

Effect of sunflower stover and nutrient management on productivity and nutrient uptake pattern of pigeonpea (*Cajanus cajan*) in pigeonpea–sunflower (*Helianthus annuus*) cropping system

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ABSTRACT

A fixed plot field experiment was carried out during *kharif* and *spring* seasons of 2008-2009 and 2009-2010 at New Delhi, to study the effect of sunflower (*Helianthus annuus* L.) stover and nitrogen + phosphorus management on pigeonpea [*Cajanus cajan* (L.) Millsp.]–sunflower cropping system. Effect of treatments on the on yield attributes, productivity, economics and nutrient uptake pattern of pigeonpea has been given in this paper. *Kharif* season experiment was laid out in split-plot design, assigning sunflower stover incorporation (8 tonnes/ha) and no stover incorporation (control) to main plots and combinations of P levels and bio-fertilizers (Control, 15 kg P/ha, 15kg P/ha+PSB and 30kg P/ha) to sub-plots. Spring season experiments was laid out in split-split plot design, in which NP doses to sunflower crop (Control, 50% recommended dose (RD) of NP and RD of NP (80 kg N+15 kg P/ha) were applied in sub-sub plots. *Kharif* season experiment in second year was laid out in split-split plot design to investigate the residual effect of NP doses applied to spring season sunflower on pigeonpea crop. Sunflower stover incorporation reduced the yield attributes (number of pods/plant, number of grains/pod, grain yield/plant, 1,000-grains weight), grain yield, nutrient uptake and gross returns, net returns and B:C ratio of pigeonpea. Adverse effect of sunflower stover incorporation was more pronounced during second year. Reduction in pigeonpea grain yield was 4.9% and 25.8% in the first and second year respectively. Effect of P levels on pigeonpea was significant and the highest number of pods/plant, number of grains/pod, grain yield/plant, 1,000-grains weight and grain yield (1.63 and 1.32 t/ha), nutrient uptake, gross and net returns and B:C ratio were recorded with the application of 30 kg P/ha, followed by 15 kg P/ha+PSB. Marked effect of PSB integration with 15 kg P over 15 kg P alone was significant only during first year. Residual effect of RD of NP applied to preceding sunflower crop also improved the yield attributes, yields, nutrient uptake and gross and net returns and B:C ratio of succeeding pigeonpea crop under pigeonpea-sunflower cropping system. Significant interaction between P applied to pigeonpea during second year and residual effect of P applied to sunflower during first year was recorded, indicating saving of 15 kg P in pigeonpea due to residual effect.

Key words : Cropping system, Nutrient management, Nutrient uptake pattern, Pigeonpea, Residual effect, Sunflower, Sunflower stover incorporation,

Sunflower has been proved to be highly promising for round the year cultivation under different agro-climatic regions owing to its thermo-photo-insensitivity, has potential of 2.0-2.5 tonnes seed yield/ha and 4-6 tonnes/ha crop residue during the spring season. This much amount of crop residues neither used as feed for livestock nor suitable for fuel due to low energy value per unit mass. However, its residues contain major plant nutrients in the range of 0.45 to 0.60% N, 0.15 to 0.22% P and 1.80 to 1.94 % K

along with secondary and micronutrients, so recycling of its residue in the soil may be one of the alternative practices for improving the depleted soil productivity. Some researchers have reported allelopathic effects of sunflower residue on different crops, which put a question on choice of crop after sunflower and its residue incorporation (Narwal *et al.*, 1999). Leachates from the plants have been shown to suppress seed germination and vegetative propagules and early seedling growth (Dhawan and Gupta, 1996). The effects may be due to a variety of processes that may include reduced cell division in the roots, suppressed hormonal activity, reduced ion uptake, inhibition of protein synthesis, inhibition of photosynthesis and respiration, inhibition of enzymatic activity and reduced

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cell membrane permeability (Batlang and Shushu, 2007). Among the pulses, pigeonpea is the second most important crop next only to chickpea, but has very less productivity (709 kg/ha). Among the various reasons for low productivity, one finds the role of phosphorus in pulses of paramount importance. Imbalanced fertilizer use especially in terms of phosphorous compared with N, has created concern in India as it may affect overall agricultural productivity and economic growth. Balanced fertilizer use, complementary use of organic nutrient inputs with fertilizers, use of bio-fertilizer such as PSB and AM and inclusion of legumes are the potential agro-techniques to sustain yields, increase fertilizer use efficiencies and restore soil fertility. Among the bio-fertilizers, phosphorus solubilizing micro-organism play a significant role for improving growth, yield attributes and yield of pigeonpea by enhancing the phosphorus availability (Singh and Yadav, 2008).

In view of the limited information available on the integrated and judicious utilization of locally available sunflower stover with P levels and sources, a fixed plot field experiment was conducted over two consecutive seasons to study the effect of sunflower stover and P management on growth, productivity, quality and nutrient uptake of pigeonpea under pigeonpea-sunflower cropping system.

MATERIALS AND METHODS

A fixed plot field experiment was carried out during *kharif* and *spring* seasons of 2008-2009 and 2009-2010 for making a comparative assessment of sunflower stover management, P levels with and without bio-fertilizers and N doses on the productivity, economics and nutrient uptake of pigeonpea under pigeonpea-sunflower cropping system at research farm of Division of Agronomy, Indian Agricultural research Institute, New Delhi. The soils of experimental field was sandy clay loam belongs to order Inceptisol and having 145.0 kg/ha alkaline permanganate oxidizable N (Jackson, 1973), 17.5 kg/ha available P (Olsen *et al.*, 1954), 226.0 kg/ha 1 N Ammonium Acetate exchangeable K (Stanford and English, 1949) and 0.40% organic carbon (Jackson, 1973). The pH of soil was 7.5 (1:2.5 soil and water ratio). *Kharif* season experiment in the first year was laid out in split-plot design, assigning sunflower stover incorporation (8 tonnes/ha) and no stover incorporation (control) to main plots and combination of P levels and bio-fertilizers (Control, 15 kg P/ha, 15kg P/ha+PSB and 30kg P/ha) to sub-plots. Before sowing the first year *kharif* pigeonpea, general crop of sunflower was grown. The *spring* season experiment after the *kharif* pigeonpea was laid out in split-split plot design in which NP doses to sunflower crop (Control, 50% recommended dose (RD) of NP and RD of NP (80 kg N+15 kg P/ha)

were applied in sub-sub plots. Data for *kharif* season experiment in second year was recorded and analyzed in split-split plot design to investigate the residual effect of NP doses applied to *spring* season crop in sub-sub plots. All the treatments replicated thrice during both the years. The plot size was 17.4 m × 15.0 m for main plots and 3.60 m × 15.0 m and 3.60 m × 4.0 m for sub-plots and sub-sub plots, respectively. Sunflower stover of the general sunflower crop grown during the *spring* season of 2008 and experimental crop of the spring season 2009 was chopped with the help of *chopper* and incorporated in the soil as per treatments (8 tonnes/ha) before the preparation of field for sowing of pigeonpea. The recommended starter dose (25 kg/ha) of N for pigeonpea was supplied through urea (after subtracting the N supplied from DAP). Diammonium phosphate was used to supply phosphorus as per treatment. Phosphorus was placed 3-5 cm below the seed with the help of metallic tube attached plough. Seeds of pigeonpea as per treatment inoculated with the PSB culture 'Microphos' containing inoculum of *Pseudomonas striata*.

Pigeonpea 'Pusa 992' was sown at the seed rate of 15 kg/ha by 'pora' method as per treatments in rows 60 cm apart and plant to plant spacing was maintained 20 cm apart by adopting gap filling and thinning at appropriate time. Pigeonpea was grown as per recommended practices and was harvested on 9th and 14th of December in both the year of experimentation (2008 and 2009) respectively.

Five plants were selected from net plot and total number of pods of the sampled plants was counted and the average pods/plant calculated. Twenty pods were randomly picked up from the sampled plants; threshed and total number of grains were counted and averaged to record number of grains/pod. The 1,000-grains, taken from sampled pods, were first counted by a seed counter and then weighed to compute the 1,000-grains weight. At maturity, the net plots were harvested and sun-dried and total biomass yield was recorded. After threshing, cleaning and drying the grain yield was recorded. Stover yield was obtained by subtracting grain yield from the total biomass yield. Yield was expressed in tonnes/ha. The plant samples were collected and ground into fine powder and pass through a 40 mm mesh sieve and used for chemical analysis to find out the nitrogen and phosphorus uptake of these nutrients at 60,120 DAS and at harvest and only at harvest in case of potassium. Nitrogen was estimated by Kjeldahl's method (Jackson, 1973), phosphorus by Vanadomolybdophosphoric yellow colour method (Jackson, 1973) and potassium content was determined using flame photometry method (Jackson, 1973). The nutrient content was expressed in percentage and uptake was calculated in kg/ha. The uptake/accumulation of NPK in

pigeonpea grain and stover were calculated by multiplying the dry matter accumulation in grain and stover yield of pigeonpea with their respective content expressed in kg/ha. Cost of cultivation was calculated based on the prevailing market prices of the inputs during the respective crop seasons. Gross returns were calculated based on the grain and stover/straw yield and their prevailing market prices during the respective crop seasons. Net returns were calculated by subtracting cost of cultivation from gross returns. Net B:C ratio was calculated by dividing the net returns with cost of cultivation.

All the data obtained from pigeonpea for two consecutive years of study were statistically analyzed using the *F*-test, the procedure given by Gomez and Gomez (1984). Critical difference (CD) values at *P*=0.05 were used to determine the significance of differences between means.

RESULTS AND DISCUSSION

Yield attributes and yields

Sunflower stover incorporation reduced the yield attributes viz. number of pods/plant, number of grains/pod, grain yield/plant and 1,000-grains weight and grain, stover and biological yields during both the years (Table 1 and 2). Adverse influence of sunflower stover incorporation was more pronounced on pods/plant, grains/pod, grain yield/plant and 1,000-grains weight and grain, stover and biological yields during the second year of experimentation than the first year. During the second year, sunflower stover incorporation induced significant reduction in pods/

plant (104.8 to 82.5), grains/pod (3.05 to 2.81), grain yield/plant (22.6 to 18.2 g) and 1,000-grains weight (69.7 to 68.0 g) and grain (1.24 to 0.92 t/ha), stover (5.2 to 3.9 t/ha) and biological yields (6.4 to 4.8 t/ha) over the control (no stover incorporation). Reduction in yield and yield attributes might be due to secretion and accumulation of allelopathic compound from the roots of sunflower and due to the decomposition of sunflower stover. Drastic reduction in second year as compared to first year may be attributed to accumulative effect, as the experiment was conducted on fixed plot. These results are in lines of Batish *et al.*, (2002); Pal and Sand, (2006) and Batlang and Shushu (2007). Among the P levels, application of 30 kg P/ha recorded highest number of pods/plant (120.9 and 102.5), number of grains/pod (3.29 and 3.18), grain yield/plant (29.9 and 24.1 g), 1,000-grains weight (75.0 and 71.5 g) and grain (1.63 and 1.32 t/ha), stover (6.0 and 5.1 t/ha) and biological (7.6 and 7.4 t/ha) yields followed by 15 kg P/ha+PSB. This could be attributed to overall improvement in crop growth. Moreover, phosphorous plays a key role in the root development, energy transformation and metabolic processes of plant, resulting in more translocation of photosynthates towards the sink development (Tisdale *et al.*, 1995). The observations of the present study are in line with the findings of Jat and Ahlawat (2001) and Singh and Sekhon (2007). Residual effects of RD of NP given to sunflower, was significant on pods/plant, grains/pod, grain yield/plant and 1,000-grains weight and grain, stover and biological yields of succeed-

Table 1. Direct effect of sunflower stover and P management and residual effect of NP on yield attributes of pigeonpea

Treatment	Pods/plant		Grains/pod		Grain yield/plant (g)		1,000-grains weight (g)	
	2008	2009	2008	2009	2008	2009	2008	2009
<i>Direct effect of SFS management</i>								
Control (without SFSI)	112.3	104.8	3.07	3.05	25.7	22.6	72.2	69.7
SFSI @8 t/ha	106.8	82.5	2.89	2.81	23.6	18.2	71.9	68.0
SEm±	0.99	0.72	0.021	0.02	0.5	0.4	0.8	0.1
CD (P=0.05)	NS	4.39	NS	0.15	NS	2.7	NS	0.8
<i>Direct effect of P levels</i>								
Control	96.8	81.1	2.56	2.50	16.7	14.2	69.4	66.8
15 kg P/ha	106.5	93.9	2.94	2.95	24.9	20.9	71.0	68.1
15 kg P/ha+PSB	114.4	97.1	3.13	3.09	27.2	22.4	72.8	68.9
30 kg P/ha	120.9	102.5	3.29	3.18	29.9	24.1	75.0	71.5
SEm±	1.62	1.89	0.07	0.02	0.7	0.4	0.7	0.5
CD (P=0.05)	4.98	5.83	0.21	0.07	2.1	1.3	2.2	1.6
<i>Residual effect of NP doses applied to sunflower</i>								
Control	-	90.9	-	2.86	-	19.2	-	67.5
50% RD of NP	-	92.2	-	2.93	-	20.1	-	68.2
RD of NP	-	97.8	-	3.01	-	21.9	-	70.8
SEm±	-	1.84	-	0.02	-	0.3	-	0.6
CD (P=0.05)	-	5.31	-	0.04	-	0.9	-	1.7

SFSI: Sunflower Stover Incorporation, RD of NP: 80 kg N+15 kg P/ha

ing pigeonpea. Similar results reported by Jat and Ahlawat (2001)

Nutrients uptake

N, P and K uptake by pigeonpea plant at 60 DAS and 120 DAS and at harvest in grain, stover and total is presented in table 3, 4 and 5. N, P and K uptake was more in the first year than in the second year, which followed the pattern set by dry matter accumulation. At harvest stage, N, P and K uptake was less in seed as compared to stover and the gap between the two was more with respect to K. With respect to duration of the crop, N and P uptake was proportionately more in the early stage of crop. At 60 and 120 DAS, sunflower stover incorporation and no stover incorporation (control) recorded similar N and P uptake during first years of the study, while in second year sunflower stover incorporation, significantly reduced the N and P uptake in plant. Significantly higher N uptake in plant at 60 and 120 DAS was recorded with 30 kg P/ha, which remained at par with 15 kg P/ha+PSB. The residual effect of RD of NP recorded higher N uptake in succeeding pigeonpea crop at both the growth stages under pigeonpea-sunflower cropping system.

At harvest, significant reduction in N, P and K uptake due to sunflower stover incorporation was noticed only during the second year of experimentation. Sunflower stover incorporation reduced the N uptake in grain by 38.6% and in stover by 37.2%. Percent reduction in P uptake was

47.8% and 79.5% in grain and stover respectively over the control. Reduction in K uptake due to sunflower stover incorporation was 38.4% in grain and 38.9% in stover. Higher concentration of allelochemicals reduced the root development and root hair formation (Caspersen *et al.*, 1999). The physiological mechanism of action of these allelochemicals involves the disruption of normal membrane functions in plant cells. These allelochemicals can depolarize the electrical potential difference across membranes, a primary driving force for active absorption of mineral ions. Allelochemicals can also decrease the ATP content of cells by inhibiting electron transport and oxidative phosphorylation, which are two functions of mitochondrial membranes. In addition, allelochemicals can alter the permeability of membranes to mineral ions (Balke, 1985).

All the P levels significantly increase the N, P and K uptake in seed and stover over the control. Among the P levels, application of 30 kg P/ha recorded maximum uptake of N in grain (53 and 43.4 kg N/ha) and stover (79 and 68.5 kg N/ha) during both the year of study. Application of 30 kg P/ha increases N uptake in grain by 79.0, 19.3 and 8.6% over control, 15 kg P/ha and 15 kg P/ha+PSB in 2008 and 105.6, 21.5 and 13.1% during 2009 respectively. Corresponding increase in stover was 67.7, 19.7 and 6.7 % during 2008 and 71.7, 14.3 and 7.7% in 2009. Increase in P uptake in grain due to 30 kg P/ha was 90.9 and 116.7%, 31.2 and 39.3%, 13.5 and 30.0% over

Table 2. Direct effect of sunflower stover and P management and residual effect of NP on grain, biological yields and an economics of pigeonpea

Treatment	Grain yield (t/ha)		Biological yield (t/ha)		Cost of cultivation ($\times 10^3$ ₹/ha)		Net returns ($\times 10^3$ ₹/ha)		B:C ratio	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
<i>Direct effect of SFS management</i>										
Control (without SFSI)	1.42	1.24	7.1	6.4	11.8	12.8	24.2	27.7	2.05	2.16
SFSI @8 t/ha	1.35	0.92	6.3	4.8	13.4	14.4	20.7	15.8	1.54	1.09
SEm $\pm$	0.02	0.02	0.164	0.06	-	-	0.42	0.58	0.03	0.04
CD (P=0.05)	NS	0.11	NS	0.34	-	-	2.38	3.55	0.18	0.27
<i>Direct effect of P levels</i>										
Control	0.99	0.74	4.9	4.1	12.3	13.4	12.9	10.9	1.06	0.84
15 kg P/ha	1.40	1.11	7.0	5.8	12.5	13.6	22.9	22.6	1.84	1.70
15 kg P/ha+PSB	1.51	1.16	7.3	6.0	12.6	13.6	25.6	24.5	2.05	1.83
30 kg P/ha	1.63	1.32	7.6	6.4	12.9	13.9	28.3	29.1	2.23	2.13
SEm $\pm$	0.03	0.02	0.18	0.09	-	-	0.64	0.75	0.05	0.05
CD (P=0.05)	0.09	0.07	0.56	0.27	-	-	1.98	2.32	0.16	0.16
<i>Residual effect of NP doses applied to sunflower</i>										
Control	-	1.02	-	5.4	-	13.6	-	19.7	-	1.47
50% RD of NP	-	1.06	-	5.5	-	13.6	-	21.1	-	1.58
RD of NP	-	1.17	-	5.9	-	13.6	-	24.5	-	1.83
SEm $\pm$	-	0.02	-	0.08	-	-	-	0.74	-	0.05
CD (P=0.05)	-	0.07	-	0.22	-	-	-	2.14	-	0.16

SFSI: Sunflower Stover Incorporation, RD of NP: 80 kg N+15 kg P/ha

Table 3. Direct effect of sunflower stover and P management and residual effect of NP on N uptake by pigeonpea

Treatment	N uptake (kg/ha)									
	Shoot					At harvest				
	60 DAS		120 DAS		Grain		Stover		Total	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
<i>Direct effect of SFS management</i>										
Control(without SFSI)	21.0	16.6	101.2	89.3	45.2	40.2	71.9	67.1	117.1	107.2
SFSI@8 t/ha	18.3	13.3	91.2	67.7	42.8	29	62.9	48.9	105.7	77.9
SEm±	0.60	0.18	2.50	0.65	0.80	0.70	2.10	0.80	3.70	1.10
CD (P=0.05)	NS	1.08	NS	3.94	NS	4.20	NS	5.00	NS	6.60
<i>Direct effect of P levels</i>										
Control	14.3	10.9	68.8	54.1	29.6	21.1	47.1	39.9	76.7	61.0
15 kg P/ha	19.3	14.4	98.0	81.4	44.4	35.7	69.7	59.9	114.1	95.6
15kg P/ha+PSB	20.8	16.0	106.2	85.4	48.8	38.1	74	63.6	122.8	101.7
30 kg P/ha	24.2	18.4	111.8	93.2	53	43.4	79	68.5	132	111.9
SEm±	1.04	0.43	2.80	1.17	1.00	1.00	2.50	1.00	2.60	1.90
CD (P=0.05)	3.19	1.34	8.63	3.60	3.10	3.20	7.80	3.10	8.00	5.80
<i>Residual effect of NP doses applied to sunflower</i>										
Control	-	13.9	-	74.6	-	32.1	-	55.6	-	87.7
50% RD of NP	-	14.4	-	77.7	-	33.6	-	57	-	90.6
RD of NP	-	16.5	-	83.2	-	38	-	61.3	-	99.3
SEm±	-	0.54	-	1.27	-	0.80	-	0.70	-	1.30
CD (P=0.05)	-	1.56	-	3.67	-	2.20	-	2.00	-	3.60

SFSI: Sunflower stover incorporation, RD of NP: 80 kg N+15 kg P/ha

Table 4. Direct effect of sunflower stover and P management and residual effect of NP on P uptake in pigeonpea

Treatment	P uptake (kg/ha)									
	Shoot					At harvest				
	60 DAS		120 DAS		Grain		Stover		Total	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
<i>Direct effect of SFS management</i>										
Control(without SFSI)	21.0	16.6	101.2	89.3	45.2	40.2	71.9	67.1	117.1	107.2
Control (without SFSI)	3.3	2.4	9.0	9.6	3.6	3.4	6.0	7.0	9.6	10.4
SFSI @8 t/ha	2.3	1.6	7.5	6.0	3.1	2.3	4.9	3.9	7.9	6.2
SEm±	0.15	0.11	0.45	0.29	0.1	0.02	0.2	0.05	0.37	0.1
CD (P=0.05)	0.91	0.68	NS	1.74	NS	0.11	NS	0.29	NS	0.6
<i>Direct effect of P levels</i>										
Control	1.3	0.7	4.3	3.9	2.2	1.8	3.6	3.2	5.8	4.9
15 kg P/ha	2.8	2.0	7.7	7.5	3.2	2.8	5.8	5.4	9.0	8.2
15 kg P/ha+PSB	3.2	2.5	9.4	9.2	3.7	3.0	5.8	6.6	9.6	9.6
30 kg P/ha	4.0	2.9	11.4	10.6	4.2	3.9	6.5	6.6	10.7	10.5
SEm±	0.17	0.11	0.49	0.34	0.15	0.09	0.3	0.18	0.39	0.3
CD (P=0.05)	0.53	0.35	1.52	1.05	0.47	0.27	0.93	0.54	1.2	0.8
<i>Residual effect of NP doses applied to sunflower</i>										
Control	-	1.8	-	6.8	-	2.6	-	5.1	-	7.6
50% RD of NP	-	1.9	-	7.9	-	2.8	-	5.6	-	7.8
RD of NP	-	2.4	-	8.7	-	3.3	-	6.2	-	9.4
SEm±	-	0.13	-	0.25	-	0.09	-	0.15	-	0.2
CD (P=0.05)	-	0.36	-	0.73	-	0.25	-	0.42	-	0.6

SFSI: Sunflower stover incorporation, RD of NP: 80 kg N+15 kg P/ha

the control, 15 kg P/ha and 15 kg P/ha+PSB during both the year respectively. Similar effect on P uptake was also observed in stover. Lowest values of K uptake in grain (8.7 and 6.6 kg/ha) and stover (53.9 and 45.2 kg/ha) was recorded with control. Maximum values of K uptake in grain (15.7 and 12.8 kg/ha) and stover (87.6 and 76.9) was recorded with the application of 30 kg P/ha during both the year of field experimentation. This could be attributed to the fact that added phosphorous increased nutrient content by providing balanced nutritional environment inside the plant and higher photosynthetic efficiency, which favoured growth and crop yield. Since, the uptake of nutrient is a function of dry matter accumulation and nutrient content, the increased dry matter accumulation together with higher nutrient content resulted in greater uptake of NPK. When P availability is enhanced in a symbiotically N-fixing system; N content in plants is normally increased (Buresh and Smithson, 1997). Microorganisms with phosphate solubilizing potential increase the availability of soluble phosphate and improving biological nitrogen fixation (Ponmurugan and Gopi, 2006). PSB increased the P content in plant because some bacterial species have mineralization and solubilization potential for organic and inorganic phosphorus, respectively (Khiari and Parent, 2005). The increase in nutrient content and uptake with phosphorous fertilization are in line those of Singh and Sekhon (2007), Singh and Yadav (2008) and Chaudhari *et al.* (2010).

Residual effect of NP nutrition was significant on N

uptake in grain and stover in succeeding pigeonpea crop in pigeonpea-sunflower cropping system. Among the doses of NP, residual effect of RD of NP recorded the higher values of N uptake in grain (38.0 kg/ha) and in stover (61.3 kg/ha). This leads to 18.4% and 13.1%, 10.2% and 7.5% increase N uptake in grain and stover over control and 50% RD of NP respectively. Among the different doses of NP applied to preceding sunflower, the residual effect of RD of N and P induced marked increase in P uptake in grain (3.3 kg/ha) and stover (6.6 kg/ha) of succeeding pigeonpea. Due to residual effect of RD of NP, 26.9% higher P uptake in grain and 20% in stover was noticed over the control in succeeding pigeonpea crop during the course of investigation. Among the different doses of NP, the residual effect of RD of NP recorded the higher values of K uptake in grain (11.2 kg/ha) and in stover (69.1 kg/ha), which were 17.9 and 10.4 % higher in grain and stover respectively over the control. The total nutrient uptake is the product of nutrient content and grain+stover yield. So, due to treatment effect, total uptake of NPK in grain and stover followed trend similar to their uptake in grain and stover.

Economics

Sunflower stover incorporation has the higher cost of cultivation ($13.41 \times 10^3/-$ and $14.45 \times 10^3/-$ ₹/ha) as compared to control. This might be attributed to additional labour required for in chopping of stover and its application. Among the P levels, application of 30 kg P/ha re-

Table 5. Direct effect of sunflower stover and P management and residual effect of NP on K uptake in seed, stover and total by pigeonpea

Treatment	K uptake (kg/ha)				Total K uptake	
	Grain		Stover		(kg/ha)	
	2008	2009	2008	2009	2008	2009
<i>Direct effect of SFS management</i>						
Control (without SFSI)	13.5	11.9	81.4	75.7	94.9	87.6
SFSI @8 t/ha	12.3	8.6	70.5	54.5	82.9	63.1
SEm±	0.4	0.2	2.7	0.9	2.3	0.5
CD (P=0.05)	NS	1.1	NS	5.3	NS	2.7
<i>Direct effect of P levels</i>						
Control	8.70	6.6	53.9	45.2	62.6	51.7
15 kg P/ha	13.0	10.5	79.1	67.5	92.1	78.0
15 kg P/ha+PSB	14.3	11.2	83.4	71.6	97.6	82.8
30 kg P/ha	15.7	12.8	87.6	76.9	103.2	88.9
SEm±	0.5	0.2	2.9	1.3	3.0	1.4
CD (P=0.05)	1.6	0.7	8.8	3.9	9.3	4.2
<i>Residual effect of NP levels applied to sunflower</i>						
Control	-	9.5	-	62.6	-	72.1
50% RD of NP	-	10.2	-	63.6	-	73.8
RD of NP	-	11.2	-	69.1	-	80.2
SEm±	-	0.2	-	1.0	-	0.1
CD (P=0.05)	-	0.6	-	2.9	-	3.0

SFSI: Sunflower stover incorporation, RD of NP: 80 kg N+15 kg P/ha

corded the maximum cost of cultivation ($12.83 \times 10^3/-$ and $13.87 \times 10^3/-$ ₹/ha) due to additional P cost. Costs of cultivation of residual effect of NP doses were same as control. Gross returns due to sunflower stover incorporation found statistically similar to no stover incorporation in 2008. However, significantly lower gross returns in 2009, net returns and B:C ratio in both 2008 and 2009 were recorded with sunflower stover incorporation as compared to control. This was probably due to lower economic yield caused by allelopathic effect of sunflower stover incorporation. Due to conductance of experiment on fixed plot, second year crop subjected to more accumulated adverse affects of the sunflower residue and also adverse effects associated with growing the same crop continuously on the same field. In the second year there was more influence of allelochemical which reduced the plant population, plant growth parameters, yield attributes and yield of crop. Pal and Sand (2006) and Srisa-ard K. (2007) recorded similar result. All the P levels fetched the higher gross returns, net returns and B:C ratio as compared to control in both 2008 and 2009. This could be attributed to higher yields in these treatments. Among the P levels, maximum gross returns ($41.15 \times 10^3/-$ and $42.93 \times 10^3/-$ ₹/ha), net returns ($28.32 \times 10^3/-$ and $29.06 \times 10^3/-$ ₹/ha) and B: C ratios (2.23 and 2.13) were recorded with 30 kg P/ha during both the years. This could be attributed to higher economic yield of the component crop of the system due to direct and residual effect of P levels, coupled with better market price. Similar findings were also reported by Kantwa *et al.* (2004). Residual effect of RD of NP (80 kg N+ 15 kg P/ha) applied to preceding sunflower crop recorded the maximum gross returns ($38.08 \times 10^3/-$ ₹/ha), net returns ($24.46 \times 10^3/-$ ₹/ha) and B: C ratio (1.83). It may be due to the fact that residual effect of RD of NP exerted favourable effect on plant growth and yield attributes and increase the economic yield.

The present study thus indicates that continuous incorporation of sunflower residue in the field may cause the negative allelopathic effect on the pigeonpea. Application of 30 kg P/ha may be a better option for achieving the higher yield of pigeonpea. Application of RD of NP to the sunflower had the appreciable residual effect on the succeeding pigeonpea crop.

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