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Effect of *Rhizobium* inoculation, plant population and phosphorus on growth and yield of summer greengram (*Phaseolus radiatus*)

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ABSTRACT

A field experiment was carried out during 1989 and 1990 to study the response of summer greengram (*Phaseolus radiatus* L.) to *Rhizobium* inoculation, plant population and phosphorus levels. *Rhizobium* inoculation increased the dry-matter accumulation, number of nodules/plant, nodule weight/plant, nutrient uptake and yield attributes. Plant population at 30 cm row spacing increased the grain yield (18.5%) and found superior to 40 and 20 cm spacings. Phosphorus @ 40 kg P_2O_5/ha increased the grain yield by 17.2% over the control. Interactions among inoculation and phosphorus, row spacing and phosphorus and inoculation and row spacing were also found significant for yield attributes, grain yield and nutrient uptake respectively.

Usually grain legumes are grown on marginal lands and poor yield in such soils are partly due to lack of effective and specific strains of *Rhizobium* in the rhizosphere (Subba Rao and Tilak, 1977). The changes in plant population within a certain range extent marked changes in yield components, without influencing the grain yield. High plant density causes heavy shedding and this largely accounts for abscission of flowers and fruits. The optimum supply of phosphorus to the plant stimulates root development and growth, thereby helping to establish seedling quickly and also hastens maturity as well as improves the quality of crop produce. Hence an attempt was made to determine the response of summer greengram (*Phaseolus radiatus* L.) to *Rhizobium* inoculation, plant population and different levels of phosphorus.

MATERIALS AND METHODS

An experiment was conducted during 1989 and 1990 at Faizabad on sandy-loam soil (Inseptisols) with N, P and K 210, 18.4 and 220 kg/ha respectively before sowing with pH 8.10. Experiment was laid out in split-plot design. The treatments of inoculation (*Rhizobium* inoculated and uninoculated), plant populations (20,30 and 40 cm row spacings) and phosphorus levels (0,20, 40 and 60 kg P_2O_5/ha) were assigned to the plots, allocating inoculation and plant population in the main plot and phosphorus levels in subplot with 3 replications. Plant-to-plant spacing was kept 10 cm common

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Table 1. Growth parameters as influenced by *Rhizobium* inoculation, plant population and phosphorus levels in greengram

Treatment	Dry matter at harvest (q/ha)		Nodules/ plant		Nodule weight/ plant (mg)		N uptake at harvest (kg/ha)		P uptake at harvest (kg/ha)		Protein content (%)	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Inoculation												
Inoculated	36.04	33.33	33.00	29.78	25.36	24.09	72.99	60.31	7.54	6.21	26.32	26.39
Uninoculated	32.47	30.32	27.88	24.55	21.36	18.77	57.44	49.24	7.08	5.85	22.62	22.93
CD (P = 0.05)	0.58	0.78	0.78	0.91	0.73	1.16	1.25	0.87	0.089	0.11	0.49	0.69
Row sapcing (cm)												
20	32.26	28.70	24.25	21.05	18.74	15.93	60.86	51.07	6.80	5.61	23.24	23.38
30	40.63	38.90	22.18	29.14	24.97	23.13	72.35	62.19	8.07	6.87	24.65	24.97
40	29.86	27.80	33.89	31.31	26.25	25.24	62.43	51.07	6.94	5.62	25.63	25.64
CD (P = 0.05)	0.71	0.96	0.96	1.11	0.91	1.42	1.54	1.11	0.11	0.13	0.60	0.84
P_2O_5 (kg/ha)												
0	31.05	28.60	27.29	23.80	21.41	18.62	58.14	49.15	6.38	5.29	23.76	24.01
20	32.96	30.77	29.05	25.33	22.56	19.78	62.30	52.16	6.91	5.74	24.08	24.35
40	36.47	33.47	32.76	29.05	24.62	23.40	69.32	58.30	7.71	6.49	24.98	25.04
60	36.53	34.49	32.65	30.08	24.68	23.87	71.09	59.51	8.01	6.63	25.22	25.24
CD (P = 0.05)	0.65	1.09	1.21	0.97	0.71	0.80	1.64	1.15	0.10	0.08	0.44	0.50

for all treatments. In all there were 24 treatment combinations. Crop was sown on 17 and 20 March in 1989 and 1990 respectively. The basal dose of 18 kg N/ha was given to all the treatments. The variety, 'Pusa Baisakhi' was used in the experiment during both the seasons. During the crop season about 716 mm and 27.2 mm rainfall was recorded in 1989 and 1990 respectively.

RESULTS AND DISCUSSION

Rhizobium *inoculation*

Rhizobium inoculation increased the dry-matter accumulation by 10.5% during both the seasons, whereas number of nodules/plant were increased by 17.0% compared with uninoculated plots (Table 1). Nodule weight/plant was also increased by *Rhizobium* inoculation (RI). It was due to higher number of bacteria present under inoculated condition than uninoculated plots. Similar results were also reported by Shrivastava and Varma (1982) and Prasad and Ram (1984). *Rhizobium* inoculation perceived maximum N uptake, i.e. 72.99 and 60.31 kg/ha during first and second season respectively. The increment in N by *Rhizobium* inoculation was 25% over the uninoculated plots. It was due to higher grain yield and nitrogenase activity under RI which ultimately increased the N uptake in grain and straw. *Rhizobium* inoculation increased 6.3% phosphorus uptake in plant over uninoculated plots. Number of pods/plant and grains/pod were also increased by RI (Table 2).

The factors favouring more dry-matter accumulation also contribute to the increased number of pods/plant and grains/pod. High dry matter accompanied by large uptake of nutrients was associated with high number of grains which consequently yielded maximum by developing large number of pods/plant and grains/pod. Test weight of grains was higher under RI than uninoculated plots. Grain yield and harvest index (HI) were increased by RI because the grain yield is the result of co-ordinated interplay of growth and developmental characters. Under inoculated treatments, plant synthesizes more photosynthates and the storage organ (seed) was better developed. Higher dry-matter accumulation and developmental attributes contributed higher seed and straw yields. Prasad and Ram (1984) and Gill *et al.* (1985) also reported similar findings. *Rhizobium* inoculation increased the protein content by 15.5% because of higher accumulation of nitrogen.

Plant population

Highest dry-matter accumulation was maintained by 30 cm row spacing level (S_2), followed by 20 (S_1) and 40 cm (S_3) levels during both the seasons (Table 1). Number of nodules/plant and weight of nodule/plant were increased by decreasing plant density. Medium level of plant population exhibited its superiority to lower and higher levels for N uptake because of higher dry-matter accumulation and high N content. Phosphorus uptake was also highest at S_2 level. Maximum number of pods/plant, grains/pod and test weight were recorded at S_3 level. Higher dry-matter accumulation/plant and efficient translocation of photosynthates from vegetative parts to sink was the only reason of superiority of S_3 to S_2 and S_1. A row spacing of 30 cm gave higher grain yield (18.5%) and harvest index (29%) than 40 cm. The plant population under S_1 was maximum but due to hard competition for space, the development of vegetative parts specially leaves was checked. Therefore, shorter leaf area was not able to synthesize large quantity of synthetase, reducing thereby the grain

Table 2. Grain yield and yield attributes as influenced by inoculation, plant population and phorphorus level in greengram

Treatment	Pods/ plant		Grains/ pod		Test weight (g)		Grain yield (q/ha)		Harvest index (%)	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Inoculation										
Inoculated	13.68	11.83	6.41	6.08	37.64	34.87	8.64	6.44	29.16	25.72
Uninoculated	13.00	10.48	6.09	5.15	36.91	34.11	7.73	5.99	27.78	24.81
CD (P = 0.05)	0.33	0.31	0.18	0.29	0.44	NS	0.31	0.18	0.62	NS
Row sapcing (cm)										
20	12.18	8.65	5.05	4.50	36.19	33.20	8.01	6.09	28.54	25.43
30	13.94	12.13	6.75	5.93	37.34	34.13	9.46	7.46	30.36	27.64
40	13.90	12.69	6.95	6.41	38.30	36.14	7.09	5.10	26.52	22.73
CD (P = 0.05)	0.40	0.38	0.22	1.36	0.53	1 76	0.40	0.22	0.76	1.27
P_2O_5 (kg/ha)										
0	12.65	10.02	5.90	5.17	35.70	33.67	7.45	5.54	27.81	24.32
20	13 02	10.53	6.10	5.48	37.02	34.10	7.93	5.95	28.27	25.03
40	13.80	11.97	6.50	5.90	38.02	35.13	8.55	6.63	28.69	25.78
60	13.88	12.10	6.50	5.90	38.28	35.05	8.80	6.73	29.18	25.93
CD (P = 0.05)	0.40	0.32	0.20	0.16	0.54	0.82	0.26	0.14	0.48	0.76

yield. Although individual plant performance was better at S_3 level, the yield/ha was significantly higher at S_2, which was due to more number of plants per unit area. Higher increase in protein content (10.0%) was recorded at 40 cm row spacing level than 30 and 20 cm row spacings. It was mainly due to higher N content and lower plant population per unit area at 40 cm.

Phosphorus

Dry-matter accumulation, number of nodules/plant and nodule weight/plant increased significantly with the increasing levels of phosphorus up to 40 kg P_2O_5/ha. Application of phosphorus influenced the vigour of the plant which has plausibly accelerated the nitrogen-fixing power of the plant by increasing the activity of nodule bacteria and resulting in more dry-matter accumulation. The N and P uptake increased with the increasing levels of phosphorus. It was due to higher dry-matter accumulation, N fixation and accumulation of phosphorus by better developed root nodules at higher levels of phosphorus. Efficient grain-filling by better-translocation of photosynthates at higher levels of phosphorus improved the test weight of grains. Number of pods/plant and grains/pod were significantly increased up to 40 kg P_2O_5/ha. It was because of higher dry-matter accumulation and translocation of photosynthates from vegetative parts to pods and increase in nutrient uptake at higher doses of P. Higher dry-matter accumulation and developmental attributes contributed higher seed yield at higher doses of P. The result confirm the findings of Akhtar *et al.* (1986) and Patel and Parmar (1986). Protein content was also increased with the increasing levels of phosphorus.

Interaction effects

Inoculation x *row spacing:* Efficiency of plants for N uptake increased in *Rhizobium*-inoculated plots at S_2 and S_3 levels of plant population. It was due to less inter-plant competition for nutrients and water at S_3 level. Thus increasing row spacing under inoculated plots resulted in vigorous growth and better development of plants which was finally responsible for higher yield.

Inoculation × *phosphorus:* Nitrogen uptake in grain and straw was higher under *Rhizobium*-inoculated plots than uninoculated plots. Levels of phosphorus had significant difference up to 40 kg P_2O_5/ha under both the levels of inoculation. Higher rate of increase was observed under *Rhizobium* inoculted plots than uninoculated plots. It was because of higher number of bacteria available under inoculated plots which increased the N fixation. Besides this, P is essential constituent of majority of enzymes which are of great importance in the transformation of energy required in cell-division, ATP, activation of aminoacids for synthesis of protein and carbohydrates metabolites. Therefore, under *Rhizobium* inoculation phosphorus was efficiently utilized and greater efficiency was achieved at higher levels of phosphorus.

Row spacing x *phosphorus :* Grain yield was significantly increased up to 40 kg P_2O_5/ha. Under all the levels of plant population, maximum increase was observed at S_2 followed by S_1. There was less inter-plant competition for nutrients and water with in creasing row spacing levels. Therefore, P was most efficiently utilized at S_2.

Higher incidence of yellow-mosaic virus was observed during 1990. It was due to higher humidity in April. Therefore growth parameters, yield-contributing characters and yield level during 1990 were lower than those during 1989. Highest net income (Rs 3,539 and Rs 2,090) was recorded at S_2 level under inoculated condition with 60 kg P_2O_5/ha during both the seasons. It was followed by 40 kg P_2O_5/ha under all other similar conditions (Rs 3,420 and Rs 1,971). On the whole net profit per rupee invested was highest (1.11 and 0.66) at 30 cm row spacing under inoculated condition with 60 kg P_2O_5/ha, whereas similar level of plant population under inoculated condition with 40 kg P_2O_5/ha earned Rs 1.07 and Re 0.62 net profit per rupee invested during both the seasons respectively.

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