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Residual effect of sunflower (*Helianthus annuus*) stover and P management and direct effect of N and P on productivity, nutrient uptake and economics of spring sunflower

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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 residual effect of sunflower (*Helianthus annuus* L.) stover and P management and direct effect of N and P on productivity, nutrient uptake and economics of spring sunflower. Residual effects of sunflower stover incorporation and 30 kg P/ha and direct effect of recommended dose (RD) of NP (80 kg N + 15 kg P/ha) resulted in higher yield attributes, seed, stover and biological yields, gross returns, net returns, B:C ratio and uptake of N, P and K. Residual effect of sunflower stover incorporation increased seed yield of sunflower by 14.9 and 25.9% over the no stover incorporation during 2009 and 2010, respectively. Residual effect of 30 kg P/ha caused 22.3% and 24.4% increase in the seed yield of sunflower over the control during 2009 and 2010, respectively. Direct effect of RD of N and P (80 kg N + 15 kg P/ha) recorded the maximum seed yield (2.85 and 2.57 tonnes/ha) during both the years, which was significantly higher than 50% RD of NP (2.56 and 2.27 tonnes/ha) and control (1.70 and 1.57 tonnes/ha). Increase in seed yield due to RD of NP was 11.3 and 13.2% higher than 50% RD of NP and 67.6 and 63.7% than control. With regards to economics and nutrients uptake, residual effect of sunflower stover incorporation and 30 kg P/ha recorded significantly higher values of gross returns, net returns and B: C ratio and NPK uptake over control (no stover incorporation) and other P levels, respectively. Among the different doses of NP applied to sunflower, direct effect of RD of NP (80 kg N + 15 kg P/ha) registered the highest gross returns (64.11 × 10^3 and 6.13 × 10^3 ₹/ha), net returns (48.76 × 10^3 and 44.66 × 10^3 ₹/ha) and B:C ratio (3.19 and 2.80).

Key words: Direct effect, Economics, Residual effect, Yield attributes

A suitable combination of N and P is the most important single factor that affects the yield and quality of sunflower (*Helianthus annuus* L.). Growing of legumes in rotation with cereals and oilseeds could increase soil N and general fertility (Aulakh *et al.* 2004) and also incorporation of crop residue, which are easily and inexpensively available on farm, in such soil may have profound effect on crop yields and rejuvenation of deteriorated soil productivity depending upon the type of residue, seasons of application, fertilizer application, soil moisture, etc. (Kabba and Aulakh 2004).

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. Crop residue incorporation in sunflower also improved the pod yield of the succeeding crop of groundnut (Aulakh and Garg 2007). Hence the residual effect of nutrient on succeeding sunflower crop was studied. Residual P improved the yield of succeeding wheat crop in pigeonpea-wheat cropping system (Idapuganti and Ahlawat 2007). 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 was conducted to find out residual effect of sunflower stover and P management and direct effect of N and P on productivity, nutrient uptake and economics of spring sunflower. It was carried out out to elucidate N and P requirement of sunflower grown after pigeonpea having treatment of sunflower stover incorporation and P levels.

MATERIALS AND METHODS

A fixed plot field experiment was carried out during *kharif* and spring seasons of 2008–09 and 2009–10 to find

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out the N and P requirement of sunflower grown after pigeonpea, which received treatments of sunflower stover incorporation and P levels and sources. Experiment was conducted at research farm of Division of Agronomy, 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 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 (Subbiah and Asija 1956), 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). Field capacity, permanent wilting point and bulk density recorded were 17.0% (w/w), 6.30% (w/w) and 1.46 Mg/m^3, respectively in 0-15 cm soil depth.

Kharif season experiment was laid out 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 spring season experiment was laid out in split-split plot design, 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 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 plot and 2.40 m ×15.0 m for sub plots and for 2.40 m × 4.0 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. Sowing was done by dibbling method on ridges spaced at 60 cm and plant to plant spacing of 20 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, 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 in the second fortnight of May during both the years of experimentation.

Five plants were selected from net plot and head diameter was measure and the average was worked out and expressed in cm. Filled seeds of five sampled heads of sunflower were counted manually and average was worked out after that unfilled seeds of these sampled heads were counted manually and average was worked out. Total seeds of sampled plants were weighed and the average was expressed as seed yield/ plant (g). One thousand of seeds were counted by a seed counter from the total seeds produce of each treatment and weighed and weight so recorded was expressed as 1 000-seed weight (g). 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 economic yield (Seed) was divided by the biological yield (Seed + stover) and harvest index was calculated. The uptake of nutrients was computed by multiplying dry matter accumulation in hectare, seed and stover yields, by their respective nutrient contents.

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. 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

Productivity

Yield attributes: Residual effect of sunflower stover incorporation results significantly higher values of head diameter (18.6 and 17.3 cm), filled seeds/head (1 137 and 1 122), seed yield/plant (42.9 and 37.9 g/plant) during both the years of study and 1 000-seed weight (42.4 g) only during 2009 and significantly lower values of unfilled seeds/head (187 and 194) during both the years over control (Table 1). This attributed to the favourable effect of crop residue on soil fertility (Hulugalle *et al.* 1996) and increased nutrient availability (Collin *et al.* 1992), which attributed to better partitioning of photosynthates from source to sink. When nutrient content in soil is enough the diversion of nutrients towards roots or below ground parts is checked and more photosynthates are translocated to the head at the commencement of reproductive phase. Since, head development occurs late in the growth stage of sunflower, so positive response of organic manures on yield attributes was due to proper decomposition resulting in increased supply of available plant material directly to the plants and increased the nutrient and water-holding capacity of the soil for longer time, which resulted into better growth and yield attributes (Dayal and Agrawal 1999). Stover incorporation also influences the physical properties of soil, which play a definite role in the transformation of nutrients to available form through their influence on organic matter mineralization (Hillel 1972). Increased nutrient availability enhanced the uptake of nutrients, which plays a major role in seed filling. Residual effect of P levels markedly influenced all the yield

Table 1 Residual effect of sunflower stover and P management and direct effect of NP on yield attributes of sunflower

Treatment	Head diameter (cm)		Filled seeds/head		Unfilled seeds/ head		Seed yield/ plant (g)		1 000 seed weight (g)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Residual effect of SFS management										
Control	16.3	15.0	1 014	955	215	231	37.7	33.5	41.0	38.6
SFSI @ 8 t/ha	18.6	17.3	1 137	1122	187	194	42.9	37.9	43.5	42.4
SEm±	0.18	0.19	7.1	6.7	4.4	4.90	0.67	0.58	0.35	0.36
CD (P=*0.05*)	1.12	1.18	42.9	40.7	26.7	29.82	4.10	3.50	2.15	2.17
Residual effect of P levels										
Control	16.2	14.9	970	953	251	271	36.8	32.5	40.2	38.6
15 kg P/ha	17.1	15.8	1 061	1 044	197	208	39.8	35.1	41.6	40.0
15 kg P/ha+PSB	17.5	16.3	1 107	1 091	192	204	40.3	36.0	41.9	40.3
30 kg P/ha	18.9	17.6	1 162	1 146	165	166	44.1	39.1	45.3	43.2
SEm±	0.31	0.28	17.7	17.4	9.0	7.45	0.82	0.88	0.76	0.38
CD (P=*0.05*)	0.95	0.85	54.5	53.6	27.6	22.97	2.52	2.72	2.35	1.16
Direct effect of NP doses										
Control	14.4	13.1	918	901	245	249	32.3	27.6	39.5	38.5
50% RD of NP	17.9	16.6	1 104	1 088	203	216	41.2	37.2	42.4	40.8
RD of NP	20.0	18.7	1 203	1 186	156	172	47.3	42.2	44.8	42.3
SEm±	0.18	0.18	10.8	10.8	5.4	5.51	0.55	0.54	0.45	0.44
CD (P=*0.05*)	0.520	0.512	31.0	31.0	15.6	15.88	1.58	1.54	1.29	1.26

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

attributes during both the years of study. Residual effect of 30 kg P/ha recorded larger head diameter (18.9 and 17.6 cm), maximum filled seeds/head (1 162 and 1 146), seed yield/ plant (44.1 and 39.1 g/plant), 1 000 grain weight (45.3 and 43.2 g) and lowest number of unfilled seeds/head (165 and 166) of succeeding sunflower crop during both the years, respectively. This remained significantly superior over the rest of the P levels applied to preceding pigeonpea crop. Because, only a fraction of applied P utilized by the preceding pigeonpea crop. The increase in the available P after harvest of pigeonpea was explained by the enhanced microbial activity resulting in dissolution of soil P. Due to this, efficient and greater partitioning of metabolites and adequate translocation of nutrients to developing reproductive structures might have taken place. Increase in yield attributes of wheat due to residual effect of P in pigeonpea-wheat system were also reported by Idapuganti and Ahlawat (2007). Due to direct effect of recommended dose (RD) of NP (80 kg N+15 kg P/ ha) marked increase in various yield attributes, viz head diameter, filled seeds/head, seed yield/plant and 1 000 seed weight and reduction in number of unfilled seeds/head of sunflower. It might be due to proper and balance supply of N and P to the crop. Head diameter of sunflower increased with the increase in nitrogen rate. Indeed, this effect was expected because of positive contribution of nitrogen on plant growth. Some research data of Oyinlola *et al.* (2010) had also shown that nitrogen fertilizer increased head diameter of sunflower. Application of P has a positive effect on the head diameter (Shivaprasad *et al.* 1996). NP fertilization leads to better assimilation of carbohydrates and increased head size (Steer *et al.* 1986). Better seed filling also might be due to the increased metabolic activity. This better metabolic activity might be due to the proper utilization of phosphorus in the presence of nitrogen, which inturn in increased filled and decreased unfilled seeds per head. A good supply of P at sowing along with N in splits associated with root growth and had absorbed plant nutrients and increased the test weight (Sathya Priya *et al.* 2009). These findings are in conformity with the results of Jahangir *et al.* (2006) and Skarpa and Losak (2008).

Yields and harvest index: Perusal of data indicates that residual effect of sunflower stover incorporation was significant on seed, stover and biological yields, which induced 14.9 % and 25.9% increment in seed, 9.3% and 19.4% in stover, 10.65% and 21.80% in biological yields and 2.40% and 3.20% in harvest index of sunflower over the control in 2009 and 2010, respectively (Table 2). Incorporation of crop residue in to the soil influencing the physical condition, improve soil productivity and crop production (Schomberg *et al.* 1994). Gradual improvement in yields of wheat, Indian mustard and gram under complete residue incorporation of sunflower by the end of fourth year of experiments were also reported by Rana *et al.* (2004). Among the different levels of P, residual effect of 30 kg P/ha recorded the significantly higher seed (2.63 and 2.45 tonnes/ha), stover (4.32 and 4.00 tonnes/ha) and biological yields (6.73 and 6.31 tonnes/ha) during both the years and harvest index (37.9%) only during 2010 over the residual effect of other P levels.This response

Table 2 Residual effect of sunflower stover and P management and direct effect of NP on seed, stover and biological yield and harvest index of sunflower

Treatment	Seed yield (tonnes/ha)		Stover yield (tonnes /ha)		Biological yield (tonnes /ha)		Harvest index (%)	
	2009	2010	2009	2010	2009	2010	2009	2010
Residual effect of SFS management								
Control	2.22	1.89	3.85	3.29	6.08	5.18	36.8	36.4
SFSI @ 8 t/ha	2.52	2.38	4.21	3.93	6.73	6.31	37.7	37.6
SEm±	0.02	0.02	0.04	0.03	0.06	0.05	0.09	0.17
CD (P=0.05)	0.14	0.14	0.24	0.21	0.36	0.30	0.55	1.07
Residual effect of P levels								
Control	2.15	1.97	3.91	3.45	6.05	5.42	36.0	36.2
15 kg P/ha	2.33	2.04	4.01	3.48	6.34	5.51	36.8	36.8
15 kg P/ha+PSB	2.37	2.08	3.90	3.52	6.27	5.59	37.8	37.0
30 kg P/ha	2.63	2.45	4.32	4.00	6.95	6.45	38.3	37.9
SEm±	0.04	0.03	0.07	0.04	0.09	0.07	0.36	0.22
CD (P=0.05)	0.11	0.08	0.21	0.13	0.27	0.21	1.01	0.72
Direct effect of NP doses								
Control	1.70	1.57	3.07	2.76	4.77	4.33	36.2	36.2
50% RD of NP	2.56	2.27	4.35	3.86	6.90	6.13	37.3	36.9
RD of NP	2.85	2.57	4.68	4.21	7.53	6.78	38.3	37.8
SEm±	0.02	0.03	0.05	0.05	0.06	0.08	0.19	0.26
CD (P =0.05)	0.06	0.90	0.14	0.13	0.17	0.24	0.56	0.75

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

can be accounted for the positive response of agronomic characteristics associated with yield attributes such as head diameter, filled seeds/head and 1 000 seed weight. Similar observations were also made by Reddy and Babu (2003). Direct application of NP to sunflower caused significant effect on yields of sunflower during both the years. Maximum seed (2.85 and 2.57 tonnes/ha), stover (4.68 and 4.21 tonnes/ha) and biological (7.53 and 6.78 tonnes/ha) yields and harvest index (38.3 and 37.8%) during both the years were recorded with the application of RD of NP (80 kg N + 15 kg P/ha) although both the doses of NP remained significantly superior over the control. This was probably due to the higher availability of NP in the initial stage, which helped to acquire a definite advantage over control in respect of growth. Better partitioning of photosynthates from source to sink might have led to higher yield attributes which finally resulted into higher yield of sunflower. Many workers also demonstrated the positive role of N and P on seed yield (Tamak *et al.* 1997), stover yield (Nawaz *et al.* 2003), biological yield (Mishra *et al.* 2010) and HI (Legha and Giri 1999) of sunflower.

Nutrient uptake

Residual effect of sunflower stover incorporation gave significantly higher N (59.9 and 57.0 kg/ha), P (8.68 and 8.93 kg/ha) and K (25.60 and 24.90 kg/ha) uptake by seed and N (25 and 24.4 kg/ha), P (8.57 and 9.80) and K (80.1 and 71.9 kg/ha) uptake by stover as compared to no stover incorporation (Table 3). Variation in nutrient uptake by seed and stover might be due to variation in availability of nutrients and yields under residual effect of sunflower stover incorporation and control (no stover incorporation). Improvements in nutrient uptake by succeeding crops due to residual effect of organic sources of nutrients were also reported by Mekki *et al.* (1999). N, P and K uptake by seed, stover and (Seed + stover) by sunflower increased due to residual effect of P levels up to 30 kg P/ha applied to pigeonpea. This could be attributed to the fact that left over P favoured the growth and crop yield increased N, P and K content in grain and stover. Similar observation was also made by Mishra and Giri 2004.

Among the NP doses directly applied to sunflower, maximum values of N uptake (67.53 and 61.80 kg/ha), P uptake (10.19 and 10.31 kg/ha) and K uptake (28.6 and 25.9 kg/ha) by seed was found with the RD of NP (80 kg N+15 kg P/ha) which was significantly superior over the 50% RD of NP. Similar trends were also found with N, P and K uptake by stover during both the years of study. The total nutrient uptake is the product of nutrients uptake by seed+stover yields. Direct application of NP increased nutrient availability. The increased nutrient uptake resulted from labile pool maintained at higher levels under recommended dose of NP, accompanied by root development and greater surface area for absorption of nutrient in sunflower. Another possible

Table 3 Residual effect of sunflower stover and P management and direct effect of NP on nutrients (NPK) uptake by seed, stover and total (seed+stover) of sunflower

Treatment	Nutrients uptake (kg/ha)																	
	N						P						K					
	Seed		Stover		Total		Seed		Stover		Total		Seed		Stover		Total	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Residual effect of SFS management																		
Control	50.2	43.0	21.1	18.1	71.3	61.1	7.11	5.97	6.73	6.40	13.9	12.4	17.8	15.6	65.4	55.5	83.2	71.1
SFSI @ 8 t/ha	59.9	57.0	25.0	24.4	84.8	81.5	8.68	8.93	8.57	9.80	17.2	18.7	25.6	24.9	80.1	71.9	105.6	96.8
SEm±	0.3	0.5	0.4	0.3	0.6	0.8	0.09	0.05	0.13	0.09	0.2	0.2	0.4	0.1	0.5	0.6	1.0	0.6
CD (P=0.05)	2.1	3.0	2.2	2.0	3.9	4.9	0.52	0.28	0.80	0.54	1.4	0.1	2.7	0.9	3.3	3.4	6.0	3.9
Residual effect of P levels																		
Control	48.9	45.6	21.6	18.8	70.5	64.3	6.68	5.86	6.38	6.51	13.1	12.4	19.4	18.2	69.2	60.5	88.6	78.7
15 kg P/ha	53.9	47.4	23.0	20.0	76.9	67.4	7.68	6.73	7.41	7.35	15.1	14.1	21.4	19.0	72.5	61.3	93.8	80.3
15 kg P/ha	55.4	48.7	22.1	21.0	77.5	69.7	7.84	7.44	7.52	8.22	15.4	15.7	21.7	19.6	70.2	61.8	91.9	81.4
30 kg P/ha	62.0	58.3	25.4	25.4	87.4	83.7	9.39	9.77	9.29	10.33	18.7	20.1	24.4	24.2	79.0	71.3	104.0	95.5
SEm±	1.2	0.7	0.5	0.3	1.4	0.9	0.18	0.22	0.16	0.23	0.3	0.4	0.6	0.3	1.4	0.8	1.6	0.9
CD (P=0.05)	3.7	2.3	1.7	0.9	4.5	2.9	0.55	0.69	0.49	0.71	0.9	1.2	1.9	0.8	4.2	2.6	4.9	2.9
Direct effect of NP doses																		
Control	38.14	35.2	14.7	13.7	52.9	48.9	5.28	4.71	5.27	4.91	10.6	9.6	13.2	13.5	53.6	46.7	66.8	60.2
50% RD of NP	59.47	53.0	24.6	22.5	84.1	75.5	8.22	7.32	8.29	8.40	16.5	15.7	23.4	21.3	78.3	67.8	101.7	89.1
RD of NP	67.53	61.8	29.7	27.6	97.3	89.4	10.19	10.31	9.39	10.99	19.6	21.3	28.6	25.9	86.3	76.7	114.9	102.6
SEm±	0.9	0.8	0.4	0.4	1.1	1.1	0.15	0.19	0.14	0.24	0.2	0.4	0.3	0.3	1.0	0.8	1.1	1.0
CD (P=0.05)	2.5	2.3	1.1	1.2	3.1	3.3	0.44	0.56	0.40	0.70	0.7	1.1	0.9	0.9	2.9	2.4	3.2	3.0

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

Table 4 Residual effect of sunflower stover and P management and direct effect of NP on economics of sunflower

Treatment	Cost of cultivation (×10³ ₹/ha)		Gross returns (×10³ ₹/ha)		Net returns (×10³ ₹/ha)		B:C ratio	
	2009	2010	2009	2010	2009	2010	2009	2010
Residual effect of SFS management								
Control	14.74	15.87	50.04	45.04	35.30	29.18	2.38	1.83
SFSI @8 t/ha	14.74	15.87	56.56	56.77	41.82	40.90	2.86	2.57
SEm±			0.51	0.53	0.15	0.53	0.01	0.03
CD (P=0.05)			3.08	3.25	0.88	3.20	0.06	0.20
Residual effect of P levels								
Control	14.74	15.87	48.31	47.06	33.56	31.19	2.31	1.95
15 kg P/ha	14.74	15.87	52.51	48.52	37.76	32.66	2.55	2.06
15 kg P/ha+PSB	14.74	15.87	53.19	49.65	38.45	33.79	2.63	2.09
30 kg P/ha	14.74	15.87	59.20	58.38	44.46	42.52	3.00	2.69
SEm±			0.79	0.65	0.49	0.47	0.03	0.03
CD (P=0.05)			2.43	1.99	1.51	1.44	0.10	0.09
Direct effect of NP doses								
Control	14.13	15.26	38.33	37.48	24.12	22.23	1.72	1.44
50% RD of NP	14.74	15.87	57.47	54.01	42.73	38.23	2.97	2.35
RD of NP	15.35	16.47	64.11	61.13	48.76	44.66	3.19	2.80
SEm±			0.44	0.75	0.35	0.52	0.02	0.03
CD (P=0.05)			1.27	2.16	1.00	1.50	0.07	0.09

SFSI, Sunflower stover incorporation; RD of NP: 80 kg N+15 kg P/ha reason is the synergetic interrelationship between NP on metabolism of plant cells and combined application of NP which enhanced the biomass production. Similar observations were also made by Muralidharudu *et al.* (2003) and Mishra *et al.* (2010).

Economics

During both the years of experimentation, residual effect of sunflower stover incorporation recorded the maximum gross returns (56.56 × 10^3 and 56.77 × 10^3 ₹/ha), net returns (41.82 × 10^3 and 40.90 × 10^3 ₹/ha) and B:C ratio (2.86 and 2.57) over the control (no stover incorporation). This may be attributed due to build up of soil fertility and productivity over the time due to sunflower stover incorporation. The results are in close conformity with the findings of Badnur *et al.* (2000) and Mangare *et al.* (2008). Residual effect of 30 kg P/ha produced the maximum gross returns (59.20 × 10^3 and 58.38 × 10^3 ₹/ha), net returns (44.46 × 10^3 and 42.52 × 10^3 ₹/ha) and B:C ratio (3.00 and 2.69). This could be ascribed to the fact that substantial fraction of P applied to pigeonpea was utilized by succeeding sunflower crop resulted in improvement in yield of sunflower without any increment in cost of cultivation, which consequently reflected in gross returns, net returns and B:C ratio accrued from sunflower crop.With regards to the direct effect of N and P doses, direct effect of RD of NP (80 kg N + 15 kg P/ha) registered the highest gross returns (64.11 × 10^3 and 61.13 × 10^3 ₹/ha), net returns (48.76 × 10^{30} and 44.66 × 10^3 ₹/ha) and B:C ratio (3.19 and 2.80) during both the years. This might be due to higher requirement of sunflower for nutrients especially N and P which were liberally available to crop at higher levels, resulting in higher grain and stover yield. This finding is corroborated by Malik *et al*. (2004) and Jahangir *et al.* (2006).

REFERENCES

Aulakh M S and Garg A K. 2007. Yields and nutrient use-efficiency in groundnut-sunflower cropping system in Punjab, India. *Journal of Sustainable Agriculture* **31**(1): 89–110.

Aulakh M S, Singh D and Sadana U S. 2004. Direct and residual effect of green manure and fertilizer nitrogen in a rice-rapeseed production system in the semiarid subtropics. *Journal of Sustainable Agriculture* **25**: 97–114.

Badnur V P, Bellakki M A and Tolnur S I. 2000. Incorporation of sunflower crop residues for integrated nutrient management of *rabi* sorghum in vertisol. *Karnataka Journal of Agricultural Sciences* **13**(3): 733–4.

Collin H P, Roymussen P E and Douglas C L J. 1992. Crop rotation and residue management effects on soil carbon and microbial dynamics. *Soil Science Society of American Journal* **56**(3): 783–8.

Dayal D and Agrawal S K. 1999. Response of sunflower genotype (*Helianthus annuus* L.) to nutrient management. *Indian Journal of Agricultural Sciences* **69**(1): 3–10.

Gomez K A and Gomaz A A. 1984. *Statistical Procedures for Agricultural Research.* John Wiley & Sons, Singapore.

Hillel D.1972. *Optimizing the Soil Physical Environment Toward Greater Crop Yields*. Academic Press, New York.

Hulugalle N R, Larsen D L and Henggester S. 1996. Effect of broadbed and dolichus residue management on properties of an irrigated vertisol. *Soil Technology* **8**(4): 275–86.

Idapuganti R G and Ahlawat I P S. 2007. Integrated phosphorus management in pigeonpea (*Cajanus cajan*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **52**(4): 289–93.

Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt Ltd, New Delhi.

Jahangir A A, Mondal R K, Katrun Nada Afroze K N R S and Hakim M A. 2006. Response of nitrogen and phosphorus fertilizer and plant spacing on growth and yield contributing character of sunflower. *Bangladesh Journal of Scientific and Industrial Research* **41**(½): 33–40.

Kabba B S and Aulakh M S. 2004. Climatic conditions and crop residue quality differentially affect N, P and S mineralization in soils with contrasting P status. *Journal of Plant Nutrition and Soil Science* **167**: 596–601.

Legha P K and Giri G. 1999. Influence of nitrogen and sulphur on growth, yield and oil content of sunflower (*Helianthus annuus* L.) grown in spring season. *Indian Journal of Agron*omy **44**(2): 408–12.

Malik M A, Saleem F, Sana M and Rehman A. 2004. Suitable Level of N, P and K for harvesting the maximum economic returns of sunflower (*Helianthus annuus* L.). *International Journal of Agriculture and Biology* **6**(2): 240–2.

Mangare P N, Shendurse S M, Matale S G and Nandapure S P. 2008. Effect of incorporation of crop residue on crop productivity and economics under greengram-sunflower sequence. *Green Farming* **2**(1): 47–9.

Mekki B B, EL-Kholy M A and Mohamed E M. 1999. Yield, oil and fatty acids content as affected by water deficit and potassium fertilization in two sunflower cultivars. *Egyptian Journal of Agronomy* **21**: 67–85.

Mishra B and Giri G. 2004. Influence of preceding season practices and direct application of fertilizer on growth, yield, oil content and oil production of Indian mustard. *Indian Journal of Agronomy* **49**(4): 264–7.

Mishra S, Tuteja S S and Lakpale R. 2010. Effect of irrigation, level and source of phosphorus, nitrogen and sulphur on growth, nutrient uptake and productivity of hybrid sunflower. *Journal of Interacademicia* **14**(1): 34–9.

Muralidharudu Y, Murthy I Y L N, Reddy K P C , Reddy B N and Chandranath, H T. 2003. Response of sunflower (*Helianthus annuus* L.) to phosphorus application in vertisols. *Helia* **26**(39): 147–54.

Nawaz N, Sarwar G, Yousaf M, Naseeb T, Ahmad A and Shah M J. 2003. Yield and yield components of sunflower as affected by various NPK levels. *Asian Journal of Plant Sciences* **2**: 561–2.

Olsen S R, Cole C V, Watanabe F S and Dean L A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. No. 939, Washington.

Oyinlola E Y, Ogunwole J O and Amapu I Y. 2010. Response of sunflower (*Helianthus annuus* L.) to nitrogen application in a savanna alfisol. *Helia* **33**(52): 115–26.

Rana D S, Giri G, Rana K S and Pachauri D K. 2004. Effect of sunflower (*Helianthus annuus*) residue management on productivity, economics and nutrient balance sheet of sunflower-maize (*Zea mays*) based cropping systems. *Indian Journal of Agricultural Sciences* **74**(6): 305–10.

Reddy B N and Babu S N S. 2003. Sustainability of sunflower-based crop sequences in rainfed alfisols. *Helia* **26**(39): 117–23.

Sathya Priya R, Yassin M M, Maheswari J and Sangeetha S P. 2009. Influence of NPK fertilization on productivity and oil yield of groundnut (*Arachis hypogaea*) and sunflower (*Helianthus annuus*) in intercropping system under irrigated condition. *International Journal of Agricultural Research* **4**(2): 97–106.

Schomberg H H, Ford P B and Hargrove W L. 1994. Influence of crop residues on nutrient cycling and soil chemical properties. *Managing Agricultural Residues*, pp 99–121. Unger P W (Ed). Lewis, Boca Raton, Florida, USA.

Shivaprasad M Sheelavantar M N, Kulkarni B S Shenoy H and Patil S. 1996. Effect of sowing dates and P levels on performance of rabi irrigated sunflower. *Farming Systems* **12**(1-2): 30–6.

Skarpa P and Losak T. 2008. Changes in selected production parameters and fatty acid composition of sunflower (*Helianthus annuus* L.) in response to nitrogen and phosphorus applications. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* **56**(5): 203–10.

Stanford S and English L. 1949. Use of flame photometer in rapid soil tests for K and Ca. *Agronomy Journal* **41**: 446–7.

Steer B T, Coaldrake P D, Pearson and C J and Canty C P 1986. Effects of nitrogen supply and population density on plant development and yield components of irrigated sunflower (*Helianthus annuus* L.). *Field Crops Research* **13**: 99–115.

Tamak J C, Sharma H C and Singh K P. 1997. Effect of phosphorus, sulphur and boron on seed yield and quality of sunflower (*Helianthus annuus*). *Indian Journal Agron*omy **42**(1): 173–6.