Indian Journal of Agronomy **62** (4): 505–509 (December 2017)

Research Paper

Cane yield and soil nutrient balance in sugarcane (*Saccharum officinarum*) plant–ratoon system under integrated nutrient management in mollisols of Uttarakhand

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Received : June 2017; Revised accepted : October 2017

ABSTRACT

A field trial was conducted during 2015–16 and 2016–17 at the NE Borlaug Crop Research Centre, Pantnagar, Uttarakhand, to study suitable integrated nutrient management module for sustaining soil health and productivity in sugarcane (*Saccharum officinarum* L.)–ratoon system. The experiment was laid out in a randomized block design with 10 treatments in 3 replications. The treatments comprised different combinations of organic sources and inorganic fertilizers along with inorganic fertilizers alone. The results revealed that application of FYM/compost @ 20 t/ha + soil test-based recommendation in both plant and ratoon crop significantly improved yield attributes and cane yield over rest of the treatments except FYM/compost @ 20 t/ha + recommended dose of fertilizer (RDF) and RDF + S + Zn. It also recorded higher cane length (439.0 and 407.4 cm), cane girth (9.6 and 9.0 cm), individual cane weight (1,268.7 and 1,175.4 g), number of millable canes (NMC) (83.6 and 75.6 thousand/ha) and cane yield (76.5 and 74.5 t/ha) in plant and ratoon crops, respectively. The net N, P and K balance in soil was found to be positive in treatments receiving integrated nutrient supply, while it was negative under application of inorganic fertilizers alone in plant and ratoon crop.

Key words : Cane yield, INM, Nutrient balance, Sugarcane, Yield attributes

Sugarcane is one of the most important cash crops in India and plays pivotal role in both agricultural and industrial economy of our country. Sugarcane is an exhaustive crop, it produces heavy tonnage and depletes more nutrients from soil. As per estimates, sugarcane crop yielding 100 t/ha removes 208, 52, 280, 30, 3.4, 1.2, 0.6 and 0.2 kg N, P, K, S, Fe, Mn and Cu respectively (Singh and Yadav, 1996). Continuous use of inorganic fertilizers and several plant protection chemicals have caused decline in the microbial activity in soil, resulting in poor soil health (Singh *et al.,* 2007). The yield of sugarcane has reached a plateau due to decline in factor productivity. The loss in organic matter is the main cause for decline in the factor productivity. To reduce continuous decline in soil fertility, it is important to use organic manure in combination with chemical fertilizers to meet adequately the nutritional requirements of sugarcane crop (Nagaraju *et al*., 2000).

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Integrated nutrient management, through balanced use of chemical fertilizers, organic manures such as farmyard manure (FYM) and biofertilizers, is considered a promising agro-technique to sustain crop yields and to restore the soil fertility. Regular inclusion of organic manures is considered to be an effective method to attain soil organic carbon (SOC) sequestration and supply of various micronutrients to crops in comparison with the application of chemical fertilizers alone (Lal, 2008). Hence, integrated nutrient-supply system is of great significance, particularly under the situation where there is negative plant available soil-nutrients balance.

Keeping the above facts in view, the present study was therefore undertaken to evaluate the effect of integrated nutrient management on yield and nutrient balance in soil.

MATERIALS AND METHODS

A field experiment was conducted during 2015–16 (planted cane) and 2016–17 (ratoon) at the N.E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, (29°N, 79°23'E, 243.84 m above mean sea level),

Uttarakhand. The soil of the experimental field was silty clay loam in texture, high in organic carbon (1.01%), low in available nitrogen (230.2 kg/ha), high in available phosphorus (43.6 kg/ha) and medium in potassium content (236.3 kg/ha). Experiment was laid out in a randomized block design with 10 treatments in 3 replications. Sugarcane variety 'Co Pant 5224' was planted in furrows at 75 cm apart on 19 February, 2015. Treatments consisted of T_1, 50% recommended dose of fertilizer (RDF) 150 kg N + 75 kg P_2O_5 + 50 kg K_2O in plant crop and 50% RDF (180 kg N + 75 kg P_2O_5 + 50 kg K_2O) + 10 t/ha trash incorporation in ratoon crop; T_2, 100% RDF in plant crop and 100% RDF + 10 t/ha trash incorporation in ratoon crop; T_3, soil test-based recommendation in plant crop and soil test based recommendation + 10 t/ha trash incorporation in ratoon crop; T_4, 20 t/ha FYM + 50% RDF to both plant and ratoon crops; T_5, 20 t/ha FYM + 100% RDF to both plant and ratoon crops; T_6, 20 t/ha FYM + soil test-based recommendation to both plant and ratoon crops; T_7, 10 t/ha FYM + biofertilizer + 50% RDF to both plant and ratoon crops; T_8, 10 t/ha FYM+ biofertilizer +100% RDF to both plant and ratoon crops; T_9, 10 t/ha FYM + biofertilizer + soil test based recommendation to both plant and ratoon crops; and T_{10}, RDF + 40 kg S/ha + 25 kg Zn/ha to both plant and ratoon crops.

Ratoon was initiated after harvesting of planted cane on 22 February 2016. Recommended dose of fertilizers applied for planted cane and ratoon were 150 : 75 : 50 and 180 : 75 : 50 kg N:P:K/ha respectively. Soil test-based recommendation is 188 : 94 : 62 kg N:P:K/ha in plant crop and 225 : 94 : 62 kg N:P:K/ha in ratoon crop. The NPK mixture and urea was used to supply nitrogen, phosphorus and potassium to the crop. Half of the N along with full P and Kwas applied basal. Remaining N was top-dressed within 90 days after the planting up to end of June in both the crops. Sulphur was supplied through elemental sulphur, zinc through zinc sulphate. Farmyard manure compost contained (0.5% N, 0.2% P_2O_5 and 0.5% K_2O). Biofertilizer [*Azotobacter* + phosphate-solubilizing bacteria (PSB)] @ 12.5 kg/ha was applied. In trash incorporation treatments, trash material of planted cane @ 10 t/ha was thoroughly applied over the ratoon field which was decomposed with *Trichoderma* culture @ 0.5 kg/t of trash. Soil samples were collected from each net plot to a depth of 0–15 cm before planting and after harvesting of the crop. The soil samples collected were air-dried in shade for a week, powdered with the help of a wooden roller and sieved. Processed soil samples were used for analysis. Plant samples of plant and ratoon crop were analyzed for determination of total N, P and K uptake by standard methods.

RESULTS AND DISCUSSION

Yield attributes and cane yield

Yield-contributing characters, viz. cane length, cane girth, individual cane weight and number of millable canes and cane yield in both plant and ratoon crops were influenced by different treatments (Table 1). Application of FYM/compost @ 20 t/ha + inorganic nutrient application based on soil test exhibited significantly higher cane length, cane girth, individual cane weight, number of millable canes and cane yield in plant and ratoon crops, over rest of the treatments, except FYM/compost @ 20 t/ha + 100% RDF and RDF + S + Zn. The increase in yield components and yield owing to conjunctive use organic with inorganic nutrient sources might be because of immediate and quick supply of nutrient through chemical fertilizers for tillers and steady supply of nutrients following 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. Because of this, the fertility status of soil might have increased and thus increasing the absorption of plant nutrients which increased the cane length, cane girth, individual cane weight and number of millable canes (NMC's) and ultimately lead to more yield. These results confirm the findings of Patil *et al*. (2012) and Kumar *et al*. (2014). They also reported higher cane yield with application of nutrients from integrated supply of organic manure with NPK as compared to NPK alone.

Nutrient uptake and balance in soil

Nitrogen uptake and balance in soil: Sugarcane is a highly nutrient-exhaustive crop as evident from nutrient removal data presented on a collective basis for plant and ratoon crops. At the end of plant-ratoon cycle, significantly higher N was removed under application of FYM/compost @ 20 t/ha + inorganic nutrient application based on soil test to both plant and ratoon crops, being statistically at par with application of FYM/compost @ 20 t/ha + 100% RDF in both plant and ratoon crop, while the lowest N was removed under application of 50% RDF in plant and 50% RDF + trash @ 10 t/ha in ratoon crop. The increase in N uptake was attributed to increased availability of N to the plants under these treatments due to integrated nutrient supply. The net N balance was found to be more negative under application of inorganic fertilizers alone in plant and ratoon crop, whereas it was positive in all other treatments with integrated nutrient supply. The highest net gains of 12.4 and 9.9 kg N/ha was recorded with application of FYM/Compost @ 20 t/ha + inorganic nutrient application based on soil test and application of FYM/compost @ 20 t/ha + 100% RDF respectively (Table 2). The

Table 1. Effect of integrated nutrient management on yield attributes, yield of sugarcane plant and ratoon crops

Treatment: Plant	Treatment: Ratoon	Cane length (cm)		Cane girth (cm)		Individual cane weight (g)		Number of millable canes (000/ha)		Cane yield (t/ha)	
		Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
T_1, 50% RDF	50% RDF + trash @ 10 t/ha	367.7	330.2	8.0	7.8	806.7	748.6	74.7	63.8	66.8	62.9
T_2, 100% RDF	100% RDF + trash @ 10 t/ha	371.7	335.3	8.2	8.0	833.3	784.2	74.7	64.4	68.3	65.5
T_3, NPK on soil test-based recommendation	Trash @ 10 t/ha + NPK on soil-test basis	378.3	337.7	8.3	8.0	836.7	786.3	75.3	66.6	70.9	67.6
T_4, FYM @ 20 t/ha + 50% RDF	FYM @ 20 t/ha + 50% RDF	403.3	381.4	8.5	8.4	1,063.3	998.7	78.6	70.0	72.4	69.8
T_5, FYM @ 20 t/ha + 100% RDF	FYM @ 20 t/ha + 100% RDF	423.3	400.2	9.4	9.2	1,225.3	1,160.3	83.3	74.5	78.5	73.7
T_6, FYM @ 20 t/ha + NPK on soil-test basis	FYM @ 20 t/ha + NPK on soil-test basis	439.0	407.4	9.6	9.0	1,268.7	1,175.4	83.6	75.6	78.8	74.5
T_7, FYM @ 10 t/ha + biofertilizer + 50% RDF	FYM @ 10 t/ha + biofertilizer + 50% RDF	381.7	372.6	8.4	8.3	856.7	803.6	77.2	68.3	71.2	68.3
T_8, FYM @ 10 t/ha + biofertilizer + 100% RDF	FYM @ 10 t/ha + biofertilizer + 100% RDF	405.0	391.0	8.5	8.5	1,080.0	1,032.5	78.6	71.1	73.4	70.3
T_9, FYM @ 10 t/ha + biofertilizer + NPK on soil-test basis	FYM @ 10 t/ha + biofertilizer + NPK on soil-test basis	390.0	375.5	8.4	8.3	926.7	876.3	77.9	68.9	71.3	68.7
T_{10}, RDF + 40 kg S + 25 kg $ZnSO_4$	RDF + 40 kg S + 25 kg $ZnSO_4$	416.7	394.3	9.3	9.0	1165.0	1086.8	80.0	72.8	77.7	72.8
SEm±		9.5	8.5	0.3	0.3	36.1	5.8	1.5	2.2	0.8	1.3
CD (P=0.05)		28.4	25.4	0.8	0.9	107.1	17.3	4.5	6.5	2.4	3.9

RDF, Recommended dose of fertilizers

gain in availability of N in soil due to application of FYM was due to addition of N through FYM in addition to native N of soil. The temporary biological immobilization and continuous mineralization of FYM on surface layer of soil was responsible for higher post-harvest N availability.

Phosphorus uptake and balance in soil: Total uptake of P was the highest (60.4 kg/ha) under application of FYM/compost @ 20 t/ha + inorganic nutrient application based on soil test to both plant and ratoon crops, which was at par with application of FYM/compost @ 20 t/ha + 100% RDF in both plant and ratoon crop (Table 3). However, lowest P uptake by both plant and ratoon crops was observed under (50% RDF in plant and 50% RDF + trash @ 10 t/ha in ratoon crop). Above-mentioned treatments recorded higher P uptake due to more root biomass which in turn was due to more P supply from integrated nutrient source, as P favours the development of more and vigorous root growth. Thus, higher root mass resulted in absorbing more phosphorus and other nutrients also such as N, K etc. At end of plant-ratoon cycle, the highest net gain of 2.2 kg P/ha was found with application of FYM/compost @ 20 t/ha + inorganic nutrient application based on soil test, followed by 1.1 kg P/ha under application of FYM/compost @ 20 t/ha + 100% RDF (Table 3). Negative net balance of phosphorus was recorded with rest of the treatments except these 2 treatments. Integration of FYM with inorganic fertilizer recorded higher net gain owing to incorporation of FYM, which reduced the fixation of water-soluble P and increased the mineralization of organic P due to microbial action leading to higher gain of P in FYM added plots.

Potassium uptake and balance in soil: Uptake of K was significantly higher under application of FYM/compost @ 20 t/ha + inorganic nutrient application based on soil test in both plant and ratoon crops, being at par with application of FYM/compost @ 20 t/ha + 100% RDF in both plant and ratoon crops (Table 4). However, application of 50% RDF in plant and 50% RDF + trash @ 10 t/ha in ratoon crop showed the lowest K uptake. The highest net gain of 14.3 kg K/ha in soil was recorded with application of FYM/compost

Table 2. Effect of integrated nutrient management on nitrogen balance in soil after harvesting of plant and subsequent ratoon crop

Treatment		Initial soil N status (kg/ha)	N added (kg/ha)	N uptake by plant + ratoon (kg/ha)	Soil N status after harvesting of ratoon (kg/ha)	Soil N balance (kg/ha)
Plant crop	Ratoon crop					
T_1, 50% RDF	50% RDF + trash @ 10 t/ha	230.2	165	279.2	206.7	–23.5
T_2, 100% RDF	100% RDF + trash @ 10 t/ha	230.2	330	299.9	209.3	–20.9
T_3, NPK on soil test-based recommendation	Trash @ 10 t/ha + NPK on soil-test basis	230.2	413	306.9	209.7	–20.5
T_4, FYM @ 20 t/ha + 50% RDF	FYM @ 20 t/ha + 50% RDF	230.2	365	380.5	238.8	8.6
T_5, FYM @ 20 t/ha + 100% RDF	FYM @ 20 t/ha + 100% RDF	230.2	530	411.2	240.1	9.9
T_6, FYM @ 20 t/ha + NPK on soil-test basis	FYM @ 20 t/ha + NPK on soil-test basis	230.2	613	419.2	242.6	12.4
T_7, FYM @10 t/ha + biofertilizer + 50% RDF	FYM @ 10 t/ha + biofertilizer + 50% RDF	230.2	265	349.3	231.2	1.0
T_8, FYM @ 10 t/ha + biofertilizer + 100% RDF	FYM @ 10 t/ha + biofertilizer + 100% RDF	230.2	430	374.0	233.3	3.1
T_9, FYM @ 10 t/ha + biofertilizer + NPK on soil test basis	FYM @ 10 t/ha + biofertilizer + NPK on soil-test basis	230.2	513	367.2	235.4	5.2
T_{10}, RDF + 40 kg S + 25 kg $ZnSO_4$	RDF + 40 kg S + 25 kg $ZnSO_4$	230.2	330	368.4	210.0	–20.2
SEm±		–	–	3.6	0.9	–
CD (P=0.05)		–	–	10.8	2.7	–

RDF, Recommended dose of fertilizers

Table 3. Effect of integrated nutrient management on phosphorous balance in soil after harvesting of plant and subsequent ratoon crop

Treatment		Initial soil P status (kg/ha)	P added (kg/ha)	P uptake by plant + ratoon (kg/ha)	Soil P status after harvesting of ratoon (kg/ha)	Soil P balance (kg/ha)
Plant crop	Ratoon crop					
T_1, 50% RDF	50% RDF + trash @ 10 t/ha	43.6	75	41.0	36.4	–7.2
T_2, 100% RDF	100% RDF + trash @ 10 t/ha	43.6	150	43.7	37.3	–6.3
T_3, NPK on soil test-based recommendation	Trash @ 10 t/ha + NPK on soil-test basis	43.6	188	44.5	38.3	–5.3
T_4, FYM @ 20 t/ha + 50% RDF	FYM @ 20 t/ha + 50% RDF	43.6	155	55.4	43.5	–0.1
T_5, FYM @ 20 t/ha + 100% RDF	FYM @ 20 t/ha + 100% RDF	43.6	230	59.2	44.7	1.1
T_6, FYM @ 20 t/ha + NPK on soil-test basis	FYM @ 20 t/ha + NPK on soil-test basis	43.6	268	60.4	45.8	2.2
T_7, FYM @10 t/ha + biofertilizer + 50% RDF	FYM @ 10 t/ha + biofertilizer + 50% RDF	43.6	115	50.7	40.9	–2.7
T_8, FYM @ 10 t/ha + biofertilizer + 100% RDF	FYM @ 10 t/ha + biofertilizer + 100% RDF	43.6	190	55.0	41.1	–2.5
T_9, FYM @ 10 t/ha + biofertilizer + NPK on soil test basis	FYM @ 10 t/ha + biofertilizer + NPK on soil-test basis	43.6	228	53.4	42.5	–1.1
T_{10}, RDF + 40 kg S + 25 kg $ZnSO_4$	RDF + 40 kg S + 25 kg $ZnSO_4$	43.6	150	54.1	38.8	–4.8
SEm±	–	–	1.1	0.8	–	
CD (P=0.05)	–	–	3.3	2.3	–	

RDF, Recommended dose of fertilizers

Table 4. Effect of integrated nutrient management on potassium balance in soil after harvest of plant and subsequent ratoon crop

	Treatment: Plant crop	Treatment: Ratoon crop	Initial soil K status (kg/ha)	K added (kg/ha)	K uptake by plant + ratoon (kg/ha)	Soil K status after harvesting of ratoon (kg/ha)	Soil K balance (kg/ha)
T_1,	50% RDF	50% RDF + trash @ 10 t/ha	236.3	50	378.0	215.8	–20.5
T_2,	100% RDF	100% RDF + trash @ 10 t/ha	236.3	100	397.7	216.5	–19.8
T_3,	NPK on soil test-based recommendation	Trash @ 10 t/ha + NPK on soil-test basis	236.3	124	406.3	217.1	–19.2
T_4,	FYM @ 20 t/ha + 50% RDF	FYM @ 20 t/ha + 50% RDF	236.3	250	520.8	245.7	9.4
T_5,	FYM @ 20 t/ha + 100% RDF	FYM @ 20 t/ha + 100% RDF	236.3	300	552.4	249.0	12.7
T_6,	FYM @ 20 t/ha + NPK on soil-test basis	FYM @ 20 t/ha + NPK on soil-test basis	236.3	324	563.1	250.6	14.3
T_7,	FYM @10 t/ha + biofertilizer + 50% RDF	FYM @ 10 t/ha + biofertilizer + 50% RDF	236.3	150	476.2	237.3	1.0
T_8,	FYM @ 10 t/ha + biofertilizer + 100% RDF	FYM @ 10 t/ha + biofertilizer + 100% RDF	236.3	200	510.6	240.6	4.3
T_9,	FYM @ 10 t/ha + biofertilizer + NPK on soil test basis	FYM @ 10 t/ha + biofertilizer + NPK on soil-test basis	236.3	224	500.2	242.2	5.9
T_{10},	RDF + 40 kg S + 25 kg $ZnSO_4$	RDF + 40 kg S + 25 kg $ZnSO_4$	236.3	100	499.6	218.8	–17.5
	SEm±		–	–	6.2	1.1	–
	CD (P=0.05)		–	–	18.5	3.2	–

@ 20 t/ha + inorganic nutrient application based on soil test (Table 4), followed by application of FYM/compost @ 20 t/ha + 100% RDF (12.7 kg K/ha). This may be due to some release of K from reserve pool of soil by the FYM. Positive balance of N, P and K in soil at the end of plant-ratoon crop cycle revealed soil fertility-enriching effect of various integrated nutrient-management strategies, indicating adequate availability of N, P and K nutrients to ensure remunerative crop production. These results are in conformity with the findings of Tyagi *et al*. (2011) and Kumar (2012), who also recorded higher uptake of nutrients and positive nutrient balance under integrated nutrient supply.

It was concluded that application of FYM/compost @ 20 t/ha + inorganic nutrient application based on soil test in both plant and ratoon crops improved yield attributes and cane yield, being at par with FYM/compost @ 20 t/ha + RDF and RDF + S + Zn. Application of FYM/compost @ 20 t/ha + inorganic nutrient application based on soil test or 100% RDF also recorded significantly higher total N, P and K uptake by crop. It also improved soil health in terms of positive N, P and K balance in soil.

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