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Effect of spatial arrangement and phosporus fertilization in pigeonpea (*Cajanus cajan*)–soybean (*Glycine max*) intercropping system

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ABSTRACT

A 2-year experiment was conducted on a clayey deep Vertisols of Bhopal to study the effect of row ratios and phosphorus fertilization on pigeonpea [*Cajanus cajan* (L.) Millsp.]–soybean [*Glycine max* (L.) (Merr.)] intercropping system. At 120 cm row spacing higher, number of branches, grains/pod and yield were recorded in sole cropping compared with intercropping systems. Among intercropping, 1 : 3 ratio gave significantly higher number of branches, pods, grains/pod, 1,000-grain weight and grain yield than 1 : 1 ratio, and pigeonpea-yield equivalent increased by 31.6 and 35.3% over 1 : 1 ratio and sole pigeonpea at 60 cm row spacing respectively. The highest land-equivalent ratio (1.39), monetary yield advantage (Rs 6,712/ha/a) and benefit : cost ratio of 2.8 were recorded at 1 : 3 row ratio, followed by 1 : 2 row ratio (27.5% higher pigeonpea-grain-yield equivalent over sole pigeonpea at 60 cm row spacing). Consumptive water use and water-use efficiency also increased with intercropping at higher row ratios of 1 : 2 and 1 : 3. Increase in the dose of 30 kg to 90 kg P_2O_5/ha resulted in increase of grain yield of both pigeonpea and soybean. The pigeonpea-grain-yield equivalent was increased by 28.2%, the water-use efficiency by 7.7 kg/ha-cm, net profit by Rs 5,733/ha and benefit : cost ratio by 3.45.

In rainfed situation in black-soil areas, the success or failure of a winter (*rabi*) crop depends mostly on the residual soil-profile moisture. Therefore an intercropping of long-duration pigeonpea [*Cajanus cajan* (L.) Millsp.] with soybean [*Glycine max* (L.) (Merr.)] is gaining popularity, as it makes the complimentary use of available resources and ensures sustainable crop production. Spatial arrangement and phosphorus application of such a system needs to be systematically studied in order to adjust the needs of the crop components to the local situations. The experiment was therefore conducted.

MATERIALS AND METHODS

The experiment was conducted during 1991–92 and 1992–93 on deep Vertisols with clayey texture (53 % clay, 32 % silt and 15% sand), receiving an annual average rainfall of 1,200 mm (90% during the monsoon). The soil was poor in organic carbon (0.54%) and available N (164 kg/ha), medium in available P (11.2 kg/ha) and K (238 kg/ha). The bulk density was 1.48 g/cm^3. Ten treatments of intercropping systems (pigeonpea and soybean in 1 : 1, 1 : 2 and 1 : 3 row ratios with pigeonpea at 60, 90 and 120 cm row spacing and soybean at 30 cm row spacing and in 1 : 1 and 1 : 2 row ratios with pigeonpea at 80 and 120 cm row spacing and soybean at 40 cm row spacing along with sole pigeonpea at 60, 90 and 120 cm and sole soybean at 30 and 40 cm row spacing) formed the main plots and 3 phospho-

rus levels (30, 60 and 90 kg P_2O_5/ha) formed the subplot in split-plot design with 3 replications. The population density of component crops in 1 : 1, 1 : 2 and 1 : 3 row ratios (with soybean at 30 cm) were 83,000; 55,000; and 41,500 plants of pigeonpea + 666,000 plants of soybean per hectare. The plant densities at 1 : 1 and 1 : 2 row ratios with soybean at 40 cm were 62,500 and 41,500 plants of pigeonpea + 500,000 plants of soybean per hectare.

'Punjab 1' soybean and 'JA 3' pigeonpea were sown in the first week of July and harvested in October and January respectively, during both the years. The phosphorus was applied equally to both the component crops at sowing. Uniform basal dose of 20 kg N/ha and 30 kg K/ha was applied in the form of urea and muriate of potash respectively.

The rainfall received during the cropping period of pigeonpea was 68.9 and 41.2 cm during 1991–92 and 1992–93 respectively. The consumptive use of water was determined from the data recorded on total rainfall, run-off and change in the moisture regime of the soil up to 90 cm depth during cropping period of pigeonpea. The run-off data recorded in lysimeter installed in the adjoining plot were used. The total run-off of 19.7 cm and of 9.35 cm occurred during 1991–92 and 1992–93 respectively.

Table 1. Growth and yield attributes of pigeonpea and soybean as influenced by intercropping row ratios and P fertilization (average data of 2 years)

Treatment	Branching/plant		Pods/plant		Grains/pod		1,000-grain weight (g)	
	PP	S	PP	S	PP	S	PP	S
Intercropping system								
Pigeonpea (PP)) sole (60 cm)	8.2		87.4		2.91		64.7	
PP (60 cm) + soybean (S) (30 cm), 1 : 1	6.0	11.7	79.6	38.7	2.91	2.07	63.6	172.0
PP (90 cm) + S (30 cm) 1 : 2	8.2	12.0	87.3	40.5	2.92	2.20	64.2	172.8
PP (120 cm) + S (30 cm) 1 : 3	9.9	14.7	98.0	42.3	2.98	2.30	64.6	174.0
PP (80 cm) + S (40 cm) 1 : 1	7.5	12.3	86.3	39.0	2.92	2.10	64.7	174.4
PP (120 cm) + S (40 cm) 1 : 2	11.3	15.4	96.3	40.8	2.95	2.33	65.1	174.8
PP sole (90 cm)	11.4		88.8		3.40		65.2	
PP sole (120 cm)	16.0		100.8		3.44		66.3	
S sole (30 cm)		15.3		38.9		2.13		175.8
S sole (40 cm)		15.7		46.8		2.30		176.8
CD (P = 0.05)	1.5	1.7	4.0	NS	0.05	0.11	0.8	1.4
P (kg P_2O_5/ha)								
30	7.5	10.7	80.7	36.7	2.95	2.07	62.0	170.2
60	9.9	13.6	91.2	41.4	3.00	2.12	63.8	172.3
90	11.8	15.7	102.9	44.9	3.05	2.18	68.1	175.9
CD (P = 0.05)	0.5	0.5	2.4	1.1	0.01	0.05	1.7	0.6
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

RESULTS AND DISCUSSION

Effect of spatial arrangement

Pigeonpea and soybean intercropping in 1 : 3 and 1 : 2 row ratios showed significant improvement in number of branches/plant, pods/plant, grains/pod and 1,000-grain weight than that in 1 : 1 ratio (Table 1). The main reason for such a reduction was poor development of plants and lesser accumulation of photosynthates due to lack of sunlight and shading effect. Pure crop of pigeonpea at 60, 90 and 120 cm or pure soybean at 30 and 40 cm had more number of branches, pods/plant, grains/pod and 1,000-grain weight than intercropping system. This was mainly due to proper utilization of resources such as water and nutrients owing to no competition from component crop.

Pure pigeonpea at 60 cm gave the yield of 20.2 and 16.8 q/ha during 1991–92 and 1992–93 respectively (Table 2). Reduction

Table 2. Effect of spatial arrangement and P fertilization on grain yield and monetary yield advantage in pigeonpea–soybean intercropping system

Treatment	Grain yield (q/ha)				Pigeonpea-grain-yield equivalent (q/ha)		LER		Monetary yield advantage (Rs/ha)	
	Y_1		Y_2		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
	Pigeonpea	Soybean	Pigeonpea	Soybean						
Intercropping system										
Pigeonpea (PP) sole (60 cm)	20.2		16.8		20.2	16.8	1.0	1.0		
PP (60 cm) + soybean (S) (30 cm) 1 : 1	15.6	6.5	11.9	6.1	21.1	17.0	1.12	1.19	2,147	2,578
PP (90 cm) + S (30 cm) 1 : 2	18.5	8.5	16.3	6.6	25.6	21.8	1.32	1.37	5,895	5,593
PP (120 cm) + (30 cm) 1 : 3	19.4	9.7	16.4	7.2	27.6	22.5	1.43	1.35	7,884	5,541
PP (80 cm) + S (40 cm) 1 : 1	17.7	5.7	13.7	6.3	22.5	19.0	1.19	1.26	3,412	3,725
PP (120 cm) + S (40 cm) 1 : 2	18.8	6.9	16.5	6.7	24.6	22.1	1.31	1.38	5,530	5,781
PP sole (90 cm)	21.1		19.2		21.1	19.2	1.0	1.0		
PP sole (120 cm)	21.2		20.9		21.2	20.9	1.0	1.0		
S sole (30 cm)		18.8		12.7	15.8	10.7	1.0	1.0		
S sole (40 cm)		16.2		11.4	13.6	9.6	1.0	1.0		
CD (P = 0.05)	2.8	1.5	1.7	1.9	2.2	2.1				
P (kg P_2O_5/ha)										
30	16.5	8.3	14.5	7.7	23.5	21.0				
60	19.5	10.6	16.6	7.9	28.4	23.1				
90	21.1	12.0	18.6	8.8	31.2	26.0				
CD (P = 0.05)	1.7	0.6	0.5	0.8	1.3	0.5				
Interaction	NS	1.5	NS	NS	NS	NS				

LER, Land equivalent ratio; Y_1, 1991–92; Y_2, 1992–93

in pigeonpea yields was noted under intercropping system in all the ratios, but the yield was lowest in 1 : 1 row ratio with soybean at 30 cm. The reduction in yield under intercropping was due to lower values of yield attributes (Table 1). Among the intercropping systems, a row ratio of 1 : 3 gave the highest seed yield than others in both the years. This was because the depressing effects of soybean on pigeonpea under 1 : 3 ratio were minimized due to more number of rows of soybean and better growth and pod development of pigeonpea, since it could utilize more space leftover by soybean after its harvest in October.

Yield of pure soybean was higher at both 30 and 40 cm row spacings. In intercropping system yield of soybean was reduced at all the ratios; however, 1 : 1 row ratio gave the lowest yield of soybean compared with the other ratios. This was mainly because of more space occupied by intercrop, and the main crop of pigeonpea could not compete with it owing to its slow growth up to flowering stage of soybean.

The highest pigeonpea-equivalent yields of 27.6 and 22.5 q/ha were recorded with 1 : 3 row ratio during 1991–92 and 1992–93 respectively (Table 2), which was significantly higher than pure pigeonpea and other row ratios except 1 : 2 (30/90) intercrop system. Similarly, a row ratio of 1 : 2 (40/120) gave higher equivalent yields of 24.6 and 22.1 q/ha compared with 1 : 1 row ratio and sole pigeonpea or soybean. Patra and Chatterjee (1986) and Tomar *et al.* (1987) also found increase in pigeonpea-equivalent yields at higher row ratios.

The land-equivalent ratio increased with the number of intercrop rows up to 1 : 3, which gave the highest values of 1.43 and 1.35 during the first and second years (Table 2). This was followed by 1 : 2 row ratios. Tomar *et al.* (1987) also reported similar results. Monetary yield advantage of the intercropping system was higher than that of monocropping system. It was also highest at 1 : 3 row ratio (Rs 7,884 and Rs 5,541/ha during 1991–92 and 1992–93). This was followed by 1 : 2 row ratio (30/90), showing monetry advantage of Rs 5,895/ha and Rs 5,593/ha during the first and second years respectively compared with the sole-cropping systems.

The consumptive water use by crop (Table 3) increased from 64.8 and 45.9 cm respectively during 1991–92 and 1992–93 in pure pigeonpea (60 cm) to 74.2 and 45.8 cm in 1 : 2 (30/90) and 71.9 and 49.1 cm in 1 : 3 row ratios (30/120). This showed that 1 : 3 and 1 : 2 (30/90) row ratios used more soil moisture than 1 : 2 (40/120) and 1 : 1 ratios due to higher plant densities. The water-use efficiency of the above systems also increased from 31.2 and 36.6 kg/ha-cm (pure pigeonpea) to 38.4 and 45.8 kg/ha-cm in 1 : 3 row ratio during 1991–92 and 1992–93 respectively. The 1 : 2 row ratio also performed equally well. The increase of water-use efficiency, with row ratios was also reported by Prasad *et al.* (1985).

The intercropping in 1 : 3 row ratio was found more profitable with the net profit of Rs 6,210 and Rs 4,595/ha during 1991–92 and 1992–93 respectively. The benefit : cost ratio for the same system for the 2 years was 3.18 and 2.41 respectively, which was also highest compared with the other row ratios (Table 3). Tomar *et al.* (1990) and Dubey *et al.* (1991) also reported higher net profit and benefit : cost ratio with higher row ratio over the lower ones.

Effect of P

Application of P up to 90 kg/ha to the intercropping system gave significantly higher

Table 3. Effect of spatial arrangement and P fertilization on water-use efficiency and economics in pigeonpea–soybean intercropping system

Treatment	Consumptive moisture use (cm)		Water-use efficiency (kg/ha-cm)		Net returns (Rs/ha)		Benefit : cost ratio	
	1991–92	1992–93	1991–92	1992–93	1991–92	1992–93	1991–92	1992–93
Intercropping system								
Pigeonpea (PP) sole (60 cm)	64.8	45.9	31.2	36.6	13,740	10,510	2.52	1.93
PP (60 cm) + soybean (S) (30 cm) 1 : 1	66.8	45.8	31.7	37.1	13,970	10,125	2.30	1.68
PP (90 cm) + S (30 cm) 1 : 2	74.2	45.8	34.5	47.6	18,150	14,540	2.94	2.35
PP (120 cm) + (30 cm) 1 : 3	71.9	49.1	38.4	45.8	19,950	15,105	3.18	2.40
PP (80 cm) + S (40 cm) 1 : 1	67.0	49.1	33.6	38.7	15,985	12,660	2.96	2.35
PP (120 cm) + S (40 cm) 1 : 2	64.6	47.4	38.1	46.6	17,650	15,305	3.11	2.69
PP sole (90 cm)	68.1	48.1	31.0	39.9	14,845	13,040	2.85	2.51
PP sole (120 cm)	69.8	51.9	30.4	40.3	15,175	14,890	3.05	3.00
S sole (30 cm)	72.8	49.1	21.7	21.8	9,010	4,185	1.50	0.69
S sole (40 cm)	71.5	48.7	19.0	19.7	7,445	3,645	1.36	0.66
P (kg P_2O_5/ha)								
30	68.5	44.1	34.3	47.6	16,531	14,156	2.85	2.44
60	96.7	47.2	40.8	48.9	21,036	16,001	3.54	2.69
90	69.1	49.8	45.2	52.2	23,547	18,607	3.86	3.05

number of branches/plant, pods/plant, grains/pod and 1,000-grain weight and grain yields of both component crops as well as pigeonpea-equivalent yield in both the years, except pigeonpea yield during 1991–92 where 60 kg P/ha remained on a par with 90 kg P/ha. The increase in pigeonpea-equivalent yield at 90 kg/ha was 9.8 and 12.5% over 60 kg/ha and 32.7 and 23.8% over 30 kg P/ha during 1991–92 and 1992–93 respectively. Similar increases in yield of both the components of legume–legume system with P fertilization was also reported by Thakre *et al.* (1988). Increase in P fertilization from 30 to 90 kg/ha also increased water-use efficiency of the system from 34.3 to 45.2 kg/ha-cm during 1991–92 and 47.7 to 52.2 kg/ha-cm during 1992–93. The net profit also increased by Rs 7,016/ha and Rs 4,451/ha during the first and second years at 90 kg P_2O_5/ha.

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