Indian Journal of Agronomy **53**(4): 310–313 (December 2008)

Productivity and profitability of sugarcane (*Saccharum* spp complex hybrid) in relation to organic nutrition under different cropping systems

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Received: October, 2007

ABSTRACT

A field experiment was conducted at Lucknow during 2003-2006 in autumn and spring-planted sugarcane (*Saccharum* spp. complex hybrid) grown in different cropping systems to assess the effect of organic nutrition on productivity, profitability and on soil health. Five organic nutrition modules were compared with the control (no manure or fertilizer). The highest number of millable canes (82.7 and 95.2 thousands/ha) and cane length (220.8 and 182.5 cm) were recorded with sulphitation pressmud (SPM) 10 t/ha + farmyard manure (FYM) 10 t/ha in autumn and spring planted crops respectively. SPM 10 t/ha + FYM 10 t/ha caused the highest uptake of N, P and K and produced the highest cane yield of 79.4 t/ha in autumn - and 68.8 t/ha in spring-planted sugarcane. The highest net profit (Rs 52,480) and benefit : cost (B: C) ratio (1.5) were recorded in autumn planted cane with FYM 20 t/ha + *Trichoderma viride* + lentil [*Lens culinaris* (L.) medic.] intercrop (1:2). In spring planted cane, the highest net profit (Rs 45,101) and B: C ratio (1.3) was recorded with FYM 20 t/ha + *Trichoderma viride* + mungbean [*Vigna radiate* (L.) hepper] intercrop (1:2). Significant improvement was observed over initial organic C (up to 70.7%), bulk density (up to 8.4%), water-infiltration rate (up to 46.7%) and total N (up to 61.5%) at crop harvest under various treatments. The finding revealed profitable sugarcane cultivation under organic nutrient management with positive effect on soil health.

Key words **:** Autumn sugarcane, Organic nutrition, Spring sugarcane, Sugarcane yield

Sugarcane production in subtropical India contributes 66% to total sugarcane production of the country, but its productivity in the region is mere 55 t/ha compared with the average productivity of 67.4 t/ha for tropical region. Overall sugarcane yield (62.2 t/ha) is declining since 1999–2000 after attaining 71.1 t/ha, despite substantial increase in the use of inputs and cost of cultivation. It has rendered sugarcane cultivation unprofitable in view of rising prices of inputs. Among various factors responsible for declining sugarcane yield and profitability, imbalanced use of nutrients is a major factor. Being a long-duration and nutrient-exhaustive crop, it suffers from macro- as well as micronutrient deficiencies in the sub-tropical soils, rendering them less productive due to excessive and continuous use of inorganic fertilizers under intensive farming systems (Yadav *et al*., 2005). Dawe *et al*. (2003) have reported that deterioration in soil health and crop productivity is associated with decline in soil-organic carbon under such farming systems. Since soil organic carbon by influencing the physical, chemical and biological properties of the soil proves a major factor in soil and crop productivity, it is necessary to device nutrient-management practices that help improve or maintain the organic C content of the soil. Integrated use of organic manures with chemical fertilizers has been found to meet adequately the nutritional requirements of sugarcane crop (Nagaraju *et al*., 2000). However, information on the effect of nutrient management solely through organic resources on sugarcane productivity and profitability and its influence on soil-health indicators such as soil-organic C, microbial activity, bulk density and water-infiltration rate is still lacking. Hence, the present investigation was carried out to assess the effects of different organic nutrition modules for two important prevalent sugarcane-based production systems under subtropical conditions.

MATERIALS AND METHODS

A field experiment was conducted at Indian Institute of Sugarcane Research, Lucknow (26^0 56 N, 80^0 52 E and 111 m above mean sea-level) during 2003-2006, involving two cycles of green manure–rice– autumn sugarcane and green manure–rice–berseem–spring sugarcane cropping sys-

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tems. The experimental soil was sandy loam with pH 7.7, low in organic carbon (0.41%) as well as in available N (208 kg/ha), medium in P (20.8 kg/ha) and low in K (158 kg/ha). All the component crops in the cropping systems were grown with organic inputs only. Five organic nutrition modules were imposed on sugarcane (Autumn and spring), viz. (i) sulphitation pressmud (SPM) 10 t/ha + *Azotobacter;* (ii) farmyard manure 20 t/ha + *Trichoderma viride* + lentil / mungbean intercrop (1:2); (iii) SPM 10 t/ha + FYM 10 t/ha, iv) SPM 10 t/ha + lentil/mungbean intercrop (1:2); (v) FYM 20 t/ha + *Acetobacter,* and (vi) control (no manure or fertilizer). A randomized block design was followed with four replications. SPM contained 1.6, 1.0, 1.2, 3.2, 2.0 and 0.5% whereas FYM contained 0.75, 0.2, 0.55, 0.91, 0.19 and 0.12% N, P, K, Ca, Mg and S, respectively. Organic manures were incorporated at the time of final land preparation, whereas bio-fertilizers were sett inoculated at the time of sugarcane planting. Sugarcane 'CoSe 92423' was planted at 90 cm row spacing in autumn (October) 2003 and 2004 and at 75 cm row spacing in spring (February) 2004 and 2005 using 3-budded setts. Two rows of intercrops viz. lentil 'K 75' in autumn cane and mungbean 'K851' in spring cane, were sown between 2 rows of sugarcane immediately after sugarcane planting.

Physical and chemical properties of the soil at both sugarcane planting and harvest stages were recorded following standard procedures. The nutrient contents in plant samples collected at harvest were determined by adopting standard protocols. Soil microbial biomass carbon (SMBC) and nitrogen (SMBN) were measured through chloroform-fumigation method. Data were analyzed following analysis of variance technique and then pooled over the years for autumn-and spring-planted sugarcane crops separately.

RESULTS AND DISCUSION

Sugarcane yield

All the organic nutrition treatments significantly increased the number of millable canes (NMC), cane length, cane thickness and cane yield over those of control for both autumn and spring planted crops (Table 1). The highest NMC in autumn cane and spring cane were recorded with the use of SPM 10 t/ha + FYM 10 t/ha. Similarly, the longest and thickest canes were produced under this treatment for autumn as well as spring-season crops. Application of FYM 20 t/ha + *Acetobacter* inoculation proved the next best treatment. Consequently the highest cane yields both for autumn (79.4 t/ha) and spring (68.8 t/ha) planted crops were recorded under SPM 10 t/ha + FYM 10 t/ha, closely followed by SPM 10 t/ha + *Azotobacter*. Cane yield under the control conditions was 59.3 t/ha for autumn and 51.0 t/ha for spring crop. These findings reveal that supply of nutrients to sugarcane crop exclusively through organic sources adequately supports the crop growth. It is evident from the data on production efficiency recorded with SPM 10 t/ha + FYM 10 t/ha (Table 2), which worked out to be 174.1 kg/ha/day under autumn planted crop and 192.2 kg/ha/day under spring planted crop compared with the corresponding values of 130.0 kg/ha/day and 144.4 kg/ha/day under the control. It is comparable with the production efficiency usually recorded with the application of recommended doses of chemical fertilizers in autumn and spring planted crops (Yadav and Prasad, 1997).

As the organic resources are carriers of all the essential nutrients and their incorporation into the soil releases the nutrients slowly through microbial mediation, it leads to their adequate availability throughout the growing season, resulting in improved cane productivity of both autumn and spring planted crops. Soil-ameliorating effects of both organic resources manures and biofertilizers (Singh *et al.*, 2007) must have further contributed to improved cane yield.

Economics

The highest net profit and benefit : cost (B : C) ratio were recorded in autumn - planted cane with FYM 20 t/ha

Table 1. Effect of organic nutrition on performance of autumn and spring planted sugarcane (pooled data of 2 years)

Treatment	NMC (x 10^3/ha)		Cane length (cm)		Cane thickness (cm)		Cane yield (t/ha)	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
SPM 10 t/ha+ *Azotobacter*	79.2	91.6	217.7	181.1	2.7	2.5	74.3	67.4
FYM 20 t/ha + *Trichoderma viride* + I.C*	77.0	88.5	207.8	167.8	2.5	2.4	70.4	58.7
S PM 10 t/ha + FYM 10 t/ha	82.7	95.2	220.8	182.5	2.8	2.6	79.4	68.8
S PM 10 t/ha + IC	79.3	85.4	210.0	167.5	2.6	2.5	69.9	57.7
FYM 20 t/ha + *Acetobacter*	81.7	92.6	211.4	180.5	2.8	2.5	71.8	64.3
Control (no manure)	73.1	79.1	195.6	161.3	2.4	2.4	59.3	51.0
SEm±	2.2	2.1	5.3	4.6	0.03	0.02	2.48	2.44
CD (P=0.05)	6.9	7.0	16.6	14.2	0.1	NS	7.6	7.6

* Intercropping of lentil mungbean (1:2)

Table 2. Effect of organic nutrition modules on production efficiency and economics of autumn - and spring - planted sugarcane (pooled data of two years for respective seasons)

Treatment	Production efficiency (kg/ha/day)		Cost of cultivation (Rs x10^3/ha)		Net profit (Rs x10^3/ha)		B : C ratio	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
SPM 10 t/ha+ *Azotobacter*	162.9	188.3	35.66	34.36	46.61	40.40	1.3	1.2
FYM 20 t/ha + *Trichoderma viride* + IC	154.4	164.0	35.57	33.96	52.48	45.10	1.5	1.3
S PM 10 t/ha + FYM 10 t/ha**	174.1	192.2	36.10	34.80	51.82	41.51	1.5	1.2
S PM 10 t/ha + IC	153.3	161.2	36.63	34.84	51.76	41.10	1.5	1.2
FYM 20 t/ha + *Acetobacter*	157.5	179.6	34.56	33.62	44.83	38.05	1.4	1.2
Control (no manure)	130.0	144.4	33.08	31.78	32.47	24.85	1.0	0.8

*Lentil yield, 0.45 t/ha (cane equivalent yield-CEY= 12.9 t/ha) / mungbean yield – 0.4 t/ha (CEY = 11.6 t/ha) sugarcane @ Rs 1,110/t
**Lentil yield, 0.48 t/ha (CEY = 13.8 t/ha)/mungbean yield – 0.38 t/ha (CEY = 11.0 t/ha) lentil /mungbean @ Rs. 32000/t

+ *Trichoderma viride* + lentil intercropping. In spring planted cane the highest net profit and B: C ratio were recorded with FYM 20 t/ha + *Trichoderma viride* + mungbean intercropping. These were closely followed by autumn and spring - planted cane with SPM 10 t/ha + FYM 10 t/ha (Table 2). SPM 10 t/ha + FYM 10 t/ha and FYM 20 t/ha + *Trichoderma viride* + lentil/mungbean intercropping proved most remunerative and ideal organic nutrition module to meet the nutritional requirements of autumn and spring sugarcane planted in two distinct diversified cropping systems in the subtropical India. Higher profitability under the treatments comprising intercrops is discernible in view of additional income obtained from these crops.

Soil health and microbial activity

Significant improvement in the uptake of nutrient (N, P and K) was recorded due various organic nutrition modules compared with that of control (Table 3) both for autumn and spring planted sugarcane crops. During both the seasons, significantly highest quantities of nitrogen (227.7 and 185.4 kg/ha for autumn and spring cane) were removed under SPM 10 t/ha + FYM 10 t/ha application compared with the uptake of 152.6 and 141.7 kg/ha nitrogen under control condition. Phosphorus uptake was also found significantly highest (17.8 and 13.4 kg/ha) under this treatment for autumn as well as spring cane. Similar trend for potassium uptake was observed as SPM 10 t/ha + FYM 10 t/ha caused the highest uptake for autumn (216 kg/ha) and spring (193.5 kg/ha) planted sugarcane compared with 134.5 and 126.4 kg/ha removal under the control for respective seasons. Improved uptake of nutrient under organic nutrition modules may be attributed to the improved nutrient availability and better crop growth as observed under the treatments.

Organic nutrition for sugarcane effectively improved the physical as well as microbial properties of the soil and significantly improved the organic carbon content of the soil as recorded at harvest of autumn-or spring-planted sugarcane crops. Significant improvement was also rated in soil-physcial properties in terms of reduced bulk density and improved water-infiltration rate over the initial values (Table 4). The highest reduction in bulk density was noticed in the plots receiving SPM 10 t/ha + FYM 10 t/ha (1.20 and 1.24 Mg/m^3 respectively for spring-and autumn-planted sugarcane) compared with the initial bulk density (1.30 Mg/m^3), and winter infiltration rate (5.2 and 6.6 mm/hr respectively) compared with the initial water infiltration rate (4.5 mm/hr). This may be attributed to cementing properties of organics, which resulted in flocculation of soil particles and consequently increase in soil porosity (Singh *et al*., 2007).

The increase in soil-organic C at sugarcane harvest over the initial content was the highest (70.73 %) due to application of FYM 20 t/ha + *Trichoderma viride* + lentil intercropping (1 : 2) or SPM 10 t/ha + lentil intercropping (1: 2) in autumn sugarcane, and corresponding highest increase (65.9%) due to the application of SPM 10 t/ha + *Azotobacter* inoculation in spring sugarcane. High content of cellulosic compounds in SPM as well as crop residues must be responsible for substantial increase in the organic carbon content of the soil under these treatments. The increase in total nitrogen content due to various organic nutrition modules varied from 15.4 to 61.5% over the initial content in the system. The highest increase was recorded with the application of FYM 20 t/ha + *Acetobacter* inoculation (0.063%) and the lowest in the control (0.045%) compared with initial value (0.039%). Similar effect of various treatments on total nitrogen was observed in the system comprising spring sugarcane (Table 4). The increase in soil organic carbon even under the control, might be attributed to the huge quantity of biomass being added in the form of sugarcane stubbles.

In the enrichment and activity of soil microbes conspicuous in SMBC and SMBN was recorded under all the organic nutrition modules at the harvest of sugarcane crop.

Table 3. Effect of organic nutrition modules on soil health indicators at harvest of sugarcane crop (pooled data of 2 years for respective seasons)

Treatment	Bulk density (Mg/m^3)		Water infiltration rate (mm/h)		Total N (%)		SOC (%)		SMBC ($mgC-CO_2$/kg soil/day)		SMBN (mg $N-NH_4$/kg soil/day)	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
SPM 10 t/ha+ *Azotobacter*	1.24	1.21	6.10	4.80	0.061	0.051	0.69	0.68	419	335	12.42	9.49
FYM 20 t/ha + *Trichoderma viride* + Intercropping	1.25	1.22	5.50	4.80	0.054	0.048	0.70	0.60	396	354	17.33	12.39
S PM 10 t/ha + FYM 10 t/ha	1.24	1.20	6.60	5.20	0.049	0.053	0.54	0.57	396	315	19.87	9.49
S PM 10 t/ha + Intercropping	1.25	1.22	5.20	4.70	0.053	0.047	0.70	0.66	293	315	12.25	11.05
FYM 20 t/ha + *Acetobacter*	1.25	1.21	6.10	4.80	0.063	0.054	0.68	0.56	356	295	8.73	9.74
Control (no manure)	1.30	1.28	5.30	4.60	0.043	0.043	0.46	0.43	232	255	7.78	8.87
SEm ±	0.006	0.006	0.02	0.02	0.003	0.003	0.026	0.024	2.91	2.87	0.46	0.49
CD (P=0.05)	0.02	0.02	0.90	0.86	0.009	0.010	0.08	0.08	9.2	8.9	1.36	1.52

SOC=Soil organic carbon, SMBC=Soil microbial biomass carbon, SMBN= Soil microbial biomass nitrogen

Compared with the initial SMBC (81 mg $C-CO_2$/kg soil/day), application of SPM 10 t/ha + *Azotobacter* inoculation resulted in production of 419 mg $C-CO_2$/kg soil/day under the autumn-sugarcane system. The highest increase in SMBC in the system comprising spring sugarcane (354 mg $C-CO_2$/kg soil/day) was found on application of FYM 20 t/ha + *Trichoderma viride* + mungbean intercropping (1 : 2). The increase in soil-microbial activity as indicated by SMBN, was highest (19.87 mg $N-NH_4$/kg soil/day) with application of SPM 10 t/ha + FYM 10 t/ha in autumn sugarcane system compared with the initial SMBN (3.9 mg $N-NH_4$/kg soil/day). However, under the spring sugarcane system, the highest increase in SMBN (12.39 mg $N-NH_4$/kg soil/day) was recorded due to the application of FYM 20 t/ha + *Trichoderma viride* + intercropping (1: 2) over the similar mungbean initial value as in case of autumn sugarcane system. Build up of soil organic carbon and improved microbial activity upon application of organic resources play a key role in controlling the nutrient cycling and energy flow due to fast turnover of microbial biomass (Li and Chen, 2004), which in turn brings about conspicuous improvement in soil fertility and crop productivity.

It was concluded that in sugarcane crop in autumn as well as spring application of SPM 10 t/ha + FYM 10 t/ha and lentil/mungbean intercropping proved the best from productivity and soil health point of view.

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