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Productivity, quality and soil fertility of sugarcane (*Saccharum* spp complex hybrid) plant and ratoon grown under organic and conventional farming system*

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Sugarcane (*Saccharum* spp complex hybrid) is an important cash crop of India which is cultivated in an area of about 5.0 million hectare with an average productivity of 68.6 tonnes/ha. The crop is of long duration and nutrient exhaustive which removes about 2.05, 0.24, 2.28 kg NPK/ tonne of cane produced (Singh *et al*. 2007). The frequent and excessive use of chemical fertilizer has created problems like deterioration of soil health and ecology. It has been observed in recent years that yield of sugarcane has reached a plateau due to decline in factor productivity. The loss in organic matter in soil is the root cause for decline in factor productivity. Soil organic matter is key factor in maintaining the soil fertility as it is reservoir of nutrients. It was found to be beneficial in arresting the decline in productivity through correction of deficiencies of secondary and micro-nutrients and its beneficial influence on physical and biological properties of soil. Restoration of organic matter is thus, needed for maintaining soil health and improving productivity. Pressmud is an organic by-product of sugar mills and a rich source of organic carbon (35-37%) and supplies 1.0-1.5% N, 1.09-1.53% P and 0.25-0.66% K (Kale 1981). Neem cake is an organic manure which protects plant roots from nematodes, soil grubs and white ants probably due to its residual limonoid content. It also acts as a natural fertilizer with pesticidal properties. Neem cake is widely used in India to fertilize paddy, cotton and sugarcane. Biofertilizers are soil energizers which can fix nitrogen and mobilize phosphorus in eco-friendly manner.

The poor yield of sugarcane in Bihar is mainly due to erratic and imbalanced use of chemical fertilizer. The available soil nitrogen is low and addition of organic matter is not practiced. Thus, improving soil organic matter and soil fertility are important factors for sustainability of sugarcane. There are many alternative farming systems such as organic farming, eco-farming, natural farming, among others to make agriculture more sustainable and productive. The proper management of such farming practices may be helpful in rejuvenation of the soils and sustaining crop yield. Organic farming is a production system which favours maximum use of organic materials, crop residues, animal excreta, legumes, on and off farm organic wastes, bio-pesticide etc. and discourage use of synthetically produced agro inputs for maintaining soil health, productivity and pest management under the condition of sustainable natural resources and healthy environment (Palaniappan 2004). Organic farming is currently restricted to few crops. Thus, scope of organic farming in sugarcane needs to be explored. This study was therefore, conducted to evaluate the productivity, quality and soil fertility of sugarcane (*Saccharum* spp complex hybrid) plant-ratoon system grown under organic and conventional farming system.

The trial was conducted in a fix plot with half portion for plant and half for ratoon during 2006–07 to 2009–10 under All India Coordinated Research Project on Sugarcane at research farm of Sugarcane Research Institute, Pusa, Bihar to study the effect of organic and conventional farming system on soil fertility, productivity and quality of sugarcane in plant and ratoon system. The farm is situated at 25º 98´ N latitude, 85º 67´ E longitude and at an altitude of 52.0 m above mean sea level. The climate of Bihar is subtropical and mean annual rainfall of the area is about 1200 mm. The soil was sandy loam, calcareous ($CaCO_3$ 30.8%) with *p*H 8.35 and EC 0.16 dS/m. The soil was low in organic C (0.478%), available N and K (232 and 91.3 kg/ha) and

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medium in P (11.9 kg/ha). The experiment was laid out in a randomised block design with five treatments having four replications comprising various combinations of organic and inorganic sources for nutrient supply and insect/pest control. The details of treatments for plant crop were T_1, 100% NPK + micronutrients + control of pests /diseases through chemical; T_2, 100% N through organics + biofertilizers + green manuring + control of pests/diseases through chemical; T_3, 100% N through organics + biofertilizers + green manuring + biopesticide + detrashing of dry leaves; T_4,75% N through organics + 25% NPK through inorganics + biofertilizers + biopesticide; T_5, 75% NPK + 25% N through organics+ biofertilizers + biopesticide and for ratoon.

T_1, 100% NPK +trash burning +control of pest /diseases through chemical: T_2, 100% N through organics + biofertilizers + trash mulching and green manuring in alternate rows + control of pest/diseases through chemical; T_3, 100% N through organics + biofertilizers + trash mulching and green manuring in alternate rows +biopesticide + detrashing of dry leaves; T_4, 75% N through organics +25% NPK+ biofertilizer + trash mulching and green manuring with moong alternate rows + biopesticides ; T_5,75% NPK + 25% N organics + biofertilizers + trash mulching and green manuring in alternate rows + biopesticide. The recommended dose of fertilizers for plant: 150-37.5-50 and ratoon 170-22-50 kg NPK/ha were applied through urea, diammonium phosphate and muriate of potash, respectively. Nitrogen was applied in split doses, half at the time of planting, one fourth at the time of first irrigation and rest one at the time of earthing up. The $ZnSO_4$ @ 50 kg/ha was applied at the time of planting in plant crop as a source of micronutrients. Pressmud cake (PMC) was analysed for nitrogen (1.02%) and used as organic sources on equivalent N basis. The neem cake containing N 4.8, P 0.40 and K 1.12% was applied @ 4 q/ha at the time of planting as biopesticide. The dose of fertilizers was adjusted as per nutrient value of the neem cake. Two rows of greengram (*Vigna radiata*) inoculated with *Rhizobium* sp. was planted at 20 cm row space between two rows of sugarcane. Green manuring was done *in situ* at eight weeks stage (4 tonnes biomass/ha). The cultures of *Azotobacter chroococcum* and PSB (*Bacillus megaterium*) were applied @ 4 kg/ha at the time of planting. Other recommended practices for sugarcane plant and ratoon crop were adopted. The mid late variety of sugarcane BO 137 was planted in last week of February and harvested after one year. Soil samples were collected at the time of planting and after harvest of crop. The processed soil samples were analysed for organic carbon, available N, P and K by standard procedure. Cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1955). Sugar yield was calculated as; sugar yield (tonnes/ha) = [S-0.4(B-S) × 0.73] × cane yield (tonnes/ha)/100; where S and B are sucrose and brix percent in cane juice. Whole cane sample was analysed for N, P and K content and their uptake was calculated. The economics was worked out on considering input and output of year of study.

The perusal data revealed that application of nutrients through both organic and inorganic sources recorded significantly higher number of tillers and millable canes (NMC) over 100% NPK through inorganics (Table 1). The T_5 receiving 75% NPK through inorganics and 25% N through organics along with biofertilisers and biopesticide recorded significantly highest number of tillers (plant 135 500 and ratoon 143 500/ha) and millable canes (plant 98 700 and ratoon 105 300/ha) over T_1. The effect of different treatments on single cane weight was non-significant. Integrated nutrient application had significant impact on cane yield in both plant and ratoon crop. The highest cane yield (plant 74.2 and ratoon 75.8 tonnes/ha) were recorded in treatment T_5 receiving 75% NPK through inorganic sources and 25% N through PMC along with biofertilisers and biopesticide which indicated saving of 25% NPK. Similar findings of integrated nutrient application were also reported by Thakur *et al.* (2007) and Virdia and Patel (2010). The plant cane yield obtained due to addition of organic manure alone (T_2 and T_3) was on par with 100% NPK through inorganics (T_1). However, in ratoon crop, cane yield obtained in organic farming treated plots (T_3) was significantly higher over T_1. This could be attributed to release of nutrients with time due to mineralisation of organic matter resulting increased absorption of nutrient by ratoon crops. The results are in agreement with findings of Srivastava *et al.* (2008)). Organic manures are not only the sources of major nutrients, but they also provide other micronutrients and plant growth promoting substances which together lead to good crop yields. Tiwari and Nema (1999) also opined that plant population and cane yield increased significantly due to application of pressmud by both direct on plant cane and residual on ratoon canes. The cane juice quality, viz brix, sucrose and purity content in cane juice did not differ significantly due to different treatments. Commercial Cane Sugar (CCS) which is a function of cane yield and sucrose content exhibited similar trend of cane yield. Similar findings were also reported by Thakur *et al*. (2007). The highest net returns of ₹ 25 746 and 61 916 were recorded in T_5 both for plant and ratoon crops, respectively. The B: C ratio (1.46) was also highest in T_5 for plant crop while, T_3 gave the highest B:C ratio (2.46) in ratoon crop. The net returns (Rs 87 662.00) and B:C ratio (3.87) were also higher T_5 in plant–ratoon system.

Nutrient uptake by both plant and ratoon crop followed similar trend of cane yield (Table 3). On an average, the uptake of nutrients by both plant and ratoon crops were 2.27-0.22-2.95 kg NPK /tonne of cane produced, respectively. The highest uptake of N, P and K was recorded in T_5 in both plant and ratoon crop. The results thus indicated that integration of nutrients had beneficial impact on availability of N, P and K in soil resulting more uptakes. Apart from this, application of biofertilizers in presence of organic manures

Table 1 Effect of farming system on yield attributes,, cane yield, and commercial cane sugar (CCS) and economics of plant and ratoon crop of sugarcane (pooled data of three years)

Treatment	Tillers (× 10^3/ha)		NMC (× 10^3/ha)		Single cane (× 10^3/ha) (g)		Cane yield (tonnes/ha)		Sucrose (%)		CCS (tonnes/ha		Net returns (₹/ha)		B:C Ratio	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
T_1	121.5	133.5	85.9	92.5	737	686	64.0	63.7	16.68	16.59	7.49	7.28	15 204	47 545	1.28	1.80
T_2	126.9	139.0	91.1	98.8	741	689	67.5	67.9	16.93	16.94	7.91	7.95	21 555	53 482	1.41	2.30
T_3	127.4	139.5	92.1	101.9	741	693	68.4	70.5	16.92	17.14	8.00	8.38	21 305	58 634	1.41	2.46
T_4	132.9	140.3	97.6	103.6	747	718	73.0	74.2	16.95	16.74	8.32	8.57	23 135	58 158	1.41	2.31
T_5	135.5	143.5	98.7	105.3	747	722	74.2	75.8	16.85	16.70	8.54	8.84	25 746	61 916	1.46	2.41
SEm±	2.2	4.4	2.3	2.6	12.4	10.8	2.1	2.1	0.41	0.16	0.22	0.24	1 963	2 473	0.04	0.20
CD (*P*=0.05)	6.5	NS	6.6	7.3	NS	NS	6.1	6.1	NS	NS	0.65	0.69	6 402	8 065	0.11	0.59

Table 2 Effect of farming system on nutrient uptake by plant and ratoon crop of sugarcane and available nutrient status of the post harvest soil. (pooled data of three years)

Treatment	Nutrient uptake (kg/ha)												Available soil nutrients (kg/ha)					
	N		P		K		*p*H		EC (dS/m)		Organic C (%)		N		P		K	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
T_1	147.5	134.2	13.9	12.8	200.3	164.0	8.32	8.36	0.17	0.37	0.471	0.464	226	218	10.6	9.9	88.8	84.7
T_2	154.7	148.0	15.3	14.3	212.5	181.8	8.23	8.31	0.16	0.38	0.524	0.528	243	242	13.5	11.9	102.4	94.6
T_3	157.6	155.6	15.8	15.0	222.0	189.5	8.22	8.29	0.15	0.39	0.526	0.559	244	245	14.0	12.4	105.4	97.1
T_4	173.3	168.4	17.2	16.1	236.3	207.3	8.25	8.31	0.15	0.36	0.508	0.513	240	236	14.0	12.2	102.1	98.8
T_5	174.3	176.2	17.9	17.1	242.0	215.7	8.28	8.31	0.15	0.38	0.501	0.503	239	237	14.2	12.8	101.3	98.8
SEm±	4.8	5.8	0.6	0.4	8.2	7.0	0.03	0.02	0.01	0.01	0.008	0.009	3.2	2.3	0.7	0.5	2.4	2.2
CD (*P*=0.05)	13.8	16.4	1.6	1.1	23.6	20.2	NS	NS	NS	NS	0.023	0.025	9.2	6.7	1.9	1.5	6.5	6.5

also helped in increasing the availability of nutrients resulting higher uptake of nutrients by crops. The results further indicated that among the major nutrients, relatively higher uptake of K was recorded followed by N and P irrespective of treatments. The results are in close agreement of findings of Virdia and Patel (2010).

The *p*H and EC of soil did not differ significantly under different treatments (Table 2). The *p*H ranged from 8.22-8.32 and 8.29-8.36 after the harvest of plant and ratoon crop, respectively. The *p*H slightly declined in all organic matter treated plots over inorganic fertilizer treated plot. The release of organic acids during decomposition of organic manures might have resulted in slight decline in soil *p*H. The pooled mean value EC was slightly higher in ratoon crop due to high value of EC (0.813- 0.841 dS/m) in the year 2008–09 might be due to low rainfall. Addition of organics alone (T_2 and T_3) or with inorganics (T_4 and T_5) recorded significant improvement in organic C content of post harvest soil over T_1. The application of organics alone or alongwith inorganics brought about an increase of 4.8–16.9% in organic C content of the soil over initial value. The highest increase was recorded in T_3 receiving 100% N through organics. Increases in soil organic C due to addition of PMC as well as crop residues were also reported by Dee *et al.* (2003) and Singh *et al.* (2007). However, a slight decrease (3.7%) in organic C was noticed in 100% NPK treated plots. Under sugarcane growing condition, the loss in organic C due to conventional agriculture was also reported by Haynes and Hamilton (1999). Available nutrient status (N, P and K) of post harvest soil also increased significantly due to application of organic manures alone or in combination with fertilizers. Higher available N was observed in organic manure (PMC) treated plots while available P and K were in integrated nutrient treated plots. Since, the data presented in table are the mean of three years the value of N in T_2 (243 and 242), T3 (244 and 245) and T_5 (239 and 237 kg/ha) are almost identical. The improvement of K in plant compared over ratoon crop could be attributed to fixation of added K with elapse of time. The nature and rate of potassium (K) fixation and release of soil K from different pools of adsorbed and structural K are important issues from a viewpoint of K availability in soil and the degree of fertilizer K uptake by plants. High K demanding crops remove enormous amounts of K, resulting in a large negative nutrient balance in soils even when recommended fertilizers are applied (Singh *et al*. 2004). The build up of soil available N could be attributed to greater multiplication of microbes due to addition of organic manures which helped in mineralization of soil N leading to higher available nitrogen. Improved P availability could be due to greater mobilization of soil P owing to reduced P sorption while, increased in available K might be due to addition of K in available pool owing to mineralization of organic matter by micro-organisms. Addition of organics alone or in combination with inorganic fertilizer and biofertilizer improved the soil fertility, viz available N, P and K in general and organic C in particular over their initial value which indicated sustaining of soil fertility. These results are in conformity of findings of Tiwari and Nema (1999), Thakur *et al.* (2007), and and Virdia and Patel (2010).

SUMMARY

It may be concluded that the application of 75% NPK through inorganics + 25% N through organic manures (PMC) + biofertilizers (*Azotobactor* + PSB) + biopesticide (neem cake) in sugarcane plant and 75% NPK through inorganics + 25% N through organic manures (PMC) + biofertilizers (*Azotobactor* + PSB) + trash mulching and green manuring with greengram inoculated with *Rhizobium* in alternate rows + biopesticide (neem cake) in ratoon were found suitable practice for sustaining sugarcane productivity, maintaining soil fertility and getting higher monetary returns in sugarcane plant and ratoon system in calcareous soil of Bihar.

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