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Evaluation of jatropha (*Jatropha curcas*) and castor (*Ricinus communis*) cake as a source of nutrient and soil amendment in spring sunflower (*Helianthus annuus*)-maize (*Zea mays*) sequence

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ABSTRACT

A fixed plot field experiment was conducted during 2007 and 2008 at New Delhi to find out the effect of de-oiled seed cake of jatropha (*Jatropha curcas* L.) and castor (*Ricinus communis* L.) as a source of nutrient alone and in various combination with inorganic sources in spring sunflower (*Helianthus annuus* L.)–maize (*Zea mays* L.) sequence. Nine combinations of three organic sources *viz.* jatropha cake (JC), castor cake (CC) and FYM @ 100%, 50% and 25% recommended dose of nitrogen (RDN) and three inorganic levels *viz.* 0%, 50% and 75% recommended dose of fertilizer (RDF) were tested in sunflower along with RDF through inorganic (80, 26.2 and 30 kg N, P and K/ha) and control. Residual effects of treatments were evaluated on the succeeding maize along with RDF to fallow-maize (120, 26.2 and 33.3 kg N, P and K/ha). In first year of experiment, RDF to sunflower produced significantly the highest seed yield (2.64 t/ha) over other fertility levels barring the treatment of 75% RDF + 25% RDN either through JC (2.61 t/ha) or CC (2.52 t/ha). In the next season, 50% RDF + 50% RDN through JC (3.43 t/ha) being on par with 50% RDF + 50% RDN either through CC (3.36 t/ha) or FYM (3.22 t/ha) produced marked increase in seed yield over remaining fertility combinations. Grain yield of succeeding maize due to residual effect of 50% RDF + 50% RDN through JC (2.72 and 2.89 t/ha in respective year) was significantly higher than other residual fertility treatments, followed by 50% RDF + 50% RDN through CC (2.45 and 2.62 t/ha) in both the years. The highest system productivity in terms of sunflower seed equivalent (3.52, 4.75 t/ha) and net returns (Rs 45,418, 69,407/ha) were recorded with the application of 50% RDF + 50% RDN through JC, followed by 50% RDF + 50% RDN through CC during both the years. Nutrient uptake followed trend similar to yield. Compared to control and RDF, pH and bulk density decreased with increase in the quantity of organics and reverse trend was recorded with respect to organic carbon content.

Key words: Castor, Farmyard manure, *Jatropha*, Maize, Productivity, Residual effects, Sunflower

Sunflower has higher yield potential and can play an important role in meeting out shortage of vegetables oils and fats among the nine oilseed crops grown in India and also holds a great promise, because of its short duration, photo-insensitivity, healthy oil quality and wider adaptability in different agro-climatic regions and soil types. After its introduction in 1970, the area under the crop has improved drastically (0.12 m ha to 1.88 m ha in 2007-08) in India. Productivity of the crop has remained very low (0.69 t/ha), when compared with world average productivity. Of all the reasons for low productivity, role of plant nutrients is of paramount importance. It is an exhaustive crop, hence nutrient management assumed significance for higher yield and fertilizer use efficiency. To meet the nutrient requirement of crops through indigenous and imported chemical sources of nutrients is difficult. The nutrients uptake through crops is creating a deficit of 8-10 m t of nutrients in the soil/year in India. Moreover, there is imbalance use of nutrients, resulting in multi-micronutrients deficiency in the soil. Under these situations, integrated nutrient management based on low cost and locally available organic sources is more rational, sustainable and economical.

Jatropha plantation is being promoted on large scale for bio-diesel production. The de-oiled non-edible cake of jatropha as well as castor has no other best option than to recycle and use them as a concentrated organic source of nutrients. The added advantage of de-oiled cakes over similar organic sources of nutrients are quick mineralization, low C:N ratio for quick decomposition, high N content and could be applied as manure just at the crop sowing or partially as top dressing too (Saxena and Singh, 1980). Hence, an experiment was laid to explore and compare the effect of jatropha-cake, castor-cake and FYM alone and in different combinations with inorganic sources in spring sunflower. Organic sources of nutrients

possess soil amendment traits and carry residual fertility, so effect of treatments given to sunflower was evaluated on the succeeding *kharif* maize and soil health.

MATERIALS AND METHODS

A fixed plot field experiment was undertaken in the research farm of Indian Agricultural Research Institute, New Delhi during the crop years 2007 and 2008, on sandy loam soils analyzing low in organic C (0.38%) and available N (169.3 kg N/ha) and medium in available P (15.2 kg P/ha) and K (182.2 kg/ha) and pH 7.9 (1:2.5 soil to water) in 0-30 cm soil layer. The total rainfall received during crop sequence was 553.3 mm and 855.3 mm in 2007 and 2008, respectively. Spring sunflower received 11 treatments consisting of control, recommended dose of NPK through inorganic fertilizer (RDF for sunflower is 80: 26.2 : 33.3 kg N: P: K/ha), recommended dose of nitrogen (RDN) through jatropha cake(JC), RDN through castor cake (CC), RDN through FYM, 50% RDF+50% RDN through JC, 50% RDF+50% RDN through CC, 50% RDF+50% RDN through FYM, 75% RDF+25% RDN through JC, 75% RDF+25% RDN through CC and 75% RDF+25% RDN through FYM along with a fallow plot in each replication. The JC, CC and FYM on an average contained 4.51-0.92-1.47, 4.12-0.73-1.28 and 0.57-0.14-0.38% of N-P-K respectively. The JC, CC and FYM applied to supply 80 kg N also added 16.3-26.1, 14.2-25.0 and 19.6-53.3 kg/ha of P-K respectively. Quantity of organic sources of nutrients was worked based on the percent of N present in each organic source and requirement of recommended dose of nitrogen (80 kg/ha). These treatments were tested in a 3 times replicated randomized block design. The residual effects of 11 treatments given to sunflower were evaluated on succeeding maize without direct application of fertilizer or organic manure to maize. An additional treatment of recommended dose of NPK (RDF in maize is 120, 26.2 and 33.3 kg NPK/ha) to maize through inorganic sources, imposed in fallow plot. A well decomposed FYM was applied 1 week before sowing, whereas JC and CC were applied at the sowing. In treatment of RDF through inorganic, half N through urea and full dose of P through single super phosphate and K through muriate of potash were applied at the time of sowing and the remaining N was top dressed at 30 days after sowing (DAS). In all treatments of integrated nutrient management, inorganic fertilizers as per treatments were applied at the time of sowing.

Sunflower 'JK Chitra' was sown on 6 March and 20 February in 2007 and 2008 at a spacing of 60 x 20 cm respectively. Crop received one weeding at 15 DAS during both the seasons. For controlling cut worm and other insect, chlorpyriphos was used along with pre-sowing irrigation. Crop received 80.4 and 123.8 mm rainfall during the respective season, but its distribution was not spread across the crop season. In the first year, rainfall received at the beginning of the season, while in the second, it was received at the end of the season. Besides rainfall, crop received 4 irrigations as per need of the crop during both the crop seasons. Crop was harvested on 11 June and 28 May in respective season. For the study of residual effect on maize 'PEHM 2' was sown on 2 July and 17 June, and harvested on 25 September and 9 September in the respective years. For weed control in maize, crop received pre-emergence application of atrazine and earthing up at 20 DAS. Crop received irrigation as per requirement of the crop in the respective season. The experiment was conducted on the same site without any change in the layout plan for 2 cycles.

Three plants were tagged randomly in the second row fixed for sampling in each plot at 50 DAS and were used for recording growth and yield attributes of the crop at harvest under different treatments. For leaf area and dry matter production, three plants were uprooted continuously from the sampling row at different growth stages. Seed/grain yield of component crops was worked out based on net plot yield. Sunflower seed equivalent yield and net returns calculated on the basis of support price for the main produce during 2007-2008 and prevailing market prices for the inputs. Soil samples were taken from 0 to 30 cm soil layer at the beginning and end of experiment and analyzed for soil organic carbon content, pH and available NPK by following standard procedure. Soil bulk density was determined at the beginning of experiment and at the end of 2 crop cycles using core sampler. N content in seed/grain and stover of components crops was estimated by Kjeldahl's method, phosphorus by Vanadomolybdophosphoric yellow colour method and potassium content by using Flame photometry method. Uptake of nutrients in seed/grain and stover of sunflower and succeeding maize was worked out by multiplying seed/grain and stalk/straw yield of the respective crop by using their respective nutrient contents. Agronomical N use efficiency, (ANUE) (kg grain/kg N applied) and physiological N use efficiency, PNUE (kg grain /kg N uptake) were computed using the standard formulae.

RESULTS AND DISCUSSION

Direct and cumulative effects of nutrient sources on sunflower

The 2 years experimental data revealed that the application of organic and inorganic sources of nutrients alone and in different combination induced marked variation in growth and yield attributes and seed yield of sunflower (Table 1). However, this variation in growth and yield at-

tributes and seed yield due to treatments across the seasons was found not similar. The variation in growth and yield parameters across the treatments over two years may be attributed to slow mineralization of organic sources of nutrients in the first year and improvement of soil productivity and residual effect of organic sources in the second year. In the first year, RDF recorded maximum plant height at harvest, leaf area index (LAI) at 60 DAS, dry matter production/plant (DMP) at 60 DAS, capitulum diameter and 1,000 seed-weight, which were significantly superior to application of RDN either through JC or CC or FYM. In integrated use of nutrients, application of 75% RDF+25% RDN through JC recorded maximum values of the aforesaid growth and yield parameters, but this treatment was statistically similar to other integrated combinations and RDF through inorganics. In the second season, integrated use of 50% RDF+50% RDN through JC recorded the highest values of growth and yield attributes closely followed by 50% RDF+50% RDN through CC. In the second season, the variation between the alone application of organic and inorganic or inorganic + organic were less when compared with first season. This behaviour of treatments effect may be ascribed to variable residual effects of treatments along with direct effects.

Seed yield followed trend similar to growth and yield attributes across the seasons. In 2007, application of RDF being on par with 75% RDF + 25% RDN either through JC or CC recorded marked improvement in seed yield over other treatments. In terms of per cent increase in seed yield, RDF and other 2 treatments recorded 120, 117 and 110% higher seed yield over control, respectively. Among the organic sources, application of 80 kg N through JC produced significantly higher seed yield over CC and FYM. JC application to supply 80 kg N was also found superior to 50% RDF+50% RDN through FYM. In the second year, the highest seed yield was recorded with 50% RDF+50% RDN through JC, which was significantly higher than remaining fertility levels except 50% RDF+50% RDN either through CC or FYM. Integration of 50% RDN either through JC or CC or FYM with 50% RDF recorded 185,180 and 168 % increase in seed yield over the control. Contrary to first year, in the second year alone application of JC or CC to supply 80 kg RDN produced significant increase in seed yield over RDF. In the second year alone application of FYM also recorded seed yield similar to RDF.

The variation in seed yield across the treatment may be traced to their favourable effects on the growth attributes, which further got translated to yield attributes and finally on seed yield. The integrated nutrient treatments might have resulted in sufficient amount of release of nutrients by mineralization at a constant level and increased the nu-

Table 1. Direct and direct + residual effect of organic and inorganic sources of nutrients on growth and yield parameters and yield (t/ha) of sunflower

Treatments	Plant height (cm)		LAI at 60 DAS		DMP at 60 DAS (g/plant)		Capitulum diameter (cm)		1,000 seed weight (g)		Seed yield	
	2007	2008	2007	2008	2007	Seed yield	2007	2008	2007	2008	2007	2008
Control	165.3	168.8	3.63	3.49	38.9	40.2	13.0	14.7	34.0	34.7	1.12	1.20
RDF (80-26.3-33.3 kg N-P-K/ha)	185.6	186.3	4.86	5.22	55.7	59.2	18.8	20.4	38.9	38.0	2.64	2.78
RDN through jatropha cake (JC)	177.3	182.3	4.00	4.95	49.5	63.8	17.8	19.6	37.7	38.4	2.38	3.10
RDN through castor cake (CC)	174.6	181.0	3.88	4.63	48.6	62.2	17.7	19.9	37.7	38.2	2.03	3.05
RDN through FYM	170.3	180.1	3.72	4.20	48.5	60.3	17.0	18.9	37.8	38.1	1.96	2.88
50% RDF + 50% RDN through JC	180.3	186.5	4.30	5.25	52.5	66.5	17.8	20.7	37.7	39.7	2.31	3.43
50% RDF + 50% RDN through CC	178.6	183.0	4.16	4.68	51.2	65.4	17.4	20.4	37.1	39.3	2.24	3.36
50% RDF + 50% RDN through FYM	175.3	182.5	3.81	4.63	51.2	64.3	18.0	19.7	37.8	38.1	2.16	3.22
75% RDF + 25% RDN through JC	184.6	178.6	4.69	4.41	55.8	60.2	18.8	18.7	38.5	38.1	2.61	2.90
75% RDF + 25%RD N through CC	183.8	177.0	4.63	4.14	54.3	58.2	18.4	18.4	38.1	38.0	2.52	2.67
75% RDF + 25% RDN through FYM	181.6	172.0	4.04	4.07	54.1	57.2	17.8	18.3	38.6	37.1	2.48	2.65
SEm±	4.0	3.4	0.19	0.09	1.2	1.3	0.5	0.6	0.6	0.7	0.05	0.08
CD (P=0.05)	11.9	10.1	0.57	0.28	3.5	3.9	1.3	1.8	1.8	2.0	0.15	0.24

RDN: Recommended dose of N (80 kg); DMP: Dry matter production

trient uptake because of the better soil environment created due to cumulative effect of organic sources combined with inorganic sources of nutrients, which improved the plant growth and consequently enhanced the yield attributes and yield. Higher yield under integrated nutrient management particularly in the second season might be attributed to rapid mineralization of organic sources of nutrients, steady supply of nutrients throughout the growth period and build up of soil fertility due to addition of organics in the fixed plots across the seasons. In the first year, with almost similar amount of major plant nutrients, performance of alone application of organics or in 50:50 combination was not superior to RDF due to slow mineralization of organics and even immobilization which resulted in less availability of nutrients at early stages of plant growth, when the demand for the same is higher. Better performance of JC and CC than FYM alone and in combination, may be ascribed to narrow C:N ratio of cakes when compared with FYM.

Direct and residual effects of nutrient sources on maize

The residual effect of organic and inorganics alone and in combination applied to the previous sunflower crop significantly affected the growth and yield attributes and productivity of succeeding maize crop (Table 2). Significantly taller plants at harvest, LAI at 60 DAS, DMP at 60 DAS, cob length and girth of cob were recorded under all fertility levels over control. Fallow–maize with RDF recorded significant increase in growth and yield attributes over the residual fertility levels. On an average, integration of 50% RDF+50% RDN had maximum residual effect on the growth and yield attributes of succeeding maize followed by alone application of organics. RDF given to sunflower recorded the lowest values of growth and yield attributes of maize except control.

Grain yield of succeeding maize due to direct and residual effect of fertility levels followed trend similar to growth and yield attributes (Table 2). Grain yield obtained in fallow-maize with RDF to maize was significantly the highest over remaining residual fertility levels and control during both the seasons. Amongst the treatments of residual impact of fertility levels, 50% RDF + 50% RDN through JC produced noticeable increase in grain yield over residual effect of other fertility levels. This treatment of 50% RDF + 50% RDN through JC recorded 262 and 217% increase over control and 142 and 106% over RDF to sunflower during 2007 and 2008, respectively. With respect to RDF to maize, shortfall in grain yield under the aforesaid treatment was 32 and 35% during 2007 and 2008. Residual impact of 50% RDF + 50% RDN through CC, being on par with 50% RDF + 50% RDN through FYM, 80 kg N either through JC or CC (except JC during 2008) recorded significant increase in grain yield over other residual fertility levels. Among the alone application of organic sources, maximum grain yield of succeeding maize was recorded due to residual effect of JC followed by CC and FYM. Variable residual effects of treatments may be attributed to variation in the quantity of nutrient addition, C:N ratio and their variable nature of decomposition/mineralization and nutrient loss. Comparatively more residual effect of organics when compared with inorganics may be attributed to slow release of nutrients over a long period, less loss of nutrients away from rhizosphere in relation to inorganic and addition of secondary and micronutrients beside primary nutrients.

Similar direct and residual effects of organic and inor-

Table 2. Direct and direct + residual effect of organic and inorganic sources of nutrients on growth and yield parameters and yield of maize

Treatments	Plant height (cm)		LAI at 60 DAS		DMP at 60 DAS (g/plant)		Length of the cob (cm)		Girth of the cob (cm)		Grain yield (t/ha)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Control	155.0	158.8	2.6	2.68	38.6	40.1	13.8	15.0	9.6	10.4	0.75	0.91
RDF	157.6	162.1	3.2	3.32	50.0	53.7	15.3	16.6	10.5	11.5	1.12	1.40
RDN through jatropha cake (JC)	167.6	171.3	4.2	4.49	55.5	53.1	17.3	18.5	11.8	12.2	2.33	2.44
RDN through castor cake (CC)	166.4	170.0	4.0	4.35	55.0	52.6	16.6	17.9	11.3	11.7	2.38	2.54
RDN through FYM	165.7	169.3	4.1	4.31	54.6	52.1	16.5	17.7	11.2	11.6	2.24	2.34
50% RDF + 50% RDN through JC	173.7	177.4	4.6	4.70	59.2	63.2	18.5	19.4	12.9	13.3	2.72	2.89
50% RDF + 50% RDN through CC	170.3	175.3	4.4	4.58	58.1	61.7	17.1	18.4	11.9	12.3	2.45	2.62
50% RDF + 50% RDN through FYM	171.6	174.0	4.1	4.21	56.9	60.5	17.0	18.3	11.4	11.8	2.38	2.54
75% RDF + 25% RDN through JC	164.1	167.8	4.0	4.10	53.0	56.6	16.5	17.8	10.7	11.1	1.68	1.85
75% RDF + 25%RD N through CC	160.7	164.4	3.8	3.88	51.7	55.3	15.6	16.9	10.5	10.9	1.36	1.86
75% RDF + 25% RDN through FYM	159.0	162.7	3.7	3.77	51.2	54.8	14.6	15.9	10.4	10.8	1.41	1.79
Fallow-maize with RDF	196.8	197.5	5.4	5.89	68.8	81.8	19.4	20.7	14.2	14.6	4.01	4.50
SEm±	3.5	3.7	0.1	0.13	1.6	1.5	0.6	0.5	0.3	0.3	0.05	0.05
CD (P=0.05)	10.3	10.8	0.3	0.37	4.7	4.5	1.8	1.4	0.8	0.9	0.13	0.15

RDF to sunflower: 80-26.2-33.3 kg N-P-K/ha and to maize 120-26.2-33.3 kg N-P-K/ha

ganic sources of nutrients on different crops grown in systems had also been reported earlier. Jat and Ahlawat (2004) also reported direct and residual effects of organic and inorganic sources of nutrients on fodder crops grown after chickpea. Roy and Prasad (2005), Laddha *et al.* (2006), Ruthiya (2007) and Panwar (2008) reported direct and residual effects of organic and inorganic sources of nutrients given to preceding crop on the succeeding crop under different agro-climatic conditions.

System productivity

The system productivity expressed as sunflower equivalent yield was recorded higher in the second year when compared with first year (Table 4). In the first year, the application of 50% RDF + 50% RDN through JC yielded the highest system productivity (3.52 t/ha), which was on par with 50% RDF + 50% RDN through CC (3.33 t/ha), 75% RDF + 25% RDN through JC (3.42 t/ha) and 80 kg N through JC (3.41 t/ha) and significantly superior over remaining fertility levels and control (1.53 t/ha). These treatments were found to increase system productivity by 130.1, 117.6, 124.5 and 122.9% over control and 12.1, 6.2, 9.0 and 8.6% over RDF to sunflower respectively. RDF to sunflower recorded system productivity on par with 80 kg RDN through FYM, 80 kg RDN through CC, 50% RDF + 50% RDN through FYM and 75% RDF + 25% RDN either through CC or FYM.

In the second year, productivity recorded with 50% RDF + 50% RDN through JC was markedly superior over other treatments except 50% RDF + 50% RDN through CC. These two treatments were found to increase system productivity by 260.8 and 183.3% over control and 38.1 and 33.4% over RDF to sunflower. In the remaining treatments, 50% RDF + 50% RDN through FYM, 80 kg N through JC and 80 kg N through CC recorded similar system productivity. RDF to sunflower was statistically similar to 75% RDF + 25% RDN either through CC or FYM and was significantly superior over control. Alone productivity of maize with RDF was significantly less than system productivity except control.

System net returns recorded was maximum (Rs 45,418/ha and Rs 69,407/ha) in the treatment comprising of 50% RDF + 50% RDN through JC during both the seasons (Table 4). The lowest value of net returns was recorded under control. As compared to first year, second year recorded appreciable improvement in net returns over control and this improvement was comparatively more in 100% organic and 50:50 organic and inorganic when compared with RDF to sunflower. Similar increase in productivity and economics of production were reported in different cropping systems due to application of organic and inorganic sources of nutrients alone or combination under different agro-climatic situations (Singh *et al.*,1998; Pathak *et al.*, 2002; Kumpawat , 2004; Roy and Prasad, 2005 and Panwar, 2008).

Nutrient uptake

Sunflower: Highest total nitrogen uptake (seed + stover)of sunflower during 2007 was recorded by RDF, which was significantly superior to other treatments except 75% RDF + 25% RDN through JC. 75% RDF + 25% RDN through CC and 75% RDF + 25% RDN through FYM also recorded similar uptake. Application of 50% RDF + 50% RDN through jatropha cake induced

Table 3. Direct and residual effect of organic and inorganic sources of nutrients on total N, P and K uptake (kg/ha) in seed/grain + stover of sunflower and maize

Treatment	Sunflower						Maize					
	N		P		K		N		P		K	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Control	36.5	43.1	11.6	14.6	40.9	45.6	16.3	21.4	4.9	6.3	15.9	22.7
RDF	102.4	106.5	33.5	33.8	104.0	112.0	27.6	35.3	8.2	10.4	27.9	39.6
RDN through jatropha cake (JC)	81.2	117.5	25.8	36.9	70.9	128.3	56.2	59.7	23.1	23.8	56.9	66.5
RDN through castor cake (CC)	66.2	115.3	21.0	36.3	62.0	125.6	57.1	62.2	22.4	24.0	57.8	70.6
RDN through FYM	59.9	109.6	20.3	33.2	71.9	128.3	53.2	57.0	20.5	21.3	55.7	65.3
50% RDF + 50% RDN through JC	86.5	139.9	27.2	44.9	85.4	156.5	62.5	73.0	25.6	28.9	61.6	78.9
50% RDF + 50% RDN through CC	81.5	135.1	25.8	42.9	80.5	145.7	57.8	66.6	22.6	25.3	56.8	72.0
50% RDF + 50% RDN through FYM	79.5	126.5	24.0	41.9	89.7	149.6	56.8	64.0	22.8	25.0	56.8	70.0
75% RDF + 25% RDN through JC	101.3	114.0	35.4	35.6	104.6	128.1	39.6	46.3	12.5	14.4	39.1	51.2
75% RDF + 25%RD N through CC	96.0	102.3	31.2	32.7	97.1	116.0	32.1	45.8	10.0	14.2	32.9	52.5
75% RDF + 25% RDN through FYM	94.7	102.4	28.5	30.6	106.9	123.5	32.8	44.6	10.0	13.2	35.3	52.3
Fallow-maize with RDF to maize							102.1	118.8	39.9	45.4	96.2	125.0
SEm±	1.5	2.8	0.6	0.9	1.8	3.2	1.0	1.2	0.6	0.6	1.1	1.3
CD (P=0.05)	4.4	8.4	1.8	2.6	5.2	9.3	3.0	3.7	1.8	1.7	3.2	3.9

RDF to sunflower: 80-26.2-33.3 kg N-P-K/ha and to maize 120-26.2-33.3 kg N-P-K/ha

marked increase in N uptake than 50% RDF + 50% RDN through CC and 50% RDF + 50% RDN through FYM. In the second year (2008), lowest total uptake of nitrogen was recorded by control. Application of 50% RDF + 50% RDN through JC being on par with 50% RDF + 50% RDN through CC exhausted significantly higher N over remaining fertility levels. 80 kg N through JC or CC and 75% RDF + 25% RDN through JC induced similar N uptake (Table 3).

In variation to N, significantly highest phosphorus uptake in sunflower was recorded by 75% RDF + 25% RDN followed by RDF and 75% RDF + 25% RDN through CC in 2007. RDF and 75% RDF + 25% RDN through CC were similar in P uptake and significantly superior over remaining fertility levels. In the second season, 50% RDF + 50% RDN through JC and 50% RDF + 50% RDN through CC being on par recorded significantly higher phosphorus uptake compared to rest of the fertility levels in 2008. In variation to N and P, 75% RDF + 25% RDN through FYM induced the highest K uptake in 2007, which was significantly superior to other fertility levels barring 75% RDF + 25% RDN through JC and RDF. On an average, treatment with FYM alone or in INM mode recorded more K uptake than similar treatments of JC and CC. In the second year, 50% RDF + 50% RDN through JC and 50% RDF + 50% RDN through FYM recorded similar K uptake and both the treatments were significantly superior over remaining fertility levels except the variation in K uptake between 50% RDF + 50% RDN through CC and 50% RDF + 50% RDN through FYM.

Maize: Application of RDF to maize (120, 26.2 and 33.3 N:P:K kg/ha) induced marked increase in total N, P and K uptake in grain + stover during both the years over other treatments. In the sequence, residual effect of 50% RDF + 50% RDN through JC showed its conspicuous superiority over other treatments in N, P and K uptake during both the seasons. Application of 50% RDF + 50% RDN through CC, 50% RDF + 50% RDN through FYM and 80 kg N through JC, 80 kg N through CC gave similar total nitrogen uptake during 2007, while in 2008, 50% RDF + 50% RDN through CC being on par with 50% RDF + 50% RDN through FYM recorded marked increase over remaining residual fertility treatments (Table 3). Lowest N, P and K uptake in maize was recorded by control treatment. These results on nutrient uptake due to organic and inorganic sources of nutrients are in accordance with Singh *et al.*(1998) and Panwar (2008)

Nitrogen use efficiency in sunflower and soil properties

The various organic and inorganic sources of nitrogen had noticeable influence on ANUE and PNUE (Table 4). In general, ANUE was found more in second year but, PNUE was slightly higher in the first year of experimentation. These parameters recorded different trend over treatments across the seasons. ANUE followed trend similar to seed yield of sunflower over the years. In 2007, the highest ANUE was recorded with RDF, closely followed by 75% RDF + 25% RDN through JC and 75% RDF + 25% RDN

Table 4. Direct and residual effect of organic and inorganic sources of nutrients on system productivity (sunflower equivalent yield, t/ha), net returns (x 10^3 Rs/ha), nitrogen use efficiencies of sunflower and physico-chemical properties of soil at the end of 2 year study

Treatment	System productivity		System net returns		ANUE		PNUE		Organic carbon	pH	Bulk density
	2007	2008	2007	2008	2007	2008	2007	2008	(%)		(Mg/m^3)
Control	1.53	1.62	12.98	14.25					0.38	7.70	1.48
RDF	3.14	3.44	39.95	44.86	19.0	19.7	23.1	24.9	0.39	7.80	1.49
RDN through jatropha cake (JC)	3.41	4.24	43.50	58.16	15.8	23.8	28.2	25.5	0.43	7.43	1.44
RDN through castor cake (CC)	3.09	4.23	37.48	58.18	11.4	23.1	30.6	25.6	0.43	7.50	1.44
RDN through FYM	2.95	3.97	35.00	53.46	10.1	21.0	35.8	25.2	0.44	7.38	1.40
50% RDF + 50% RDN through JC	3.52	4.75	45.52	69.41	14.9	27.9	23.8	23.0	0.42	7.55	1.45
50% RDF + 50% RDN through CC	3.33	4.59	42.97	65.76	14.0	27.0	24.9	23.5	0.41	7.53	1.45
50% RDF + 50% RDN through FYM	3.22	4.41	40.95	62.40	13.0	25.3	24.2	24.2	0.42	7.51	1.43
75% RDF + 25% RDN through JC	3.42	3.77	43.80	50.96	18.6	21.3	23.0	24.0	0.40	7.66	1.46
75% RDF + 25% RDN through CC	3.13	3.54	39.42	46.76	17.5	18.4	23.5	24.8	0.41	7.67	1.47
75% RDF + 25% RDN through FYM	3.11	3.48	38.90	45.51	17.0	18.1	23.4	24.4	0.42	7.64	1.42
Fallow-maize with RDF to maize	2.02	2.40	24.66	30.52					0.38	7.81	1.48
SEm±	0.07	0.08	0.84	1.12							
CD (P=0.05)	0.22	0.25	2.45	3.28							
Initial soil fertility									0.38	7.70	1.48

RDF to sunflower: 80-26.2-33.3 kg N-P-K/ha and to maize 120-26.2-33.3 kg N-P-K/ha

through CC. In the same year, the lowest ANUE was recorded due to 80 kg RDN through FYM, closely followed by 80 kg RDN through castor. In the second season, integrated use of 50% RDF with 50% RDN through JC recorded the highest ANUE closely followed by 50% RDF with 50% RDN through CC. 80 kg RDN through JC or CC recorded ANUE higher than RDF and 75% RDF + 25 % RDN either through JC or CC or FYM. The lowest ANUE was recorded with 75% RDF + 25% RDN through FYM. This trend of ANUE across the seasons and treatments can be traced to the reasons given for seed yield variations (Table 4).

Maximum PNUE in 2007 was recorded with 80 kg N through FYM (35.9), followed by CC (30.6) and JC (28.2). The lowest PNUE was recorded with 75% RDF + 25% RDN through JC (23.0), closely followed by RDF and 75% RDF + 25% RDN through FYM or CC. In 2008, application of 80 kg N through CC recorded maximum PNUE (25.6), which was close to PNUE of 80 kg N through CC (25.5) or FYM (25.2). In the remaining treatments, the lowest PNUE was recorded with 50% RDF + 50% RDN through JC (23.0) and the gap between the lowest and highest was of only 1.6. PNUE recorded was higher with 80 kg N either through JC or CC or FYM than remaining treatments during both the seasons, because improvement in yield is not only the effect of N applied and its uptake by the plant but also the other secondary and micronutrients nutrients, which were present only in organic sources of nutrient (Table 4). Similar effects of integrated nitrogen management on nitrogen use efficiency were observed by Singh *et al.* (1998) in maize-wheat system and Kumpawat (2004) in maize-mustard system under different locations.

Application of organics alone or alongwith fertilizers decreased pH and bulk density of soil as compared to RDF and control. However, organic carbon (OC) content increased with addition of organics. Production of organic acids and direct addition of carbon to soil as manures resulted in changes in pH and OC of soil. Similar results were reported by Sharma and Gupta (1998), Vani and Bheemaiah (2003) and Rana *et al.* (2006).

Two years fixed plot study indicated that integration of 25% RDN through de-oiled cake of jatropha or castor with 75% RDF produced sunflower seed yield comparable with RDF in the first season. In the second season, replacement of 50% RDN through JC or CC recorded perceptible increase in seed yield over RDF. Residual effect of treatment on succeeding maize and system productivity was found more pronounced with 50% RDF + 50% RDN through JC.

REFERENCES

Jat, R.S. and Ahlawat, I.P.S. 2004. Effect of vermi-compost, biofertilizer and phosphorus on growth, yield and nutrient uptake by chickpea (*Cicer arietinum*) and their residual effect on fodder maize *(Zea mays*). *Indian Journal Agricultural Sciences* **74**(7): 359–361.

Kumpawat, B.S. 2004. Integrated nutrient management for maize (*Zea mays* L)–mustard (*Brassica juncea*) cropping system. *Indian Journal of Agronomy* **49**(1): 18–21.

Laddha, K.C., Sharma, R.K., Sharma, S.K. and Jain, P. M. 2006. Integrated nitrogen management in maize and it's residual effect on black gram under dryland conditions. *Indian Journal of Dryland Agricultural Research and Development* **21**(2): 177–184.

Panwar, A. S. 2008. Effect of integrated nutrient management in maize (*Zea mays* L.) - mustard (*Brassica campestris* var. *toria*) cropping system. *Indian Journal of Agricultural Sciences* **78**(1): 27–31.

Pathak, S. K., Singh, S. B. and Singh, S. N. 2002. Effect of integrated nutrient management on growth, yield and economics of maize (*Zea mays* L.)–wheat (*Triticum aestivum)* cropping system. *Indian Journal of Agronomy* **47**(3): 325–332.

Rana, D.S., Giri G. and Pachauri, D.K. 2006. Evaluation of castor (*Ricinus communis)* genotypes for productivity, economics, litter fall and changes in soil properties under different levels of inter-row spacing and nitrogen. *Indian Journal of Agronomy* **51**(4): 318–322

Roy, M.K. and Prasad, N.K. 2005. Effect of organic and inorganic sources of nutrients on productivity of wheat-forage maize system. *Journal of Research, Birsa Agricultural University* **17**(1): 87–90.

Ruthiya, G.R., Singh, R.N., Chowdhary, T. and Tiwari, S.P. 2007. Effect of different organic sources combination with different doses of chemical fertilizer on growth and yield parameters of sunflower. *Plant Archives* **7**(2): 869–870.

Saxena, R.K. and Singh, H.G. 1980. Effect of rates and times of application of castor-cake on potato production on vertisols in Rajasthan. *Indian Journal of Agronomy* **25**(4) : 651.

Sharma, M.P. and Gupta, J.P. 1998. Effects of organic materials on grain yield and soil properties in maize (*Zea mays*)-wheat (*Triticum aestivum)* cropping system. *Indian Journal of Agricultural Sciences* **68**(11): 715–717.

Singh, M.K., Pal, S.K., Thakur, R. and Verma, U.N. 1998. Integrated nutrient energy management for sustainability in maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* **68**(12): 784–787.

Vani, K.P. and Bheemaiah, G. 2003. Effect of alley cropping of castor (*Ricinus communis*) and integrated nutrient management practices on productivity status of soil under SAT regions. *Indian Journal of Agronomy* **48**(3): 224–228.