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Original Research Article

Effect of Phosphorus and Biofertilizer on Growth, Yield and Economics of Pigeonpea (*Cajanus cajan* L. Millsp.) Under Rainfed Condition

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Keywords

Pigeonpea, Phosphorus, Biofertilizer

A B S T R A C T

The field investigation entitled "Effect of phosphorus and biofertilizers on growth, yield and economics of pigeon pea (*Cajanus cajan* L. Millsp.) under rainfed condition" was conducted at Experimental Farm, Agronomy Section, College of Agriculture, Latur. The experimental field was leveled and well drained.). The soil was medium and black in colour with good drainage. The soil was clayey in nature and slightly alkaline (7.8) in reaction, low in nitrogen, medium in available phosphorus and rich in available potassium. The environmental conditions were favorably congenial for normal growth and maturity of pigeonpea crop. The experiment was laid out in Factorial Randomized Block Design with two factors and replicated thrice. Whereas first factor comprises levels of phosphorus *viz.* 0 (control), 40, 50 and 60 kg P ha^{-1}, second factor comprises seed inoculations with biofertilizer *viz.* alone inoculation of *Rhizobium* @ 6 ml kg^{-1} seeds, alone inoculation PSB @ 6 ml kg^{-1} seeds and dual inoculation *Rhizobium* + PSB each of @ 6 ml kg^{-1} seeds. The application of phosphorus @ 60 kg ha^{-1} given significantly higher growth and yield attributes, gross monetary return, net monetary return and B: C ratio over the rest of the levels of phosphorus. Whereas NMR was remained at par with 50 kg P ha^{-1}. Among three biofertilizer treatments, dual seed inoculation with *Rhizobium* + PSB was recorded higher growth and yield attributes, gross monetary return, net monetary return and B: C ratio than the individual seed inoculation of *Rhizobium* or PSB.

Introduction

Pigeonpea (*Cajanus cajan* L. Millsp.) is one of the major grain legume (pulse) crop of the tropics and subtropics, endowed with several unique characteristics. It finds an important place in the farming system adopted by small holder farmer in a large number of developing countries. Although, globally pigeon pea ranks sixth in area and production in comparison to other grain legumes such as beans, peas and chickpeas, it is used in more diversified ways than other.

Phosphorus is a key element involved in various function in growth and metabolism of pulses. It is frequently a major limiting nutrient for plant growth in most Indian soils. Only a part of the phosphorus supplemented through fertilizers is utilized by the plants and a large portion of it is converted into insoluble fixed forms, the recovery efficiency of phosphorus in crops of is generally 10-30% (Swarup, 2002). Phosphorus solubilising bacteria (PSB) can play an important role in increasing phosphorus availability by solubilising the P and supplying it to plants in a more available form (Khan *et al.,* 2007).

Phosphorus deficiency in soils is usually the key factor for poor yield of pulses. Yield of pulses can significantly be increased by applying phosphorus on the basis of soil test information. Phosphorus applied to pulse crops may yield residual effect up to a limit of 20-35 kg P_2O_5 ha^{-1}. Inoculation of seeds with phosphorus solubilising organisms like PSB (phosphate solubilising bacteria) and PSF (phosphate solubilising fungi) results in increase of phosphorus use efficiency. The degree of response to applied phosphorus can further be improved management practices.

Phosphorus is an important mineral element for grain legumes as it helps in root development, participates in synthesis of phosphates and phosphoprotiens and takes part in energy fixing and releasing process in plants. Significant response of pigeon pea to phosphate nutrition has been reported by several workers (Singh and Yadav, 2008). Biofertilizers enhance soil fertility and crop yield by solubilizing unavailable sources of elemental nitrogen and bound phosphate into available forms in order to facilitate the plant to absorb them. *Rhizobium* fixes nitrogen up to 4-200 kg ha^{-1} in pigeon pea. *Rhizobium* inoculation improved nodulation, nitrogen fixation, crop growth and yield. Efficiency of bacteria is more than fungal strains. PSB substitutes 15-20 percent dose of phosphorus and this mechanism governed by phosphates production.

The term biofertilizer, represent everything from manures to plant extracts. Biofertilizers are those substances that contain living microorganisms and they colonize the rhizosphere of the plant increase the supply or availability of primary nutrient and or growth stimulus to target crop. There are numerous species of soil bacteria that colonize mainly in the rhizosphere of plants. Rhizobium belongs to family *Rhizobiaceae*, it is the symbiotic in nature, it fixes 50-100 kg ha^{-1} nitrogen with legumes only. It includes following genera*: Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium and Allorhizobium*. Rhizobium is the most studied and important genera of nitrogen fixing bacteria (Odame, 1997). Phosphate solubilising microorganisms releases metabolite such as organic acid latter being converted into the soluble form (Nahas, 1996). Phosphate solubilising microorganisms dissolve soil through production of low molecular weight organic compound mainly gluconic and ketogluconic acid (Khan *et al.,* 2009)

Inoculants of efficient nitrogen fixing *Rhizobium* and phosphate solubilizing bacteria (PSB) which have established their capability in augmenting the productivity of pulses may fulfill the nitrogen and phosphorus needs considerably. The prices of inorganic fertilizers are beyond the reach of marginal farmers. Under these circumstances the present investigation is proposed to undertake entitled as "Effect of phosphorus and biofertilizers on growth, yield and economics of pigeonpea (*Cajanus cajan* L. Millsp.) under rainfed condition"

Materials and Methods

The field investigation entitled "Effect of phosphorus and biofertilizers on growth, yield and economics of pigeon pea (*Cajanus cajan* L. Millsp.) under rainfed condition" was conducted during kharif season 2016-2017 at Experimental Farm, Agronomy Section, College of Agriculture, Latur. The experimental field was leveled and well drained.). The soil was medium and black in colour with good drainage. The soil was clayey in nature and slightly alkaline (7.8) in reaction, low in nitrogen, medium in available phosphorus and rich in available potassium. The environmental conditions were favorably congenial for normal growth and maturity of pigeonpea crop.

The experiment was laid out in Factorial Randomized Block Design with two factors and replicated thrice. Whereas first factor comprises levels of phosphorus *viz*. 0 (control), 40, 50 and 60 kg P ha^{-1}, second factor comprises seed inoculations with biofertilizer *viz*. alone inoculation of *Rhizobium* @ 6 ml kg^{-1} seeds, alone inoculation PSB @ 6 ml kg^{-1} seeds and dual inoculation *Rhizobium* + PSB each of @ 6 ml kg^{-1} seeds. The experimental site having gross and net plot size was 5.4 x 4.5 m^2 and 4.2 x 3.9 m^2 respectively. The recommended dose of fertilizer was applied at time sowing (25:50:00 NPK kg ha^{-1} where P applied as per treatments). The sowing was done on 22nd June 2016 by dibbling and harvested on 3rd January 2017. All the cultural practices were followed by as per package of practices. The yield data for seed and straw yield for all plots were collected at the end of experimentation. Processed seed sample were digested and N was determined by micro kjeldahal method as advocated by Piper (1966). Protein content was calculated by multiplying N content by the factor 6.25.

Results and Discussion

Growth parameters

The effect of different treatments was noticed on important growth parameters viz., plant height, number of nodules plant-^{1}, number of braches plant^{-1}, dry matter plant$^{-1,}$ leaf area index, was influenced significantly due to the application of phosphorus and biofertilizer.

The application of 60 kg P ha^{-1} produced more vegetative growth in early period of crop growth. The effect of different levels of phosphorus on plant height was found to be significant and higher plant height was observed by the application of 60 kg P ha^{-1} at all the growth stages. It was remained at par with 50 and 40 kg P ha^{-1} and significantly superior over control (0 kg P ha^{-1}). The increase in plant height due to higher levels of phosphorus might be resulted towards beneficial effect of phosphorus on root proliferation, nodulation and accelerating effect of P on the synthesis of protoplasm there by plants grew taller. Similar results were reported by Kumar and Kushwaha (2006), singh and Ahlawat (2007), Singh and Yadav (2008), Kumar *et al.,* (2012), Singh and Singh (2012), Malik *et al.*, (2013) and Singh *et al.*, (2014).

The inoculation of *Rhizobium* + PSB recorded significantly the highest mean plant height (175.6 cm) followed by the individual seed inoculation of *Rhizobium* (165.8 cm) and PSB (162.6 cm). Seed inoculation of PSB found to be at par with *Rhizobium* inoculation at all growth stages. Combined seed inoculation with *Rhizobium* + PSB improved N and P status of soil and ultimately increased N and P uptake which enhance the plant growth attaining higher plant height. Similar findings reported by Singh and Yadav (2008), Singh and Singh (2012), Malik *et al.*, (2013).

It was observed from data on number of nodules plant^{-1} that the rate of increasing number of nodules plant^{-1} was slow up to 30 DAS, fast between 30-60 DAS and reduced from 90 DAS to maturity. The application of 60 kg P ha^{-1} was produced higher number of nodules plant^{-1} (23.1) at 90 DAS and found to be at par with 50 and 40 kg P ha^{-1} and remained significantly superior over no phosphorus application (P_0). The nodules plant^{-1} with addition of successive doses of P increased because phosphorus helps the plant to provide favourable condition for nodulation. Close confining results were given by Kumar and Kushwaha (2006) and Mahetale and Kushwaha (2011).

The application of 60 kg P ha^{-1} was recorded higher number of branches (7.9) and found to be at par with 50 and 40 kg P ha^{-1} and significantly superior over control. Phosphorus improved the nutrient availability resulting greater nutrient uptake which might have increased the photosynthesis and translocation of assimilates to different parts for enhanced growth of number of primary and secondary branches. Similar results were confined by Singh and Sekhon (2007), Singh and Ahlawat (2007), Singh and Yadav (2008), Mahetale and Kushwaha (2011), Kumar *et al.*, (2012), Singh and Singh (2012), Malik *et al.*, (2013) and Singh *et al.*, (2014). The application of 60 kg P ha^{-1} was recorded higher dry matter accumulation (34.9 g) and found significantly superior over without application of phosphorus. Beneficial effect of P attributed towards root proliferation, nodulation and synthesis of protoplasm gave higher pace of dry matter accumulation. The results are in close conformity with the findings of Kumar *et al.*, (2012), Singh and Singh (2012), Malik *et al.*, (2013) and Singh *et al.*, (2014).

Dual seed inoculation of *Rhizobium* + PSB (B_3) was recorded higher dry matter and found significantly superior over *Rhizobium* or PSB inoculation alone at all growth stages. Seed inoculation of PSB found to be at par with Rhizobium inoculation at all the growth stages. The application of phosphorus @ 60 kg ha^{-1} recorded higher LAI (0.25) than rest of phosphorus levels at all growth stages. The dual seed inoculation of *Rhizobium* + PSB (B_3) recorded higher LAI than either seed inoculation of *Rhizobium* or PSB at 90,120 DAS and harvest.

Yield parameters

The yield and contributory attributes viz., Seed yield kg ha$^{-1,}$ No of pods plant $^{-1}$, protein content, protein yield and harvest index.

The application of 60 kg P ha^{-1} recorded higher seed yield kg ha^{-1} (2613 kg ha^{-1}) followed by the application of 50 (2475 kg ha^{-1}), 40 kg P ha^{-1} (2231 kg ha^{-1}) and control (1828 kg mha^{-1}). Phosphorus plays a pivotal role in the higher yield, by stimulation of root development, energy transformation and metabolic processes in the plants, which turn, resulted in greater translocation of photosynthates towards the sink development. Ultimately the seed yield plant^{-1} was improved which resulted in higher seed yield (kg ha^{-1}) These results are in close conformity with the findings of Singh and Sekhon (2007), Singh and Yadav (2008), Deshbhratar *et al.*, (2010), Pramod *et al.*, (2012), Singh and Singh (2012), Malik *et al.*, (2013) Kumar and Singh (2014), Singh *et al.*, (2014), Aher *et al.*, (2015) and Kumar *et al.*, (2015).

The highest seed yield (kg ha^{-1}) obtained due to dual seed inoculation of *Rhizobium* + PSB (2660 kg ha^{-1}) followed by PSB (2279 kg ha^{-1}) and *Rhizobium* (1921 kg ha^{-1}). Combined effect *Rhizobium* + PSB improved N and P status of soil and ultimately increased N and P uptakes which enhanced yield attributes and yield of crop. The results are close of conformity with the findings of Singh and Yadav (2008), Goud and Kale (2010), Subba *et al.*, (2011), Singh and Singh (2012), Malik *et al.*, (2013), Kumar *et al.*, (2015), Pandey and Kushwaha (2009), Reddy *et al.*, (2011) and Tiwari *et al.*, (2011).

Table.1 Effect of phosphorus and biofertilizer on growth attributes of pigeonpea

Treatments	**Plant height (cm)**	**No.of nodules plant^{-1} at 90 Days**	**No. of branches plant^{-1} at harvest**	**Total dry matter plant^{-1}**	**Leaf area index at 120 days**
A) Phosphorus levels (kg ha^{-1})					
P_0 : Control	157.8	19.8	6.8	149.7	0.22
P_1 : 40	169.9	22.0	7.4	177.0	0.25
P_2 : 50	170.8	22.3	7.5	186.7	0.24
P_3: 60	173.8	23.1	7.9	188.1	0.25
SE m±	3.9	0.6	0.2	4.3	-
CD at 5 %	11.6	1.9	0.6	12.6	-
B) Biofertilizers					
B_1 : *Rhizobium*	162.6	21.2	6.9	165.8	0.23
B_2 : PSB	165.8	20.8	7.3	173.7	0.23
B_3 : *Rhizobium* + PSB	175.6	23.4	7.9	186.6	0.26
SE m±	3.4	0.5	0.2	3.7	-
CD at 5 %	10.1	1.6	0.5	10.9	-
Interaction (P x B)					
SE m±	6.9	1.1	0.4	7.5	-
C.D. at 5 %	**NS**	**NS**	**NS**	**NS**	**-**
General Mean	**168.1**	**21.8**	**7.4**	**175.4**	**0.24**

Table.2 Effect of phosphorus and biofertilizer on yield attributes of pigeonpea

Treatments	Seed yield kg ha^{-1}	No.of pods $plant^{-1}$ at harvest	Harvest index (%)	protein content(%)	protein yield (kg/ha)
A) Phosphorus levels (kg ha^{-1})					
P_0 : Control	1828	172.2	24.33	18.62	340
P_1 : 40	2231	189.4	24.60	18.75	419
P_2 : 50	2475	207.8	24.65	18.92	467
P_3: 60	2613	209.3	25.57	19.32	505
SE m±	63	5.5	-	0.18	12
CD at 5 %	184	16.2	-	NS	34
B) Biofertilizers					
B_1 : *Rhizobium*	1921	187.7	24.28	18.66	357
B_2 : PSB	2279	189.2	24.36	18.91	432
B_3 : *Rhizobium* + PSB	2660	207.1	24.93	19.15	510
SE m±	55	4.8	-	0.15	10
CD at 5 %	159	14.1	-	NS	30
Interaction (P x B)					
SE m±	108	9.3	-	0.30	20
C.D. at 5 %	**NS**	**NS**	**-**	**NS**	**NS**
General Mean	**2287**	**194.7**	**24.63**	**18.90**	**433**

Table.3 Effect of phosphorus and biofertilizer on **economics** of pigeonpea

Treatments	Gross monetary return(`)	Net monetory return(`)	B:C Ratio
A) Phosphorus levels (kg ha^{-1})			
P_0 : Control	93751	59037	2.7
P_1 : 40	114374	76407	3.0
P_2 : 50	126895	88098	3.3
P_3: 60	133994	94405	3.4
SE m$\pm$	3177	3177	-
CD at 5 %	9317	9317	-
B) Biofertilizers			
B_1 : *Rhizobium*	98550	60796	2.6
B_2 : PSB	116858	79104	3.1
B_3 : *Rhizobium* + PSB	136353	98560	3.6
SE m$\pm$	2751	2751	-
CD at 5 %	8069	8069	-
Interaction (P x B)			
SE m$\pm$	5503	6276	-
C.D. at 5 %	**NS**	**NS**	-
General Mean	**117254**	**79486**	**3.1**

It was observed from data on mean number of pods plant^{-1} it was increased progressively from 150 DAS till to maturity. The application of 60 kg P ha^{-1} produced higher mean number of pods plant^{-1} (209.3) which was at par with 50 kg P ha^{-1} (207.8) and significantly superior over 40 kg P ha^{-1} (189.4) and control (172.2). Phosphorus improved in the rate of symbiotic N fixation and it turn, stimulates the growth and number of pods plant^{-1}.The similar findings was reported by Kumar and Kushwaha (2006), Singh and Sekhon (2007), Singh and Ahlawat (2007), Deshbhratar *et al.*, (2010), Mahetale and Kushwaha (2011), Kumar *et al.*, (2012) Kumar and Singh (2014), Singh *et al.*, (2014) and Aher *et al.*, (2015).

The higher number of pods plant^{-1} were 198.6 and 207.1 obtained due to dual seed inoculation of *Rhizobium* + PSB at 150 DAS and at harvest respectively. It was found significantly superior over *Rhizobium* or PSB inoculation alone. Seed inoculation of PSB and *Rhizobium* was remaining at par with each other.

The highest harvest index was obtained (25.57%) by application of 60 kg P ha^{-1} but differences between the harvest index was nearly same at all treatments. The results are close conformity to the findings of Mahetele and Kushwaha (2011), Singh and Singh (2012) and Ahet *et al.*, (2015).

Data on harvest index was shown that the there was no any significant effect by inoculation with biofertilizer. Dual seed inoculation of *Rhizobium* + PSB was recorded the highest harvest index (24.93%) followed by individual inoculation PSB (24.36%) and *Rhizobium* (24.28%). This may be happens due to the increased economic yield in comparison with biological yield. Increase in economic yield due to more availability of N and P. These results are close of conformity with the findings of for *Rhizobium* and PSB inoculation by Sing *et al.*, (1978) and Mahetele and Kushwaha (2011) respectively.

Quality parameters

The effect of different levels of phosphorus on mean protein content and mean protein yield was found to be significant. Phosphorus is structural element of certain co-enzyme involved in protein synthesis, while the increase in protein content in grain and grain yield. The application of 60 kg P ha^{-1} recorded significantly higher mean protein content and mean protein yield (19.32 % and 505 kg ha^{-1}) followed 50 kg P ha^{-1} (18.92 % and 467 kg ha^{-1}), 40 kg P ha^{-1} (18.75 % and 419 kg ha^{-1}) and control (18.62 % and 340 kg ha^{-1}).

The significant differences were not evident in respect of protein content in pigeonpea seeds due to different levels of phosphorus. However, the highest protein content (19.32 %) was observed with the application of 60 kg P ha^{-1}.

The highest protein content in pigeonpea was not significantly influenced by biofertilizer treatments. However, the highest protein content (19.15%) was observed due to the dual seed inoculation of *Rhizobium* + PSB.

Economics

The gross monetory return, net monetory return and benefit cost ratio are influenced by different levels of application of phosphorus and biofertilizers. The higher gross monetary return (` 133994 ha^{-1}) was obtained due to the application of 60 kg P ha^{-1} and it was significantly superior over rest of the levels of phosphorus.

The maximum gross monetary return (` 136353 ha^{-1}) was obtained due to the dual seed inoculation of *Rhizobium* + PSB treatment which was found significantly superior over individual inoculation of *Rhizobium* or PSB.

The significantly highest net monetary return (` 94405 ha^{-1}) was received due to the application of 60 kg P ha^{-1}. It was remained at par with 50 kg P ha^{-1} and found significantly superior than 40 kg P ha^{-1} and without application of phosphorus (P_0).

The net monetary return due to individual inoculation of *Rhizobium* or PSB was obtained significantly lowest net monetary return than dual inoculation of *Rhizobium* + PSB culture. The dual seed treatment of *Rhizobium* + PSB culture gave the highest net monetary return (` 98560 ha^{-1}). Whereas treatment of PSB was found significantly superior than *Rhizobium* treatment.

The application of phosphorus @ 60 kg ha^{-1} was recorded highest benefit cost ratio (3.4) followed by 50 kg P ha^{-1} and 40 kg P ha^{-1}.Highest benefit: cost ratio was recorded due to the dual seed inoculation of *Rhizobium* + PSB (3.6) followed by *Rhizobium* and PSB culture treatment.

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