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Research Paper

Effect of levels and sources of phosphorus on morpho-physiological, seed yield and quality parameters in garden pea (*Pisum sativum*)

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ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2014–15 and 2015–16 at ICAR–Indian Agricultural Research Institute, New Delhi to study the effect of different levels and sources of phosphorus (P) on growth, seed yield and quality attributes in garden pea [*Pisum sativum* (L.) hortense]. There were 10 treatments, consisting of 9 combinations of 3 doses (30, 45 and 60 kg P_2O_5/ha) and sources [diammonium phosphate (DAP), single super phosphate (SSP) and rock phosphate (RP)] of P + absolute control, which were laid out in randomized block design with 3 replications. The seeds were treated with phosphorus solubilising bacteria (PSB) and arbuscular mycorrhiza (AM) in the treatment of RP. Results of the study indicated that increase in level of phosphatic fertilizers significantly increased different growth characters, seed yield and seed quality parameters of garden pea. Most of the traits were the highest with 60 kg P_2O_5/ha. Among the different sources of P, RP + PSB + AM resulted in significantly higher yield and quality attributes over control and other P sources and their levels. P-content in seed was also greatly affected by the different doses and sources of P. Protein, P, K and micronutrients content in seed (except zinc) increased with the increase in levels of P. Germination percentage was at par under different treatments. Effect of treatments was also observed on vigour test in normal as well as harsh conditions.

Key words **:** Garden pea, Phosphorus levels, Phosphorus sources, Seed quality, Seed yield

Garden pea is very important winter (*rabi*) season vegetable crop in India and mostly used for green seed consumption (Kumar *et al.,* 2017). In India, it occupies an area of 0.42 million ha with annual productivity of 9.5 t/ha. Like other pulses, its productivity is also low, mainly due to less availability of quality seed. The high quality seed production with higher productivity will also minimize the seed prices and it will attract farmers to adopt improved varieties with higher yield.

Phosphorus (P) is very important for the production of leguminous crops, which determine the nodulation, root proliferation and other growth factors (Sammauria *et al.,* 2009) and is involved in several energy transformation and biochemical reactions including biological N fixation. P as ATP plays the key role in photosynthesis. There are some analogs to ATP, namely, uridine triphosphate, cytidine triphosphate (CTP), and guanosine triphosphate, which also function as a source of energy and act as a substrate for the synthesis of RNA (Berg *et al.,* 2002; Blackburn, 2006). CTP is also involved in the synthesis of phospholipids. Another biological phosphorus molecule, nucleotide adenosine diphosphate, is involved in the electron transfer in photosystem I of photosynthesis (Salisbury and Ross, 1992). P is an integral part of the DNA and the RNA. P helps in the development of a better root system (Drew 1975; Zhang and Barber 1992). Phosphorus has a major role in reproduction in plants and is reported to hasten maturity in a number of crops including some vegetables (Anonymous, 1999). In a study in Kansas, the application of 19.1 kg P/ha reduced the thermal units (degree days) from emergence to mid-silk in corn by 110 units (Gordon, 2003). A recent study on plant species diversity in Eurasian wetlands and grasslands (Fujita *et al.*, 2014) showed that plants in phosphorus-deficient communities

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had shorter flowering periods and lesser seed production, and therefore, endangered species were more frequent in phosphorus-deficient environments.

Very high proportion of P in soil is insoluble and hence not available to the plants directly. About three fourth of the soluble P applied to the soil is converted in to insoluble form and only about one-fourth remained is available to the plants in the year of its application (Dubey, 1997). There is very meager information with reference to seed yield and seed quality of garden pea along with nutritional status of the seed using various levels and sources of phosphatic fertilizers. Keeping these facts in view, an experiment on vegetable pea 'Pusa Pragati' was conducted at research farm of the ICAR-Indian Agricultural Research Institute, New Delhi during 2014-15 and 2015-16 to find out the effect of different sources and levels of phosphatic fertilizers on growth, yield and seed quality.

MATERIALS AND METHODS

A field experiment was conducted during the winter season of 2014–15 and 2015–16 at seed production unit of Vegetable Division, ICAR-Indian Agricultural Research Institute, New Delhi to study the effect of phosphorus levels + sources on garden pea. There were 10 treatments viz. T_1, 30 kg P_2O_5/ha in the form of DAP; T_2, 45 kg P_2O_5/ha in the form of DAP; T_3, 60 kg P_2O_5/ha in the form of DAP; T_4, 30 kg P_2O_5/ha in the form of SSP; T_5, 45 kg P_2O_5/ha in the form of SSP; T_6, 60 kg P_2O_5/ha in the form of SSP; T_7, 30 kg P_2O_5/ha in the form of rock phosphate (RP) + AM + PSB; T_8, 45 kg P_2O_5/ha in the form of RP + AM + PSB; T_9, 60 kg P_2O_5/ha in the form of RP + AM + PSB and T_{10}, control (no phosphorus). Treatment consisted of different sources of phosphorus viz. diammonium phosphate (DAP), single super phosphate (SSP) and rock phosphate (RP) as well as different levels viz. 30, 45 and 60 kg P_2O_5/ha. Experiment was conducted in factorial randomized block design with 3 replications. Seeds of garden pea 'Pusa Pragati' were sown in experimental plot on 5 November 2014–15 and 2015–16 in 3 replications. Plot size was 5 m × 2 m with 8 rows per plot and row to row spacing was maintained at 25 cm with the seed rate of 125 kg/ha in all the plots.

Recommended dose of N and K_2O i.e. 20 and 50 kg/ha respectively was applied to each of the treatment in all replications. Seeds were treated with PSB and AM in the plots where phosphorus was applied through RP and PSB was applied with cow dung @ 12.5 kg/ha. The effect of different treatments was studied on growth, flowering, yield and seed quality attributes of the crop on ten randomly selected plants. Data recorded on plant height (cm), days to flowering, primary branches/plant, pods/plant, pod length (cm), seeds/pod, seed yield/plant (g), seed index, seed germination percentage, seedling length, seedling dry weight, vigour index, electrical conductivity and plant nutrient contents. The statistical analysis of the pooled data of 2014–15 and 2015–16 was carried out using SAS software.

RESULTS AND DISCUSSION

Growth and yield parameters

Data pertaining to the growth and yield parameters of garden pea 'Pusa Pragati' showed that application of phosphatic fertilizers caused significant increase in the recorded growth and yield parameters, viz. plant height, and primary branches/plant of garden pea compared with control in both the years of experimentation (Table 1). However, increase in the dose of P decreased the time taken to initiate the flowering irrespective of the source of P. Plant height and primary branches/plant were recorded the highest with RP + PSB + AM followed by DAP and SSP. Days to flowering were recorded the lowest in the highest dose of RP (41.5 days) followed by DAP (42.8 days) and SSP (43.7 days).

The increase in plant height and primary branches due to P application might be due to stimulating effect of P on plant metabolic processes being a major constituent of cell nucleus and growing root tips helping in cell division and root elongation, which ultimately results in more meiotic activities, thus the development of more apical bud primordia took place which produced more number of branches (Pandey *et al.,* 2003). Similar trend was also observed by Chattopadhyay and Dutta (2003) and Majumdar *et al.* (2004). Shortening of time taken to initiate flowering might be due to the key role of phosphorus in energetic metabolic and bio-synthesis reaction, which govern the cell multiplication resulting in rapid completion of vegetative growth (Mishra, 1999). Verma *et al.* (2018) also observed increase in plant height by increasing of P, which may be due to adequate nutrients, which in turns help in vigorous vegetative growth of plants and subsequently increase the plant height through cell elongation cell division, photosynthesis and turbidity of plant cell.

Application of P significantly increased the yield parameters, viz. pods/plant, pod length, seeds/pod and seed yield/plant over the control. Application of RP + PSB + AM recorded significantly higher values for yield parameters compared to DAP and SSP. However, the application of P in any form improved the yield attributes over the absolute control. Pods/plant was maximum (17.1) with RP @ 60 kg P_2O_5/ha) + PSB + AM and minimum (11.2) with SSP @ 30 kg P_2O_5/ha. The maximum pod length (9.9 cm) was recorded with RP @ 60 kg P_2O_5/ha + PSB + AM followed by RP 45 kg P_2O_5/ha + PSB + AM (9.58 cm) and

DAP @ 60 kg P_2O_5/ha (9.52 cm), while minimum 8.93 cm was recorded with SSP @ 30 kg P_2O_5/ha over the control (8.4 cm). The maximum seeds/pod (9.07) was obtained with application of RP (60 kg P_2O_5/ha) + PSB + AM followed by RP (45 kg P_2O_5/ha) + PSB + AM (8.95) and DAP @ 60 kg P_2O_5/ha (8.85) over the control (7.92). Seed yield/plant was significantly affected by the application of phosphorus and the highest seed yield/plant (22.02 g) was obtained with RP @ 60 kg P_2O_5/ha) + PSB + AM followed by RP (45 kg P_2O_5/ha) + PSB + AM (21.77 g) and DAP @ 60 kg P_2O_5/ha (21.25 g) over the control (19.16 g).

Final seed yield is a function of cumulative effect of various yield parameters. Application of phosphorus at higher level significantly affected the seed yield and yield attributes. It might be attributed to profuse nodulation leading to increased N fixation, which in turn had positive effect on photosynthetic organs and rate to produce and retain photosynthetic activity, uptake of other nutrients, reproductive activity and photosynthetic translocation from source to sink. The increase in seed yield (Table 1) with increase in the levels of phosphorus might also be attributed to the role of phosphorus in the energetisation processes and being the constituent of ribonucleic acid, deoxyribonucleic acid and ATP, which regulate vital metabolic processes in the plant, helping in root formation and nitrogen fixation which in turn favours better yield of the crop (Negi *et al.*, 2006). The findings of the experiments are in line with the observations of Shrivastava and Ahlawat (1995); Gupta *et al.* (2000); Majumdar *et al.* (2004) and Vikrant *et al.* (2005).

Seed quality attributes

Data in Table 2 showed that seed quality parameters viz. seed index, seedling length, seedling dry weight, seed vigour index and electrical conductivity recorded marked variations with P-levels and sources. Maximum value for seed index obtained with RP @ 60 kg P_2O_5/ha) + PSB +

Table 1. Effect of levels and sources of P fertilizers on growth and yield parameters of garden pea *cv* 'Pusa Pragati' (pooled mean of 2 years)

Source of P	Level of P_2O_5	Plant height (cm)	Primary branches/ plant	Days to flowering	Pods/ plant	Pod length (cm)	Seeds/ pod	Seed yield/ plant (g)
DAP	30 kg/ha	59.4	2.32	45.5	11.3	9.0	8.5	20.13
	45 kg/ha	61.6	2.48	43.8	11.4	9.1	8.7	20.48
	60 kg/ha	66.6	3.03	42.8	14.4	9.5	8.9	21.25
SSP	30 kg/ha	59.9	2.33	45.7	11.2	8.9	8.7	20.18
	45 kg/ha	62.4	2.53	44.8	11.7	9.1	8.6	20.61
	60 kg/ha	64.9	2.82	43.7	13.6	9.3	8.8	20.87
RP + PSB + VAM	30 kg/ha	62.6	2.67	43.7	12.5	9.2	8.7	21.05
	45 kg/ha	66.3	3.00	42.3	15.7	9.6	9.0	21.77
	60 kg/ha	69.0	3.33	41.5	17.1	9.9	9.1	22.02
Control	No P applied	52.7	1.90	46.8	9.8	8.4	7.9	19.16
SEm±		1.46	0.05	0.52	0.47	0.06	0.13	0.18
CD (P=0.05)		2.84	0.16	1.09	1.48	0.20	0.40	0.56

Table 2. Effect of levels and sources of P fertilizers on seed quality attributes of garden pea *cv* 'Pusa Pragati' (pooled mean of 2 years)

Source of P	Level of P_2O_5	Seed index (g)	Germination (%)	Seedling length (cm)	Seedling dry weight (mg)	Vigour index I	Vigour index II	EC (µS/cm/g)
DAP	30 kg/ha	22.7	97.5	21.9	0.02	2136	2.11	19.7
	45 kg/ha	23.3	97.8	22.4	0.03	2189	2.48	18.0
	60 kg/ha	24.8	97.3	24.8	0.04	2409	4.02	16.3
SSP	30 kg/ha	22.8	96.7	22.3	0.02	2154	2.09	18.3
	45 kg/ha	23.9	97.2	22.5	0.02	2188	2.40	17.8
	60 kg/ha	24.8	97.5	24.4	0.04	2378	3.71	17.1
Rock P + PSB + VAM	30 kg/ha	23.5	97.8	23.4	0.03	2286	3.29	17.0
	45 kg/ha	24.9	98.5	26.1	0.04	2569	4.33	15.9
	60 kg/ha	25.2	97.5	26.4	0.05	2573	4.51	15.3
Control	No P applied	22.1	96.3	21.4	0.02	2060	1.80	20.6
SEm±		0.32	0.18	0.53	0.003	54.35	0.31	0.49
CD (P=0.05)		1.50	NS	0.89	0.011	95.51	1.36	2.37

Table 3. Effect of levels and sources of P on nutrient content of seeds of garden pea *cv* 'Pusa Pragati' (pooled mean of 2 years)

Source of P	Level of P_2O_5	Protein (%)	N (%)	P (mg/kg of seed)	K (%)	Cu (mg/kg of seed)	Fe (mg/kg of seed)	Mn (mg/kg of seed)	Zn (mg/kg of seed)
DAP	30 kg/ha	17.54	2.81	446.3	0.93	114.9	220.4	113.4	43.4
	45 kg/ha	18.22	2.92	474.1	0.97	116.5	239.9	115.2	42.0
	60 kg/ha	18.71	2.99	504.3	1.03	117.2	254.3	116.8	41.1
SSP	30 kg/ha	17.45	2.79	439.6	0.93	114.7	220.1	112.1	42.9
	45 kg/ha	17.91	2.87	468.4	0.96	116.0	235.0	115.6	41.7
	60 kg/ha	18.91	3.02	485.3	1.01	116.6	251.5	116.9	41.0
Rock P + PSB + VAM	30 kg/ha	18.09	2.89	477.1	0.94	116.0	229.2	113.9	43.4
	45 kg/ha	19.33	3.09	502.3	1.00	116.7	250.6	116.0	42.3
	60 kg/ha	20.60	3.30	530.5	1.08	118.0	273.6	117.5	41.4
Control	No P applied	16.10	2.58	378.6	0.87	112.6	162.9	110.7	45.0
SEm±	–	0.38	0.06	13.34	0.02	0.48	9.45	0.70	0.39
CD (P=0.05)	–	1.04	0.16	24.74	0.03	2.39	20.98	3.69	NS

AM (25.24 g) and minimum when P_2O_5 was supplied in the form of DAP and SSP @ 30 kg/ha, but all these were significantly higher over the control (22.1 g). Seed germination was not affected by treatments. Vigour indices and electrical conductivity significant effect was noted in field emergence as seedling length, seedling dry weight and hence both the vigour indices was higher in the treatments supplied with higher doses of phosphorus. The highest values for seedling length, seedling dry weight and both the vigour indices was recorded with RP @ 60 kg P_2O_5/ha + PSB + AM. The electrical conductivity (EC) was the highest in the control (20.56 µS/cm/g), whereas it was recorded minimum for the plants treated with RP @ 60 kg P_2O_5/ha + PSB + AM.

The higher seed index of plants treated with higher doses of phosphorus may be attributed to involvement of P in activities of photosynthetic translocation from source to sink and also higher growth period as P hastened the flowering, thereby providing higher seed fill duration to plants. Vigour indices improved due to the application of P levels as reported by earlier workers (Shukla and Kohli, 1991 and Amjad *et al.*, 2004). The EC test is a measurement of electrolytes leaching from seeds and EC readings is inversely related to seed vigour. Results showed that EC of seed leachates decreased with increasing rates of P applied to the mother plants from which it was harvested and it might be owing to effect of phosphorus on cell membrane integrity and hence may cause the seeds to leach out the nutrient during EC tests and hence might affect seed vigour (Mullins *et al.*, 1996).

Nutrient contents of seed

The nutrient contents, viz. N, P, K, Cu, Fe and Mn in the seeds were significantly increased by increasing the levels of phosphorus except zinc (Table 3) which decreased significantly with increase in level of P and was recorded maximum in control (45.0 mg/kg of seed).

The maximum protein content (20.6%) and primary nutrients (3.3%, 530.5 mg/kg and 1.08% N, P and K, respectively) were recorded the highest from the plots treated with RP 60 kg P_2O_5/ha) + PSB + VAM and minimum was found in control. Micronutrients viz. Cu 118.0, Fe 273.6 and Mn 117.5 mg/kg of seed was also recorded the highest with application of RP @ 60 kg P_2O_5/ha + PSB + AM but Zn content in seeds was not affected significantly. Rathi *et al.* (1993) also observed increase in crude protein content with higher P application in field pea. The nutrient status of the seed was in conformity with the report of Kandil *et al.* (2013) and Kandil (2014).

Suitable sources and doses of phosphatic fertilizers plays important role in influencing growth, yield attributes and yields of seed crop of garden pea and also with positive influence on quality. The seed nutrient composition (macro and micronutrient) is also positively affected by increasing the dose of phosphorus. RP can be used as a source of phosphorus with PSB + AM.

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