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Research Paper

Effect of sunflower stover and nutrients management on energetics, nutrient acquisition and soil nutrient balance of pigeonpea (*Cajanus cajan*)–sunflower (*Helianthus annuus*) cropping system

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ABSTRACT

A fixed plot field experiment was carried out during rainy (*kharif*) and spring seasons of 2008–09 and 2009–10 at New Delhi, to assess the effect of sunflower stover and nutrients management on energetics, nutrient acquisition and soil-nutrient budgeting of pigeonpea [*Cajanus cajan* (L.) Millsp.]–sunflower (*Helianthus annuus* L) cropping system. Direct effect of sunflower stover incorporation had negative impact on pigeonpea productivity; however; it excreted positive effect on productivity of succeeding sunflower crop in system mode. With respect to energetics, sunflower stover incorporation in pigeonpea under pigeonpea–sunflower cropping system reduced the gross and net energy output, energy-use efficiency and energy intensity in economic terms. Among the various levels of P imposed to pigeonpea only, an application of 30 kg P/ha recorded significantly higher values of gross energy output (160.02 × 10^3 MJ/ha), net energy output (144.88 × 10^3 MJ/ha), energy-use efficiency (10.56) and energy intensity in economic terms (5.61MJ/₹) of pigeonpea-sunflower cropping system. Significantly higher values of gross energy output (146.24 × 10^3 MJ/ha), net energy output (128.36 × 10^3 MJ/ha) and energy intensity in economic terms (4.86 MJ/₹) lower values of energy use efficiency (8.17%) were recorded with the recommended dose of NP (80 kg N+15 kg P/ha) applied to sunflower crop in pigeonpea–sunflower cropping system. With respect to nutrient acquisition, sunflower stover incorporation in pigeonpea only recorded the higher nutrients uptake by the pigeonpea–sunflower cropping system compared to the control. Among the P levels applied to pigeonpea and NP to sunflower, application of 30 kg P/ha and recommended dose of NP to pigeonpea and sunflower, respectively, recorded the maximum N, P and K uptake by pigeonpea–sunflower cropping system. With regards to NPK balance in soil, direct and residual effect of sunflower stover, N and P management exerted positive impact on NPK balance sheet at the end of experiment.

Key words : Energy input, Energy-use efficiency, Nutrient uptake, Soil NPK balance, Sunflower stover incorporation

Sunflower has potential to yield 4–6 t/ha crop residue and 2–2.5 t/ha seed yield. This residue has very low energy value per unit mass. However, it contains major plant nutrients in range of 0.45–0.60% N, 0.15–0.22% P and 1.80–1.94% K along with secondary and micronutrients, so its recycling in the soil may be one of the best alternative practices for replenishing the depleted soil fertility. Among the pulses, pigeonpea is the one of most important crops, which plays a pivotal role for maintaining the soil fertility. Due to longer root system of pigeonpea, it is often considered as a natural and/or biological plough. In spite of that its productivity in India is very low (709 kg/ha). Among the various reasons for low productivity, one finds the role of phosphorus in plant growth of paramount importance. The importance of adequate supply of phosphorus for higher yields of pigeonpea has long been recognized. In India, responses of pigeonpea to phosphorus have been generally positive and in some cases highly significant. Phosphorus exists in nature in either insoluble or very poorly soluble inorganic forms this often leads to an excess application of P fertilizer to crop land. Excess application of phosphatic fertilizers not only caused the environmental problem but economic losses to the farmer too, because now-a-days the cost of phosphatic fertilizers increases day by day. Bio-fertilizer has emerged as a promising component in integrated nutrient supply system for

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sustaining the crop production. Among the bio-fertilizers, phosphorus-solubilizing micro-organism plays a significant role for improving growth, yield attributes and yield of pigeonpea by enhancing the phosphorus availability (Khan *et al.,* 2009) through excretion of phosphatase enzymes (Eichler *et al.,* 2004), mineralization of P from organic sources (Gressel and McColl, 1997). Since crop residue and nutrients applied to preceding crops exhibit residual effect on succeeding crops, fertilization must be done keeping the whole cropping system in view rather than the individual crops. Energy is one of the most valuable inputs in production agriculture. Sufficient availability of right energy and its effective and efficient use are pre-requisites for improved agricultural production. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Baum *et al.* (2009) estimated energy-use efficiencies for an organic *vis a vis* conventional farm. In general, it is assumed that the risk of harmful environmental effects is lower under organic than conventional farming methods, though not necessarily so (Hansen *et al.,* 2001). Application of integrated production methods are recently considered as a means to reduce production costs and enhanced the energy use efficiency. In view of the limited information available on the direct and indirect effect of crop residue and externally inputs especially fertilizers management for long-term basis and their effect on nutrient acquisition and nutrient budgeting of the cropping systems. And there are no studies that directly compare direct and residual effect of sunflower stover incorporation and nutrients management on energy budgeting under pigeonpea-sunflower cropping system. Keeping these points in view, direct and residual effects of sunflower stover recycling and nutrient management on the energetics, nutrients acquisition and budgeting of pigeonpea–sunflower cropping system are presented in this paper which is based on results of the 2 years fixed plot field experimentation.

MATERIALS AND METHODS

A fixed plot field experiment was carried out during the rainy (*kharif*) and spring seasons of 2008–09 and 2009–10 at Indian Agricultural Research Institute, New Delhi (28°40’ N, 77°12’ E and 228.6 above the mean sea level). The soils was sandy clay loam belongs to Inceptisols having 145.0 kg/ha alkaline permanganate–oxidizable N, 17.5 kg/ha available P, 226.0 kg/ha 1 N ammonium acetate-exchangeable K and 0.40% organic carbon. The pH of soil was 7.5 (1:2.5 soil and water ratio). Field capacity, permanent wilting point and bulk density were 17.0% (w/w), 6.30% (w/w) and 1.46 Mg/m^3, respectively, in 0–15 cm soil depth. The rainy 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, 15 kg P/ha + phosphate solubilizing bacteria (PSB) and 30 kg P/ha) to subplots. The spring season experiment was laid out in split-split plot design in which NP doses to sunflower crop (control, 50% recommended dose of NP and recommended dose of NP (80 kg N + 15 kg P/ha) were applied in sub-subplots. Data for rainy season experiment in second year was recorded and analysed in split-split plot design to investigate the residual effect of NP doses applied to spring season crop in sub-subplots. All the treatments replicated thrice during both the years. Main field was irrigated, ploughed with tractor-drawn disc plough followed by harrowing after the soil reached tilth conditions, and leveling was done with land leveler. Sunflower stover of the general sunflower grown during the spring season of 2008 and experimental crop of the spring season 2009 was chopped with the help of chopper and incorporated to the soil as per treatments (8 t/ha) before the preparation of field for sowing of pigeonpea. The chemical composition and nutrients added by sunflower residue is given below.

Table 1. Chemical composition (NPK) of sunflower residue and plant nutrients added through the stover incorporation

Plant nutrients	Concentration (g/kg)		Nutrients (kg/ha) added to soil through SFSI @ 8 t/ha (at 50% moisture content)	
	2008	2009	2008	2009
Nitrogen	5.80	5.50	23.2	22.0
Phosphorus	2.20	1.80	8.8	7.2
Potassium	17.00	17.90	68.0	71.6

The recommended starter dose (25 kg/ha) of N for pigeonpea was supplied through urea (after subtracting the N supplied from DAP). Diammonium phosphate (DAP) 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. Pigeonpea ‘Pusa 992’ was 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. Pigeonpea was grown as per recommended practices and was harvested on 9 and 14 of November in both the year of experimentation respectively. After harvesting of pigeonpea and field preparation, sunflower ‘JK Chitra’ was sowing by dibbling method @ 4 kg/ha with row spacing of 60 cm and plant-to-plant spacing of 20 cm. The recommended dose of N and P 80 and 15 kg/ha respectively, was supplied through urea and diammonium phosphate as per treatments. The nitrogen was applied in 2 splits, at sowing and the remaining half at first irrigation at 30 days after sowing. Full dose of phosphorus was applied basal, placed 3–5 cm below the seed on the top of the ridges manually. Sunflower was grown as per recommended practices and was harvested on 12 and 16 of April in both the years. The nutrients (NPK) acquisition by the pigeonpea–sunflower system was recorded at the maturity of both the crops. Standard chemical procedure was followed for the determination of the nutrients in soil and plant sample. A balance sheet of N, P and K was determined at the end of the experiment by using the following formulae:

$$X = (A+B)-C,\ Y = (D-A),\ Z = (D-X)$$

where: A = Initial available nutrient, B = nutrient added, C = system uptake, D = final value of available nutrient after harvest of crop, X = expected nutrient balance, Y = actual gain/loss, Z = apparent gain/loss.

For energy indices analysis, input energy divided into direct and indirect and renewable and non-renewable forms (Hatirli *et al.,* 2006). The direct energy consists of diesel, human power and electricity, while the indirect energy contains seed, fertilizers, farmyard manure, chemicals and machinery (Singh *et al.,* 2007). Total physical output referred to both grain/seed and by-product yields. To calculate the input energy, quantity/numbers of all inputs used in the form of labour, seed, chemical fertilizer, herbicides, diesel and pesticides used in both crops were taken into consideration and converted to energy equivalents by multiplying their per unit energy equivalents as given in (Table 2).

The farm produce (seed yield+stover yield) was also converted into energy in terms of energy output (MJ) and for that 2 year's average crop yield was multiplied by their energy equivalents per unit. Energy equivalent of sunflower stover incorporation was not considered because its yield has no economical returns to farmers. Based on the energy equivalents of the inputs and output, energy-use efficiency and energy intensity in economic terms were calculated.

Energy use efficiency = Gross energy output (MJ/ha)/ Energy input (MJ/ha)

Net energy output (MJ/ha) = Gross energy output (MJ/ ha) – Energy input (MJ/ha)

Energy intensity in economic terms (MJ/kg) = Gross energy output (MJ/ha)/Cost of cultivation (₹/ha)

All the data obtained from the experiment during 2 consecutive years were statistically analyzed using the *F*-test procedure given by Gomez and Gomez (1984). Critical difference (CD) values at *P*=0.05 were used for determine the significance of differences between means.

Table 2. Energy equivalents conversion factors for various inputs and outputs used in the study

Items	Unit	Energy equivalent (MJ/unit)
Diesel	l	56.31
N	kg	60.60
PK	kgkg	11.106.70
Herbicides	kg	288.00
Insecticides	kg	237.00
Stover	(dry mass)	12.50
Pigeonpea (seed)	kg	14.07
Sunflower (seed)	kg	27.20
Machines	hour	108.00
Labour (adult man)	Man-hour	1.96

Sources: Chaudhary *et al.* (2006)

RESULTS AND DISCUSSION

Productivity

Yield of pigeonpea: Direct effect of sunflower stover incorporation recorded lower grain and stover yield of pigeonpea compared with the control (Table 3). Causing 17.69% and 22.47% reduction in grain and stover yields, respectively, from the control. It might be due to release of secondary and primary metabolites during the decomposition of sunflower stover, causing more inhibitory effect on the plant growth, yield attributes and ultimately yield of pigeonpea. Our results confirm the findings of Rana *et al.* (2004). All the P levels recorded significantly higher grain and stover yields of pigeonpea than the control. Among P levels, application of 30 kg P/ha recorded the maximum grain and stover yields followed by 15 kg P/ha + PSB. This could be attributed to overall improvement in crop growth as reflected by growth and yield attributes. A similar increase in grain yield by application of phosphorus was also reported by Chaudhari *et al.* (2010). Residual effect of recommended dose of NP applied to preceding sunflower recorded significantly higher grain and stover yields of succeeding pigeonpea. The finding confirm the results of Shivran *et al.* (2000) with the residual effect of nutrients on the succeeding crops.

Yield of sunflower: Residual effect of sunflower stover recorded significantly higher grain and stover yields of succeeding sunflower than the control (Table 3). Rana *et al.* (2004), also reported gradual improvement in yields of wheat, Indian mustard and gram under complete residue incorporation of sunflower by the end of fourth year of experiments. Residual effect of 30 kg P/ha markedly improved the seed and stover yields of succeeding sunflower under pigeonpea–sunflower cropping system. This led to

23.30% and 13.04% increments in seed and stover yield of succeeding sunflower over the control respectively. This response can be accounted for the positive response of agronomic characteristics associated with yield. Similar observations were also made by Reddy and Babu (2003). Direct application of NP in sunflower, significantly increased the yields of sunflower. Among the both doses, recommended dose of NP (80 kg N + 15 kg P/ha) resulted in the maximum seed (2.46 t/ha) and stover (4.47 t/ha) yields followed by 50% recommended dose of NP. This was probably owing to the higher availability of NP in the initial stage, which helped to acquire a definite advantage over the control in respect of growth. These results confirm the findings of Nawaz *et al.* (2003).

Energetics

Energy input, gross and net energy output: Pooled data pertaining to energy input, gross and net energy output of pigeonpea–sunflower cropping system showed the highest energy inputs of cropping system under recommended dose of NP followed by 50% recommended dose of NP. Under P management treatments in pigeonpea, the maximum energy input ($15.14 x 10^3$ MJ/ha) was recorded with 30 kg P/ha in pigeonpea-sunflower cropping system (Table 4). Rathke and Diepenbrock (2006) also reported similar results. Due to sunflower stover incorporation in pigeonpea under pigeonpea–sunflower cropping system recorded numerically lower value of gross energy output and net energy output as compared to the control, but the variations were insignificant. This was mainly due to the allelopathic effect of sunflower stover incorporation on the growth and yields of pigeonpea. Negative allelopathic effect of sunflower stover incorporation on pigeonpea was also reported by Pal and Sand (2006). Among the various levels of P imposed to pigeonpea only, application of 30 kg P/ha recorded significantly higher values of gross energy output and net energy output of pigeonpea–sunflower cropping system. This might be due to cumulative synergetic response of phosphorus on the total biological yield of both the crops in the system, which ultimately increased the gross and net energy output. Doses of N and P applied to sunflower crop under pigeonpea–sunflower cropping system also have significant effect on gross energy output and net energy output. Significantly higher values of gross energy output and net energy output were recorded with the recommended dose of NP (80 kg N+15 kg P/ha) applied to sunflower crop in pigeonpea–sunflower cropping system. This increment in gross energy output was 10.0 and 30.5% higher than 50% recommended dose of NP and control, respectively. Corresponding increase in net energy output was 9.44 and 29.17%.

Energy use efficiency and energy intensity in economic terms: Sunflower stover incorporation in pigeonpea under pigeonpea–sunflower cropping system had non-significant effect on the energy-use efficiency and energy intensity in economic terms (Table 3). This was probably due to deleterious effect of sunflower stover incorporation on pigeonpea growth and yield and favourable residual effect on sunflower growth and yield. Reduction in growth and dry matter production of crops at higher concentration of allelochemical were reported by Ashrafi *et al*. (2008).

Application of different levels of P to pigeonpea also has significant effect on energy-use efficiency and energy intensity in economic terms of pigeonpea–sunflower cropping system. Maximum energy-use efficiency and energy intensity in economic terms was recorded with the application of 30 kg P/ha in pigeonpea crop under pigeonpea–sunflower cropping system. This was mainly owing to more dry-matter yield of both the crop in sequences due to 30 kg P/ha which led to more energy generation. Recommended dose of NP registered lowest values of energy-use efficiency and reverse trend was found with energy intensity in economic terms. Lower value of energy use efficiency was due to higher energy input of chemical fertilizer especially nitrogen. These results are in close conformity with the findings of Wood *et al.* (2006).

Nutrients (NPK) acquisition

Sunflower stover incorporation in pigeonpea recorded the higher values of N, P and K uptake by the pigeonpea–sunflower cropping system (Table 3). However, difference was non-significant statistically. Various levels of P applied to pigeonpea in pigeonpea–sunflower cropping system had significant influence on system N, P and K uptake. The N, P and K uptake by pigeonpea–sunflower cropping system under application of 30 kg P/ha was significantly higher than other P levels. This led to 65.20%, 66.20% and 38.84% increase in N, P and K uptake over the control, respectively. It was due to the fact that higher nutrient uptake and dry-matter accumulation takes place in this treatment in both the crops. Similar observations were also made by Chaudhari *et al.* (2010).

Doses of NP applied to sunflower crop under pigeonpea–sunflower cropping system increased the N, P and K uptake by pigeonpea–sunflower cropping system. Of the 2 doses, recommended dose of NP registered the maximum total N, P and K uptake in pigeonpea–sunflower cropping system which was significantly higher than 50% recommended dose of NP. The Recommended dose of NP exerted favourable effect on plant growth and even having residual effect on succeeding crop and increased the growth and yield attribute and ultimately seed and stover yields and also nutrient uptake in both the crops in system and increased the system nutrient uptake.

Table 3. Effect of sunflower stover and nutrient management on crop yields and nutrient (NPK) acquisition of pigeonpea–sunflower cropping system (pooled data of 2 years)

Treatment	Pigeonpea yield(t/ha)		Sunflower yield (t/ha)		Nutrients uptake (kg/ha)		
	Grain	Stover	Seed	Stover	N	P	K
SFS management in pigeonpea							
Control	1.33	5.45	2.0 5	3.33	175.15	23.1	168.4
SFSI @ 8 t/ha	1.13	4.45	2.45	4.07	178.35	25.05	174.2
SEm±	0.02	0.10	0.02	0.03	3.3	0.4	2.0
CD (P=0.05)	0.11	0.23	0.14	0.22	15.6	1.3	NS
P applied to pigeonpea							
Control	0.86	3.65	2.06	3.68	136.2	18.05	140.8
15 kg P/ha	1.25	5.15	2.18	3.74	193.9	23.15	172.1
15 kg P/ha + PSB	1.33	5.35	2.22	3.71	204.9	25.05	176.8
30 kg P/ha	1.47	5.55	2.54	4.16	225	30	195.5
SEm±	0.02	0.12	0.03	0.05	3.4	0.6	2.25
CD (P=0.05)	0.08	0.38	0.09	0.17	10.45	1.85	6.95
NP doses applied to sunflower							
Control	1.03	4.5	1.64	2.95	180.4	17.3	132.2
50% RD of NP	1.08	4.7	2.44	4.16	186.4	23.5	162.9
RD of NP	1.19	4.8	2.46	4.47	204.9	30.7	182.8
SEm±	0.02	0.05	0.02	0.05	2.5	0.4	1.4
CD (P=0.05)	0.06	0.16	0.48	0.14	7.3	1.2	4.1

RD, Recommended dose; PSB, phosphate solubilizing bacteria; SFSI: sunflower stover incorporation; RD of NP, 80 kg N + 15kg P/ha

Table 4. Effect of sunflower stover and nutrients management on energetics of pigeonpea–sunflower cropping system (pooled data of 2 years)

Treatment	Energy input ($\times 10^3$MJ/ha)	Gross energy output ($\times 10^3$MJ/ha)	Net energy output ($\times 10^3$MJ/ha)	Energy-use efficiency (%)	Energy intensity in economic terms (MJ/₹)
SFS management in pigeonpea					
Control	14.76	142.76	128.0	9.67	5.19
SFSI @ 8 t/ha	14.76	138.76	124.0	9.40	4.76
SEm±	-	1.87	1.67	0.12	0.16
CD (*P*=0.05)	-	NS	NS	NS	NS
P applied to pigeonpea					
Control	14.37	114.69	100.32	7.98	4.09
15 kg P/ha	14.75	141.85	127.10	9.61	5.02
15 kg P/ha+PSB	14.77	141.85	127.08	9.60	5.18
30 kg P/ha	15.14	160.02	144.88	10.56	5.61
SEm±	-	2.04	1.86	0.14	0.07
CD (*P*=0.05)	-	6.31	5.72	0.42	0.22
NP doses applied to sunflower					
Control	12.65	112.02	99.37	8.85	3.88
50% RD of NP	15.26	132.84	117.28	8.70	4.51
RD of NP	17.88	146.24	128.36	8.17	4.86
SEm±		1.36	1.10	0.08	0.05
CD (*P*=0.05)		3.91	3.17	0.23	0.13

RD, Recommended dose; PSB, phosphate solubilizing bacteria; SFSI, sunflower stover incorporation; RD of NP, 80 kg N + 15 kg P/ha

Soil nutrient (NPK) balance: There was a marginal but positive increase in available N, P and K over the initial values after the experiment. The N, P and K added, system N, P and K uptake and available N, P and K in soil were higher with the sunflower stover incorporation in pigeonpea as compared to control (Tables 5, 6 and 7).

Expected N balance was lower but expected P and K balance were higher owing to sunflower stover incorporation compared to the control. This might be owing to higher C: N ratio of sunflower residue which may cause

Table 5. Effect of sunflower stover and nutrient management on soil N balance after 2 years of field experiment

Treatment	A	B	C	D	(A+B)-C=X	(D-A)=Y	(D-X)=Z
SFS management in pigeonpea							
Control	145	130.00	356.70	141.99	-81.70	-3.01	223.70
SFSI @ 8 t/ha	145	175.20	349.81	145.24	-29.61	0.24	174.84
P applied to pigeonpea							
Control	145	152.60	272.50	141.99	25.10	-3.01	116.88
15 kg P/ha	145	152.60	353.98	143.39	-56.38	-1.61	199.77
15 kg P/ha + PSB	145	152.60	371.58	143.58	-73.98	-1.42	217.57
30 kg P/ha	145	152.60	414.96	145.50	-117.36	0.50	262.86
NP doses applied to sunflower							
Control	145	72.60	189.47	139.75	28.13	-5.25	111.62
50% RD of NP	145	152.60	250.21	144.54	47.39	-0.46	97.15
RD of NP	145	232.60	285.95	146.55	91.65	1.55	54.91

RD, Recommended dose; PSB, phosphate solubilizing bacteria; A, initial available nutrient; B, nutrient added; C, system uptake; D, final value of available nutrient after harvest of crop; X, expected nutrient balance; Y, actual gain/loss; Z, apparent gain/loss; RD of NP, 80 kg N + 15kg P/ha, SFSI, sunflower stover incorporation

Table 6. Effect of sunflower stover and nutrient management on soil P balance after 2 years of field experiment

Treatment	A	B	C	D	(A+B)-C=X	(D-A)=Y	(D-X)=Z
SFS management in pigeonpea							
Control	17.5	45.03	46.23	19.33	16.30	1.83	3.03
SFSI @ 8 t/ha	17.5	61.03	50.06	20.13	28.47	2.63	-8.34
P applied to pigeonpea							
Control	17.5	23.13	36.11	19.22	4.52	1.72	14.70
15 kg P/ha	17.5	53.00	46.29	19.60	24.21	2.10	-4.61
15 kg P/ha + PSB	17.5	53.00	50.23	19.78	20.27	2.28	-0.49
30 kg P/ha	17.5	83.00	59.95	20.33	40.55	2.83	-20.21
NP doses applied to sunflower							
Control	17.5	38.00	27.80	18.75	27.70	1.25	-8.95
50% RD of NP	17.5	53.10	40.03	19.93	30.57	2.43	-10.64
RD of NP	17.5	68.00	50.36	20.53	35.14	3.03	-14.62

RD, Recommended dose; PSB, phosphate solubilizing bacteria; A, initial available nutrient; B, nutrient added; C, system uptake; D, final value of available nutrient after harvest of crop; X, expected nutrient balance; Y, actual gain/loss; Z, apparent gain/loss; RD of NP, 80 kg N + 15 kg P/ha; SFS, sunflower stover; SFSI, sunflower stover incorporation

Table 7. Effect of sunflower stover and nutrient management on soil K balance after 2 years of field experiment

Treatment	A	B	C	D	(A+B)–C=X	(D–A)=Y	(D–X)=Z
SFS management in pigeonpea							
Control	226	0.00	336.82	224.69	-110.82	-1.31	335.52
SFSI @ 8 t/ha	226	139.60	348.47	234.47	17.13	8.47	217.35
P applied to pigeonpea							
Control	226	69.80	281.59	227.17	14.21	1.17	212.96
15 kg P/ha	226	69.80	344.22	229.00	-48.42	3.00	277.42
15 kg P/ha + PSB	226	69.80	353.69	229.83	-57.89	3.83	287.72
30 kg P/ha	226	69.80	391.09	232.33	-95.29	6.33	327.62
NP applied to sunflower							
Control	226	69.80	199.04	227.29	96.76	1.29	130.53
50% RD of NP	226	69.80	264.57	229.63	31.23	3.63	198.39
RD of NP	226	69.80	297.67	231.83	-1.87	5.83	233.70

RD, Recommended dose; PSB, phosphate solubilizing bacteria; A, initial available nutrient; B, nutrient added; C, system uptake; D, final value of available nutrient after harvest of crop; X, Expected nutrient balance; Y, actual gain/loss; Z, Apparent gain/loss; RD of NP, 80 kg N + 15 kg P/ha; SFS, sunflower stover; SFSI, sunflower stover incorporation the immobilization of N in initial stages and mineralization of P and K. Actual N, P and K gain was higher but apparent N, P and K gain was lower due to sunflower stover incorporation because it added the nutrient in soil after decomposition and reduced the uptake of nutrients by retarding the growth and yield of pigeonpea during both the years although yields and uptake was higher in succeeding sunflower crop.

Among the P levels applied to pigeonpea , application of 30 kg P/ha recorded higher P added, system N, P and K uptake and final values of available N, P and K, expected P, while expected N and K balance and apparent P gain was lower due to 30 kg P/ha. This might be due to positive impact of N, P and K on plant metabolism, which enhanced the nutrient uptake. Recommended dose of NP applied to sunflower in pigeonpea–sunflower cropping system registered the maximum NP added, system N, P and K uptake, and final values of available N,P and K in soil, expected NP balance and lowest expected K balance, higher actual gain of N, P and K. However, apparent gain of NP was lowest but apparent gain of K higher with the recommended dose of NP applied to sunflower

On basis of the results it is concluded that sunflower stover incorporation improves the nutrient status of pigeonpea–sunflower cropping system and soil fertility on long-term basis. Application of phosphorus @ 30 kg P/ha in pigeonpea and 50% recommended dose of NP in sunflower is advisable for obtaining the higher yield and improving the energy use efficiency.

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