inoculations. Similar behaviour of these inoculations on nutrient uptake was observed by Elenkela *et al.* (1985).

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