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Effect of sunflower stover and nutrients management on productivity, nutrient economy and phosphorus use efficiencies of pigeonpea (*Cajanus cajan*)-sunflower (*Helianthus annuus*) cropping system

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ABSTRACT

A fixed plot field experiment was carried out during *kharif* and spring seasons of 2008–09 and 2009–10 at Research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi, to study the effect of sunflower stover and nutrients management on productivity, nutrient economy and phosphorus use efficiencies of pigeonpea (*Cajanus cajan*)-sunflower (*Helianthus annuus*) cropping system. In 2008–09, sunflower stover incorporation caused 6.17, 6.05, 4.90 and 5.1 percent increment in system productivity, production efficiency, per day returns and net returns over no stover incorporation, respectively. However, sunflower stover incorporation was failed to affect the system productivity and production efficiency during the second year of experimentation. Application of 30 kg P/ha to pigeonpea recorded maximum system productivity (4.17 and 3.24 tonnes/ha), production efficiency (11.42 and 8.88 kg/ha/day), net returns (₹ 72.8 and 71.6x10^3/ha), per day returns (199 and 196 ₹/ha) during 2008–09 and 2009–10, respectively. Recommended dose (RD) of NP applied directly to sunflower produced the markedly higher productivity (3.18 t/ha), production efficiency (8.71 kg/ha/day) net returns ₹ 69.1x10^3/ha and per day returns (189 ₹/ha). Residual effect of 8 tonnes/ha sunflower stover incorporation and 30 kg/ha P was significant on nutrient economy of succeeding sunflower crop and reduced up to 50% recommended dose of P. Direct effect of sunflower stover incorporation had significant effect on agronomic P use efficiency (APUE), agro physiological P use efficiency (APPUE), physiological efficiency index of P (PEIP) during 2009 only, while residual effect of sunflower stover incorporation significantly affected the agronomic P use efficiency (APUE), physiological efficiency index of P (PEIP) during both the years and agro physiological P use efficiency (APPUE) only during 2009. With regards to the direct and residual effect of P levels, the direct effect of 15 kg P/ha+PSB recorded the higher values of APUE during both the years. However, the maximum values of APPUE and PEIP recorded with the direct effect of 15 kg P/ha. The residual effect of P levels applied to preceding pigeonpea crop showed perceptible reduction in APPUE during both years of study, and APUE in 2009 and PEIP during 2010 with successive increment of P levels. Direct effect of 50% RD of NP had marked increase of APUE and APPUE, over control and RD of NP. In contrast and PEIP reduced with successive doses of NP up to RD of NP. The residual effect of RD of NP applied to preceding sunflower crop recorded the minimum values of APUE, APPUE and PEIP in pigeonpea.

Key words: Agronomic P use efficiency, B:C ratio, Net returns, Production efficiency

Pulses occupy an indispensable place in our daily diet as a source of protein. Pulse crops also have the unique potentiality to associate symbiotically with *Rhizobium* spp and fix atmospheric nitrogen, thereby enriching the soil. Among the pulses, pigeonpea is the second most important crop next only to chickpea. It is cultivated over an area of 3.6 mha, with production of 2.6 mt and productivity of 709 kg/ha. Among the various reasons for low productivity of pigeonpea [*Cajanus cajan* (L.) Millsp.], one finds the role of phosphorus in plant growth of paramount importance. In India, responses of pigeonpea to phosphorus have been generally positive and in some cases highly significant. Judicious use of P is a key factor in the pulses based system of India for sustainable agriculture. The cost of P fertilizer is increasing day by day and it may goes beyond the buying capacity of resource poor farmers of India. Bio-fertilizer has emerged as a promising component in integrated nutrient supply system for sustaining the crop production. Among the

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bio-fertilizers, phosphorus solubilizing micro-organism play a significant role for improving growth, yield attributes and yield of pigeonpea by enhancing the phosphorus availability.

In north India, where pigeonpea–wheat system is followed, there are several reason for low productivity of the system, of which delay in wheat sowing due to long duration of pigeonpea and high input requirements of wheat are of paramount importance, so it hold a opportunity to replace wheat in pigeonpea–wheat system with sunflower (*Helianthus annuus* L.) for economizing nutrients and increasing productivity and economics of production. Sunflower by virtue of short duration, wide adaptability, photoperiod insensitivity and availability of promising hybrids and varieties hold very good promise. Spring sunflower in the north-west part of India has potential to yield 4-6 tonnes/ha crop residue and 2-2.5 tonnes/ha seed yield. 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 residue 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 best alternative practices for replenishing the depleted soil fertility and improving the physical, chemical and biological properties of the soil. Researchers have reported allelopathic effects of sunflower residue on different crops, which put a question on choice of crop after using sunflower residue. Normally pulse and oilseed crops are raised under low input and poor management practices leading to lower productivity level. However, information on fertilizer NP requirements of sunflower, when grown in rotation with pigeonpea, is not available. Since, the farmers of the region are largely cash-limited, which restricts their capacity to buy fertilizers, the improvement in nutrient use efficiency in the cropping systems, and incorporation of crop residues are crucial. Getting maximum profitability lies not only in reducing use of input per unit area but also in lowering costs per unit crop production through higher yields. Therefore, economic analysis is required for making recommendation for farmers from agronomic experiments. Farmers in India are profit-oriented, and therefore, they are interested in net returns than the gross returns. Adoption of inefficient P management practices is responsible for low partial factor productivity and agronomic efficiency. Agronomic efficiency is a useful measure of nutrient use efficiency. Application of a unit fertilizer is economical, if the value of the increase in the crop yield due to the quantity of fertilizer added is greater than the cost of fertilizer used. If a unit of fertilizer does not increase the yield enough to pay for its cost, its application will not be economical and will not return profit even after a constant increase in the yield (Singh 2004). Since, higher fertilizer use efficiency is always associated with efficient use of fertilizer, cultural practices meant for promoting integrated nutrient management will help to affect saving in the amount of fertilizer applied to the crops and therefore to improve fertilizer use efficiency (Karim and Ramasamy 2000). Keeping these point in view a fixed plot field experiment on ''Recycling of sunflower residue for nutrients management in pigeonpea-sunflower cropping system'' was conducted to find out the effect of sunflower stover and nutrients management on productivity, nutrient economy and phosphorus use efficiencies in pigeonpea-sunflower system.

MATERIALS AND METHODS

A fixed plot field experiment was carried out during *kharif* and spring seasons of 2008-09 and 2009-10 for making a comparative assessment of sunflower stover management, P levels and N doses on the productivity, nutrient economy and phosphorus use efficiencies of pigeonpea-sunflower cropping system at research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi. It is situated at latitude of 28°40' N, longitude of 77°12' E and altitude of 228.6 meters above the mean sea level (Arabian Sea). The soil 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). The mean annual rainfall is about 650 mm, of which nearly 80 per cent is received during the monsoon period from July to September and the rest during the period between October and May. The mean maximum temperature in June, which is the hottest month of the year, ranges from 40 to 45°C, while the mean minimum temperature in the coldest month of January is as low as 1.9°C. *Kharif* season experiment in the first year was laid out in split-plot design, assigning sunflower stover incorporation (8 t/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. The *spring* season experiment 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) was 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 2.40 m × 15.0 m, 2.40 m × 4.0 m for sub- plots and sub-sub plots, respectively. Main field was irrigated, ploughed with tractor-drawn disc plough followed by harrowing after the soil reached to tilth conditions and leveling was done with land leveler. Sunflower stover of the general 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 Pusa 992 inoculated with the PSB culture 'Microphos' containing inoculum of *Pseudomonas striata* and sown at the seed rate of 15 kg/ha by '*pora'* method as per treatments in rows 60 cm apart, plant to plant spacing was maintained 15-20 cm apart by adopting gap filling and thinning at appropriate time. For weed control pre-emergence spray of stomp (pendimethalin) @ 1.0 kg /ha was done. Beside, herbicide application one hand weeding was done at 30 DAS. Irrigation to crop was provided only to supplement the rainfall. For control of blister beetle and pod borer in pigeonpea, two spraying of monocrotophos @ 0.04% were given. Pigeonpea was grown as per recommended practices and was harvested on 9^{th} and 14^{th} of November in both the year of experimentation (2008 and 2009), respectively.

After the harvesting of pigeonpea crop, the field was ploughed with the help of a tractor drawn disc plough running in both the direction. The tractor drawn ridge maker was used to make the ridges at row distance of 60 cm for sowing of sunflower crop. The plan of layout was made exactly same as previous crop, only sub-plots were divided into sub-sub plots in sunflower so the same treatments will come on the same plot in order to observe the residual effect of treatments. The RD of N and P 80:15 kg/ha, respectively was supplied through urea and diammonium phosphate as per treatments. The nitrogen was applied in two splits, half at sowing and the remaining half at first irrigation at 30 DAS. Full dose of phosphorus was applied as a basal, placed 3-5 cm below the seed on the top of the ridges manually with the help of metallic tube. Sunflower (JK Chitra) sowing was done by dibbling method with row spacing of 60 cm and plant to plant spacing of 20 cm. For weed control, pre-emergence spray of stomp (pendimethalin) @ 1.0 kg/ha was done, crop also received one hand weeding at 20 DAS. Crop received four irrigations beside pre-sowing irrigation. First irrigation was applied at 30 DAS subsequent irrigations as per need of the crops. For controlling leaf eating caterpillar one spraying of monocrotophos @ 0.05% was given. Sunflower was grown as per recommended practices and was harvested on 12^{th} and 16^{th} of April in both the years of experimentation (2009 and 2010), respectively.

At the time of maturity, the net plots (leaving 2 border rows on each side) were harvested. After harvesting, threshing, cleaning and drying the grain yield was recorded and expressed in tonnes/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 yield and their prevailing market prices during the respective crop seasons. Net returns were calculated by subtracting cost of cultivation from gross returns.

Pigeonpea equivalent as well as system productivity, production efficiency of the system (PES) and per day returns were worked out by using the following formulae:

Pigeonpea grain eq. yield (tonnes/ha) = Productivity of the component crop (kg/ha) × Price of component (₹/kg)/ Price of pigeonpea (₹/kg)

System productivity = Pigeonpea grain yield (kg/ha) + Pigeonpea grain equivalent yield of sunflower

PES (kg/ha/day) = Pigeonpea equivalent yield of the system (kg/ha) in a year/365

Per day returns = Net returns (₹/ha)/Cropping period (days)

P use efficiencies such as agronomic P use efficiency (APUE), agro-physiological P use efficiency (APPUE) and physiological efficiency index of P (PEIP) of pigeonpea/ sunflower worked out as per the following details

APUE (kg grain/ kg P applied) = $Y_t - Y_0 / A_t$

APPUE (kg grain/kg P uptake) = $Y_t - Y_0 / Ut - U_0$

PEIP (kg grain/kg P uptake) = Y_g / P_b

where, Y_t, Grain yield in the test treatment (kg/ha); Y_o, grain yield in the control plot (kg/ha), A_t, units of P applied in the test treatment (kg/ha); U_t, uptake of P (grain+stover) in the test treatment (kg/ha); U_o, uptake of P (grain+stover) in the control plot (kg/ha); Y_g, grain yield (kg/ha); P_b, P absorbed by biomass (kg/ha).

All the data obtained from pigeonpea and sunflower for two consecutive years of study were statistically analyzed using the *F*-test as per 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

System productivity, production efficiency and per day returns

The yield of component crops of the system as expressed as pigeonpea grain equivalent under different treatments has been presented in Table 1. In general, system productivity, production efficiency and per day returns were recorded higher in first year as compared to second year of experimentation. Timely sowing and congenial environmental condition promoted the growth and yield attributes and ultimately higher grain yields of both the crops. During first year, sunflower stover incorporation had 6.17, 6.05 and 4.90% higher system productivity, production efficiency and per day returns over the control. In second year of experimentation, effect of sunflower stover incorporation was non-significant on system productivity and production efficiency. This could be due to reduction in economic yield of pigeonpea with the buildup of allelopathic affect and also

Table 1 Effect of sunflower stover, N and P management on system productivity and production efficiency (PES) of pigeonpea-sunflower cropping system

Treatment	Pigeonpea yield (tonnes/ha)		Seed yield (tonnes/ha)		Pigeonpea grain equivalent system productivity (tonnes/ha)		Production efficiency (kg/ha/day)	
	2008–09	2009–10	2008–09	2009–10	2008–09	2009–10	2008–09	2009–10
SFS management in pigeonpea								
Control	1.42	1.24	2.22	1.89	3.56	2.72	9.75	7.45
SFSI @8 t/ha	1.35	0.92	2.52	2.38	3.78	2.79	10.34	7.64
SEm±	0.02	0.02	0.02	0.02	0.03	0.03	0.08	0.05
CD (P=0.05)	NS	0.11	0.14	0.14	0.18	NS	0.50	NS
P levels applied to pigeonpea								
Control	0.99	0.74	2.15	1.97	3.06	2.28	8.38	6.25
15 kg P/ha	1.40	1.11	2.33	2.04	3.65	2.70	9.99	7.40
15 kg P/ha +PSB	1.51	1.16	2.37	2.08	3.79	2.80	10.38	7.67
30 kg P/ha	1.63	1.32	2.63	2.45	4.17	3.24	11.42	8.88
SEm±	0.03	0.02	0.04	0.03	0.05	0.03	0.13	0.09
CD (P=0.05)	0.09	0.07	0.11	0.08	0.15	0.10	0.41	0.28
NP doses applied to sunflower								
Control		1.02	1.70	1.57		2.25		6.16
50% RD of NP		1.06	2.56	2.27		2.84		7.78
RD of NP		1.17	2.85	2.57		3.18		8.71
SEm±		0.02	0.02	0.03		0.03		0.10
CD (P=0.05)		0.07	0.06	0.90		0.10		0.28

lower yield of sunflower in second year due to continuous cropping of sunflower on the same plot. However, per day returns was decreased marginally due to sunflower stover incorporation as compared to control. Application of 30 kg P/ha to pigeonpea registered highest system productivity (4.17 and 3.24 tonnes/ha), production efficiency (11.42 and 8.88 kg/ha/day) and per day returns (199 and 196 ₹/ha). This has 36 –42% higher system productivity and production efficiency of the system and 56-70% higher per day returns as compared to control. This might be attributed to increase in economic yields of both the component crops due to direct and residual effects of phosphorus. Similar results were also reported by Idapuganti and Ahlawat (2007) with pigeonpea-wheat cropping system. RD of NP applied to sunflower produced the maximum system productivity, production efficiency and per day returns. It indicates the NP requirement of the sunflower under pigeonpea sunflower cropping system. In the present study it was noted that, sunflower needs ample supply of NP for higher productivity because it has exhaustive nature towards the nutrient requirements.

Economics of pigeonpea-sunflower system

Perusal of data given in Table 2 indicates that sunflower stover incorporation recorded the higher cost of cultivation (28.15×10^3 and 30.32×10^3 ₹/ha) of pigeonpea-sunflower cropping system during both the years. In general, this was 5.80–6.28% higher over the control with no stover incorporation. In 2008-09, sunflower stover incorporation recorded significantly higher net returns (62.52×10^3 ₹/ha) over the no stover incorporation. Sunflower stover incorporation was not able to cause any significant difference in net returns in 2009-10 and in B:C ratio in both 2008-09 and 2009-10. P levels have higher cost of cultivation as compared to control. Maximum cost of cultivation (27.57 x10^3 and 29.73×10^3 ₹/ha) was observed with 30 kg P/ha followed by 15 kg P/ha + PSB in both the years, respectively. RD of NP (80 kg N + 15 kg P/ha) applied to sunflower has higher cost of cultivation (30.09×10^3 ₹/ha). In 2008-09, sunflower stover incorporation recorded 5.44% higher gross returns and 5.07% net returns over the control. However, sunflower stover incorporation was not able to cause any significant difference in gross and net returns during first year and B:C ratio in both years. This behavior of returns due to sunflower stover incorporation is attributed to comparatively more favourable effect of the treatment on the sunflower yield than adverse effect on pigeonpea yield in 2008-09. While in 2009-10 adverse affect on pigeonpea was more pronounced than the favourable effect on the sunflower. Detrimental effect of sunflower stover incorporation on test crops was recorded by many workers (Narwal *et al.* 2003 on wheat; Batlang and Shushu 2007 on bambara groundnut and Batish *et al.* 2002 on lobia, sorghum, bajra and maize) and beneficial effect on succeeding crops by Badnur *et al.* (2000) on greengram-sunflower cropping system and Mangare *et*

Table 2 Effect of sunflower stover, N and P management on economics of pigeonpea-sunflower cropping system

Treatment	Cost of cultivation (×10³ ₹/ha)		Net returns (×10³ ₹/ha)		Per day returns (₹/ha/day)		B:C ratio	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
SFS management in pigeonpea								
Control	26.49	28.65	59.50	56.92	163	156	2.25	1.98
SFSI @8 t/ha	28.15	30.32	62.52	56.69	171	155	2.24	1.87
SEm±			0.52	1.05	1.4	1.6	0.02	0.04
CD (*P*=0.05)			3.17	NS	8.7	NS	NS	NS
P levels applied to pigeonpea								
Control	27.06	29.23	46.45	42.11	127	115	1.75	1.44
15 kg P/ha	27.32	29.48	60.75	55.28	166	151	2.23	1.88
15 kg P/ha +PSB	27.34	29.50	64.07	58.26	176	160	2.37	1.96
30 kg P/ha	27.57	29.73	72.78	71.58	199	196	2.64	2.41
SEm±			0.67	0.78	1.8	2.4	0.02	0.03
CD (*P*=0.05)			2.07	2.42	5.7	7.3	0.08	0.08
NP doses applied to sunflower								
Control		28.87		41.98		115		1.45
50% RD of NP		29.48		59.32		163		1.98
RD of NP		30.09		69.12		189		2.35
SEm±				0.85		2.4		0.03
CD (*P*=0.05)				2.44		6.9		0.08

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

al. (2008) on *rabi* sorghum. All the P levels had produced the significantly higher gross returns, net returns and B: C ratio as compared to control. Among the P levels, application of 30 kg P/ha has 56.70%, 69.97% higher net returns and 50.58%, 67.36% higher B: C ratio over the control. RD of NP (80 kg N+15 kg P/ha) applied to sunflower produced the maximum gross return (99.22 × 10^3 ₹/ha) net returns (69.12 × 10^3 ₹/ha) and B: C ratio (2.35). Such types of trends were observed due to better soil fertility, which provides the nutrients in available form to crops and responsible for higher economic yield.

Phosphorus use efficiencies

Phosphorus use efficiencies in pigeonpea

During 2008, sunflower stover incorporation had non-significant effect on APUE. However, during 2009 sunflower stover incorporation significantly reduced the APUE over the control (Table 3). This might be due to initial immobilization of applied P resulted in lower uptake of P and other nutrients which further contributed for lower grain yield. Allelopathic effect of sunflower stover may be other reason for lower grain yield. Reduction in grain yield of pigeonpea after incorporation of sunflower residue was also reported by Narwal *et al.* (1999). APUE increased up to 15 kg P/ha+PSB after that declined in both the years of study. The higher recovery of P at lower levels of P application may be consequence of higher competition among the roots and lesser priming effect to mobilize native P which resulted in an efficient exploitation of applied P for absorption. Conversely, at higher P application rates, plants used smaller proportions of fertilizer P and contribution of biofertilizer in increasing the productivity. Similar findings were also reported by Batten *et al.* (1999) and Kantwa *et al.* (2006). Residual effect of RD of NP applied to preceding sunflower was recorded the minimum value of APUE. This may be due to less increase in grain yield due to residual effect of P.

APPUE was found higher under the sunflower stover incorporation as compared to control during both the years of study. This might be due to lower P uptake by the pigeonpea crop due to sunflower stover incorporation. Several allelochemicals were released from sunflower stover during the course of decomposition, which reduced the root development and root hair formation (Hegde and Miller 1992 and by Caspersen *et al.* 1999), and reduced the P uptake because the major mechanism of P uptake in plants is diffusion; diffusion distance of P is very less. P uptake in plant is strongly correlated with root length in soil (Otani and Ae 1996). Different levels of P were not able to cause any significant effect on APPUE during first year. In contrast, during second year higher values of APPUE at lower level of P, viz. 15 kg P/ha after that every successive unit of P decreases the APPUE. This might be due to higher uptake of P at higher doses.

During first year, sunflower stover incorporation had non-significant effect on PEIP although in 2009 it had

Table 3 Direct and residual effect of sunflower stover and nutrients management on agronomic P use efficiency (APUE), agro-physiological P use efficiency (APPUE) and physiological efficiency index of P (PEIP) of pigeonpea and sunflower

Treatment	APUE (kg grain/kg P applied)				APPUE (kg grain/kg P uptake)				PEIP (kg grain/kg P uptake			
	Pigeonpea		Sunflower		Pigeonpea		Sunflower		Pigeonpea		Sunflower	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
SFS management in pigeonpea												
Control	27	27	16.7	12.9	132	94	29.2	26.0	149	122	31.5	31.4
SFSI @8 t/ha	28	21	18.9	17.0	139	129	25.8	26.1	174	155	30.1	29.6
SEm±	1.3	0.5	0.2	0.1	2.1	1.4	0.4	0.4	5.0	1.3	0.15	0.07
CD(*P*=0.05)	NS	3.2	1.2	0.6	NS	8.6	2.3	NS	NS	7.6	0.93	0.43
P levels applied to pigeonpea												
Control	0.0	0.0	20.5	14.5	0.0	0.0	30.9	28.7	176	155	30.7	31.2
15 kg P/ha	27	24.	18.8	15.5	133	127	25.4	26.0	159	143	31.0	30.7
15 kg P/ha +PSB	34	28	18.4	14.7	138	100	27.4	26.0	159	126	31.0	30.4
30 kg P/ha	21	19	13.7	15.0	135	107	26.2	23.5	154	129	30.4	29.7
SEm±	1.2	0.6	0.5	0.4	2.2	3.7	0.6	1.0	7.1	4.1	0.2	0.12
CD (*P*=0.05)	7.4	1.9	1.5	NS	NS	12.2	1.9	3.0	NS	12.6	NS	0.38
NP dose applied to sunflower												
Control		25	0.00	0.00		110	0.00	0.00		142	32.3	32.4
50% RD of NP		25	21.3	17.5		118	28.8	27.5		143	30.6	30.3
RD of NP		22	14.4	12.4		106	26.1	24.5		129	29.5	28.9
SEm±		0.7	0.3	0.2		3.5	0.5	0.4		2.7	0.3	0.22
CD (*P*=0.05)		2.0	0.9	0.7		NS	1.6	1.1		7.8	0.8	0.63

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

significantly lower values of PEIP (Table 3). P levels failed to cause any significant effect on PEIP in 2008, while during 2009 values of PEIP were declined with every successive unit of P up to 30 kg P/ha. This could be attributed to beneficial effect of residual NP on the growth and yield attributes which enhanced the economic yield of pigeonpea. In contrast, significantly lower value of PEIP recorded with the residual effect of RD of NP.

Phosphorus use efficiencies in sunflower

Residual effect of sunflower stover incorporation caused marked increase in APUE during both the years of experimentation (Table 3). This may be due to the fact that sunflower stover incorporation had favourable residual effect on growth parameters, yield attributes and yields of succeeding sunflower. Favourable residual effect of crop residue on the succeeding crops was also noticed by Mahavishnan *et al.* (2005). In contrast, residual effect of sunflower stover incorporation recorded significantly lower values of PEIP as compared to control (no stover incorporation) during both the years, except APPUE during 2010 (Table 3). This was due to the fact that, residual effect of sunflower stover resulted in better soil fertility and increase the availability of soil P and increase the P uptake more efficiently as compared to dry matter production. Higher uptake of nutrients by sunflower crops due to residual effect of crop residue also reported by Kumari and Reddy (2010). The higher availability of P to crops in summer season may be because of relatively higher temperature (Brar and Bishnoi 1987). The residual effect of P levels applied to preceding pigeonpea crop showed perceptible reduction in APPUE during both years of study, and APUE in 2009 and PEIP during 2010 with successive increment of P levels. This could be ascribed to lower dry matter production and grain yield and comparatively higher P uptake by the sunflower, successive levels of P increase the P availability due to fertility build up.

Direct application of NP had marked influences on APUE, APPUE and PEIP during both the years. Direct effect of 50% RD of NP had marked increase of APUE and APPUE, over control and RD of NP. This may be due to the fact that initial application of NP gave more response on dry matter accumulation and yields of sunflower and latter responses was declined as compared to previous unit of application. In contrast and PEIP reduced with successive doses of NP up to RD of NP due to increase in the P uptake with increase in doses of NP.

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