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Effect of planting system and phosphorous on productivity, moisture use efficiency and economics of sole and intercropped pigeonpea (*Cajanus cajan*) under rainfed conditions of northern India

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ABSTRACT

A field experiment was conducted at IARI, New Delhi during 2007 and 2008 to study the effect of planting system and phosphorus on productivity, moisture use efficiency and economics of sole and intercropped pigeonpea [*Cajanus cajan* (L.) Millisp.] under rainfed conditions on a sandy loam soil. There was significant superiority in growth and yield attributes as well as yield of pigeonpea under sole pigeonpea as compared to their intercropping with mungbean. However, pigeonpea equivalent yield (1.86 tonnes/ha) was the highest under intercropped pigeonpea. Intercropping system recorded the higher consumptive use (380.1 mm), moisture use efficiency (4.25 kg/ha-mm), moisture use rate (2.62 mm/day) as well as nutrient uptake and fetched higher net returns (₹ 21.91 × 10^3/ha) and B: C ratio (2.1) over sole pigeonpea. Results showed significant improvement in yield attributes and yield under different planting systems (Broad bed and furrow (BBF) and paired row planting) over the uniform row planting. The highest value of moisture use indices (consumptive use, moisture use efficiency and moisture use rate) and economics (net returns and B: C ratios) were recorded with broad-bed and furrow planting and lowest in uniform row planting. Among phosphorus levels, application of 80 kg P_2O_5/ha followed by 40 kg P_2O_5/ha with biofertilizers (phosphate solubilizing bacteria and vesicular and arbuscular mycorrhizae) resulted in better performance of crops over other treatments.

Key words: Cropping system, Moisture use indices, Phosphorus, Pigeonpea, Pigeonpea equivalent yield, Planting system

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is the most important rainy season (*kharif*) grain legume, grown predominantly under rainfed conditions in India. It occupies 16-17% of total pulse area and accounts for only 17% of gross pulse production in the country. Limited and scanty rainfall in the rainfed areas makes pigeonpea vulnerable to experience moisture-stress conditions during the later part of its growth, resulting in severe yield reduction. Sufficient soil moisture is the key to successful crop production in dryland areas. The major source of soil moisture loss is evapotranspiration. The cropping systems and planting patterns are effective in increasing the productivity and water use by pigeonpea under rainfed conditions (Ghosh *et al*. 2006). The moisture deficiency in the post-monsoon period adversely affects the development of a reproductive organs leading to depressed yields. Like other field crops, pigeonpea also requires essential elements such as nitrogen, phosphorus and potassium for balanced nutrition. This crop, being a legume, requires adequate available P for nodulation, nitrogen fixation, growth and development for higher production. To improve and stabilize the productivity of pigeonpea under such adverse situations, intercropping with short-duration legumes like greengram (*Phaseolus radiatus* L.) has been recommended (Ahlawat and Gangaiah 2010). However, with the changing scenario of crop improvement in pulses intercropping system, there is a need to relook and investigate low cost technology. Therefore, the present experiment was conducted to study the productivity and moisture-use efficiency of pigeonpea + greengram intercropping system as influenced by planting systems and phosphorus management.

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MATERIALS AND METHODS

A field experiment was conducted at the research farm of the Division of Agronomy, Indian Agricultural Research

Institute, New Delhi for two consecutive *kharif* seasons of 2007 and 2008. This location has a typical semi-arid and sub-tropical climate characterized by hot and dry summers and cool winters. The mean annual rainfall of Delhi is 650 mm 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 soil was sandy loam in texture with pH 8.2, organic C 0.3%, available N 134.85 kg/ha, available P 11.4 kg/ha and available K 186.7 kg/ha. The moisture content at field capacity at different depth was 18.82, 19.14 and 19.32% and bulk density was 1.50, 1.53 and 1.55 g/cc at 0-30, 30-60 and 60-90 cm soil depth, respectively. The permanent wilting point was 6.75. The experiment was laid out in split plot design with six combinations including two cropping systems [pigeonpea sole (50 cm row spacing) and pigeonpea + greengram] and three planting methods [uniform row planting (50 cm row spacing), paired row planting (30/70 cm spacing) and broad-bed and furrow planting (100 cm width with furrow 50 cm between beds were made)] in the main plot and 4 phosphorus levels (control, 40 kg P_2O_5/ha, 40 kg P_2O_5/ha + PSB + VAM and 80 kg P_2O_5/ha) in the sub plots were replicated thrice.

Crops were grown as per recommended package of practices.The spacing between row to row in sole was maintained at 50 cm greengram was adjusted as intercrop at 25 cm row distance. Fertilizer was placed in bands 8-10 cm below the surface. Full dose of phosphorus was applied as per treatments through single super phosphate before sowing of crops. The placement was done through an iron pipe (*pora*) attached to the bullock drawn country plough. Pusa 991 and Asha cultivar 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 seeds were inoculated with biofertilizers [Phosphate solubilizing-bacteria (PSB) and vesicular and arbusicular mycorrhizae (VAM)] @ 20 g/kg seed. Pigeonpea matured in first fortnight of December and greengram in the first fortnight of September.

Seasonal consumptive use (SCU) and moisture use rate were computed using the following formula:

$$\text{SCU} = \sum_{i=1}^{n} (\text{bj} + \text{ej}) + \text{effective rainfall}$$

where,bj = total profile moisture content at the beginning of the jth interval, ej = total profile moisture content at the end of the jth interval, and, n = number of time interval

$$\text{Moisture use rate (mm/day)} = \frac{\text{Consumptive use (mm)}}{\text{Crop duration (days)}}$$

RESULTS AND DISCUSSION

Yield attributes and crop yield

The cropping system had no significant effect on growth attributes (plant height, dry matter accumulation and crop growth rate), yield attributes and yield, viz pods/plant, grains/pod and 1000-grain weight and grain yield of pigeonpea (Table 1 and 2). This could be attributed to the similar conditions of plant growth and development of pigeonpea in both sole as well as intercropping system. Similar result was reported by Ahlawat and Gangaiah (2010).

Pigeonpea intercropped with mungbean recorded significantly higher pearlmillet equivalent yield (PEY) as compared to pigeonpea sole cropping (Table 3). It was due to almost similar yield of intercropped pigeonpea (1.55 tonnes/ha) as that of its sole stand (1.60 tonnes/ha), and additional yield of mungbean as a bonus in intercropping system. Planting systems had significant effect on growth attributes (plant height, dry matter accumulation and crop growth rate) and yield attributing parameters of pigeonpea, viz. number of pods/plant, number of grains/pod and 1 000-grain yield and grain, and stalk yield of pigeonpea (Table 1 and 2). Broad-bed and furrow planting method was recorded significantly higher numerical value in respect of yield attributes and yields as compared to uniform row planting. Application of phosphorus with and without biofertilizers significantly increased the growth attributes (plant height, dry matter accumulation and crop growth rate), yield attributes (pods/plant and grains/pod) and grain and stalk yield of

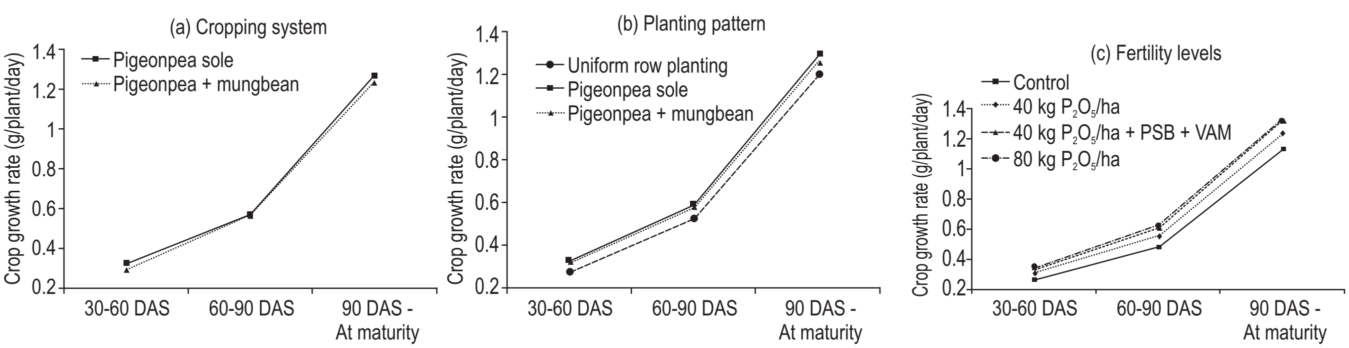

Fig 1 Effect of cropping system, planting system and fertility levels on crop growth rate (g/plant/day) of pigeonpea (mean of two years)

Table 1 Effect of cropping system, planting system and fertility levels on plant height and dry matter accumulation of pigeonpea (mean of two years)

Treatment	Plant height (cm)				Dry matter accumulation (g/plant)			
	30 DAS	60 DAS	90 DAS	At maturity	30 DAS	60 DAS	90 DAS	At maturity
Cropping system								
Pigeonpea sole (50 cm)	37.2	108.4	130.9	149.9	4.9	14.7	31.8	70.0
Pigeonpea + greengram	38.5	109.4	131.6	151.2	4.8	13.7	30.6	67.6
SEm±	1.0	1.5	1.5	1.7	0.1	0.3	0.8	1.4
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Planting system								
Uniform row planting	34.5	102.6	125.9	144.8	4.5	13.0	28.8	64.7
Broad-bed and furrow	39.5	112.2	134.5	154.1	5.1	14.9	32.7	71.6
Paired row planting	39.6	112.1	133.3	152.7	4.9	14.6	32.1	70.1
SEm±	0.9	1.8	1.9	2.0	0.1	0.4	1.0	1.7
CD (P=0.05)	2.9	5.8	5.9	6.4	0.5	1.3	3.2	5.3
Fertility level								
Control	33.3	99.8	117.7	134.0	4.1	12.0	26.5	60.4
40 kg P_2O_5/ha	36.7	106.7	128.8	147.9	4.7	14.0	30.6	67.6
P_2O_5/ha+PSB+VAM	40.3	113.7	138.5	159.7	5.2	15.2	33.5	73.2
80 kg P_2O_5/ha	41.1	115.6	140.0	160.6	5.3	15.5	34.2	74.1
SEm±	1.3	1.9	2.0	2.5	0.2	0.5	0.8	1.5
CD (P=0.05)	3.8	5.7	5.7	7.2	0.5	1.5	2.3	4.3

Table 2 Effect of cropping systems, planting systems and fertility levels on yield attributes, yield and pearlmillet equivalent yield (PEY) of pigeonpea (mean of two years)

Treatment	Yield attributes			Yield (tonnes/ha)		PEY
	pods/plant	grains/ pod	1000-grain weight	Grain yield	Stalk yield	(tonnes/ha)
Cropping system						
Pigeonpea sole	162.06	3.63	74.32	1.61	5.36	1.62
Pigeonpea + mungbean	161.04	3.55	74.01	1.55	5.30	1.86
SEm±	1.45	0.04	0.95	0.02	0.04	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	0.07
Planting system						
Uniform row planting	156.92	3.44	73.81	1.42	5.19	1.59
Broad-bed and furrow	164.53	3.68	74.48	1.69	5.42	1.85
Paired row planting	163.22	3.65	74.21	1.63	5.37	1.79
SEm±	1.78	0.05	1.17	0.03	0.05	0.03
CD (P=0.05)	5.61	0.17	NS	0.09	0.16	0.09
Fertility level						
Control	144.36	3.05	70.61	1.30	4.51	1.43
40 kg P_2O_5/ha	157.99	3.48	73.51	1.54	5.08	1.67
40 kg P_2O_5/ha+PSB+VAM	170.52	3.86	75.76	1.70	5.76	1.89
80 kg P_2O_5/ha	173.35	3.95	76.79	1.78	5.98	1.97
SEm±	1.96	0.08	2.22	0.03	0.08	0.04
CD (P=0.05)	5.62	0.22	NS	0.09	0.23	0.10

Table 3 Effect of cropping system, planting system and fertility levels on moisture extraction pattern and moisture indices of pigeonpea (mean of two years)

Treatment	Moisture extraction pattern (%)			Moisture indices			Economics	
	0-30 cm	30-60 cm	60-90 cm	CU (mm)	MUE (kg/ha-mm)	MUR (mm/day)	Net returns ($\times10^3$ ₹/ha)	B:C ratio
Cropping system								
Pigeonpea sole	51.31	27.99	20.71	357.86	4.69	2.47	18.91	2.03
Pigeonpea + mungbean	50.87	27.97	21.17	380.15	4.25	2.62	21.29	2.10
SEm+				5.28	0.09	0.04		
CD (P=0.05)				16.63	0.28	0.12		
Planting system								
Uniform row planting	51.15	28.01	20.85	354.66	4.26	2.45	18.03	1.94
Broad-bed and furrow	51.02	27.96	21.03	376.75	4.63	2.60	21.73	2.16
Paired row planting	51.07	27.99	20.95	375.61	4.52	2.59	20.52	2.09
SEm+				6.47	0.11	0.05		
CD (P=0.05)					20.37	0.34	0.14	
Fertility level								
Control	51.23	27.94	20.84	342.22	3.96	2.36	16.21	1.81
40 kg P_2O_5/ha	51.11	27.98	20.92	368.55	4.35	2.55	19.60	2.03
40 kg P_2O_5/ha+PSB+VAM	51.07	28.00	20.94	379.27	4.68	2.62	22.48	2.32
80 kg P_2O_5/ha	51.00	28.05	20.96	385.99	4.88	2.66	22.10	2.10
SEm+				7.06	0.14	0.05		
CD (P=0.05)				20.27	0.40	0.14		

CU, MUE and MUR represents consumptive use, moisture use efficiency and moisture use rate, respectively.

pigeonpea as compared to control. The maximum grain yield of pigeonpea was obtained with 80 kg P_2O_5/ha (1.77 tonnes/ha) followed by 40 kg P_2O_5/ha + PSB + VAM (1.70 tonnes/ha) and the minimum with control (1.29 tonnes /ha) (Table 3). The % increase in PEY was 38.7, 33.1 and 17.7% with the application of 80 kg P_2O_5/ha, 40 kg P_2O_5/ha + PSB + VAM and 40 kg P_2O_5/ha over control, respectively. This might be resulted from favourable influence of phosphorus nutrition on the growth parameters (plant height, LAI, branching and dry matter production), which was improve greater nutrient uptake, efficient partitioning of metabolites, adequate translocation and accumulation of photosynthates. The observations of the present study are in line with the findings of Kumar and Rana (2007).

Phosphorus uptake

Cropping system had significant effect on total phosphorus uptake by pigeonpea. Pigeonpea sole improved the total phosphorus uptake over pigeonpea + greengram intercropping system by 2.54%. Planting systems significantly influenced the total phosphorus uptake by pigeonpea. The highest total phosphorus uptake was obtained with broad-bed and furrow planting (12.01 kg/ha) and lowest with uniform row planting (10.9 kg/ha) (Fig 2). The maximum

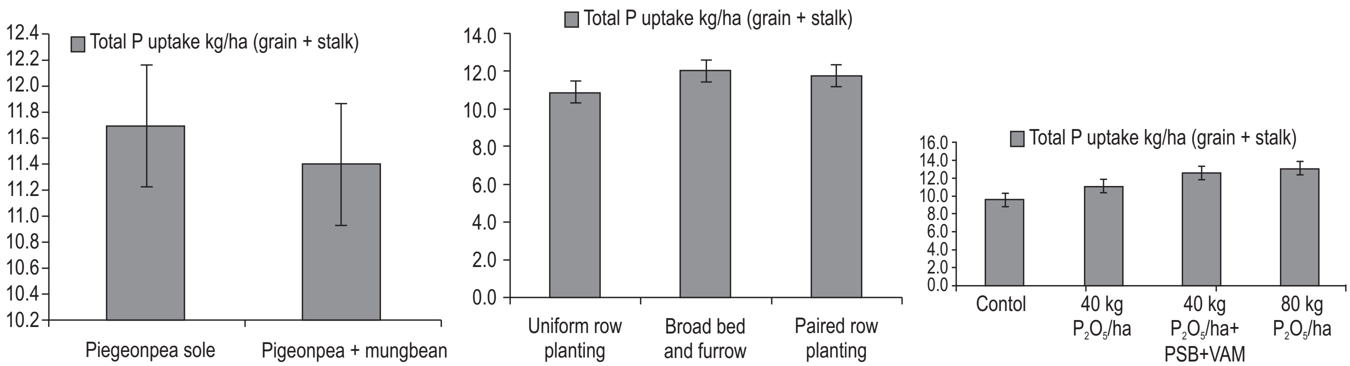

Fig 2 Effect of cropping systems, planting systems and fertility levels on total phosphorus uptake (kg/ha) of pigeonpea (mean of two years). Vertical bar represents LSD (P = 0.05).

total phosphorus uptake (grain and stover) was recorded with 80 kg P_2O_5/ha but remained at par with 40 kg P_2O_5/ha + PSB + VAM. The percent increase in total phosphorus uptake by 36.03, 30.55 and 15.55% with the application of 80 kg P_2O_5/ha, 40 kg P_2O_5/ha + PSB + VAM and 40 kg P_2O_5/ha over control. These results are in close agreement with Shivran *et al*. 2000.

Moisture use indices

Pigeonpea + mungbean intercropping system on an average register 22.3 mm more consumptive use and thus has 0.24 kg/ha-mm more moisture-use efficiency (MUE) and 0.15 mm/day more moisture use rate than sole pigeonpea (Table 3). The higher consumptive use and moisture use efficiency due to the grain yield of both the crops were proportionately higher under intercropping than the amount of water used for biomass production. Intercropping system increased consumptive use of water by 6.2% over sole cropping of pigeonpea. Similar results were reported by Ansari and Rana (2012). Crops extracted greater amount of soil moisture from top 0-30 cm soil layer. Crops extracted greater amount of soil moisture from top 0-30 cm soil layer than 30-60 and 60-90 cm soil depths in both the systems. It might be due to more availability of soil moisture in this soil layer and the maximum root biomass existed in this soil depth which resulted in the maximum extraction of soil moisture from this profile layer. Moisture depletion from deeper layers intercropping system might be due to moisture stress in upper 0-30 cm soil profile compelling roots to go deeper in search of moisture. It explains more depletion of soil moisture from deeper soil profiles (Ansari and Rana 2012). The maximum consumptive use (376.75 mm) of water was recorded with broad-bed and furrow planting systems closely followed by paired row planting (375.61 mm) and lowest in uniform row planting (354.66 mm) (Table 3). This might be due to availability of more moisture for a longer period of time in broad-bed and furrow planting which give the proper growth and development of crops. These results are in close agreement with those of Ahlawat and Gangaiah (2010). Broad-bed and furrow planting system increased the 8.75% moisture-use-efficiency and 6.14% rate of moisture use rate as compared to uniform planting method. It was due to more absorption and utilization of water for metabolic activities in broad-bed and furrow planting and paired row planting. In uniform row planting, relatively more moisture was extracted from 0-30 cm soil profile, while 30-60 and 60-90 cm soil profile contributed more in case of broad-bed and furrow and paired row planting system. It could be attributed to root proliferation in different depths in these planting systems. The highest moisture use efficiency was recorded with the application of 80 kg P_2O_5/ha followed by 40 kg P_2O_5/ha + PSB + VAM, 40 kg P_2O_5/ha and minimum with control. The per cent increases in moisture-use efficiency with aforesaid treatments were 22.1, 19.1 and 11.2% as compared to control, respectively. It might be due to increase in yield of higher magnitude than the corresponding increase in consumptive use of water, eventually resulting in considerable increase in moisture-use efficiency due to increased fertility levels (Singh *et al.* 2010). Moisture use were also increased with different fertility levels that might have attributed to enhanced vegetative growth and extensive root system that enabled the plants to utilize more moisture from soil layers (Kumar and Rana 2007). Phosphorus fertilization with and without biofertilizers applied to the crops induced deeper moisture extraction than control. This might be attributed to increased root activity and proliferation of root system due to translocation of more photosynthates to roots thereby resulting in more extraction of moisture from deeper layers (30-60 and 60-90 cm) of soil. However, under control treatment root growth was not much extensive and hence, moisture extraction was confined to the upper soil layer (0-30 cm).

Economics

Pigeonpea + mungbean system on an average fetched ₹ 2.4×10^3/ha more net returns and thus has 0.10 more B: C ratio than sole pigeonpea, respectively (Table 3). The higher PEY coupled with the corresponding stover yield and with minimal increases in cost of cultivation has resulted in higher net returns and B: C ratio in pigeonpea + mungbean system (Chaudhary and Thakur 2005). The maximum net returns (₹ 21.7×10^3/ha) and B: C ratios (2.2) were recorded with broad-bed and furrow planting system. This might be due to significantly higher pigeonpea equivalent yield (Table 3). The minimum net returns and B:C ratio were recorded with paired row planting and uniform row planting systems, respectively which might be due to less additional yield in these treatments. Kantwa *et al.* (2005) reported that planting of pigeonpea on broad bed and furrow fetched higher net returns over flat sowing. The maximum net returns and B: C ratio were recorded with application of 40 kg P_2O_5/ha + PSB + VAM, followed by 80 kg P_2O_5/ha (Table 3). 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).

Thus results of the present investigation clearly demonstrate that pigeonpea + mungbean intercropping system can be practiced to achieve better high yield as well as profitability and moisture-use efficiency than their sole crop at 50 cm row spacing under rainfed sandy loam soils. Broad-bed and furrow was found most suitable planting system for pigeonpea. Application of 80 kg P_2O_5/ha was found to be more productive over other fertilizer doses.

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