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Research Paper

Effect of phosphorus and bioinoculants on yield, nutrient uptake and economics of long duration pigeonpea (*Cajanus cajan*)

AMITESH KUMAR SINGH[1] AND R.S. SINGH[2]

Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005

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ABSTRACT

A field experiment was conducted during *kharif* season of 2008-09 and 2009-10 to study the response of phosphorus (0, 25, 50 and 75 kg P_2O_5/ha) and bioinoculants (control, PSB, PGPR and PSB + PGPR) on yield and yield attributes, nutrient uptake and economics of pigeonpea (*Cajanus cajan* L.). Application of 75 kg P_2O_5/ha recorded the highest grain yield (2.19 t/ha) and yield attributes, nutrient uptake, gross returns (₹1,19,858/ha), net returns (₹90,500/ha) and B:C ratio (3.09), which was significantly superior over 25 kg P_2O_5/ha. Agronomic (AEp), recovery (REp) and physiological (PEp) efficiency was the highest with 25 kg P_2O_5/ha, followed by 50 and 75 kg P_2O_5/ha. REp was the highest with 50 kg P_2O_5/ha. Dual seed inoculation with PSB + PGPR produced the highest yield (2.24 t/ha) and yield attributes, nutrient uptake, gross returns (₹1,22,377/ha), net return (₹93,498/ha) and B: C ratio (3.23), being significantly superior over PGPR, PSB and control. AEp and REp was the highest with PSB followed by PSB + PGPR and PGPR, while PEp was the maximum with PGPR. The available phosphorus in soil after harvest of the crop was the highest (22.2 kg/ha) with application of 75 kg P_2O_5/ha.

Key words : Agronomic efficiency, Bioinoculents, P balance, Physiological efficiency, Pigeonpea, Phosphorus, Recovery efficiency

India is the major pulse growing country, ranking first with about 90% of world area and 85% world's production of grain legumes. During 2010-11, the production of pigeonpea in India was as 2.89 million tonnes from 3.9 million hectares with a productivity of 914 kg/ha (DES, 2011). Pigeonpea is the fifth prominent grain legume crop in the world and holds second position in India after chickpea. The low yield of pigeonpea is not only due to its cultivation on marginal land, but also because of inadequate and imbalanced fertilization. Phosphorus is an important plant nutrient and it affects seed germination, cell division, flowering, fruiting, synthesis of fat, starch and infact most biochemical activities. It also induces root proliferation and nodulation. Significant response of pigeonpea to phosphorus has been reported by several workers (Kumar and Kushwaha, 2006, Singh and Yadav, 2008). Some heterotrophic bacteria (*Bacillus* spp.) are known to have the ability to solubilize phosphorus from insoluble sources. Phosphate solubilizing microbes help in the solubilization of phosphorus from rock phosphate and sparingly soluble forms of native soil phosphorus by secreting organic acid i.e. citric, gluconic, succinic, lactic, oxalic, glycolic, malic, formic, maleic and alpha ketogluconic. Normally, these bacteria can solublize about 15-20 kg P_2O_5/ha per season (Chandra and Kumar, 2005). Plant growth-promoting rhizobacteria (PGPR) are a group of free-living bacteria that colonize the rhizosphere and benefit the root growth. Bacteria of diverse genera were identified as plant growth promoting rhizobacteria of which Bacillus and Pseudomonas spp. are predominant. Plant growth promoting rhizobacteria exert a direct effect on plant growth by production of phytohormones and solubilization of inorganic phosphates. PGPR reduce the populations of root pathogens and other deleterious microorganisms in the rhizosphere, thus benefiting the plant growth. PGPR also enhance root colonizing bacteria (rhizobacteria) that exert beneficial effects on plant development via direct or indirect mechanisms. Beneficial effect of plant growth promoting rhizobacteria (PGPR) on pigeonpea has been reported by Tilak *et al.* (2006) and Vargas *et al.* (2010).

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season of 2008-09 and 2009-10 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu

[2]**Corresponding author Email**: singhrs.bhu@gmail.com
[1]Research Scholar, [2]Professor, Department of Agronomy

University, Varanasi. The experimental soil was sandy clay loam in texture having pH (7.46, 7.53). It was moderately fertile being low in organic carbon (0.34 and 0.37 %). The available N, P, K and S was 188.7, 18.5, 205.3 and 19.3 kg/ha in first year and 194.2, 22.4, 210.6 and 21.5 kg/ha in second year, respectively. The experiment was laid out at the same site and same plots during both the years in split plot design replicated thrice keeping phosphorus levels (control, 25, 50 and 75 kg P_2O_5/ha) in main plots and bioinoculants (control, PSB, PGPR and PSB + PGPR) in sub plots. Phosphorus applied as per treatment through diammonium phosphate (DAP). A uniform dose of nitrogen, potassium and sulphur @ 30, 40 and 30 kg/ha were applied through urea, muraite of potash and elemental sulphur (90 %). Pigeonpea seed were inoculated with phosphate solubilizing bacteria (*Bacillus polymyxa*), PGPR (*Rhizobium + Pseudomonas florencenses*) and dual inoculation with PSB + PGPR (*Bacillus polymyxa + Rhizobium + Pseudomonas florencenses*) before sowing. Long duration pigeonpea cv. Bahar was sown by ridge-furrow method of planting on 14 and 20 July in 2008 and 2009 and the respective crop was harvested on 06 and 12 April in 2009 and 2010. The required plant population (60 cm row to row and 20 cm plant to plant) was obtained after a month of seeding by thinning of the plant. During first year more favorable weather conditions specially rainfall which was comparatively higher (528.60 mm during, first year than second year 420.41 mm). During second year at flowering time fogy days (January to February) caused flower dropping, less yield attributes and finally affected yield. Phosphorus efficiency was calculated using following formulae.

$$\text{Agronomic Efficiency of P (AEp)} = \frac{\text{Yp - Yc}}{\text{P applied}}$$

$$\text{Apparent Recovery of P (REp)} = \frac{\text{Up - Uc}}{\text{P applied}}$$

$$\text{Physiological Efficiency of P (PEp)} = \frac{\text{Yp - Yc}}{\text{Up - Uc}}$$

Where,

'Y' and 'U' refer to yield of pigeonpea and P uptake by pigeonpea and subsequently 'p' and 'c' refer to phosphate fertilized and control (no P) plots, respectively. P applied is kg P_2O_5/ha. All values are in kg/ha.

The curve estimation of phosphorus levels (kg P_2O_5/ha) and grain yield (kg/ha) pooled data was done with the Microsoft office excels 2007 and optimum economic dose calculated by regression equation:

Optimum economic dose = (Output/Input)-b/2c

RESULTS AND DISCUSSION

Yield attributes and grain yield

Application of 75 kg P_2O_5/ha being on par with 50 kg P_2O_5/ha significantly increased yield attributes *viz.* pod length, pods/plant, pod weight/plant, grains/pod, grain weight/plant and 1000-grain weight over 25 kg P_2O_5/ha and control (Table 1). The maximum grain yield (2.19 t/ha) was obtained with application of 75 kg P_2O_5/ha being significantly superior over application of 25 kg P_2O_5/ha (1.87 t/ha) and control (1.59 t/ha). The higher values of yield and yield attributes may be ascribed to the effect of P on root development, energy transformation and metabolic processes of the plant, which in term resulted in greater translocation of photosynthates towards the sink development. These results are in conformity with Singh and Ahlawat (2007).

Dual seed inoculation with PSB + PGPR recorded higher values of yield attributes (pod length, pods/plant,

Table 1. Effects of phosphorus levels and bioinoculants on yield attributes and yield of pigeonpea (Pooled data)

Treatment	Pod length (cm)	Pods/plant	Pods weight/ plant (g)	Grains/pod	Grains weight/plant (g)	1,000-grains weight (g)	Grain yield (t/ha)
Phosphorus (kg/ha)							
Control	3.4	249.8	87.4	3.3	74.1	84.3	1.59
25	4.0	288.9	100.8	3.8	87.3	103.5	1.87
50	4.5	318.0	112.7	4.3	97.6	115.5	2.14
75	4.6	334.6	115.7	4.4	99.4	120.0	2.19
SEm±	0.08	5.81	2.01	0.08	1.72	2.02	0.04
CD (P=0.05)	0.27	20.12	6.95	0.26	5.97	7.00	0.13
Bio-inoculants							
Control	3.5	253.3	91.4	3.3	77.6	90.8	1.61
PSB	4.1	293.9	102.8	3.9	88.1	102.8	1.92
PGPR	4.2	301.4	105.5	4.0	91.4	106.8	2.02
PSB + PGPR	4.7	342.7	117.0	4.5	101.3	123.0	2.24
SEm±	0.06	4.36	1.50	0.06	1.29	1.55	0.03
CD (P=0.05)	0.17	12.73	4.47	0.17	3.77	4.52	0.08

pod weight/plant, grains/pod, grain weight/plant, 1000-grain weight and grain yield (2.24 t/ha) of pigeonpea over PGPR, PSB and control. Structural and functional characteristics of roots contribute to rhizosphere processes and both have significant influence on the capacity of roots to acquire nutrients. Roots also interact extensively with soil microorganisms, which further impact plant nutrition either directly, by influencing nutrient availability and uptake, or indirectly through plant (root) growth promotion. These observations are in agreement with those of Singh and Yadav (2008).

Interaction effect of phosphorus and bioinoculants on grain yield

As referred, grain yield, interaction between phosphorus levels and bioinoculants (Table 2) was significant. Higher grain yield was recorded with a combined application of 75 kg P_2O_5/ha + PSB + PGPR, being on par with application of 50 kg P_2O_5/ha + PSB + PGPR and significantly superior over 25 kg P_2O_5/ha + PSB + PGPR. The increases in grain yield was due to increase in LAI, dry matter accumulation and yield attributes due to increased P availabilities. Similar results have been reported by Kumar and Kushwaha (2006) and Singh and Singh (2012).

Nutrient uptake

The application of 75 kg P_2O_5/ha gave higher total nitrogen, phosphorus, potassium and sulphur uptake, being on par with 50 kg P_2O_5/ha and significantly superior over 25 kg P_2O_5/ha and control (Table 3). These results corroborated with the finding of Jain *et al.* (2007).

Dual seed inoculation with PSB + PGPR recorded highest total nitrogen, phosphorus, potassium and sulphur uptake and this treatment was, significantly superior over seed inoculation with PGPR, PSB and control. Direct enhancement of mineral uptake due to increases in specific ion fluxes at the root surface in the presence of PGPR. Similar results reported by Singh and Yadav (2008) and Gupta *et al.* (2009).

Phosphorus use efficiency

Agronomic and physiological efficiency (AEp and PEp) was the maximum with application of 25 kg P_2O_5/ha followed by 50 kg P_2O_5/ha and the lowest was with application of 75 kg P_2O_5/ha (Table 3). Recovery efficiency

Table 2. Interaction effect of phosphorus levels and bioinoculants on grain yield (t/ha)

Treatment	Control	PSB	PGPR	PSB + PGPR
Control	1.30	1.58	1.65	1.84
25	1.55	1.81	1.93	2.21
50	1.78	2.13	2.24	2.43
75	1.83	2.18	2.27	2.51
		SEm±	CD (P=0.05)	
M at same P		0.06	0.18	
P at same/diff M		0.19	0.58	

Table 3. Effect of phosphorus levels and bioinoculants on total nutrient uptake (Pooled) and phosphorus efficiency (Mean) of pigeonpea

Treatment	Total nutrient uptake (kg/ha)				AEp (kg grain/kg P_2O_5)	REp (%)	PEp (kg/kg P_2O_5)
	N	P	K	S			
Phosphorus (kg/ha)							
Control	104.0	14.8	47.6	13.6	-	-	-
25	136.7	19.3	69.0	18.4	11.20	19.80	61.80
50	177.2	25.4	96.9	24.0	11.05	22.05	51.85
75	186.0	26.8	102.0	25.5	8.05	16.55	50.15
SEm±	2.81	0.41	1.50	0.38	-	-	-
CD (P=0.05)	9.74	1.42	5.18	1.33	-	-	-
Bioinoculants							
Control	108.6	15.5	55.2	14.7	-	-	-
PSB	146.4	20.4	72.5	19.4	12.45	21.00	63.95
PGPR	156.8	21.9	77.1	20.7	8.20	13.45	64.50
PSB + PGPR	192.0	28.5	110.8	26.8	8.45	17.90	48.50
SEm±	2.32	0.34	1.27	0.32	-	-	-
CD (P=0.05)	6.77	0.98	3.71	0.93	-	-	-

AEp = Agronomic efficiency of P, REp= Recovery of P and PEp= Physiological efficiency of P

Table 4. Effect of phosphorus levels and bioinoculants on economics (Pooled) and P balance sheet (Mean) of pigeonpea

Treatment	Cost of cultivation (×10³ ₹/ha)	Gross return (×10³ ₹/ha)	Net return (×10³ ₹/ha)	B: C ratio	Phosphorus (kg/ha) Initial soil P status (A)	P added (B)	P uptake by crop (C)	Soil P status after harvest (D)	Actual gain/loss over initial status (A-D)	P balance (A+B)-(C+D)
Phosphorus (kg/ha)										
Control	27.9	88.5	60.6	2.17	20.45	0.0	14.8	14.9	-5.55	-9.25
25	28.4	103.1	74.7	2.63	20.45	25.0	19.3	19.6	-0.85	6.55
50	28.8	117.5	88.6	3.07	20.45	50.0	25.4	21.6	1.15	23.45
75	29.3	119.9	90.5	3.09	20.45	75.0	26.8	22.2	1.75	46.45
SEm±	0.6	2.1	1.5	0.05	-	-	0.41	0.36	-	-
CD (P=0.05)	1.9	7.1	5.1	0.18	-	-	1.42	1.26	-	-
Bioinoculants										
Control	28.4	89.9	61.471	2.16	20.45	0.0	15.5	16.7	-3.75	-11.75
PSB	28.6	105.9	77.390	2.70	20.45	25.0	20.4	19.1	-1.35	5.95
PGPR	28.6	110.7	82.130	2.87	20.45	50.0	21.9	20.6	0.15	27.95
PSB + PGPR	28.9	122.4	93.498	3.23	20.45	75.0	28.5	22.0	1.55	44.95
SEm±	0.4	1.6	1.166	0.04	-	-	0.34	0.29	-	-
CD (P=0.05)	1.1	4.5	3.404	0.12	-	-	0.98	0.83	-	-

Sale price of pigeonpea grain= ₹35.0 /kg; pigeonpea stalk= ₹5.0/kg and Common cost= ₹25,206.0/ha

(REp) was the highest with application of 50 kg P_2O_5/ha followed by 25 kg P_2O_5/ha and 75 kg P_2O_5/ha. The phosphorus efficiency with P application was recorded due to higher amount of biomass production and subsequently P accumulation of plant observed by Kumar and Kushwaha (2006).

All the determinants of phosphorus use Efficiency (AEp and REp) except, PEp were the highest with PSB followed by dual inoculation of PSB + PGPR and the lowest with PGPR alone. Physiological efficiency of P (PEp) was the maximum with PGPR followed by PSB and the lowest with dual inoculation of PSB + PGPR. Similar results were reported by Singh and Ahlawat (2007).

Economics and phosphorus balance

The highest gross returns (₹1,19,858/ha), net returns (₹90,545/ha) and benefit: cost ratio (3.09) was obtained with 75 kg P_2O_5/ha (Table 4) and this treatment was significantly superior to 25 kg P_2O_5/ha. In this study, the highest available P (22.2 kg/ha), the actual P gain (1.75 kg/ha) and the highest P balance (46.5 kg/ha) was observed with 75 kg P_2O_5/ha followed by 50 kg P_2O_5/ha, 25 kg P_2O_5/ha and control. Dual seed inoculation with PSB + PGPR recorded the maximum gross returns (₹1,22,377/ha), net returns (₹93,498/ha) and benefit: cost ratio (3.23); significantly superior to inoculation with PGPR, PSB and control. The available P (22.0 kg/ha), the actual P gain (1.55 kg/ha) and P balance (44.9 kg/ha) was the highest with dual inoculation of PSB + PGPR followed by PGPR, PSB and control.

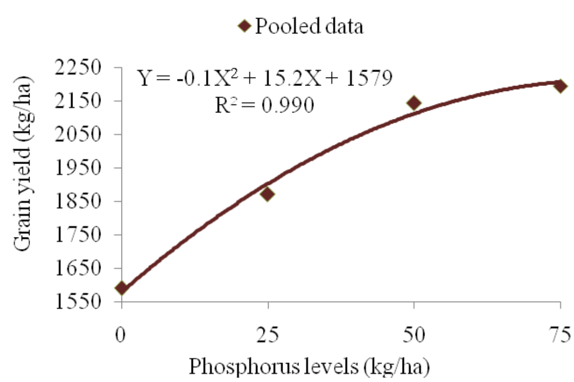

Fig. 1. Quadratic relationship between phosphorus levels and grain yield.

Curve fitting, correlation study and optimum economic dose

Quadratic relationship between phosphorus application and grain yield was observed. The correlation coefficient (r = 0.990) between phosphorus and grain yield showed that it was highly correlated (Fig. 1). From the regression equation of pigeonpea, the economic optimum levels of P_2O_5 was estimated as 72.7 kg P_2O_5/ha of maximum grain yield.

REFERENCES

Chandra, R. and Kumar, S. 2005. Biofertilizers: An eco-friendly source of plant nutrient. *Indian Farmers Digest* **4**: 8-9.

DES. 2011. Directorate of Economics and Statistics, Department of Agriculture and Cooperation. Economic Survey, pp. A 17-19.

Gupta, S.C. Singh, R.P. and Verma, R. 2009. Response of chickpea

(*Cicer arietinum* L.) to phosphorus levels from different sources with various PSB species. *Legume Research* **32**(3): 212-14.

Jain, A.K., Kumar, S. and Panwar, J.D.S. 2007. Response of mungbean (*Vigna radiata*) to phosphorus and micronutrients on N and P uptake and seed quality. *Legume Research* **30**(3): 201-04.

Kumar, A. and Kushwaha, H.S. 2006. Response of pigeonpea (*Cajanus cajan* L.) to sources and levels of phosphorus under rainfed condition. *Indian Journal of Agronomy* **51**(1): 60-62.

Singh, A.K. and Singh, R.S. 2012. Effect phosphorus levels and bioinoculants on growth and yield of long duration pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Journal of Food Legumes* **25**(1): 73-75.

Singh, R.S. and Yadav, M.K. 2008. Effect of phosphorus and biofertilizers on growth, yield and nutrient uptake of long duration pigeonpea under rainfed condition. *Journal of Food Legume* **21**(1): 46-48.

Singh, U. and Ahlawat, I.P.S. 2007. Phosphorus management in pigeonpea (*Cajanus cajan* L.)-wheat (*Triticum aestivum* L.) cropping system. *Indian Journal of Agronomy* **52**(1): 21-26.

Tilak, K.V.B.R., Ranganayaki, N. and Manoharachari, C. 2006. Synergistic effects of plant growth promoting rhizobacteria and Rhizobium on nodulation and nitrogen fixation by pigeonpea (*Cajanus cajan* L.). *European Journal of Soil Science* **57**: 67-71.

Vargas, L.K., Lisboa, B.B., Giongo, A., Beneduzi, A. and Passaglia, L.M.P. 2010. Potential of rhizobia as plant growth-promoting rhizobacteria. M.S. Khan *et al.* (eds.). *Microbes for Legume Improvement* **7**: 137-55.