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Effect of planting systems and phosphorus with bio-fertilizers on the performance of sole and intercropped pigeonpea (*Cajanus cajan*) under rainfed conditions

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ABSTRACT

A field experiment was conducted during *kharif* seasons of 2007 and 2008 for two consecutive years at New Delhi, to study the effect of planting systems and phosphorus management in sole and intercropped pigeonpea [*Cajanus cajan* (L.) Millsp.] under rainfed conditions. The treatment comprised of 2 cropping systems [pigeonpea sole and pigeonpea + mungbean (2:1) {*Vigna radiata* (L.) Wilczek}] and 3 planting systems (uniform row planting, broad-bed and furrow planting and paired row planting) as main plots and 4 levels of phosphorus and biofertilizers (control, 40 kg P_2O_5/ha. 40 kg P_2O_5/ha + PSB +AM and 80 kg P_2O_5/ha) as sub-plots replicated thrice in a split-plot design. Significant improvement in the yield attributes and yield of component crops was observed under modified planting systems (BBF and paired row planting) over the uniform row planting. On an average, BBF and paired row planting recorded 16.0 and 11.1% increase in pigeonpea equivalent yield and 20.1and 13.8% in net returns over flat row planting. Sole and intercropped pigeonpea recorded statistically similar growth and yield attributes and yields during both the seasons. Pigeonpea equivalent yield (1.71 and 2.01 t/ha) of intercropped stand was 14.0 and 16.1% higher than sole stand in respective season. In term of net returns, the increase was 12.6 and 12.5% respectively. Application of 80 kg P_2O_5/ha, being on par with 40 kg P_2O_5/ha + PSB + AM, recorded significantly higher growth parameters, yield attributes (except 1,000-grain weight), grain yield (1.67 and 1.87 t/ha) and stalk yield of pigeonpea over control (1.18 and 1.41 t/ha) and 40 kg P_2O_5/ha (1.43 and 1.64 t/ha). Similar effect of these treatment was observed on P content and total P uptake in grain (12.31, 13.75 kg/ha) and in stalk (11.82, 13.19 kg/ha) of pigeonpea over rest of treatments. Application of 80 kg P_2O_5/ha, being on par with 40 kg P_2O_5/ha + PSB + AM, recorded significantly higher pigeonpea equivalent yield (1.84 and 2.11 t/ha) over rest of treatments. On an average, 40 kg P_2O_5/ha + PSB + AM, recorded higher net returns and B:C ratio over remaining treatments.

Key words: Bio-fertilizers, Intercropping, Mungbean, Pigeonpea, Pigeonpea equivalent yield, Planting system, System P-uptake

Presently we are experiencing the shortage of pulses in India. Dosmestic production of pulses has been around 14-14.8 million tonnes during the last three years, while the demand is estimated at around 17-18 million tonnes. The gap between demand and supply is met by import of pulses from different countries (Economic Survey, 2009-10). Among the pulses, pigeonpea is the major rainy season (*kharif*) pulse of India and is grown either as a sole or in combination with various other crops. Being pulse crop, pigeonpea play an important role in nitrogen economy in the cropping systems by virtue of their ability to fix atmospheric nitrogen in symbiotic association with *Rhizobium* (Ahlawat *et al*., 1986). Pigeonpea, being a legume require adequate availability of P for nodulation, nitrogen fixation, growth and development and finally higher yield. It plays a vital role in the energy transformation, cell division and meristematic growth in living tissues. It is an important constituent of nucleic acids, protein, enzyme and phospholipids. Phosphorus nutrition in desired and balanced dose enhances root development, nodulation and hastens maturity (Tisdale *et al*., 1995). Phosphorus is the most limiting nutrient for legume.

The use efficiency of applied P is only 15-20% and the remaining gets fixed in the soil. To increase the efficiency of applied and native P, phosphate solubilizing bacteria (PSB) plays an important role in the solubilization of soil P through secretion of various organic acids (formic, acetic, butyric, propionic and lactic acids). These acids may bring down the soil pH resulting in the dissolution of

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bound form of phosphate. Beside PSB, favourable response of phosphate mobilizing arbuscular mycorrhizae (AM) has been reported by worker to improve the efficiency of phosphorus. However, information regarding performance of phosphorus with and without combined use of biofertilizer (PSB + AM) under various planting systems on pigeonpea intercropped situation is meager. Among the abiotic stresses, moisture deficiency as well as moisture excess or waterlogging conditions during wet season create unfavourable environment for nodulation, and nutrient uptake and favourable conditions for disease incidence, finally leading to reduced crop stand. Moisture deficiency in the post-monsoon period adversely affects the development of reproductive organs leading to depressed yields. To alleviate the problems of waterlogging, planting on modified land configuration such as broad-bed and furrow (Desai *et al*., 2000) has been advocated. Keeping this in view the present investigation was undertaken to evaluate the effect of land configuration and phosphorus levels with and without bio-fertilizers on the productivity of sole and intercropped pigeonpea.

MATERIALS AND METHODS

A field experiment was conducted on a sandy loam soil at the research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi for two consecutive *kharif* seasons of 2007 and 2008. The geographical location of the site is at a latitude of 28°40'N, longitude of 77°12'E and altitude of 228 metres above the mean sea level. This location has a typical semi-arid and sub-tropical climate characterized by hot dry summers and cool winters. The mean annual rainfall of Delhi is 650 mm and more than 80% of which generally occurs during the south-west monsoon season (July to September) with mean annual evaporation of 850 mm. The rainfall received during the crop growing period from July to December was 381.8 mm in 2007 and 582.9 mm in 2008. The experimental soil was sandy loam having pH 8.2, low in organic carbon (0.3%), medium in available phosphorus (11.4 kg/ha) and available K (186.70 kg/ha) as determined by standard methods. The moisture content at field capacity, permanent wilting point and bulk density at 0-30, 30-60 and 60-90 cm depth were 18.82, 19.14 and 19.32%, 6.48, 6.72 and 6.75; 1.50, 1.53 and 1.55 g/cc, respectively. The experiment was laid out in split-plot design with 3 replications. The treatment combinations comprised 2 cropping systems viz., pigeonpea sole (50 cm row spacing) and pigeonpea + mungbean and 3 planting systems (uniform row planting 50 cm row spacing, paired row planting 30/70 cm row spacing, broad-beds 150 cm width with a furrow 50 cm between beds were made) in main plots and four phosphorus levels (control, 40 kg P_2O_5/ha, 40 kg P_2O_5/ha + PSB + AM and 80 kg P_2O_5/ha) in sub-plots.

Fertilizers were placed in bands 8-10 cm below the surface. Full dose of phosphorus as per treatments through single super phosphate were applied just before sowing of crops. The placement was done through an iron pipe (*pora*) attached to the bullock drawn country plough. "Pusa 991" and "Asha" varieties of pigeonpea and mungbean respectively were used for experimental purpose. Sowing of the crop was done on 10 July in 2007 and 12 July in 2008. The pigeonpea seeds were sown @ 15 kg/ha by *kera* (dropping the seeds in furrows behind the plough). The spacing between row to row in sole pigeonpea was maintained at 50 cm. Between two rows of pigeonpea, a row of mungbean was sown. Broad-beds of 150 cm width and furrow of 50 cm between beds were made and 3 rows of pigeonpea and 2 rows of mungbean were planted on each bed. The plants from net plot were harvested from the ground level and were left for sun drying *in- situ*. The pigeonpea and mungbean were threshed manually. Grains were cleaned and weighed for expressing yield in tonnes/ha. The weight of stalk was recorded separately and used for estimating stover yield.

RESULTS AND DISCUSSION

Growth and yield attributes of Pigeonpea

Cropping system had no significant effect on growth, yield attributes and yield viz. plant height, pods/plant, grains/pod and 1,000-grain weight and grain and stalk yield of pigeonpea (Table 1). This could be attributed to the similar conditions of plant growth and development of pigeonpea in both sole as well as intercropping system. Similar observations were made by Ahlawat and Gangaiah (2010).

Planting systems brought a marked variation in yield attributes and yields of pigeonpea, viz., number of pods per plant, number of grains per pod and 1,000-grain weight of pigeonpea and grain, and stalk yield and harvest index (Table 1). Broad-bed and furrow planting remained at par with paired row planting recorded markedly higher values of yields attributes and yields when compared with uniform row planting. This could be attributed to improvement in growth attributes through adequate availability of nutrients and soil moisture, which in turn, favourably influenced number of physiological processes and build up of food material. Increase in yield attributes and yield of pigeonpea due to broad-bed and furrow system of planting was also reported by (Kantwa *et al.,* 2006).

Application of phosphorus with and without biofertilizers significantly increased the yield attributes (pods/plant and grains/pod) and yield components (grain, stalk and biological) of pigeonpea, which might be resulted from favourable influence of phosphorus nutrition on the growth parameters (plant height, LAI, branching and dry matter production), leading to greater nutrient uptake and efficient partitioning of metabolites. Adequate translocation and accumulation of photosynthates, aminoacids, vitamins etc. The observations of the present study are in line with the findings of Kumar and Rana (2007).

Mungbean yield and yield attributes

Planting systems produced measurable improvement in yield attributing characters and yield *viz.,* pods per plant, grains per pod, grain yield and stover yield of mungbean, but failed to produce marked influence on 1,000-grain weight and harvest index (Table 2). The highest values in respect of yield attributing characters and yield were observed under broad-bed and furrow (BBF) planting and minimum with uniform row planting. Phosphorus levels significantly affected the grain yield in both the years of study. Maximum grain yield was recorded with the application of 80 kg P_2O_5/ha (281 and 319 kg/ha), followed by 40 kg P_2O_5/ha + PSB + AM (260 and 298 kg/ha), which was 8.3, 6.96 and 7.18, 5.85 per cent higher over control during 2007 and 2008, respectively.

Phosphorus uptake

Cropping system had significant effect on total phosphorus uptake by pigeonpea during both the years of study, but found at par with each other in respect of phosphorus uptake in grain and stalk of pigeonpea (Table 3). Pigeonpea sole improved the total phosphorus uptake over pigeonpea + mungbean intercropping system by 3.12 and 1.96 per cent during 2007 and 2008, respectively. This might be due to the combined effect of grain and stalk yield and their contents. P application increases the P content in grain and stalk of pigeonpea and mungbean (Shivran *et al.*, 2000) A further examination of data (Table 3) indicated that planting systems significantly influenced the phosphorus uptake by grain and stalk as well as total uptake by pigeonpea and mungbean crop during two years of experiment. Highest phosphorus uptake by grain (5.59, 6.65 kg/ha) of pigeonpea and mungbean (0.76, 0.90 kg/ha) and stalk (5.66, 6.22 kg/ha) of pigeonpea and mungbean (0.91, 1.00 kg/ha) and total uptake (11.24, 12.77) pigeonpea and (1.67, 1.90 kg/ha) mungbean during respective years was obtained with broad-bed and furrow planting, followed by with paired row planting. The increased nutrient uptake under broad-bed and furrow planting and paired row planting mainly because of higher biomass production resulting from enhanced plant growth and development over uniform row planting (Shaikh *et al.*, 1995).

A significant improvement in phosphorus uptake by grain and stalk of pigeonpea and mungbean was noted with application of fertilizers during both the years of investigation (Table 3). Maximum phosphorus uptake by grain and stalk as well as total uptake of crop was recorded with 80 kg P_2O_5/ha, but remained at par with 40 kg P_2O_5/ha + PSB + AM. The per cent increase in total phospho-

Table 1. Effect of cropping system, planting system and fertility levels on growth, yield attributes and yield of pigeonpea

Treatment	Plant height at maturity (cm)		No. of grains/pod		No. of pods/plant		1,000-grain weight (g)		Grain yield (t/ha)		Stalk yield (t/ha)		Harvest index (%)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Cropping Systems														
Pigeonpea sole (50 cm)	145.1	154.6	153.6	170.5	3.6	3.7	74.2	74.4	1.50	1.71	5.17	5.54	22.4	23.6
Pigeonpea + Mungbean	146.9	155.6	152.4	169.7	3.5	3.6	73.7	74.3	1.45	1.65	5.12	5.48	22.0	23.1
SEm±	1.7	1.6	1.36	1.54	0.04	0.04	0.79	1.11	0.020	0.027	0.021	0.063	0.26	0.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting systems														
Uniform row planting	140.2	149.4	149.1	164.7	3.4	3.5	73.5	74.0	1.34	1.49	5.01	5.37	21.1	21.7
Broad bed and furrow (BBF)	149.1	159.2	155.4	173.7	3.6	3.7	74.3	74.6	1.57	1.81	5.24	5.60	23.0	24.4
Paired row planting	148.7	156.8	154.5	171.9	3.6	3.6	74.0	74.4	1.51	1.75	5.18	5.55	22.6	24.0
SEm±	2.1	1.9	1.67	1.89	0.05	0.05	0.97	1.36	0.024	0.032	0.026	0.078	0.32	0.43
CD (P=0.05)	6.7	6.1	5.26	5.95	0.16	0.17	NS	NS	0.076	0.095	0.080	0.244	NS	NS
Fertility levels														
Control	129.6	138.5	137.6	151.1	2.9	3.1	70.3	70.9	1.18	1.41	4.31	4.70	21.5	23.1
40kg P_2O_5/ha	143.3	152.4	149.6	166.4	3.4	3.5	73.3	73.7	1.43	1.65	4.85	5.30	22.8	23.7
40kg P_2O_5+PSB+AM/ha	155.0	164.4	160.8	180.2	3.8	3.9	75.6	75.8	1.60	1.80	5.62	5.90	22.2	23.3
80kg P_2O_5/ha	156.1	165.1	163.9	182.8	3.9	4.0	76.6	76.9	1.68	1.87	5.80	6.15	22.4	23.3
SEm±	1.9	3.1	1.74	2.18	0.07	0.08	2.14	2.30	0.026	0.038	0.071	0.085	0.45	0.31
CD (P=0.05)	5.3	9.0	5.00	6.24	0.21	0.22	NS	NS	0.075	0.113	0.210	0.254	NS	NS

rus uptake was 18.60 and 12.85% with 40 kg P_2O_5/ha, 36.48 and 25.61% with 40 kg P_2O_5/ha + PSB + AM and 42.14 and 30.95% with 80 kg P_2O_5/ha over no phosphorus applied in respective years. This could be attributed to higher P concentration in grain where pigeonpea was grown with P-fertilizer.

System P-uptake and productivity

Cropping systems exhibits significant improvements in pigeonpea equivalent yield (PEY) and system-P uptake in both the years (Table 4). Pigeonpea intercropped with mungbean recorded significantly higher pigeonpea equivalent yield and system-P uptake in intercropping treatment, which was due to similar yield of pigeonpea to that of its sole stand, and additional yield of mungbean as a bonus in intercropping system. The results are in accordance with the findings of Jat (2002).

Various planting systems showed remarkable improvement in pigeonpea equivalent yield and system-P uptake in both the years of investigation. Broad-bed and furrow planting, being at par with paired row planting, recorded maximum pigeonpea equivalent yield and system-P uptake with minimum under uniform row planting. It might be due to the fact that significant increases in grain yield of mungbean in aforesaid treatment over uniform row planting in higher pigeonpea equivalent yield and system-P

Table 2. Effect of planting system and fertility levels on growth, yield attributes and yield of mungbean

Treatment	Plant height at maturity (cm)		Pods/plant		Grains/pod		1,000-grains weight (g)		Grain yield (t/ha)		Stover yield (t/ha)		Harvest index (%)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Planting systems														
Uniform row planting	45.7	49.1	17.3	19.0	5.0	5.2	45.7	45.8	0.20	0.23	1.11	1.16	15.1	16.9
Broad-bed and furrow (BBF)	48.0	51.4	18.5	20.2	5.9	6.0	45.9	46.0	0.24	0.28	1.19	1.23	16.9	18.7
Paired row planting	47.6	51.1	18.3	19.8	5.7	5.8	45.8	45.9	0.24	0.27	1.18	1.21	16.7	18.4
SEm±	0.94	0.97	0.34	0.30	0.12	0.12	0.81	0.88	0.006	0.006	0.024	0.017	0.69	0.72
CD (P=0.05)	2.76	2.79	1.00	0.87	0.36	0.35	NS	NS	0.016	0.017	0.072	0.050	NS	NS
Fertility levels														
Control	41.2	44.9	15.7	16.9	4.8	4.9	45.2	45.3	0.15	0.19	0.81	0.93	15.8	16.8
40 kg P_2O_5/ha	45.0	48.8	16.4	19.2	5.4	5.6	45.6	45.7	0.21	0.25	1.08	1.16	16.3	17.5
40 kgP_2O_5/ha+PSB+ AM	50.6	54.0	19.9	21.1	6.0	6.1	46.1	46.2	0.26	0.30	1.34	1.30	16.2	18.6
80 kg P_2O_5/ha	51.5	54.6	20.2	21.5	6.1	6.1	46.3	46.4	0.28	0.32	1.41	1.41	16.6	18.6
SEm±	1.08	1.12	0.39	0.34	0.14	0.14	0.93	1.02	0.006	0.007	0.042	0.052	0.58	0.67
CD (P=0.05)	3.18	3.29	1.15	1.00	0.41	0.41	NS	NS	0.019	0.019	0.123	0.154	NS	NS

Table 3. Effect of cropping system, planting system and fertility levels on phosphorus uptake of pigeonpea and mungbean

Treatment	P uptake in pigeonpea (kg/ha)						P uptake in mungbean (kg/ha)					
	Grain		Stalk		Total		Grain		Stalk		Total	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Cropping systems												
Pigeonpea sole (50 cm)	5.36	6.30	5.58	6.14	10.94	12.45	-	-	-	-	-	-
Pigeonpea + mungbean	5.08	6.11	5.53	6.09	10.60	12.19	0.74	0.86	0.87	0.98	1.60	1.84
SEm ±	0.11	0.13	0.03	0.07	0.15	0.14						
CD (P=0.05)	NS	NS	NS	NS	0.49	0.45						
Planting systems												
Uniform row planting	4.70	5.72	5.42	5.96	10.11	11.68	0.71	0.82	0.78	0.95	1.48	1.77
Broad-bed and furrow (BBF)	5.59	6.55	5.66	6.22	11.24	12.78	0.76	0.90	0.91	1.00	1.67	1.90
Paired row planting	5.37	6.36	5.60	6.16	10.95	12.51	0.75	0.86	0.89	0.98	1.64	1.86
SEm±	0.14	0.15	0.06	0.09	0.19	0.18	0.01	0.01	0.01	0.02	0.02	0.02
CD (P=0.05)	0.41	0.44	0.17	0.25	0.60	0.55	0.03	0.03	0.03	0.04	0.06	0.06
Fertility levels												
Control	4.00	5.29	4.66	5.21	8.66	10.50	0.63	0.76	0.73	0.87	1.37	1.63
40 kg P_2O_5/ha	5.06	5.97	5.24	5.88	10.30	11.84	0.70	0.83	0.80	0.95	1.50	1.79
40 kg P_2O_5/ha +PSB+AM	5.75	6.64	6.07	6.55	11.82	13.18	0.79	0.92	0.93	1.03	1.72	1.96
80 kg P_2O_5/ha	6.05	6.93	6.26	6.82	12.30	13.76	0.82	0.94	0.96	1.06	1.79	2.00
SEm±	0.16	0.16	0.10	0.08	0.23	0.28	0.01	0.01	0.01	0.02	0.02	0.02
CD (P=0.05)	0.47	0.48	0.31	0.24	0.66	0.79	0.04	0.04	0.04	0.05	0.07	0.07

Table 4. Effect of cropping system, planting system and fertility levels on system P-uptake and productivity and economics of pigeonpea

Treatment	System uptake-P (kg/ha)		Pigeonpea equivalent yield (t/ha)		Net returns (x10^3 ₹/ha)		B:C ratio	
	2007	2008	2007	2008	2007	2008	2007	2008
Cropping systems								
Pigeonpea sole (50 cm)	10.94	12.45	1.50	1.73	17.26	20.55	1.88	2.17
Pigeonpea + mungbean	12.19	14.04	1.71	2.01	19.44	23.13	1.97	2.23
SEm ±	0.15	0.14	0.02	0.03				
CD (P=0.05)	0.49	0.44	0.07	0.08				
Planting systems								
Uniform row planting	10.85	12.57	1.46	1.72	16.90	19.16	1.83	2.04
Broad-bed and furrow (BBF)	12.07	13.73	1.71	1.98	19.99	23.47	2.03	2.29
Paired row planting	11.77	13.43	1.65	1.92	18.16	22.88	1.91	2.27
SEm±	0.19	0.17	0.03	0.03				
CD (P=0.05)	0.60	0.54	0.08	0.10				
Fertility levels								
Control	9.35	11.32	1.27	1.58	14.54	17.88	1.67	1.94
40 kg P_2O_5/ha	11.05	12.74	1.55	1.79	17.94	21.25	1.89	2.17
40 kg P_2O_5/ha +PSB+AM	12.68	14.16	1.76	2.02	21.03	23.92	2.20	2.43
80 kg P_2O_5/ha	13.20	14.76	1.83	2.11	19.89	24.31	1.94	2.26
SEm±	0.23	0.28	0.03	0.04				
CD (P=0.05)	0.65	0.79	0.08	0.12				

uptake. Kantwa *et al.* (2006) reported similar results. The fertility levels markedly enhanced the pigeonpea equivalent yield and system-P uptake in both the years of investigation. Application of 80 kg P_2O_5/ha recorded significantly higher system-P uptake and pigeonpea equivalent yield over control and being at par with 40 kg P_2O_5/ha + PSB + AM. This might be attributed to increase in economic yield of both the component crops with phosphorus application. This contributing effect of various yield attributes and yield fetched the maximum pigeonpea equivalent yield and system-P uptake with fertility levels. Similar results were also reported by Kantwa *et al*. (2005).

Economics

Pigeonpea + mungbean intercropping system fetched higher net returns (₹19.4 and ₹23.1 thousands/ha 2007 and 2008 respectively) as well as B:C ratio over sole pigeonpea (₹17.3 and ₹20.5 thousands/ha) (Table 4) due to more combined yield. This might be due to marginal difference in pigeonpea yield and additional yield of mungbean, which resulted in higher net returns in pigeonpea + mungbean cropping system than sole pigeonpea. Similar results were reported by Chaudhary and Thakur (2005). Planting systems brought about considerable variation in net returns and B:C ratio (Table 4). Maximum net returns (₹20 and ₹ 23.5 thousands/ha) and B:C ratio (2.0 and 2.3) were recorded with broad-bed and furrow planting system closely followed by paired row planting. This might be due to significantly higher pigeonpea equivalent yield under this treatment. Minimum net returns (₹16.1 and ₹19.2 thousands/ha) and B:C ratio (1.8 and 2.0) were recorded with paired row planting systems and uniform row planting systems, respectively, which might be due to less additional yield in these treatments. Results are in close conformity with the findings of Kantwa *et al*. (2005). Maximum net returns and B:C ratio were recorded with application of 40 kg P_2O_5/ha + PSB + AM, followed by 80 kg P_2O_5/ha (Table 4). This might be due to the fact that 40 kg P_2O_5/ha with biofertilizers and 80 kg P_2O_5/ha recorded similar yield but lower cost of kg P_2O_5/ha + biofertilizers resulted in the highest net returns and B: C ratio (Kumar and Rana 2007).

Based on two years study, intercropping of one row of mungbean between two rows of pigeonpea (50 cm), broad-bed and furrow planting (100/50 cm) of pigeonpea and application of 40 kg P_2O_5/ha + PSB + AM to pigeonpea was found more productive and remunerative compared to sole planting , flat planting and 80 kg P_2O_5/ha application respectively.

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