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Sustainable soil and crop productivity of sugarcane multiratooning system with integrated nutrient management under *Inceptisols* of Andhra Pradesh

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ABSTRACT

Field experiments were conducted consecutively for six years in the same field (2012−13 to 2018−19) at Regional Agricultural Research Station, Anakapalle to study the effect of sugarcane multiratooning on soil and crop productivity of sugarcane with different nutrient management practices. Results revealed that, irrespective of year of ratooning plots which received 50% fertilizer nitrogen + 25% N though vermicompost + 25% N green manure incorporation recorded significantly higher organic carbon (OC) status (0.80%) with less bulk density and highest water holding capacity and percent pore space. There was a substantial increase in the available nitrogen status upto 4th ratoon and later the availability was found to be decreased. Similarly, decrease in availability of potassium was observed due to continuous ratooning of the crop from its initial ratooning stage. Regarding available phosphorus, no particular trend was noticed among different treatments, however significant buildup of available phosphorus from its initial value was observed in all the treatments with increasing ratooning. Significant improvement in available zinc was observed upto 3rd ratoon. Around 16% reduction in available Fe from its initial status was observed in post harvest soils of 6th ratoon crop compared to its initial status. Integrated use of inorganic and organic nutrients recorded at par yields with 100% recommended dose of chemical fertilizers. Inclusion of different organic sources in sugarcane monocropping not only enhanced the soil physical properties and soil organic carbon (SOC) but also adequately met the nitrogen requirement leading to on par yield as with recommended fertilizers.

1. INTRODUCTION

Sugarcane is one of the important commercial crops of India, grown in an area of 3.93 M ha with annual production of 170 M t Sugarcane is one of the most important food−cum−cash crops grown in the country, providing employment to a larger number of people, in addition to earning considerable foreign exchange. Sugarcane cultivation in India is characterized by raising of as many numbers of ratoons owing to its substantially low cost of production by reduction of cost incurred on seed, field preparation and planting. Ratoon crops however, seldom receive proper care and inputs due to being considered a free crop by majority of farmers poor in resources. Such an approach for a long duration production system, often leads to significant deterioration in soil health (Singh *et al.,* 2007).

Multiratooning of sugarcane is highly profitable to the farmers and sugar industry as it reduces the production cost by 30−40%. But productivity of sugarcane under multiratooning is declined by 30−50% every year due to alteration of soil physical, physicochemical and biological properties which leads to reduction in cane population per hectare. Sugarcane crop produces a heavy tonnage and tends to remove substantial quantum of plant nutrients from the soil. The soils of north coastal zone are mostly light textured with low organic matter content and low to medium in soil available nitrogen and responds largely to nitrogenous fertilizers. Sugarcane being long duration crop with higher nutrient and water requirement needs to be supplied with large quantities of nutrients and water. Water requirement of sugarcane varies from 2000 mm to 2200 mm depending upon its duration, soil type and climatological factors.

Fertilizer management plays an important role in the growth, development, yield, yield attributes and finally quality characters of sugarcane compared to other management factors. It is widely recognized that neither use of organic manures alone nor chemical fertilizers can achieve the sustainability of crop yield at desired level under the modern intensive farming. The escalating costs of fertilizers on one hand and their undesirable effects on soil properties on the other have led to inclusion of organic manures in cultivation of crop (Bajpai *et al.,* 2006) and slow release of nutrients from organics, could help a long duration sugarcane crop to take their complete benefit (Acharya, 1954). Sugarcane farmers are applying huge quantities of nitrogen fertilizers and ignoring the use of organic manures and balanced nutrition, particularly and they are going for raising as many as ratoons in the same piece of land, so yield reduction is being observed in multiratooning sugarcane fields which leads to reduction of average productivity. Keeping these points in view, the present study was undertaken to study the long−term effect of different nutrient management practices for sustainable soil and crop productivity under sugarcane multiratooning in *Inceptisols* of Andhra Pradesh.

2. MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Anakapalle, Andhra Pradesh consecutively for six years (2012−13 to 2018−19) in an *Inceptisols*. During 2011−12, plant crop was raised as bulk crop without imposing any treatments and applied recommended dose of chemical fertilizers only (112:100:120 kg NPK ha^{-1}) and post harvest soils of plant crop were analyzed and taken as initial soil data. The experimental soils are neutral in reaction, non saline in conductivity, medium in percent OC (0.54%), low in available nitrogen (254 kg ha^{-1}) and high status of available phosphorus and potassium. From 2012−13 onwards subsequent ratoon crops were raised with different nutrient management practices and ratoon management practices *i.e.* stubble shaving, off bearing and intercultivation in between the rows (except farmer practice *i.e.* T6). The treatmental details are:

Treatment	Details
T1	100% recommended dose of chemical fertilizers (224:100:120 kg NPK ha^{-1})
T2	75% recommended dose of nitrogen fertilizers + KNO_3 @ 1% foliar spray + cane trash *in−situ* decomposition
T3	50% recommended dose of nitrogen fertilizers + 25% N though trash compost + green manure incorporation
T4	150% recommended dose of nitrogen fertilizers
T5	200% recommended dose of nitrogen fertilizers
T6	Farmers Practice (only N as initial dose (250 kg N + 60 kg K ha^{-1} in the form of urea and muriate of potash, no stubble shaving, no off bearing and no inter cultivation) and
T7	100% recommended dose of nitrogen fertilizers + Hormonal spray *i.e.* GA @ 50 ppm

Common dose of 100 kg phosphotic fertilizers and 120 kg potassic fertilizers per ha were applied uniformly to all the treatments in the form of single super phosphate and muriate of potash. Experiment was laid out in a randomized block design with 3 replications. Sugarcane was planted at 80 cm spacing in the first week of March, 2011. Sugarcane plant crop was harvested at ground level during February, 2012 and subsequent ratoon crops were maintained upto 2018−19. Organic manures were applied as basal and recommended dose of nitrogen fertilizers were applied at 0 and 45 days after ratooning and phosphorus and potassic fertilizers were applied at the time of stubble shaving. During germination stage (0−35 days) irrigations were provided at weekly intervals, during tillering stage (36−100 days) provided at 10 days interval. At crop critical stages *i.e.* formative and grand growth stages (101−270 days) provided irrigations as and when required (but ensured moisture availability at weekly intervals) based on soil moisture availability as rainy season was coincided with this stage, given less number of irrigations as rainfall taken care from July to September months. Soil samples were collected after harvest of the plant crop and taken as initial soil status for subsequent ratoon crops. Post harvest soils of ratoon crops were collected for analysis of soil physical, physico−chemical and chemical properties. Initial and final soil samples were air dried, sieved to pass a mesh of 2 mm size for determination of soil physico−chemical properties (pH, EC, OC) and available nitrogen, phosphorus, potassium, zinc, iron, copper and manganese as per standard procedures given by Jackson, 1973. Soil pH and electrical conductivity was measured by using digital pH meter and EC bridge. SOC content was determined by using wet digestion method (Walkley and Black, 1934). The available nitrogen was estimated by alkaline permanganate method as described by Subbaiah and Asija (1956), available phosphorus was determined by using Olsen *et al.* (1954), Available potassium was determined by using Flame photometer. The available micro− nutrients (Fe, Cu, Mn and Zn) were estimated in the DTPA extract according to the procedure given by Lindsay and Norvell (1978). Soil bulk density by Core Sampler method (Black and Hartge, 1986), physical constants *i.e.* water holding capacity, pore space was determined by following Keen Rackzowski's method as described by Sankaram (1966). Juice analysis was carried out prior to harvesting, observations on juice quality *i.e.* % CCS, % purity and sucrose percent was estimated as per the method suggested by Meade and Chen (1977). Shoot population was taken at formative and grand growth stages and number of milleable canes were taken at harvest alongwith cane yield data. Sugar yields were computed from the cane yield multiplied with % CCS. Water use efficiency (WUE) was calculated by dividing the cane yield (t ha^{-1}) by the total amount of water added (mm) according to Condon and Hall (1997) and Bhattacharya (2019) as following: WUE = Cane yield (ton) / Total water used (mm).

Statistical Analysis

In order to compare the effect of various treatments on yield and fertility status, Analysis of variance (ANOVA) was performed using standard procedures for randomized block design (Chandel, 2002). Individual character datasets were subjected to analysis of variance and the means were separated at the 0.05 level of probability by using the statistical software, Statistical Package for Social Sciences (SPSS).

3. RESULTS AND DISCUSSION

Soil Organic Carbon (SOC) and Macro-Nutrient Status

Irrespective of the year of ratooning, plots which received 50% recommended dose of chemical fertilizers + 25% nitrogen though vermicompost + 25% nitrogen through green manure incorporation resulted in the higher OC content, it was increased to 0.80% from its initial value of 0.54% (Table 1). Lowest OC content was recorded in the farmer's practice. Combined application of organic manures with inorganic fertilizers significantly increases the SOC content due to addition of organic matter through manures than chemical fertilizers alone. This corroborates the findings of Singh *et al.* (2010) and Ramalingaswamy *et al.* (2004). OC content was gradually increased from initial year to final year under multiratooning system. Dee *et al.* (2003) reported enhanced OC upon organic manure application under sugarcane multiratooning. Soil enrichment in terms of OC due to addition of manures, *in−situ* decomposition and green manure incorporation is attributable to increased soil microbial activity as observed in this study. Lowest OC content in farmers practice is due to imbalanced nutrition with low biomass both root and shoot. With increasing ratooning, increasing trend in OC was observed from its initial value of 0.54% to 0.80%, it might be due to less disturbance of soil, reduces the loss of oxidizable carbon and continuous addition of root biomass to the soil increases the SOC content. Kumar *et al.* (2014) reported that application of sugarcane trash @ 3 t ha^{-1} in combination with fertilizer nitrogen significantly increased the OC, available P and K, infiltration rate and moisture retention in the soil over no trash. Sinha *et al.* (2017) reported that integrated use of organics with inorganic fertilizers facilitated the accumulation of OC which in turn had significant increment effect on the soil carbon pool and fertility status (N, P, K and S) of soil with reduction in bulk density beneficial for sustaining productivity of sugarcane plant−ratoon system. Thus, it is imperative that application of either 100% NPK recommended dose of fertilizer along with bio−compost 20 t ha^{-1} or 100% NP along with bio−methanated distillery effluent 150 m^3 ha^{-1} (supplying 100% K) improved the fertility of soil which were reflected in increased productivity of sugarcane plant−ratoon system.

Data presented in Fig. 1 revealed that, with increasing the levels of fertilizer nitrogen the available nitrogen status was also increased and significantly highest available nitrogen status was recorded in the plots which received highest fertilizer nitrogen *i.e.* 150% fertilizer nitrogen, 200% fertilizer nitrogen and farmer practice. Up to 4^{th} ratoon, available nitrogen status was increased from its initial value of 254 kg ha^{-1} to 300 kg ha^{-1} later it was reduced in 5^{th} and 6^{th} ratoons, It might be due to less nitrogen use efficiency and more consumption of nitrogen with increasing ratooning compared to initial ratoons. Though integrated nutrient management plots received lower fertilizer nitrogen over 100% recommended dose of chemical fertilizers, available nitrogen status was at par with 100%

Table: 1
Effect of different nutrient management practices on soil organic carbon status (%) under sugarcane multiratooning

	2013−14	2014−15	2015−16	2016−17	2017−18	2018−19	Mean
Initial	0.54						
T1 − 100% recommended dose of chemical fertilizers (224:100:120 kg NPK ha^{-1})	0.50	0.52	0.68	0.62	0.79	0.74	0.64
T2 − 75% recommended dose of nitrogen fertilizers + KNO_3 @ 1% foliar spray + cane trash *in−situ* decomposition	0.55	0.57	0.65	0.88	0.80	0.76	0.70
T3 − 50% recommended dose of nitrogen fertilizers + 25% N though trash compost + green manure incorporation	0.56	0.62	0.71	0.79	0.82	0.80	0.72
T4 − 150% recommended dose of nitrogen fertilizers	0.54	0.58	0.68	0.67	0.83	0.79	0.68
T5 − 200% recommended dose of nitrogen fertilizers	0.53	0.60	0.65	0.72	0.78	0.78	0.68
T6 − Farmers practice (only N as initial dose (250 kg N + 60 kg K in the form of urea and muriate of potash, no stubble shaving, no off bearing and no inter cultivation)	0.54	0.59	0.66	0.81	0.77	0.73	0.67
T7 − 100% recommended dose of nitrogen fertilizers + Hormonal spray *i.e.* GA @ 50 ppm	0.52	0.53	0.66	0.76	0.81	0.76	0.67
Mean	0.53	0.57	0.67	0.75	0.79	0.76	0.68
SEm±	0.018	0.027	0.021	0.022	0.021	0.011	0.020
CD (5%)	0.040	0.058	0.055	0.061	0.045	0.031	0.054

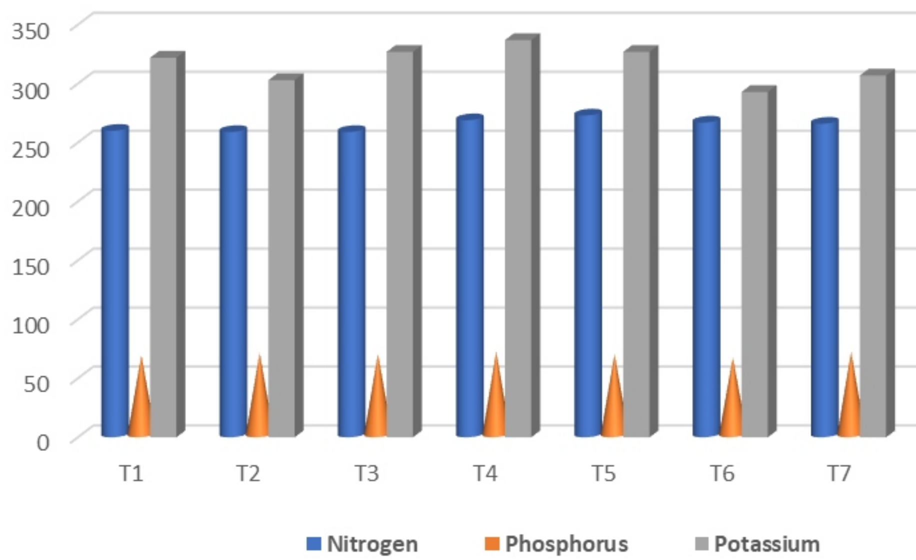

Fig. 1. Effect of different nutrient management practices on soil available macro−nutrients (kg ha^{-1}) under sugarcane multiratooning (mean of six years)

fertilizer nitrogen. In this study clearly indicated that, there was a buildup of available nitrogen status upto 4th ratoon, later it was decreased with ratooning and reached to a mean value of 251 kg ha^{-1}, lower than initial value of 254 kg ha^{-1}. Kadam *et al.* (2005) reported similar results. Regarding available phosphorus there is no particular trend with in the treatments, might be due to same dose of phosphotic fertilizers were applied to all the treatments except farmers' practice. However significant build up of available phosphorus from its initial value was observed in all the treatments with increasing ratooning. Highest available phosphorus status of 84.6 kg ha^{-1} was observed in the treatment with integrated nutrient supply through inorganics and organics, same trend was observed in 4th, 5th and 6th ratoons also in same treatment. Lowest available nitrogen of 75.0 kg ha^{-1} was recorded with 150% fertilizer nitrogen + 100% fertilizer phosphorus and potassium, similar trend was observed in 4th, 5th and 6th ratoons also in same treatment. Around 22.2 kg ha^{-1} phosphorus build up was observed in 6th ratoon from its initial value of 57.10 to mean value of 79.40 kg ha^{-1}. This study clearly indicated that, integrated nutrient management with reduced levels of nitrogen also can meet the phosphorus requirement of the sugarcane crop. There was no particular trend with available potassium within the treatments like available phosphorus, and up to third ratoon soil available status was maintained to its initial value, later it was decreased drastically. After completion of 6 ratoons, highest available potassium status was recorded in plots which received integrated nutrient management over 100% chemical fertilizers, significantly lowest available nitrogen status (224 kg ha^{-1}) was recorded in the plots which received imbalanced nutrition *i.e.* farmer's practice. Mean available potassium status of 252 kg ha^{-1} was recorded after completion of 6 ratoons, around 82 kg ha^{-1} available potassium was reduced from its initial value of 334 kg ha^{-1}. Continuous cropping of sugarcane in the same piece of land could not maintain the available potassium. Similar results were reported by Madhu *et al.* (2018) and Bhattacharya *et al.* (2016) in different soils and cropping systems of India. He also reported that, a high yielding irrigated crop, producing 165 t ha^{-1} can remove 650 kg potassium ha^{-1}. The high rate of K uptake is exceptional and can largely be attributed to luxury uptake of K in a plant crop of sugarcane growing in a deep, fertile sandy clay loam soil on relatively new alluvial land. Results from an adjoining lysimeter trial located adjacent to the field trial showed a potassium uptake of 250 kg ha^{-1} for similar biomass yield. There was no significant difference in case of pH and electrical conductivity among different treatments and among number of ratoons. Few researchers were of the opinion that maintaining adequate levels of macro and micro-nutrients were essential to obtain higher cane yields. Allelochemicals can interfere with nitrogen, phosphorus, potassium, magnesium, calcium and iron uptake (Hasse *et al.,* 2011; Bokhtiar and Sakurai, 2005; Choudhary and Behera, 2020). They reported that the rhizosphere soil N, P and K levels under monocropping were negatively influenced with increasing frequency of ratooning significant reduction in NPK level might be due to disturbance in the relationship between the root system of cane plant and rhizosphere soil. The one−sided soil exhaustion of NPK during monoculturing has been reported where NPK levels were found to be correlated with yield potential in ratoon. Kalaiselvi *et al.* (2019) reported the soil fertility status of semi−arid regions of Tamil Nadu uplands as low to medium OC and medium to high available phosphorus status.

Soil Micro−Nutrient Status

Data presented in Table 2 revealed that, available zinc status was slightly increased (0.83 ppm) after completion of 6th ratoon from its initial value (0.76 ppm). Significantly highest available zinc status of 0.96 ppm was recorded in the plots with integrated nutrient management and lowest available zinc status of 0.73 ppm was recorded in 200% chemical fertilizer treatment in 6th ratoon crop, it might be due to high uptake as this treatment recorded higher yields. It was observed that upto third ratoon significant improvement in available zinc status, later it was decreased in all the treatments. Data on available iron status revealed that around 16% reduction in iron status from its initial value, among all the treatments, more reduction was observed in farmers practice and less reduction was observed in 100% recommended dose of chemical fertilizers. Slight reduction in available copper status from initial to 6th ratoon, upto 4th ratoon available status was maintained later it was slightly reduced, but there were no significant differences among treatments (Table 3) and with the rationing for copper and manganese. Nutrient management and ratooning did not influence available copper status. Similar results were reported by Kumar *et al.* (2014) and Gupta *et al.* (1994).

Soil Physical Properties

Data of soil physical properties *i.e.* bulk density, water holding capacity and pore space was presented in Fig. 2. Soil bulk density was found to be 1.31 Mg m^{-3} and 1.33 Mg m^{-3} for integrated nutrient management and farmer practice, respectively. Guimarães Júnnyor *et al.* (2015) evaluated physical quality of *Inceptisol* and found BD of 1.36 Mg m^{-3}. In the plots which received integrated nutrient management practices recorded low values of bulk density than other treatment, might be due to more organic matter and soil micropores and consequently low bulk density. On the other hand, the farmers practice (*i.e.* without intercultivation between the rows) presented higher bulk density and comparatively low water holding capacity and poresprace. These results demonstrate a positive effect of intercultivation in between rows at tillering stage in all other treatments. Traditionally, no−tillage and minimum tillage systems demonstrate limitations related to superficial soil compaction due to natural arrangement of particles and in−field machinery traffic (Tormena *et al.,* 2007). Bulk density was slightly increased in all the treatments except farmers practice, it was increased to 1.33 Mg m^{-3} from its initial value of 1.31 Mg m^{-3}. Over a period of 6 years, it was enhanced to 0.2 units in *Inceptisols* with high sand and silt content. Water holding capacity and percent poresprace also followed the same trend. It is clearly indicated that in Inceptisols of sandy clay loams, succeeding ratoons upto 5 ratoons did not influence any physical properties. Improvement in soil physical properties *i.e.* bulk density, water holding capacity and percent pore space was recorded

Table: 2
Effect of different nutrient management practices on available zinc and iron (ppm) under sugarcane multiratooning

Treatment	Zinc							Iron						
	2013−14	2014−15	2015−16	2016−17	2017−18	2018−19	Mean	2013−14	2014−15	2015−16	2016−17	2017−18	2018−19	Mean
Initial	0.76							14.30						
T1	0.66	0.78	0.74	0.71	0.59	0.79	0.71	14.2	12.20	8.58	12.42	9.69	13.1	11.70
T2	0.81	0.86	1.01	0.63	0.55	0.83	0.78	11.25	12.38	9.38	10.84	7.29	11.9	10.51
T3	0.77	0.76	1.07	0.64	0.50	0.77	0.75	16.23	11.16	27.00	7.72	8.39	12.1	13.77
T4	0.98	1.16	1.21	0.71	0.59	0.96	0.94	14.20	12.40	15.00	10.31	9.29	12.1	12.22
T5	0.76	0.92	1.20	0.71	0.53	0.73	0.81	12.30	11.28	22.42	12.72	8.03	12.9	13.28
T6	0.69	0.72	0.89	0.76	0.57	0.91	0.76	15.34	10.80	7.14	10.44	8.83	10.3	10.48
T7	0.81	0.86	0.94	0.64	0.53	0.82	0.77	12.40	10.82	13.96	10.95	10.15	12.2	11.75
Mean	0.78	0.87	1.01	0.69	0.55	0.83	0.79	13.70	11.58	13.35	10.77	8.81	12.1	11.72
SEm±	–	–	0.022	0.019	–	0.020	0.028	–	–	0.24	0.57	0.27	–	0.39
CD (5%)	NS	NS	0.056	0.062	NS	0.045	0.061	NS	NS	0.96	1.20	0.75	NS	0.98

Table: 3
Effect of different nutrient management practices on available copper and manganese (ppm) under sugarcane multiratooning

Treatment	Copper							Manganese						
	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	Mean	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	Mean
Initial	2.85							19.50						
T1	3.22	3.09	2.12	3.01	2.28	2.91	2.77	18.20	17.25	9.73	15.99	17.71	20.90	16.63
T2	2.95	2.70	2.28	3.25	2.05	2.97	2.70	22.40	20.54	24.80	17.71	20.51	22.31	21.38
T3	3.04	3.03	1.66	2.95	2.15	2.69	2.59	18.10	24.10	26.16	17.30	16.25	21.67	20.60
T4	2.55	2.93	2.16	3.24	2.29	3.19	2.73	17.50	19.44	9.98	16.75	15.80	19.60	16.51
T5	2.95	3.16	1.76	2.60	2.10	2.38	2.49	17.92	20.14	25.62	18.96	17.47	20.33	20.07
T6	2.12	2.85	2.40	3.22	2.27	2.99	2.64	15.42	17.20	10.16	19.44	16.84	24.47	17.26
T7	3.11	3.04	1.64	2.95	2.23	2.56	2.59	17.48	14.22	23.34	18.50	16.19	16.67	17.73
Mean	2.85	2.97	2.00	3.03	2.20	2.81	2.64	18.15	18.98	18.54	17.81	17.25	20.85	18.60
SEm±	–	–	–	–	–	–	–	–	0.97	–	–	–	–	0.69
CD (5%)	NS	NS	NS	0.15	NS	NS	NS	NS	2.15	NS	0.68	NS	1.25	1.38

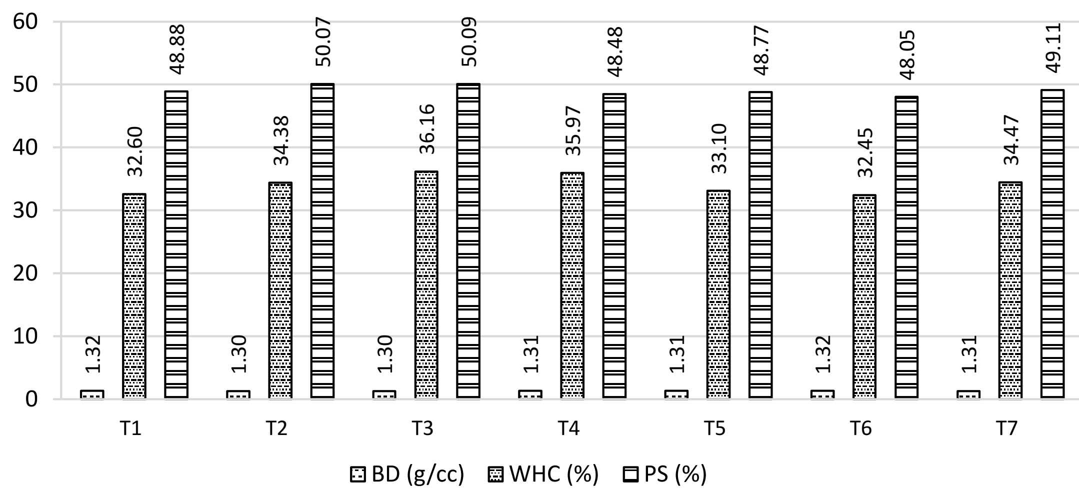

Fig. 2. Effect of different nutrient management practices on soil physical properties (bulk density, water holding capacity and pore space) under sugarcane multiratooning

due to different management practices. Addition of organic manures and incorporation of green manure crop with in the rows decreased the bulk density and farmer practice recorded slightly higher bulk density. Significant increase in water holding capacity and percent pore space was observed in the treatments which received organic manures and incorporation of green manures with inter cultivation in between the rows. Enhanced soil physical properties due to incorporation of organic manures and in situ decomposition is attributed to the granulation of soil leading to porous condition and low bulk density that help to increased porosity as encountered in this study. These findings are in agreement with Kumar and Chand (2013) and Singh *et al.* (2010).

Nutrient Uptake

Macro–nutrient uptake was increased in all the treatments from first ratoon to sixth ratoon (Table 4), though the yield trend was not similar, clearly indicated that nutrient uptake was influenced with multiratooning, it was supported by Singh *et al.* (2010). Among different treatments highest nitrogen uptake of 241 kg ha^{-1} was recorded in the treatment which received highest fertilizer nitrogen, and lowest nitrogen uptake was recorded in the integrated nutrient management treatments with slight reduction in yields, this once again proved the better nutrient use efficiency with integrated nutrient management. Compared to recommended dose of chemical fertilizers alone *in–situ* decomposition of cane trash and green manure incorporation also adequately meet the nitrogen requirement of sugarcane crop in a multiratooning system, which may corroborates the findings of Singh *et al.* (2007). Phosphorus also followed the same trend, but there is no particular trend with potassium uptake, may be under *Inceptisols* clay mineralogy also played a major role in potassium uptake.

Water Use Efficiency (WUE)

Data presented in Table 5 on WUE under sugarcane multiratooning revealed that, highest mean WUE of 39.40 kg yield ha^{-1} mm water was recorded in the plots with 200% fertilizer nitrogen and it was closely followed by 150% fertilizer nitrogen might be due to higher yields compared to other treatments. However, WUE of 100% chemical fertilizers and integrated use of 75% chemical fertilizers + 25% organic sources are recorded similar values and lowest WUE of 34.08 kg yield ha^{-1} mm water was observed in the farmer practice. All the treatments received equal volume of water *i.e.* 1861 mm (rainfall + irrigations) hence the variations in WUE is due to biomass production. Chatterjee *et al.* (2017) reported highest WUE of maize under mulch conditions over without mulch.

Juice Quality

Data presented in Table 6 on juice quality revealed that highest juice sucrose was recorded with the treatment which received 50% recommended dose of fertilizer nitrogen + 25% nitrogen though vermicompost + green manure incorporation, and lowest juice sucrose was recorded in the plots which received higher doses of nitrogen fertilizers. Superior cane juice quality in integrated nutrient management plots with low chemical nitrogen might be due to

Table: 4
Effect of different nutrient management practices on macronutrient uptake (kg ha^{-1}) by sugarcane whole plant (2018−19)

Treatments	Nitrogen	Phosphorus	Potassium
T1 − 100% recommended dose of chemical fertilizers (224:100:120 kg NPK ha^{-1})	162	54.0	226
T2 − 75% recommended dose of nitrogen fertilizers + KNO_3 @ 1% foliar spray + cane trash *in−situ* decomposition	167	51.2	235
T3 − 50% recommended dose of nitrogen fertilizers + 25% N though trash compost + green manure incorporation	158	54.9	234
T4 − 150% recommended dose of nitrogen fertilizers	181	58.7	246
T5 − 200% recommended dose of nitrogen fertilizers	195	58.3	248
T6 − Farmers practice (only N as initial dose (250 kg N + 60 kg K in the form of urea and muriate of potash, no stubble shaving, no off bearing and no inter cultivation)	181	47.3	215
T7 − 100% recommended dose of nitrogen fertilizers + Hormonal spray *i.e.* GA @ 50 ppm	166	53.5	227
Mean	173	54.0	233
S.Em±	4.7	1.48	7.40
CD (5%)	12.5	3.70	18.40

Table: 5
Effect of different nutrient management practices on Water Use Efficiency (kg per ha−mm) of sugarcane under multiratooning (mean of 6 years)

Treatments	Water Use Efficiency
T1 − 100% recommended dose of chemical fertilizers (224:100:120 kg NPK ha^{-1})	36.15
T2 − 75% recommended dose of nitrogen fertilizers + KNO_3 @ 1% foliar spray + cane trash in situ decomposition	35.88
T3 − 50% recommended dose of nitrogen fertilizers + 25% N though trash compost + green manure incorporation	34.83
T4 − 150% recommended dose of nitrogen fertilizers	38.50
T5 − 200% recommended dose of nitrogen fertilizers	39.40
T6 − Farmers practice (only N as initial dose (250 kg N + 60 kg K in the form of urea and muriate of potash, no stubble shaving, no off bearing and no inter cultivation)	34.08
T7 − 100% recommended dose of nitrogen fertilizers + Hormonal spray *i.e.* GA @ 50 ppm	36.46
Mean	36.15

Table: 6
Effect of different nutrient management practices on juice quality (mean of 6 years) under sugarcane multiratooning

Treatments	Juice Sucrose (%)	Commercial Cane Sugar (%)	Juice purity (%)
T1 − 100% recommended dose of chemical fertilizers (224:100:120 kg NPK ha^{-1})	18.74	13.36	87.22
T2 − 75% recommended dose of nitrogen fertilizers + KNO_3 @ 1% foliar spray + cane trash *in−situ* decomposition	18.67	13.18	87.79
T3 − 50% recommended dose of nitrogen fertilizers + 25% N though trash compost + green manure incorporation	18.84	13.45	86.85
T4 − 150% recommended dose of nitrogen fertilizers	18.44	13.06	86.55
T5 − 200% recommended dose of nitrogen fertilizers	17.91	12.62	82.59
T6 − Farmers practice (only N as initial dose (250 kg N + 60 kg K in the form of urea and muriate of potash, no stubble shaving, no off bearing and no inter cultivation)	18.23	12.92	85.23
T7 − 100% recommended dose of nitrogen fertilizers + Hormonal spray *i.e.* GA @ 50 ppm	18.50	13.15	87.17
Mean	18.47	13.11	86.20

organic manures are responsible for utilization of assimilated nitrogen in cane and conversion of reducing sugars to recoverable sugars and the decrease in juice quality with an increase in nitrogen was observed due to the hydration and succulence of plant tissue (Ramalkingaswamy *et al.,* 2004). Whereas lowest percent juice sucrose and commercial cane sugar was recorded in the plots with 200% recommended dose of fertilizer nitrogen followed by farmers practice might be imbalanced nutrition to the crop. Cane juice sucrose was decreased from 4th ratoon onwards and from first ratoon to 3rd ratoon juice sucrose was increased. Though climate plays a major role in juice sucrose recovery, in this study nutrient management and ratooning also contributed for cane juice recovery. Commercial cane sugar (CCS) and Juice purity also followed the same trend.

Yield Attributing Characters (Shoot Population and Number of Millable Canes)

Data on shoot population counts at formative and grand growth stage and number of millable canes at harvest was presented in Table 7 and results revealed that, highest shoot population counts of 1,04,557 ha^{-1} was recorded with 200% fertilizer nitrogen at formative phase and lowest shoot population counts of 95,035 ha^{-1} was recorded in 50% inorganic and 50% organic sources. However, mean shoot population at formative phase (120 days) recorded in 75% RDFN + 25% organic sources (1,02,970) were on par with 150% fertilizer nitrogen. Data clearly indicating that, conversion of shoots into millable canes was significantly highest in integrated treatments over higher doses of fertilizer nitrogen. Highest tiller mortality of 27.87% was recorded in 150% fertilizer nitrogen treatment, it was closely followed by 200% fertilizer nitrogen and lowest mortality percent of 25.19% was recorded in 50% chemical fertilizers + 50% organic sources from formative to maturity stage, whereas from grand growth to maturity stage highest mortality percentage of 12.22% was recorded in the plots with 200% fertilizer nitrogen and lowest mortality of 10.67% was recorded with integrated use of inorganic and organic nutrients.

Cane and Sugar Yields

The results presented in Table 8 and Table 9 revealed

Table: 7
Effect of different nutrient management practices on shoot population and NMC (No/ha) at different growth stages of sugarcane (2018−19)

Treatments	Formative	Grand growth	Harvest
T1: 100% RDF	95827	90924	86250
T2: 75% RDFN + KNO3 @ 1% foliar spray + cane trash *in−situ* decomposition	102970	86892	81350
T3: 50% RDFN + 25 % N though vermicompost + green manure incorporation	95035	87990	82550
T4: 150% RDFN	103952	93684	88450
T5: 200% RDFN	104557	96111	89560
T6: Farmers practice	99002	90436	86100
T7: 100% RDF + Hormonal spray	102567	92039	88950
Mean	100559	91154	86173
SEm±	2186	2047	895
CD (5%)	5835	5387	3266

Table: 8
Effect of different nutrient management practices on Cane yields (t ha^{-1}) under sugarcane multiratooning

Treatments	2013−14	2014−15	2015−16	2016−17	2017−18	2018−19	Mean
T1 − 100% recommended dose of chemical fertilizers (224:100:120 kg NPK ha^{-1})	59.60	70.50	69.38	69.05	66.47	68.70	67.28
T2 − 75% recommended dose of nitrogen fertilizers + KNO_3 @ 1% foliar spray + cane trash in situ decomposition	61.78	71.32	67.66	68.10	65.74	66.14	66.79
T3 − 50% recommended dose of nitrogen fertilizers + 25% N though trash compost + green manure incorporation	60.59	69.97	65.87	65.22	62.81	64.50	64.83
T4 − 150% recommended dose of nitrogen fertilizers	66.13	75.10	75.66	71.43	69.38	72.24	71.66
T5 − 200% recommended dose of nitrogen fertilizers	68.71	74.80	77.38	73.05	72.35	73.75	73.34
T6 − Farmers practice (only N as initial dose (250 kg N + 60 kg K in the form of urea and muriate of potash, no stubble shaving, no off bearing and no inter cultivation)	56.60	61.20	65.41	63.30	65.54	68.57	63.44
T7 − 100% recommended dose of nitrogen fertilizers + Hormonal spray *i.e.* GA @ 50 ppm	62.77	73.43	71.23	69.80	66.86	63.12	67.87
Mean	62.31	70.90	70.37	68.56	67.06	68.15	67.89
SEm±	−	2.20	−	2.74	1.47	1.65	1.39
CD 5%)	NS	5.80	NS	6.10	4.20	4.50	4.85

Table: 9
Effect of different nutrient management practices on sugar yields (t ha^{-1}) under sugarcane multiratooning

Treatments	2013−14	2014−15	2015−16	2016−17	2017−18	2018−19	Mean
T1 − 100% recommended dose of chemical fertilizers (224:100:120 kg NPK ha^{-1})	7.72	9.33	10.6	9.13	8.65	8.63	9.01
T2 − 75% recommended dose of nitrogen fertilizers + KNO_3 @ 1% foliar spray + cane trash in situ decomposition	7.48	9.31	10.5	9.15	8.71	7.78	8.82
T3 − 50% recommended dose of nitrogen fertilizers + 25% N though trash compost + green manure incorporation	7.77	9.35	10.54	8.49	8.32	7.98	8.74
T4 − 150% recommended dose of nitrogen fertilizers	8.33	9.52	11.31	9.76	8.69	8.72	9.39
T5 − 200% recommended dose of nitrogen fertilizers	8.62	9.43	10.7	9.27	9.02	8.61	9.28
T6 − Farmers Practice (only N as initial dose (250 kg N + 60 kg K in the form of urea and muriate of potash, no stubble shaving, no off bearing and no inter cultivation)	7.19	8.16	9.2	8.19	8.68	8.19	8.27
T7 − 100% recommended dose of nitrogen fertilizers + Hormonal spray *i.e.* GA @ 50 ppm	7.93	9.62	10.99	8.85	8.79	7.59	8.96
Mean	7.86	9.25	10.55	8.97	8.71	8.22	8.92
SEm±	0.22	−	0.18	0.24	−	0.19	0.28
CD 5%)	0.68	NS	0.49	0.54	NS	0.48	0.69

that the cane and sugar yields were increased with increasing levels of nitrogen up to 150% recommended dose. During first year, highest cane yield was recorded with 200% recommended dose of chemical fertilizers and on par with 150% recommended dose of chemical fertilizers, whereas during second year highest cane yield of 75.10 t ha^{-1} and sugar yield of 9.52 t ha^{-1} was recorded with 150% recommended dose of fertilizer nitrogen, however it was on par with 200% recommended dose of fertilizer nitrogen and 100% recommended dose of fertilizers + hormonal spray of gibberilic acid. The increase in cane yield with increase in nitrogen application in sugarcane was due to the increase in yield attributing characters of sugarcane. Significantly lowest cane and sugar yields were recorded with farmers practice. Integrated nutrient management treatments (75% recommended dose of fertilizer nitrogen + organics and 50% recommended dose of fertilizer nitrogen + organics) recorded at par yields with 100% recommended dose of fertilizer nitrogen. Kumar *et al.,* 2014 reported that application of 150 kg N ha^{-1} for the plant and 225 kg N ha^{-1} for the ratoon crops is required for substantial increase in cane yield and net return over without fertilizers.

4. CONCLUSIONS

To maintain the productivity of sugarcane at a high level on a long−term basis it is necessary to evolve a system whereby adequate supplies of organic manures along with chemical fertilizers can be assured without deteriorating the soil physical, chemical and biological properties. A judicious combination of inorganic and organic is a potential tool for sustaining the soil fertility in sugarcane multiratoon. Though higher yields were recorded with higher doses of chemical fertilizers, highest tiller mortality and low juice quality was observed over integrated use of organics and inorganics. It can be summarized that inclusion of different organic sources alongwith reduced doses of chemical fertilizers in sugarcane multi−ratoon system enhanced the soil physical properties, SOC and microbial activity but also adequately met the nitrogen requirement leading to at par yields with recommended dose of chemical fertilizers.

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