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Influence of sunflower stover and nutrient management on growth, yield and energetics of sunflower (*Helianthus annuus*) in a pigeonpea *(Cajanus cajan)*-sunflower 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 New Delhi, to study the effect of sunflower stover and nutrient management on growth, yield and energy dynamics of sunflower in a pigeonpea [*Cajanus cajan* (L.) Millsp.] -sunflower (*Helianthus annuus* L.). cropping system. Results revealed that residual effects of sunflower stover incorporation resulted in higher values of growth attributes, seed yield (2.45 tonnes/ha), oil content (41.3%) and energy use efficiency (8.3) in succeeding sunflower crop in a pigeonpea-sunflower cropping system. Residual effect of sunflower stover incorporation increased seed yield of sunflower by 19.5% over the no stover incorporation. Among the P levels applied to preceding pigeonpea, residual effect of 30 kg P/ha recorded the highest values of growth parameters resulted in 23.3% increase in the seed yield of sunflower over the control. Direct effect of RD of N and P (80 kg N+15 kg P/ha) recorded the significantly higher values of growth parameters, seed (2.71 tonnes/ha) and stover (4.44 tonnes/ha) yields, oil (42.3 %) and protein (14.9%) contents and net energy output (120.0 × 10^3 MJ/ha)). Increase in seed yield due to RD of NP was 12.4% and 66.3% higher than 50% RD of NP and control, respectively.

Key words: Dry matter accumulation, Energy use efficiency, Oil content, Residual effect

Sunflower (*Helianthus annuus* L.) is highly promising for around-the-year cultivation under different agro-climatic regions owing to its thermo-photo-insensitivity, it has potential to yield 4-6 tonnes/ha crop residue and 2-2.5 tonnes/ha seed yield. Over the years, productivity of sunflower in India has remained around 0.6 tonnes/ha, which is very low compared to world average productivity of 1.3 tonnes/ha due to lack of sound scientific management practices. Among the various reasons for low productivity, one finds the role of plant nutrients, especially N and P of paramount importance. Nitrogen and phosphorus are the primary limiting nutrients under most of the conditions. Hence, there is ample scope of increasing production by use of good agronomic practices as well as proper fertility management (Choudhary *et al.* 2013). Cropping systems are often devoid of legumes and organic nutrient inputs. Previously crop residues have been regarded as a waste material and therefore are either removed or burned *in situ* resulted in reduction of energy use efficiency and deteoration in soil productivity in agricultural production systems.

Energy is one of the most important indicators of crop performance. It provides financial savings, fossil resource preservation and air pollution reduction (Uhlin 1998). Sufficient availability of the right energy and its effective and efficient use are prerequisites for agricultural production. Growing of legumes in rotation with cereals and oilseeds could increase soil N and general fertility (Babu *et al.* 2014; Pooniya *et al.* 2015). 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 (Choudhary *et al.* 2013). Since, sunflower is an exhaustive crop; pigeonpea in the sequence is a good choice as it helps in building up the nutrient status of soil being a leguminous crop. Keeping these aspects in view, a fixed plot field experiment entitled ‘‘effect of sunflower stover and nutrient management on growth, yield and energetics of sunflower under pigeonpea-sunflower cropping system’’ was conducted to find out optimum levels of nutrients for enhancing productivity and energy use efficiency of sunflower production after pigeonpea having treatment of sunflower stover incorporation and P levels.

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MATERIALS AND METHODS

A fixed plot field experiment was carried out during spring seasons of 2008-09 and 2009-10 at Research Farm, Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi, which is situated at a latitude of 28°40' N, longitude of 77°12' E and altitude of 228.6 m above the mean sea level. It has a semi-arid and sub-tropical climate with hot dry summers and severe cold winters. 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. Sand storms and ground frost are commonly associated with summer and winter seasons, respectively. The mean annual rainfall is about 650 mm, of which nearly 80% is received during the monsoon period from July to September and the rest during the period between October and May. The soil of experimental field was sandy clay loam and belongs to order Inceptisol and having 145 kg/ha alkaline permanganate oxidizable N, 17.5 kg/ha available P, 226 kg/ha 1 N ammonium acetate exchangeable K and 0.4% organic carbon. The pH of soil was 7.5. The preceding pigeonpea crop was grown in split-plot design, assigning sunflower stover incorporation (8 tonnes/ha) and no incorporation (control) to main plots and combination of P levels and bio-fertilizers (Control**,** 15 kg P/ha, 15/kg P/ ha+PSB**,** 30 kg P/ha) to sub-plots. The plan of layout for sunflower was made exactly same as previous crop, only sub plots were divided into sub-sub plots in which N and P doses to sunflower crop [(Control, 50% RD of NP, RD of NP (80 kg N+15 kg P/ha)] were applied, so the same treatments will come on the same plots in order to observe the residual effect of treatment given to component crops of the system. The data obtained from sunflower were analyzed in split-split plot design. All the treatments were replicated thrice during both the years. The plot size was 17.4 × 15 m for main plot and 2.4 ×15 m for sub plots and for 2.4 × 4 m for sub-sub plots. N and P to sunflower as per treatment supplied through urea (after subtracting the N supplied from DAP) and diammonium phosphate. The nitrogen was applied in two splits, half at sowing and the remaining half at 30 DAS. Sunflower JK Chitra was sown at the seed rate of 4 kg/ha. After field preparation sowing was done by dibbling method on ridges spaced at 60 x20 cm. Gap filling and thinning was also done at appropriate stage. For weed control, pre-emergence spray of stomp (pendimethalin) @ 1.0 kg/ha was done; besides one hand weeding at 20 DAS. Crop received four irrigations beside pre-sowing irrigation. First irrigation was applied at 30 DAS and subsequent irrigations as per need. For controlling leaf eating caterpillar one spray of monocrotophos @ 0.05% was given. Sunflower was grown as per recommended practices and was harvested in the second fortnight of May during both the years of experimentation.

For recording of plant height five randomly selected and tagged plants in each plot was measured from the base to the tip of the plant at 20, 40, 60, 80 DAS and at harvest by using standard metre scale. Leaf area was measured by separating leaves of five randomly selected plants from the stem and cleaned with de-ionized water and then dried with tissue paper. The area of fresh green leaves for each treatment was measured by using leaf area meter (Model LICOR 3000, USA) and was expressed in cm^{-2}/plant. Leaf area index (LAI) was calculated at 20, 40, 60, 80 DAS and at harvest using the formula as suggested by Evans (1972). These plants were sun-dried for 2-3 days and oven-dried at 60-65±2°C for 48 hours and dry and weight was recorded with the help of an electronic pan balance (Mettler, Type K7T, Swiss made) and expressed as g/plant. Crop growth rate were calculated by using the fallowing formula and expressed as/g/m^2/day.

$$\text{CGR} = (W_2 - W_1/T_2 - T_1) \times A$$

where, W_2 and W_1 are final and previous dry weight, T_2 and T_1 is the time of final and previous observation, A is the area/plant.

At the time of maturity, the net plots (leaving 2 border rows on each side) were harvested and threshed and sun-dried for three days in the field and then the stover yield was recorded. After threshing, cleaning and drying the grain yield was recorded and expressed in tonnes/ha.

The protein content and protein yield was calculated by the following formula:

$$\text{Protein content} = \text{Nitrogen content} \times 6.25$$

Grain protein yield (kg/ha) = 6.25 × nitrogen uptake in grain (kg/ha)

Similarly, the oil content in seed was estimated by Pulse Nuclear Magnetic Resonance Technique (Tiwari and Burk 1980) and oil yield was calculated by the following formula:

$$\text{Oil yield (kg/ha)} = \frac{\text{Oil \%} \times \text{Seed yield (kg/ha)}}{100}$$

For energy calculation, input energy divided into direct and indirect and renewable and non-renewable forms (Hatirli *et al.* 2006). Standard energy equivalents suggested by (Chaudhary *et al.* 2006) were used for energy calculations. Based on the energy equivalents of the inputs and output, energy use efficiency, energy productivity (Shahan *et al.* 2008), energy intensity in physical terms and energy intensity in economic terms (Deike *et al.* 2008) were calculated.

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

Energy productivity (kg/MJ) = [Total output (grain+stover) (kg/ha)]/Total energy input (MJ/ha)

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

Energy intensity in physical terms (MJ/kg) = Total energy input (MJ/ha)/Total output (kg/ha)

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

All the data obtained from sunflower 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 for determine the significance of differences between means.

RESULTS AND DISCUSSION

Growth attributes

In general, plant height (Table 1), LAI (Table 2), DMA (Table 3) and crop growth rate (Table 4), increased as the crop advanced in age and reached to the maximum at maturity except LAI and CGR, which recorded increase only up to 80 DAS and 60 DAS, respectively. Residual effect of sunflower stover incorporation exerted significant effect on all the growth parameters, viz. plant height, LAI, DMA and crop growth rate (CGR) of succeeding sunflower crop at all the growth stages. Well decomposed sunflower stover provides adequate amount of mineralized nutrients to plants, which may induced high photosynthetic activity, vigorous growth.

Among the P levels applied to preceding pigeonpea crop, residual effect of 30 kg P/ha was found significantly superior over other P levels. It might be due to residual P, which has favourable effect on better equilibrium of nutrients in soil solution and its higher absorption due to larger root biomass of sunflower. Direct NP application on sunflower improved the growth in terms of plant height, LAI, DMA and CGR significantly over control. Among the NP doses applied to sunflower, RD of NP (80 kg N+15 kg P/ha) recorded maximum plant height, LAI, DMA

Table 1 Effect of sunflower stover and nutrient management on plant height of sunflower (Mean data of two years)

Treatment	Plant height (cm)				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Residual effect of SS management					
Control	6.5	67.5	80	107.3	111.8
SSI @ 8 t/ha	7.1	73.1	92.3	118.9	125.3
SEm±	0.07	0.70	1.65	1.02	1.20
CD (P=0.05)	0.42	4.20	9.85	6.00	7.30
Residual effect of P levels applied to pigeonpea					
Control	6.1	64.3	78.9	105.2	111.2
15 kg P/ha	6.8	70.3	85	12.1	117.3
15 kg P/ha+PSB	6.9	71.2	86.3	111.9	118.1
30 kg P/ha	7.4	75.3	94.3	123.2	128.5
SEm±	0.13	0.80	1.10	1.35	1.65
CD (P=0.05)	0.42	2.40	3.30	4.20	5.10
Direct effect of NP levels					
Control	5.7	62.1	77.6	100.5	110.1
50% RD of NP	7.1	71.2	86.6	114	118.3
RD of NP	7.4	77.5	94.2	124.8	128.3
SEm±	0.09	0.90	1.00	1.10	0.90
CD (P=0.05)	0.26	2.54	2.80	3.20	2.65

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

Table 2 Effect of sunflower stover and nutrient management on leaf area index (LAI) of sunflower (mean data of two years)

Treatment	Leaf area index (LAI)				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Residual effect of SS management					
Control	0.14	1.54	4.53	3.94	2.44
SSI @ 8 t/ha	0.17	1.75	4.74	4.20	2.90
SEm±	0.002	0.010	0.03	0.03	0.02
CD (P=0.05)	0.016	0.063	0.18	0.19	0.09
Residual effect of P levels applied to pigeonpea					
Control	0.14	1.58	4.22	3.63	2.46
15 kg P/ha	0.15	1.64	4.69	3.95	2.50
15 kg P/ha+PSB	0.16	1.65	4.77	4.17	2.62
30 kg P/ha	0.18	1.72	4.87	4.53	3.00
SEm±	0.003	0.024	0.05	0.10	0.06
CD (P=0.05)	0.010	0.074	0.16	0.31	0.19
Direct effect of NP levels					
Control	0.14	1.45	4.31	3.70	2.31
50% RD of NP	0.15	1.66	4.65	4.07	2.61
RD of NP	0.17	1.82	4.96	4.45	3.09
SEm±	0.002	0.018	0.04	0.07	0.06
CD (P=0.05)	0.007	0.052	0.12	0.19	0.14

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

Table 3 Effect of sunflower stover and nutrient management on dry matter accumulation of sunflower (mean data of two years)

Treatment	Dry matter accumulation (g/plant)				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Residual effect of SS management					
Control	1.50	26.3	64.8	81.2	95.6
SSI @ 8 t/ha	1.80	30.4	73.1	93.9	108.2
SEm±	0.02	0.30	0.40	1.25	1.25
CD (P=0.05)	0.14	2.05	2.60	7.35	7.60
Residual effect of P levels applied to pigeonpea					
Control	1.51	25	61.5	75.5	88.9
15 kg P/ha	1.62	27.6	69.4	86.7	100.7
15 kg P/ha+PSB	1.65	28.2	70.1	89.2	101.9
30 kg P/ha	1.81	32.6	74.8	98.8	116
SEm±	0.03	0.40	1.15	1.85	1.55
CD (P=0.05)	0.11	1.40	3.50	5.70	4.80
Direct effect of NP levels					
Control	1.17	18.4	55.7	76.1	83.0
50% RD of NP	1.78	31.5	67.6	87.6	105.8
RD of NP	1.99	35.2	81.7	99.0	117.0
SEm±	0.03	0.50	1.11	1.35	1.40
CD (P=0.05)	0.10	1.50	3.40	3.85	4.19

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

Table 4 Effect of sunflower stover and nutrient management on crop growth rate (CGR) of sunflower (Mean data of two years)

Treatments	CGR (g/m^2/day)				
	0-20 DAS	20-40 DAS	40-60 DAS	60-80 DAS	80 DAS-At harvest
Residual effect of SS management					
Control	0.62	11.05	15.44	6.52	2.94
SSI @ 8 t/ha	0.75	12.61	17.18	8.69	2.89
SEm±	0.01	0.13	0.15	0.09	0.04
CD (P=0.05)	0.05	0.8	0.91	NS	NS
Residual effect of P levels applied to pigeonpea					
Control	0.62	10.5	14.56	5.81	2.73
15 kg P/ha	0.67	11.5	16.76	7.21	2.84
15 kg P/ha + PSB	0.69	11.76	16.94	7.96	2.59
30 kg P/ha	0.76	13.53	17.39	9.43	3.52
SEm±	0.01	0.17	0.33	0.20	0.06
CD (P=0.05)	0.04	0.54	1.01	0.62	0.21
Direct effect of NP levels					
Control	0.48	9.28	14.31	6.28	1.44
50% RD of NP	0.74	12.38	15.09	8.40	3.47
RD of NP	0.83	13.83	19.45	8.13	3.85
SEm±	0.01	0.21	0.50	0.24	0.06
CD (P=0.05)	0.04	0.60	1.45	0.70	0.18

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

and CGR followed by 50% RD of NP at all the growth stages under study owing to the fact that nitrogen, promoted the vegetative growth and increased carbohydrate in leaves, which resulted in more leaf expansion and total DMA (Mundstock and Zagonel 1994). Similarly, phosphorus plays a pivotal role in energy transfer and oxidation reduction reactions and metabolic process of plant. It prevents leaf fall and rolling of leaf margin and tips and chlorosis.

Yield

Mean data of two years showed that residual effect of sunflower stover incorporation recorded significantly higher values of seed (2.54 tonnes/ha) and stover (4.07 tonnes/ha) yields (Table 5). This might be due to the positive effect of sunflower stover incorporation on soil fertility. An improvement in soil fertility due to sunflower stover incorporation was also reported by Babu *et al.* (2015). Among different P levels, as a result of residual fertility of 30 kg P/ha recorded significantly higher seed (2.54tonnes/ha), stover (4.16 tonnes/ha) over other P levels. This response can be accounted for better growth attributes. Direct application of NP to sunflower also caused significant effect on seed and stover yield of sunflower. Maximum seed (2.71 tonnes/ha) and stover (4.43 tonnes/ha) were recorded by the application of RD of NP (80 kg N+15 kg P/ha). This was probably due to the higher N and P availability at initial stages, which helped to acquire a definite advantage in respect of growth.

Table 5 Effect of sunflower stover and nutrient management on yield and quality of sunflower (Mean data of two years)

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Protein content (%)	Protein yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
Residual effect of SS management						
Control	2.05	3.57	14.0	291.1	40.3	834.1
SSI @ 8 t/ha	2.45	4.07	14.8	365.3	41.3	1019.6
SEm±	0.02	0.03	0.1	2.65	0.4	8.9
CD (P=0.05)	0.14	0.22	0.4	16	NS	53.7
Residual effect of P levels applied to pigeonpea						
Control	2.06	3.68	14.2	295.1	40.1	830
15 kg P/ha	2.18	3.74	14.3	316.6	40.6	893.7
15 kg P/ha+PSB	2.22	3.71	14.5	325.1	40.8	9.14
30 kg P/ha	2.54	4.16	14.7	376	41.9	1070.3
SEm±	0.03	0.05	0.1	6.1	0.3	14.9
CD (P=0.05)	0.09	0.17	0.3	18.75	1.1	46.1
Direct effect of NP levels						
Control	1.63	2.91	13.9	229	39.5	648.2
50% RD of NP	2.41	4.10	14.5	351.5	40.8	986.2
RD of NP	2.71	4.44	14.9	404.2	42.3	1146.2
SEm±	0.02	0.05	0.1	5.2	0.4	13.6
CD (P=0.05)	0.48	0.13	0.3	15.1	1.3	39.2

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

Quality

Mean data of two years in Table 5 showed that protein content (14.8%) and seed protein yield (365.3 kg/ha) significantly increased due to residual effect of sunflower stover incorporation. In contrast, residual effect of sunflower stover incorporation could not bring out significant difference in oil content of succeeding sunflower, but increase in oil yield (1019.6 kg/ha) was significant. Incorporation of sunflower residue improves the fertility status of soil (Babu *et al.* 2014), which may promotes N uptake and finally protein synthesis. Residual effect of sunflower stover incorporation also recorded significantly higher protein and oil yield of succeeding sunflower owing to significantly higher seed yield of sunflower in respective treatments compared to control. Among the P levels applied to preceding pigeonpea, application of 30 kg P/ha exerted maximum residual effect on protein content (14.7%), protein yield (376 kg/ha), oil content (41.85%) and oil yield (1070.3 kg/ha) of succeeding sunflower. This indicates a beneficial residual effect of P applied to preceding pigeonpea at higher levels. As a major portion of the P applied to pigeonpea was left behind for use by the succeeding crop, it creates a balanced nutritional environment inside the plant leading to higher photosynthetic efficiency favouring plant growth and yield. Direct application of NP up to recommended dose (80 kg N+15 kg P/ha) increased the protein content and protein yield and oil content and oil yield significantly. This was probably due to continuous and regular supply of NP to sunflower. Composition and quantitative changes in fatty

Table 6 Effect of sunflower stover and nutrients management on on energetics of sunflower (Mean data of two 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 productivity (kg/MJ)	Energy intensity in physical terms (MJ/kg)	Energy intensity in economic terms (MJ/₹)
Residual effect of SS management							
Control	7.4	101.2	93.8	6.8	0.77	1.32	3.7
SSI @ 8 t/ha	7.4	118.2	110.9	8.3	1.13	1.13	4.4
SEm±		1.1	0.9	0.04	0.01	0.01	0.04
CD (P=0.05)		6.4	5.1	0.24	0.07	0.07	0.24
Residual effect of P levels applied to pigeonpea							
Control	7.4	102.6	95.1	6.8	0.78	1.30	3.7
15 kg P/ha	7.4	106.8	99.4	7.3	0.81	1.25	3.9
15 kg P/ha + PSB	7.4	107.5	100.1	7.5	0.82	1.25	4.0
30 kg P/ha	7.4	121.9	114.4	8.7	0.95	1.10	4.5
SEm±		1.3	0.9	0.9	0.01	0.01	0.06
CD (P=0.05)		4.0	2.8	0.3	0.03	0.05	0.17
Direct effect of NP levels							
Control	4.8	81.5	76.6	8.3	0.94	1.09	3.0
50% RD of NP	7.4	117.6	110.2	7.9	0.87	1.16	4.3
RD of NP	10.0	130.0	120.0	6.5	0.71	1.42	4.7
SEm±		1.1	0.9	0.1	0.01	0.01	0.04
CD (P=0.05)		3.2	2.5	0.2	0.03	0.04	0.13

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

acids of oil seeds during maturation and germination in response to fertilization were noticed by Teama and Mahmound, (1994). N application increased oil content due to a positive impact on conversion of sugar to lipids. N application, in the absence of P, decreased oil percentage in sunflower seed. P application up to 30 kg P_2O_5/ha resulted in significant increase in oil content. Increase in oil content in sunflower up to the recommended dose of N along with basal application of P was also recorded by Sathya Priya *et al.* (2009).

Energy dynamics

Mean data presented in Table 6 indicates that direct application of RD of NP (80 kg N+15 kg P/ha) recorded maximum energy input used (10 × 103 MJ/ha). This was mainly due to utilization of mineral fertilizers, and nitrogen in particular, represented a larger contribution to the energy input. These results are supported by the findings of Ozkan *et al.* (2004). Highest values of gross (118.2 × 10^3 MJ/ha) and net energy (110.8×10^3 MJ/ha) output, energy use efficiency (EUE) and energy productivity of succeeding sunflower was observed due to residual effect of sunflower stover incorporation. Presumably, the residual effect of sunflower stover incorporation led to higher yield due to better nutrient supply and improved humus reproduction. Increase in energy output and net energy due to application of FYM was also reported by Deike *et al.* (2008). P levels applied to preceding pigeonpea also has significant residual effect on gross and net energy output, EUE and energy productivity of succeeding sunflower, especially residual effect of 30 kg P/ha recorded significantly higher values of gross (121.9×10^3 MJ/ha) and net energy (114.4×10^3 MJ/ha) output, EUE (8.7) and energy productivity compared to residual effect of other P levels. Residual P modified and improved the overall nutritional environment of the soil conducive for growth, development and yield of sunflower. Direct application of NP up to the RD (80 kg N+15 kg P/ha) significantly increased gross and net energy output. In contrast, lowest EUE and energy productivity recorded with RD of NP. This was due to higher rate of NP application, which enhanced the seed and by product yield of sunflower.

Residual effect of sunflower stover incorporation caused 16.8% reduction in energy intensity in physical terms over control (Table 6). Residual effect of sunflower stover incorporation resulted in better soil fertility which exerted favourable effect on growth and yield of sunflower and increase the energy output. In contrast, energy intensity in economic terms was significantly higher due to residual effect of sunflower stover incorporation. This was mainly due to no price values of sunflower stover because it incorporated in preceding crop so, the cost of cultivation was lower and energy output was higher due to higher biological yield. Among the P levels, residual effect of 30 kg P/ha recorded lowest values of energy intensity in physical terms (1.1 MJ/kg). In contrast, maximum values of energy intensity in economic terms were observed with the residual effect of 30 kg/P ha. Such type of trends might be due to lower energy input and cost of cultivation and higher energy output. NP levels applied to sunflower crop directly had significant effect on energy intensity in physical and economic terms. RD of NP (80 kg N+15 kg P/ha) recorded significantly higher energy intensity in physical terms (1.42 MJ/kg) and energy intensity in economic terms (4.7 MJ/‘) compared to control. Higher energy intensity in physical terms was mainly due to the use of N fertilizer having higher energy coefficient. Higher energy output due to chemical fertilizer use is also responsible for higher energy intensity in economic terms.

Overall it is concluded that sunflower stover incorporation and application of phosphorus @ 30 kg/ha in preceding pigeonpea exerted appreciable residual effect on succeeding sunflower crop. The application 80 kg N+18 kg P/ha also proved superior in obtaining higher seed and stover yield in sunflower besides higher oil content, protein content and net energy output.

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