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SOIL SCIENCE

Effect of phosphorus and biofertilizers on phosphorus use efficiency, biological N-Fixation and yield of pigeonpea (*Cajanus cajan* L.)

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Abstract

A field experiment was conducted during rainy seasons of 2013-14 and 2014-15 at the Rajola Krishi Research Farm, Faculty of Agricultural Sciences, Mahatma Gandhi Chitrakoot Gramodaya Vishwa Vidyalaya, Chitrakoot – Satna, Madhya Pradesh, India to study the effect of phosphorus and biofertilizers on phosphorus use efficiency (PUE) and biological N-fixation (BNF) yield of pigeonpea (*Cajanus cajan* L.) variety UPAS-120. The agronomical and physiological PUE and its recovery were found significantly higher (10.40, 44.83 and 13.09 respectively) under the lowest level of phosphorus (P_{30}). The reserve was true in case of P_{90}. Dual biofertilizers (*Rhizobium* + PSB) gave significantly higher physiological PUE over single biofertilizer; where as agronomical PUE and recovery were found identical. Application of phosphorus up to 90 kg P_2O_5/ha gave maximum grain yield (16.06 q/ha). The dual biofertilizers also gave maximum yield up to 15.56 q/ha. The BNF was highest in these treatments. Hence the N-balance in soil was maximum (230 kg/ha).

Highlights

- Application of P_{60} or P_{90} with *Rhiz.*+ PSB resulted in maximum N-up take by the crop (87.3 to 89.3 kg/ha). Consequently, the apparent N-balance was form lowest (13.77 to 139.7 kg/ha). Since both these treatment combinations resulted in highest biological N-fixation by the crop.
- The highest P-level significantly increased all the yield attributes of pigeonpea as compared to the lower P-level.
- The combined applications of *Rhizobium* +PSB augmented all these parameters almost significantly over *Rhizobium* alone and control treatment.

Keywords: Biofertilizers, pigeonpea, yield, BNF, PUE, *Rhizobium* and PSB

Phosphorus plays a vital role in photosynthesis, respiration, energy storage, energy transfer, cell division cell elongation and several other processes within plant system (Rakshit *et al.*, 2015). It promotes early root formation, growth and improves harvest index of crops. Phosphorus, when applied to legumes, enhances the activity of *Rhizobium* by increasing nodulation and thereby helps in atmospheric nitrogen fixation.

Biofertilizers having the capability to fix atmospheric nitrogen or to transform native soil nutrients such as phosphorus, zinc, copper, iron, sulphur etc., from the non useable (fixed) to form through biological processes. Biofertilizers are the ultimate renewable sources and have played potential role in evolving judicious combinations with chemical fertilizers to further supplement the nutrient requirements of crops (Nyekha *et al.*, 2015).

Rhizobium inoculation has been proved as the cheapest source in place of nitrogen fertilizer input for better crop yield particularly in legumes. Mungbean is capable to fixing atmospheric nitrogen through *Rhizobium* species living in root nodules. In natural ecosystems, phosphorus availability in soil is governed by dynamic equilibrium that exists between solid and solution phase via-a- vis soil constituent affecting transformation of applied phosphorus. Both phosphorus status and P-fixing capacity of soil strongly influences the phosphorus availability (Bhal and Aulakh, 2003) and Tiwari *et al.* (2015). Application of phosphorus increased the production of pulse crops (Sharma *et al.* 2014) Gulpadiya and Chhonker (2014). Looking to above facts in view the present experiment was taken up.

Methods and Materials

The experiment was conducted during two *kharif* (rainy) seasons of 2013 and 2014 at the Rajola Krishi Research Farm, Faculty of Agricultural Sciences, Mahatma Gandhi Chitrakoot Gramodaya Vishwa Vidyalaya, Chitrakoot – Satna, Madhya Pradesh, India. The soil of the field was sandy-loam having pH 7.7-7.8, electrical conductivity 0.28 to 0.30 dS/m, organic carbon 0.33-0.34%, available N 205 to 208.8 kg/ha, P_2O_5 15.38 to 16.44, K_2O 237.6 to 242.0 kg/ha in both years. The treatments comprised four phosphorus levels (0, 30, 60 and 90 kg/ha) and four treatments of biofertilizers (no biofertilizer, *Rhizobium*, PSB and *Rhizobium*+ PSB alone as well as in combination).

Thus, the sixteen treatment combinations were laid out in the field in a factorial randomized block design keeping three replications. Pigeonpea variety UPAS-120 has sown @ 15 kg seed/ha in rows 60 cm apart on 21st July in 2013 and 2014. A uniform dose of 20 kg N and 20 kg K_2O/ha was applied through urea and MOP as basal in all the treatments in 60 cm apart open furrows just before sowing of seed on the same furrow. Among the phosphorus levels all were applied as basal through single superphosphate having 16% P_2O_5. Before sowing, the seeds were first treated with thirum fungicides @ 3 g/kg seed and after that the seed were further treated with *Rhizobium* biofertilizer @ 20 g/kg seed as per treatment. The PSB (Phosphate-solubilizing bacteria) biofertilizer was also applied in the same furrows @ 20 g/kg seed mixed with farm yard manure in third treatment. The fourth treatment was the combined application of both the biofertilizers in furrows. The pigeonpea was grown as per recommended package of practices. Seed protein was estimated by multiplying % N content with 6.25 (A.O.A.C., 1997).

Results and Discussion

Phosphorus Use Efficiency (PUE)

The pooled data in summery table 6.4 indicate the agronomical and physiological phosphorus use efficiency as well as its recovery was found significantly higher under lowest level of applied phosphorus (P_{30}). The corresponding values were 10.40, 44.83 and 13.09, respectively. With the increase in phosphorus levels up to P_{90} these were lowest down significantly. Thus at P_{90} the agronomical and physiochemical PUE as well as recovery were found lowest (6.37, 17.85 and 6.94), respectively. Thus it is apparent that there is inverse relationship between PUE and P-levels. These results are in close conformity with those the finding of Nandini Devi *et al*. (2012).

In case of biofartilizer treatments, agronomical PUE and recovery were found to be statistically identical, whereas physiological PUE was differed up to significant extent. Dual biofartilizer (*Rhiz*. + PSB) resulted in significantly higher physiological PUE (24.62) as compared to single applied biofartilizer (21.89 to 23.31) and control (19.21). In case of biofertilizer treatment, it is interesting to note that the increase supply of phosphorus tender to lowered down in physiological PUE, whereas action of dual biofartilizer supplying N and P, respectively brought about enhanced physiological PUE up to significant extent. More over the agronomical PUE as well as recovery did not change and remained equally in the lower range. The present findings are in close agreement with those of Parewa *et al.,* (2010) Kushwaha (2011) and Nandini Devi *et al.* (2012).

Grain yield per hectare

The application of phosphorus up to P_{90} resulted in significantly higher grain yield of pigeonpea variety UPAS-120 (Table 1). This might to be as a result of maximum plant growth associated with greater

Table 1: Effect of P-levels and biofertilizers on phosphorus use efficiency and recovery and yield of pigeonpea and N-balance in soil (pooled for 2 seasons)

Treatment	Agronomical PUE	Physiological PUE	Recovery	Seed yield (q/ha)	Biological N – fixation by crop (Kg/ha)	Actual N balance in soil after harvest of crop (Kg/ha)
Phosphorus Levels (Kg/ha)						
Control	0.00	0.00	0.00	10.33	41.60	215.10
P_{30}	10.40	44.83	13.09	13.45	63.20	220.90
P_{60}	9.14	26.35	9.60	15.81	79.40	227.60
P_{90}	6.37	17.85	6.94	16.06	84.50	230.30
CD (P=0.05)	1.22	0.98	0.87	0.45	—	—
Biofertilizers						
Control	6.07	19.21	7.11	12.03	47.90	214.4
Rhizobium	6.93	21.89	7.54	13.57	64.90	222.50
PSB	6.95	23.31	7.87	14.49	73.60	226.60
Rhiz + PSB	5.97	24.62	7.12	15.56	82.20	230.50
CD (P=0.05)	NS	0.98	NS	0.45	—	—
PxB interaction	NS	1.97	NS	NS	—	—

Table 2: Biological Nitrogen Fixation (BNF) as influenced by different treatment combination of phosphorus and biofertilizers (two years mean data)

Treatment combination	Initial –N	N-added through fertilizers	Total initial -N	N-uptake by crop	Apparent–N balance	Actual N balance in soil after harvest of crop	Biological N – fixation by crop
	(Kg ha^{-1})	(Kg ha^{-1})	(Kg ha^{-1})	(Kg ha^{-1})	(Kg ha^{-1})	(Kg ha^{-1})	(Kg ha^{-1})
	A	B	C= (A+B)	D	E= (C-D)	F	G= (F-E)
$P_0 BF_0$	207	20	227	42.9	184.1	210.3	26.2
$P_0 BF_1$	207	20	227	51.6	175.4	215.4	40.0
$P_0 BF_2$	207	20	227	56.6	170.4	216.2	45.8
$P_0 BF_3$	207	20	227	62.8	164.2	218.6	54.4
$P_1 BF_0$	207	20	227	59.0	168.0	213.8	45.8
$P_1 BF_1$	207	20	227	69.0	158.0	219.2	61.2
$P_1 BF_2$	207	20	227	73.4	153.6	221.9	68.3
$P_1 BF_3$	207	20	227	75.6	151.4	228.7	77.3
$P_2 BF_0$	207	20	227	68.4	158.6	215.6	57.0
$P_2 BF_1$	207	20	227	78.1	148.9	224.3	75.4
$P_2 BF_2$	207	20	227	81.7	145.3	233.3	88.0
$P_2 BF_3$	207	20	227	87.3	139.7	237.0	97.3
$P_3 BF_0$	207	20	227	71.7	155.3	218.0	62.7
$P_3 BF_1$	207	20	227	79.1	147.9	230.9	83.0
$P_3 BF_2$	207	20	227	84.4	142.6	234.8	92.2
$P_3 BF_3$	207	20	227	89.3	137.7	237.6	99.9

accumulation of the protein, carbohydrates and their translocation to the reproductive organs under increased supply of phosphorus. These results are in close assortment with those of Nyekha *et al.* (2015), Singh *et al*. (2008), Kumar and Singh (2011) and Singh *et al*. (2016). Seed inoculation with *Rhizobium* + PSB enhanced grain yield (15.56 q/ha) over the individual biofertilizers. These results corroborate with these of Kumawat and Kumawat (2009), Marko *et al.* (2013), Sharma *et al*. (2006), Raj *et al*. (2014), Singh *et al*. (2016).

Table 3: Nitrogen balance in post harvest soil (kg/ha) under different treatments their interactions

Biofertilizers	Phosphorus levels				Mean
	P_0	P_{30}	P_{60}	P_{90}	
Actual N- balance in soil					
Control	210.3	213.8	215.6	218.0	214.4
Rhizobium	215.4	219.2	224.3	230.9	222.5
PSB	216.2	221.9	233.3	234.8	226.5
Rhiz + PSB	218.6	228.7	237.0	237.6	230.5
Mean	215.1	220.9	227.6	230.3	
Biological N-fixation by crop					
Control	26.2	45.8	57.0	62.7	47.9
Rhizobium	40.0	61.2	75.4	83.0	64.9
PSB	45.8	68.3	88.0	92.2	73.6
Rhiz + PSB	54.4	77.3	97.3	99.9	82.2
Mean	41.6	63.2	79.4	84.5	

Nitrogen balance in soil (kg/ha)

The results in Table-2 and 3 indicate that the actual N-balance (kg/ha) in the post-harvest soil was estimated treatment wise based on the total N-additions in the soil and N-taken up/ha by the crop. Increasing levels of phosphorus up to P_{90} as well as dual biofertilizers (*Rhizobium* +PSB) resulted in maximum N-balance in the soil (230.03 to 230.5 kg/ha.) the biological N-fixation was also found highest in these treatment (82.2 to 84.5 kg/ha). This was owing to the combined unique role of micro biological activities in the soil under increased root nodulation in the rhizosphere as a result of applied phosphorus and dual biofartilizers. The details on these aspects have already been discussed earlier.

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