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Soil properties, productivity and juice quality of sugarcane through integration of organic and inorganic nutrient sources in calcareous soil

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Abstract
The present study was undertaken to assess the magnitude of changes in soil properties and productivity of sugarcane with integration of inorganic (chemical fertilizer) and organic (vermicompost, neem cake and castor cake and biofertilizers) nutrient sources of fertilizer during 2016-18 in calcareous soil. Integration of organic and inorganic nutrient sources *showed* significant increase in organic carbon and respiration rate of soil after sugarcane harvest. The mean organic carbon (4.28-4.93g kg^{-1}) and CO_2 evolution (9.91-17.10 mg^{-1}100gm soil day^{-1}) varied significantly. Increased soil respiration rate indicating higher microbial activity and high rate of decomposition of organic matter in soil. The integrated nutrient management practices was also found effective in improving soil fertility in terms of available NPK content of post-harvest soil over control. The significant improvement in bulk density and porosity were observed with increasing proportion of various organic with inorganic fertilizer. Plant population, number of millable cane, cane length, single cane weight and cane yield were significantly affected due to integrated use of nutrients through inorganic and organic sources. The significantly higher cane yield (83.86t/ha) were recorded in treatment receiving 50% N through inorganics + 50% N through organics (Vermicompost + castor cake + neem cake) 1/3eah along with bio-fertilizer followed by treatment receiving 50% NPK+ 50% N (Vermicompost + castor cake) ½ each + biofertilizer (78.88 t ha^{-1}). The juice quality parameters *viz.* brix, pol, purity and commercial cane sugar percent remains unaffected due to integrated use of organic and inorganic fertilizer however, juice recovery (61.23-66.48%) and sugar yield (7.70-9.48 t/ha) varied significantly. Integration of chemical fertilizer with organic nutrient combinations of vermicompost and neem/castor oil cakes along with biofertilizers was more effective for sustainable sugarcane production and maintenance of soil health.

Keywords: Soil properties, available nutrient, bulk density, juice quality, sugarcane yield

Introduction

Sugarcane (*Saccharum spp. hybrid complex*) being a heavy feeder and long duration crop suffers from persistent nutrient unbalance due to gap between nutrient removal and application. A cane yield of 100 t/ha may remove 205 kg N, 55 kg P and 275 kg K, 30 kg S, 3.5 kg Fe, 1.2 kg Mn, 0.6 kg Zn, 0.2 kg Cu from the soil besides the losses of nutrients during cropping season. The depleting soil health and crop productivity in the sugarcane cultivating area of sub-tropical states are a major concern because of reduced yields clearly visualized from the static average productivity hovering close to 50-60 t/ha in last five years compared to its potential yield of 150 ton/ha (Srivastava *et al.*, 2014) [20]. Crops generally require adequate quantities of major nutrients especially nitrogen during most of the crop growth period. The availability of nitrogen in soils is the key factor to determine the growth and yield of the crop.

The available N in the soil plays a dominant role in the nutrition of crops. Incorporation of organic materials along with fertilizer-N affects the amount and distribution of organic N-fraction in soil (Santhy *et al*. 1998) [14]. Results from the long-term experiments envisaged that application of organic or chemical fertilizers alone failed to maintain the productivity of soil and sugarcane. The application of organic fertilizer in combination of chemical fertilizers will not only helps sugarcane growing better, but also will reduce the cost of cultivation, dependency on the chemical fertilizers, environmental pollution and soil health deterioration. For sustainability in sugarcane and sugar production, neither chemical fertilizer nor organic manures alone but their integrated use has been observed to be highly beneficial. Integrated use of organic and inorganic nutrient sources resulted in enrichment of soil fertility and cane yield (Jha *et al*. 2019) [5].

Soil quality holds the prime importance for productivity of long duration nutrient exhaustive sugarcane as it describe the sum total of physical, chemical and biological properties of soil and thus regulate the nutrient and moisture availability dynamics and rooting behaviour. Various organic sources like farmyard manure, oil cakes, pressmud cake, vermicompost, green manure, legume as intercrops and sugarcane trash are used as sources of nutrients since ages. Organic sources of nutrients not only help in supplementing the nutrients to sugarcane but also maintain favourable physical, chemical and biological soil environment. This will help in not only utilizing locally available bio-resources to be tapped as sources of nutrients for crop cultivation, but also disposal of such resources in an effective manner. No single source of plant nutrients i.e. chemical fertilizers, organic manures or bio-fertilizers can meet the entire nutrient demand of crop in intensive agriculture. Vermicompost is the microbial composting of organic wastes through earth worm activity to form organic fertilizer which contains higher level of organic matter, organic carbon, total and available N, P, K and micronutrients, microbial and enzyme activities (Parthasarthi *et al.* 2007) [10]. The N, P and K fertilizers are generally applied to sugarcane. The concentrate organic manure *viz*. oil cakes (Neem cake/castor cake) has an adequate quantity of macro and micronutrients for plant growth. Neem cake is a nitrification inhibitor and prolongs the availability of nitrogen to crops and contains N 2.0 to 5.0%, $P_2 0_5$ 0.5 to 1.0%, K 1.0 to 2.0%, Ca 0.5 to 3.0%, Mg 0.3 to 1.0%, S 0.2 to 3.0 and micronutrients in appreciable quantity. The soil fertility is declining due to non-addition of organic matter.

The loss in organic matter in soil is the root cause for decline in factor productivity. Restoration of organic matter is thus, needed for maintaining soil health and improving productivity. Soil organic matter is key factor in maintaining the soil fertility as it is reservoir of nutrients and provides metabolic energy for biological processes. In present situation, there is great need for nutrient replenishment through addition of organic material along with inorganic fertilizer for achieving higher yield under sugarcane production system without deterioration of soil health. Keeping in view the above facts the present experiment was formulated to study the effect of INM on restoration of soil properties productivity and juice quality of sugarcane in calcareous soil.

Materials and Methods

The present study was undertaken to assess the magnitude of soil physical, chemical and biological changes and yield of sugarcane with integration of inorganic (chemical fertilizer) and organic (vermicompost, neem cake and castor cake and biofertilizers) nutrient sources of fertilizer during 2016-18 in calcareous soil at crop research centre, Dr. Rajendra Prasad Central Agricultural University, Pusa Bihar. The climate of study area was sub-tropical. The farm is situated at 25° 98' N latitude, 85° 67' E longitude and at an altitude of 52.0 m above mean sea level. The experimental soil was sandy- loam in texture with rich in free calcium carbonate (25.23%), low in organic carbon (<0.50%) and available NPK. The treatments consisted of 100% NPK (Control) and substitution of N with various organic nutrient sources *viz*., vermicompost (VC), Neem cakes (NC) and castor cake (CC). The dose of RDF was curtail and integration was done on the basis of fertilizer-N. The experiment was laid down in RBD with four replications. The details of treatments comprised of T_1- RDF, T_2 -75% RDF + 25% N as VC, T_3 -75% RDF + 25% N as VC + biofertilizers, T_4 -50% RDF+ 25% N as VC + biofertilizers, T_5 -50% RDF + 25% N as VC +25% N, CC + biofertilizers, T_6 -50% RDN + 100% P K+ 25% N VC + 25% N, CC + 25% N, NC+ biofertilizers. The composition of organic nutrient sources has been presented in table 1. The organic manure and biofertilizer (*Azotobacter* and Phosphate solubilising bacteria @ 4.0 kg/ha each) was applied at the time of planting in furrows and mix well in surface soil. Plot size was 9.24 m x 5.40m. Test crop was sugarcane (cv. BO 154). The RDF (150-33-50kg N-P-K/ha) were applied through urea, DAP and MOP. The half of N and whole P and K were applied before planting of sugarcane and the rest half N was top dressed at the time of earthing up. The experimental soils (0-30cm depth) were collected at the time of harvesting. Postharvest soil samples were divided into two parts, one for chemical analysis and another stored at low temperature (0 °C) for biological properties analysis. The processed surface soil samples (0-30cm) were collected and analyzed. Soil sample were analyzed for pH and EC in 1:2 soils: water ratios (Jackson, 1973) [3]. The available N was estimated using alkaline permanganate method (Subbiah and Asijia., 1956) [22], available P by double beam spectrophotometer (Olsen *et al.*, 1954) [9] and available K was determined flame photometrically (Jackson, 1973) [3]. Soil samples were analyzed for organic carbon (Walkey and Black, 1934) [26]. Carbon dioxide (CO_2) evolution in soil by the method described by Pramer and Schmidt (1964) [13]. Core samples were collected at harvest of crop for determination of bulk density (Black, 1965) [1]. The cane juice quality was determined using procedure outlined by Spencer and Meade (1964) [19]. The data were analyzed statistically.

Table 1: Chemical composition of vermicompost and oil cakes

Particulars	Vermicompost (VC)	Neem cake (NC)	Castor cake (CC)
Organic carbon %	28.25	16.52	38.8
Nitrogen (%)	1.60	4.25	3.95
Phosphorus (%)	1.48	1.02	1.58
Potash (%)	1.10	1.38	1.20
C:N ratio	17.6:1	3.9:1	9.8:1

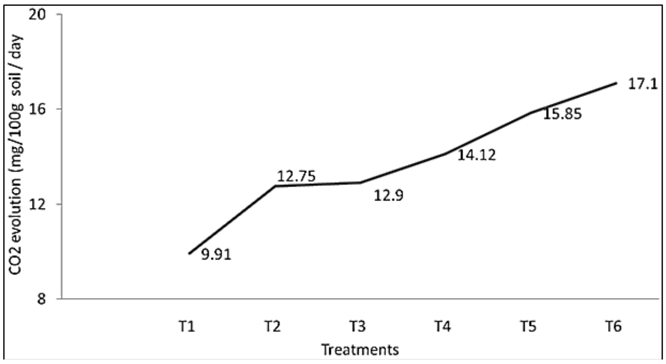
Results and Discussion

Soil properties and nutrient availability

Nutrient management through organic and inorganic combinations significantly increased EC, organic carbon and available NPK content of postharvest soil (Table 2). However, the effect of treatments on pH of the soil was found non-significant. Integration of organic and inorganic nutrient sources showed significant increase in organic carbon and soil respiration rate of soil after sugarcane harvest (Fig 1). Soil organic carbon content of the postharvest soil was significantly influenced by increasing level of organic nutrient source applied in combination. The mean value for organic carbon (4.28-4.93g kg^{-1}) and CO_2 evolution (9.91-17.10 mg^{-1} 100gm soil day^{-1}) varied significantly and being lowest in plots receiving 100% NPK (Control). The data further revealed that there was a significantly higher evolution of CO_2 indicating higher soil respiration due to greater microbial activity in soil with increasing organic manure in integration with chemical fertilizer (Fig. 1). The integrated nutrient management module was also found effective in improving soil fertility in terms of available NPK content of postharvest soil over control. However, the effect of treatments on pH and EC of the soil was found non-significant. The results indicated that application of different level of organics brings significant changes in pools of SOC indicates improvement in soil quality. Increased soil respiration rate indicating higher microbial activity and high rate of decomposition of organic matter in soil. The application of 100% NPK (Control) indicated considerable reduction in soil carbon as compared to application of nutrient in organic and inorganic combination. The build-up of organic carbon due to application of organic manure over control may be ascribed due to addition of ample quantity of various organic manures in combination and its higher rate of mineralization. The low CN ratio of vermicompost and oil cakes favour rapid decomposition and mineralization of nutrients in soil. Singh *et al.* (2007) [17] also observed substantial increase in organic carbon content of the soil due to addition on organic manures. The data also indicated that substitution of 50% N through organic nutrient combination through vermicompost + neem cake + castor cake improved soil quality.

The available nitrogen, phosphorus and potash increased significantly with increasing levels of organics particularly in plots receiving vermicompost and oilcakes in combination (Table 2). Application of 50% N through inorganic and 50% N through organic nutrient combinations along with *Azotobacter* and PSB applied @ 4.0 kg/ha each (T_6) recorded highest available N, P & K and being lowest in control receiving 100% NPK through chemical fertilizer. Integration of organic matter along with biofertilizers enhanced soil organic carbon and activity of microbes during decomposition of organic manure. The mineralization of organic manure especially oil cakes rich in nutrients and low in C: ratio (Table 1) improved availability of nutrient in soil. Neem cake is a nitrification inhibitor and prolongs the availability of nitrogen to crops. These results corroborates with the findings of Lakshmi *et al.* (2011) [8], Kumar and Prasad (2008) [7] and Jha and Thakur (2018) [4]. The release of abundant quantities of CO_2 in organic added plots in increased the availability of phosphorus. Further, soil of present experiment was calcareous in nature and CO_2 production play a dominant role in enhancing the phosphate availability (Gaffar *et al.* 1992) [2] and due to increase in the labile P in soil through complexation of cation like Ca^{2+} and Mg^{2+} responsible for the fixation of phosphorus in calcareous soil (Yashpal *et al.* 1993) [27]. These result are in conformity of this finding of Patel *et al*. (2010) [12]. The reduction in fixations of released K due to interaction of organic matter with clay and direct K addition to the available K pool of the soil increased availability of K in soil. (Kumar and Prasad, 2008) [7]. Integrated use of organic and inorganic nutrient sources resulted in enrichment of soil fertility (Jha *et al*. 2019) [5].

The significant improvement in bulk density and porosity were observed with increasing proportion of various organic with inorganic fertilizer. It varies from 1.40-1.45 MgM^{-3} due to application organic and inorganic fertilizer (Table 2). In the present experiment, initial soil having bulk density of 1.44 Mg m^{-3} with porosity of 45.28% which improved significantly in organic treated T, T_5 and T_6 plots. The maximum reduction in bulk density was recorded in treatments T_5 and T_6 over control. The mean pore space ranged from 45.28-47.16 per cent and it increased with reduction of bulk density. Bulk density decreased with higher proportion of organic. This situation favored nutrient release and uptake through crop which resulted better crop growth and yield. The improvement in bulk density and porosity of soil may be attributed due to improvement in organic matter in content of postharvest soil over control and initial soil value. The production of higher biomass and better root resulted in lower bulk density in organic treated plots. The results are in agreements with findings of Virdia and Patel (2010) [12] and Sinha *et al*., (2014) [18]. The higher rate of respiration and carbon storage with improved bulk density in T_6 treatment receiving organics in combination indicating better soil health. Similar findings were also reported by Shukla *et al*. (2015) [16] and Srivastava *et al.* (2018) [21].



T_1-100% NPK (Control), T_2-75% NPK + 25% N, VC, T_3-75% NPK + 25% N, VC + BF, T_4-50% NPK+ 25% N, VC +BF, T_5-50% NPK+ 50% N (VC + CC) ½ each + BF, T_6-50% N+ 100% P K + 50% N (VC + CC + NC) 1/3 each + BF

Fig 1: Effect of Integration of organic and inorganic nutrient sources on CO_2 evolution in soil

Table 2: Effect of integration of Organic and inorganic nutrient sources on soil properties and availability of nutrients after sugarcane harvest

Treatments		pH	EC (dSm^{-1})	Organic carbon ($g\ kg^{-1}$)	Bulk density ($Mg^{-1}\ m^3$)	Available nutrients (kg ha^{-1})		
						N	P	K
T_1:	100% NPK (Control)	8.31	0.13	4.28	1.45 (45.28)	218.76	14.21	115.06
T_2:	75% NPK + 25% N, VC	8.21	0.14	4.58	1.43 (46.03)	227.78	15.90	119.66
T_3:	75% NPK +25% N, VC + BF	8.27	0.18	4.65	1.42 (46.41)	228.75	18.54	120.34
T_4:	50% NPK+ 25% N, VC + BF	8.24	0.14	4.70	1.41 (46.79)	235.75	18.30	121.15
T_5:	50% NPK+50% N (V+ CC) C ½ each + BF	8.25	0.19	4.93	1.40 (47.16)	238.43	19.45	125.10
T_6:	50% N+ 100% P K + 50% N (VC +CC + NC) 1/3 each + BF	8.25	0.20	4.95	1.40 (47.16)	239.44	19.79	129.14
S.Em ±		0.043	0.013	0.10	0.011	1.68	0.38	1.82

CD (P=0.05)	NS	0.04	0.32	0.033	5.05	1.15	5.47
Initial	8.62	0.18	4.4	1.44 (45.66)	222.2	15.8	118.3

VC; Vermicompost, CC; Castor cake. NC; Neem cake, BF; biofertilizer

Yield attributes and cane yield

The application of organic and inorganic fertilizer had significant effect on growth yield attributes and yield of sugarcane (Table 3). The biometric observations indicated that plant population, number of millable cane (NMC), cane length, single cane weight (SCW) and cane yield were significantly affected due to integrated use of nutrients through inorganic and organic sources. The effect of treatments on cane germination and cane girth was found non-significant. The highest plant population was recorded in treatment T_5 receiving 50% NPK+ 50% N (VC + CC) ½ each + biofertilizer (159.05 x 10^3/ha ha^{-1}) which was at par with T_3 (143.25 x 10^3/ha ha^{-1}) receiving 75% NPK + 25% N, VC and T6 (155.0 x 10^3/ha ha^{-1}) having 50% N+ 100% P K + 50% N (VC + CC + NC) 1/3 Each + biofertilizer and the lowest number of plant was recorded in the treatment receiving 100% NPK through chemical fertilizer (124.05 x 10^3/ha ha^{-1}). The NMC indicated significant variations due to application of nutrient in organic and inorganic combination. The maximum NMC was observed in T_6 (105.60 x 10^3 ha^{-1}) which was significantly superior with rest of the treatments and at par with T_5 (102.75 x 10^3 ha^{-1}). The result indicated that more number of tiller was converted to NMC in plots receiving nutrient in organic and inorganic combination especially in treatment T_5 and T_6 receiving concentrate organic manure. Further, application of biofertilizer with organic manure improved growth character and yield attributes of cane. The single cane weight at maturity increased significantly in T_5 and T_6 treatments. Cane yield under various integrated organic nutrition in T_1, T_2, T_3 and T_4 treatments was at par with RDF. The application of organic fertilizer through vermicompost could not meet the requirement of NKP fertilizer in T_1, T_2, T_3 and T_4 treatments resulted in lower cane yield. The significantly higher cane yield (83.86t/ha) were recorded in treatment T_6 receiving 50% N through inorganics + 50% N through organics (Vermicompost + castor cake + neem cake) 1/3 eah along with bio-fertilizer *Azotobacter* and PSB applied @ 4.o kg /ha followed by treatment T_5 receiving 50% NPK+ 50% N (VC + CC) ½ each + biofertilizer (78.88 t ha^{-1}). Application of organic nutrient combination with inorganic sources accelerated yield attributing characters i.e. NMC and SCW resulting higher cane yield. The application of organics released nutrient through decomposition and mineralization that would have increased the availability of plant nutrients at later stage and brought improvement in physical, chemical and biological properties of soil (Virdia and Patel, 2010) [12]. The immediate and quick supply of nutrients through inorganic fertilizer and steady supply of plant nutrients by organics throughout the growth period of the crop resulted in higher cane yield. Further, number of tillers were converted into NMC with significantly more cane weight which led to higher cane yield. These results are in agreement with the findings of Venkatakrishnan and Ravichandran (2012) [24], Selvamurugan *et al.* (2013) [15] Patel *et al.* (2013) [11], Thakur *et al.* (2013) and Jha *et al.* (2015) [6].

Table 3: Effect of integration of Organic and inorganic nutrient sources on growth, yield and yield attributes of sugarcane

Treatments		Germination (%)	Plant population (x $10^3 ha^{-1}$)	NMC (x $10^3 ha^{-1}$)	Cane length (cm)	Cane weight (g)	Girth (cm)	Cane yield (t/ha)
T_1:	100% NPK (Control)	40.43	124.05	95.03	222.08	738.75	2.10	71.37
T_2:	75% NPK + 25% N, VC	42.68	143.25	101.15	241.25	743.75	2.20	73.54
T_3:	75% NPK + 25% N, VC + BF	45.73	125.35	100.50	241.67	771.25	2.10	75.79
T_4:	50% NPK+ 25% N, VC +BF	42.68	130.40	99.20	233.75	713.75	2.11	68.71
T_5:	50% NPK+ 50% N (VC + CC) ½ each + BF	51.00	159.05	102.75	233.75	832.50	2.13	78.88
T_6:	50% N+ 100% P K + 50% N (VC + CC + NC) 1/3 each + BF	50.02	155.00	105.60	244.90	850.00	2.12	83.86
S.Em ±		4.29	9.44	2.71	6.02	16.02	0.034	2.03
CD (P=0.05)		NS	28.30	8.13	18.04	48.03	NS	6.11

VC; Vermicompost, CC; Castor cake. NC; Neem cake, BF; biofertilizer

Juice quality and sugar yield

The juice quality parameters *viz.* brix, pol, purity and commercial cane sugar (CCS) percent remains unaffected due to integrated use of organic and inorganic fertilizer however, juice recovery and sugar yield varied significantly (Table 4). The cane juice extraction (61.23-66.48%) and sugar yield (7.70-9.48 t/ha) varied significantly due to various treatments. The maximum sugar yield was registered in T_6 and lowest in T_4. Treatment T_6 receiving 50% N+ 100% P K + 50% N (VC + CC + NC) 1/3 Each+ biofertilizer was significantly superior over rest of the treatment except T_5. The combination of organic nutrient source was found beneficial in improving cane juice and sugar recovery. Sugar yield followed the similar trend of yield of sugarcane. Sugar yield is function of cane yield, juice quality and juice recovery. Higher cane yield and juice recovery due to application of nutrients from organic and inorganic sources resulted in high sugar yield. Similar findings were also reported by and Thakur *et al.* (2012) [23] and Jha and Thakur (2018) [4].

Table 4: Effect of integration of organic and inorganic nutrient sources on juice quality and sugar yield of sugarcane

Treatments		Juice quality (%)			Juice recovery (%)	CCS (%)	Sugar yield (t ha^{-1})
		Brix	Pol	Purity			
T_1:	100% NPK (Control)	18.75	16.44	87.50	61.23	11.32	8.07
T_2:	75% NPK + 25% N, VC	19.05	16.76	87.95	61.76	11.56	8.49
T_3:	75% NPK + 25% N, VC + BF	18.85	16.63	88.20	64.26	11.48	8.71
T_4:	50% NPK+ 25% N, VC +BF	18.60	16.30	87.58	60.21	11.22	7.70
T_5:	50% NPK+ 50% N (VC + CC) ½ each + BF	18.80	16.44	87.40	66.48	11.30	8.91

$T_{6:}$	50% N+ 100% P K + 50% N (VC + CC + NC) 1/3 each + BF	18.70	16.41	87.58	66.06	11.31	9.48
S.Em ±		0.13	0.17	0.33	1.20	0.14	0.23
CD (P=0.05)		NS	NS	NS	3.59	NS	0.71

VC; Vermicompost, CC; Castor cake. NC; Neem cake, BF; biofertilizer

Conclusion

Sugarcane yield increased significantly with integration of organic and inorganic nutrient sources and combinations of vermicompost and neem/castor oil cakes along with biofertilizers was more effective for sustainable sugarcane production and maintenance of soil health. Nutrient combination supplying either 50% N + 100% PK through chemical fertilizer + 50% N through organic sources (Vermicompost + castor cake + neem cake) 1/3 each or 50% NPK + 50% N (VC + CC) ½ each along with *Azotobacter and PSB* each applied @ 4 kg /ha meet the demand of N for obtaining higher cane and sugar yield besides improvement in quality of soil.

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