Studies on the efficiency of rock phosphate as a source of phosphorus to pigeonpea (*Cajanus cajan*) in acid laterite soil of West Bengal

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ABSTRACT
Field experiment on pigeonpea [*Cajanus cajan* (L.) Millsp.] with cultivar 'UPAS 120' was conducted during rainy *(kharif*) seasons of 2004 and 2005 at the Regional Research Substation, Sekhampur, to evaluate the effect of Rock Phosphate (RP) alone and with single super phosphate (SSP), farm yard manure (FYM) and phosphate-solubilizing bacteria (PSB) on crop productivity, phosphorus uptake and availability of phosphorus in acid laterite soil of West Bengal. The results revealed that the root nodulation, growth and yield parameters were highest in the treatment which received 50 % RP + 50 % SSP along with FYM and PSB, which was significantly different from the treatment with 100 % SSP alone. This treatment produced significantly higher seed yield (28.20 % and 8.29 %) over the control (no phosphorus) and 100 % SSP alone respectively. The phosphorus availability in soil was gradually increased from the initial stage in all RP treated plots, while a declining trend up to harvest stage was found with 100 % SSP alone. The highest uptake of phosphorus in the crop was also registered by the treatment with 50 % RP + 50 % SSP in combination with FYM and PSB. The study indicated that the integrated use of the indigenous source of phosphorus (RP), SSP, organic manure (FYM) and bio-fertilizer (PSB), besides curtailing the input cost, can effectively be used to improve yield of the long duration pigeonpea crop and to increase phosphorus availability in soil.

Key words : Pigeonpea, Rock Phosphate, Phosphorus.

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is one of the most important *kharif* pulses suitable for rainfed upland situation. With regards to its production, the average yield of the crop is low mainly due to lack of proper nutrient management. Phosphorus is the backbone of any nutrient management programme for intensive cropping system. It is well known that the phosphorus is one of the major nutrients which is required in large quantities particularly for pulse crop for nodulation, N fixation, optimal growth and yield, but it is a major constraints as 98 % of soils in India have inadequate supply of P (Kanawar and Grewal, 1990). So, there is an imminent need for application of P to achieve higher yields of crops in the soils having low P availability (Goswami and Kamath, 1999). However, phosphatic fertilizer is a costly input. Large amounts of low-grade rock phosphate have been located in some parts of India, of which an economically viable deposit occurs in Mussoorie (U.P). In order to make economic use of these materials, they have to be directly used as fertilizer. Keeping this in view, the present investigation was under taken to elicit information on the crop yield, P availability and uptake of P as influenced by application of Mussoorie Rock Phosphate alone and in conjugation with SSP, organic manure (FYM) and bio-fertilizer (PSB) to pigeonpea in acid laterite soil of West Bengal.

MATERIALS AND METHODS

The field experiment was conducted during rainy (*kharif*) seasons of 2004 and 2005 at the Regional Research Substation, Sekhampur, Birbhum, West Bengal ($23^0 54^/$ N latitude and $87^0 34^/$ E longitude), using pigeonpea variety 'UPAS 120'in rainfed upland situation. The soil of the experimental site was acid lateritic (Entisol) having sandy-clay loam in texture with a pH of 5.6, organic carbon 0.46%, available P11.88 kg/ha, available K 210 kg/ha. The experiment was laid out in a randomized block design with three replications and fourteen treatments given below.

T_1-Control (no phosphorus); T_2-100 % P_2O_5 as SSP (50 kg P_2O_5 /ha); T_3-100 % P_2O_5 as RP (50 kg P_2O_5/ha); T_4-T_3 + Phosphate-solubilizing bacteria (PSB) for seed inoculation as well as soil application; T_5-T_3 + Farm yard manure (FYM) @ 5 t /ha; T_6-T_5 + PSB (seed inoculation as well as soil application); T_7-75 % P_2O_5 as RP + 25 % P_2O_5 as SSP; T_8-T_7 + PSB (seed inoculation as well as soil application); T_9-T_7 + FYM @ 5 t /ha; T_{10}-T_9 + PSB (seed inoculation as well as soil application); T_{11}-50 % P_2O_5 as RP + 50 % P_2O_5 as SSP;

T_{12} -T_{11} + PSB (seed inoculation as well as soil application); T_{13}-T_{11} + FYM @ 5 t /ha and T_{14}-T_{13} + PSB (seed inoculation as well as soil application).

The crop was sown at 50 cm x 20 cm spacing during the month of July and harvested during December. Well-decomposed FYM was applied first to the plots as per the treatment schedule and incorporated to the soil 7 days prior to sowing. A basal dose of N @ 20 kg /ha and K_2O @ 30 kg /ha were given uniformly to all the plots. Mussoorie rock phosphate (contains 18 % P_2O_5) was mixed thoroughly in the soil and the entire dose of P was applied as basal as per the treatments. Phosphate-solubilizing bacteria (*Psuedomonas striate*) was applied @ 2 kg /ha to soil and 600 g for inoculation of 20 kg seed before sowing. The total rainfall during the crop period was 1050 and 1130 mm in 1^{st} and 2^{nd} year of experimentation.

Soil samples were collected at 50, 100 and 150 days after sowing (at harvest stage) and analyzed for available P by Olsen's method (Jackson, 1973). P content in the crop (seed and stover) at harvesting stage was determined by

Vanadomolybdate yellow colour method (Jackson, 1973) and the nutrient uptake was calculated for seed and stover individually by multiplying the respective P contents and yields. The data on root nodulation, growth and yield parameters of pigeonpea were statistically analyzed.

RESULTS AND DISCUSSION

Growth parameters and root nodulation

Growth parameters namely, plant height, number of branches /plant, root length etc. and nodules /plant showed a variation due to different treatments (Table 1). Plant height, number of branches per plant, root length and nodules / plant were recorded highest by application of 50 % RP + 50 % SSP along with FYM and PSB compared to other treatments. This might be due to the application of 50 % RP + 50 % SSP in combination with organic manure (FYM) and bio-fertilizer (PSB) enhance the availability of P in the rhizosphere and favour better root growth and nodulation which in turn enables plant to extract more water and nutrient from soil as well as to assimilate greater atmospheric nitrogen resulting in to taller plant with more branches. Similar effects of rock phosphate on green gram was also reported by Bagavathiammal and Mahimairaja (1999). The lowest values in regard to these characters were registered in control (no phosphorus).

Table 1: Effect of treatments on growth parameters and root nodulation of pigeonpea (mean data of 2 years)

Treatment	Plant height (cm)	Number of branches /plant	Root length (cm)	Nodule no. /plant
T_1 - Control	130.63	13.72	41.39	12.13
T_2 - 100% SSP	140.69	16.37	48.92	19.63
T_3 - 100% RP	136.92	15.03	44.93	16.12
T_4 - T_3 + PSB	137.59	15.52	45.69	18.02
T_5 - T_3 + FYM	138.45	15.91	46.54	17.18
T_6 - T_5 + PSB	141.16	15.72	47.62	18.89
T_7 - 75 % RP + 25 % SSP	139.35	15.24	46.75	16.93
T_8 - T_7 + PSB	142.65	16.14	47.39	17.95
T_9 - T_7 + FYM	141.77	16.43	48.35	18.31
T_{10} - T_9 + PSB	143.78	16.87	49.23	19.73
T_{11} - 50 % RP + 50 % SSP	145.35	16.67	48.68	19.14
T_{12} - T_{11} + PSB	146.44	17.32	50.52	20.85
T_{13} - T_{11} + FYM	147.13	17.15	51.19	21.48
T_{14} - T_{13} + PSB	148.32	17.87	52.48	22.79
CD (P = 0.05)	6.02	1.13	2.96	1.87

Yield and yield attributes

The seed yield of pigeonpea ranged from 897 to 1150 kg /ha (Table 2). Among the different treatments tried, the treatment that received 50 % RP + 50 % SSP along with FYM and PSB recorded the highest seed yield, which might be due to more number of pods /plant and seeds /pod. This treatment produced significantly higher (8.29 %) seed yield than 100 % SSP alone. A positive and significant correlation (r = 0.79**) existed between available P and seed yield sustaining the positive role of P. The solubility of RP might be enhanced by the FYM and PSB which enabled the availability of P in the later stages also and thus favouring the increased uptake of nutrients and improved the seed yield. The increased seed yield owing to the increasing availability as well as uptake of P in pigeonpea corroborates the findings of Singh *et al*. (1985). Regarding stover yield, the similar trend was also observed among the various treatments.

Application of 50 % RP + 50 % SSP with FYM and PSB was also effective in increasing the yield attributing characters of pigeonpea and recorded maximum number of pods /plant, seeds/pod and 100-seed weight (Table 2). However, the variation in 100-seed weight was not significant among the different treatments. Phosphorus fertilization through 100 % SSP alone was superior to 100 % RP alone in producing significantly more pods /plant and higher seed yield. The results indicated the need of organic manure and bio-fertilizer application with RP for increasing its fertilizer-use efficiency. Bolland and Gilkes (1990) also reported similar results.

Soil available phosphorus

A variation in the available P content in soil was pronounced among the treatments (Table 3). The treatment that received 100 % SSP registered the highest available P content in early stages due to its more readily available water soluble P as compared to RP, followed by the treatment of 50 % RP + 50 % SSP along with FYM and PSB. The results are in agreement with the findings of Kabeerathumma and Mohankumar (1990). The P availability was gradually increased towards harvest stage in all the RP treated plots. This might be due to slow rate of

Table 2 : Effect of treatments on yield attributes and yield of pigeonpea (mean data of 2 years)

Treatment	Number of pods /plant	Number of seeds /pod	100-seed weight (g)	Seed yield (kg /ha)	Stover yield (kg /ha)
T_1 - Control	227.14	4.21	75.78	897	1401
T_2 - 100% SSP	245.23	4.63	76.16	1062	1654
T_3 - 100% RP	230.71	4.55	75.86	906	1513
T_4 - T_3 + PSB	232.26	4.34	75.89	913	1542
T_5 - T_3 + FYM	235.49	4.48	75.93	924	1581
T_6 - T_5 + PSB	239.98	4.56	76.08	1002	1613
T_7 - 75 % RP + 25 % SSP	238.17	4.45	75.81	997	1642
T_8 - T_7 + PSB	241.46	4.51	76.15	1036	1687
T_9 - T_7 + FYM	243.82	4.56	75.99	1053	1702
T_{10} - T_9 + PSB	246.91	4.67	76.11	1077	1768
T_{11} - 50 % RP + 50 % SSP	248.08	4.69	75.91	1093	1795
T_{12} - T_{11} + PSB	251.25	4.75	76.11	1115	1811
T_{13} - T_{11} + FYM	253.56	4.82	76.13	1137	1864
T_{14} - T_{13} + PSB	258.42	4.87	76.19	1150	1902
CD (P = 0.05)	10.12	0.17	NS	48	101

NS, Not significant

dissolution of RP and consequently slow release of P increased its availability for a long duration. These findings are in line with Bolland and Gilkes (1990). In the control and 100 % SSP applied plots, a declining trend in P availability up to the harvest stage was noticed; possibly due to the fixation of readily available P in acidic laterite soil.

Phosphorus uptake

The nutrient uptake is governed by dry matter

Table 3 : Effect of treatments on soil available phosphorus, phosphorus content and uptake in pigeonpea (mean data of 2 years)

Treatment	Available phosphorus (kg /ha)			Phosphorus content (%)		Phosphorus uptake (kg /ha)		
	50 DAS	100 DAS	Harvest	Seed	Stover	Seed	Stover	Total
T_1 - Control	11.36	10.92	9.53	0.50	0.49	4.48	6.86	11.34
T_2 - 100% SSP	26.37	23.19	20.85	0.62	0.60	6.58	9.92	16.50
T_3 - 100% RP	13.69	14.42	16.15	0.58	0.55	5.25	8.32	13.57
T_4 - T_3 + PSB	15.65	16.74	17.28	0.59	0.57	5.39	8.79	14.18
T_5 - T_3 + FYM	16.28	17.28	18.47	0.59	0.56	5.45	8.85	14.30
T_6 - T_5 + PSB	16.52	17.14	19.16	0.60	0.56	6.01	9.03	15.04
T_7 - 75 % RP + 25 % SSP	16.46	17.87	18.67	0.60	0.58	5.98	9.52	15.50
T_8 - T_7 + PSB	17.24	18.81	20.11	0.61	0.57	6.32	9.61	15.93
T_9 - T_7 + FYM	18.13	19.46	21.62	0.62	0.59	6.53	10.04	16.57
T_{10} - T_9 + PSB	17.57	18.93	21.94	0.62	0.60	6.68	10.61	17.29
T_{11} - 50 % RP + 50 % SSP	18.91	19.32	20.83	0.63	0.58	6.88	10.41	17.29
T_{12} - T_{11} + PSB	19.15	20.18	21.10	0.64	0.60	7.14	10.87	18.01
T_{13} - T_{11} + FYM	19.23	21.51	22.88	0.65	0.61	7.39	11.37	18.76
T_{14} - T_{13} + PSB	20.67	22.74	24.19	0.65	0.62	7.47	11.79	19.26
CD (P = 0.05)	1.29	1.38	1.45	0.04	0.03	0.59	0.95	1.18

DAS, Days after sowing

production (both seed and stover yield) and nutrient concentration in plant. Application of 50 % RP + 50 % SSP with FYM and PSB recorded the highest uptake of P by the crop (Table 3). In this study, P uptake increased with increasing P availability. Subehia and Minhas (1993) reported that application of inorganic P along with organic manures and their combination increased the P uptake over inorganic P alone. This was ascribed to the solubilization of insoluble P from rock phosphate by organic acids produced during decomposition of organic manure leading to the increased availability of P, higher P content as well as uptake in plant and this lend support to the present findings.

Moreover, integrated use of inorganic P, organic manure and bio-fertilizer registered higher P uptake because plant use more P from insoluble phosphatic fertilizer in the presence of phosphate dissolving organisms (PSB) due to maximum solubilization of phosphate by microorganisms (Vaisha *et al*., 1996) and more utilization of added P and the findings are in the line with the present findings as evidenced from the significant and positive correlation between P uptake and dry matter production (r = 0.98**).

Hence, the study has revealed that indigenously available rock phosphate can be effectively and economically used as phosphorus source to pigeonpea crop in combination with SSP, FYM and PSB for increasing the production of pigeonpea under acid laterite soil of West Bengal. To increase the use of this cheaper and effective alternate phosphorus source is an imperative need for decimating the cost of phosphatic fertilizer.

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Received : May, 2006; Accepted : November, 2006