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Influence of fertilizer application methods, fertilizer levels and split application of potassium cane yield and nutrient uptake in sugarcane

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Abstract
In plant and ratoon crop ploughsole method along with vermicompost recorded significantly higher cane yield (113.06 and 99.75 t ha^{-1} respectively), organic carbon (0.43 and 0.41 %), nitrogen uptake (258.15 and 197.99 kg ha^{-1} respectively), phosphorus uptake (27.25 and 22.75.72 kg ha^{-1} respectively) and potassium uptake (216.69 and 180.48 kg ha^{-1} respectively) compared to farmers practice of surface broadcasting. Application of 100 % RDF higher cane yield in plant and ratoon crop (122.60 and 109.21 t ha^{-1} respectively), organic carbon (0.47 and 0.44 % respectively), nitrogen uptake (313.22 and 212.17 kg ha^{-1} respectively), phosphorus uptake (33.12 and 24.88 kg ha^{-1} respectively) and potassium uptake (284.93 and 214.15 kg ha^{-1} respectively) than applying 75 and 50 % RDF in plant and ratoon crop. Split application of potassium 50 % as basal and 50 % at earthing up recorded significantly higher cane yield (109.51 and 95.79 t ha^{-1} respectively), organic carbon (0.43 and 0.46 % respectively), nitrogen uptake (232.54 and 167.89 kg ha^{-1} respectively), phosphorus uptake (24.44 and 19.59 kg ha^{-1} respectively) and potassium uptake (207.32 and 165.73 kg ha^{-1} respectively) than entire potassium as basal. Among all treatment combinations, application of 100 % RDF along with vermicompost in plough sole method and potassium 50 % as basal and 50 % at earthing up recorded the higher cane yield (142.84 and 117.40 t ha^{-1} respectively), organic carbon (0.51 and 0.48 % respectively), nitrogen uptake (434.72 and 282.15 kg ha^{-1} respectively), phosphorus uptake (48.26 and 34.27 kg ha^{-1} respectively) and potassium uptake (382.20 and 272.09 kg ha^{-1} respectively).

Keywords: Uptake fertilizer application, fertilizers level, potassium

Introduction
The challenge of feeding an ever increasing population coupled with the changing environmental situation demands concerted efforts to address the food and nutritional insecurity of the nation. In agricultural sector, sugarcane plays a key role in Indian economy by contributing more to the national income through excise duty and payment to cane growers. India's share in the world sugar production was 17 per cent in 2014-15 (Singh and Katiyar, 2016). Sugarcane farmers are normally practicing surface broadcasting method of fertilizer application with low nutrient use efficiency except in drip irrigation. Fertilizer application is one of the important agronomic practices which highly influence the rapid growth of sugarcane plants. Proper time, quantity and frequency of application were important information which farmers should follow, when they apply fertilizer.

Most of the sugarcane growing soils are generally deficit in nitrogen and medium in phosphorus, potassium which needs their replenishment. Optimum application of fertilizer in appropriate methods is a key to success in increasing sugarcane productivity, production and increasing the nutrient use efficiency by avoiding losses. Furrow application of fertilizers at the time of planting using planters has been found to be effective. But applications of fertilizer even by these methods do not distribute fertilizer evenly as per the needs of plant roots. Placement of fertilizer in bands increases the concentration of nutrients in specific root zones which reduces the risk of fixation by decreasing the soil contact area and increases their availability to the plants. For maximum efficiency of applied fertilizer, it is essential to arrange the flow of nutrients to the roots of the plants at a rate which is sufficient for maximum uptake as per crop demand. By increasing the fertilizer use efficiency, the same level of yield could be obtained with lower amount of fertilizer.

All farmers does not have complete knowledge about the requirements of chemical fertilizers and time of fertilizer application. As per Bhingardeve *et al.* (2013), Soil testing was not adopted by 80 per cent of farmers for nutrient management. Sixty per cent of farmers in India are not adopting the proper time and quantity of fertilizer application for all the planting season sugarcane. But due to the poor knowledge fertilizer application was adopted by only 24 % of farmers. Since the fertilizers are too costly and involve heavy investment, they have to be properly managed efficiently to increase fertilizer use efficiency at present which is very poor.

Materials and methods

A field experiment was conducted during the seasons of 2014-15 and 2015–16 at Agricultural Research Farm of S. Nijalingappa Sugar Institute (SNSI) Belagavi, which lies in Northern Transitional Zone of Karnataka (Zone-8). The experimental site located at 15° 46' 03.8" North latitude and 74° 29' 16.27" East longitude with an altitude of 534 m above the mean sea level. The soil of the experimental site was medium deep black soil, order vertisols, low in organic carbon (0.41 %) and available N (276.23 kg ha^{-1}), medium in available P (30.98 kg ha^{-1}) and available K (244.46 kg ha^{-1}). The experiment was laid out in split- split plot design with three methods of fertilizer application in main plots, three fertilizer levels in sub plots and split application of potassium in sub – sub plots for plant and ratoon crops. In both the experiments of plant and ratoon crop, NPK, were applied in the form of urea, Di-ammonium phosphate, and muriate of potash. Fertilizers were applied to plots as per the treatment combinations. The nitrogen was applied in four splits as per recommendation in plant crop. *i.e.* basal (10 %), 6th week (20 %), 10th week (30 %) and 14th week (40 %) after planting and entire phosphorus as basal dose and potassium was applied in two splits 50 % as basal and 50 % at the time of earthing up showed below.

Fertilizer dose and split application nitrogen for plant crop					
Fertility levels (RDF)	**Nitrogen (Kg ha^{-1})**				
	Basal (10 %)	**2nd split (6th week) (20 %)**	**3rd split (10th week) (30 %)**	**4th split (14th) (40 %)**	**Total (100 %)**
F_1	12.5	25.0	37.5	50.0	125.0
F_2	18.7	37.4	56.14	64.8	187.5
F_3	25.0	50.0	75.0	100	250.0

For ratoon crop, same amount of phosphorous and potassium, but 25 per cent of extra nitrogen was applied in similar method as applied to plant cane crop. Nitrogen was applied in three splits *viz.*, 30 per cent after one month of ratoon initiation and remaining nitrogen in two equal splits at 8th week (35 %) and 12th week (35 %). While 50 per cent potassium was applied at one month after ratoon initiation and remaining 50 per cent of potassium was applied at 12th week after ratoon initiation. The fertilizers were incorporated into the soil as per main plot treatments by using bullock drawn desi plough.

Fertilizer dose and split application nitrogen for ratoon crop				
Fertility levels	**Nitrogen (Kg ha^{-1})**			
	Basal One month after ratooning initiation (30 %)	**1st split (8th week) (35 %)**	**2nd split (12th week) (35 %)**	**Total (100 %)**
F_1	46.8	54.7	54.7	156.2
F_2	70.2	81.9	81.9	234.0
F_3	93.7	109.4	109.4	312.5

Results and discussion

Cane yield of sugarcane was significantly influenced by methods of fertilizer application (Table 4). Significantly higher cane yield was recorded in ploughsole method with vermicompost in plant (113.56 t ha^{-1}) and ratoon crop (99.75 t ha^{-1}) than ploughsole method in plant (106.18 t ha^{-1}) and ratoon crop (94.31 t ha^{-1}) over only surface application which recorded significantly lower cane yield in both plant (99.78 t ha^{-1}) and ratoon (88.01 t ha^{-1}) crop. Earlier reports of Serigio *et al.*, 2016 and Mandal and Thakur, 2010, also indicated increased cane yield due to sub soiling-cum-deep fertilizer placement method to the extent of 15.9 per cent over control. Higher yield of cane in ploughsole method with vermicompost might have been due to reduced losses of nutrients as a result of deep placement and greater adsorption of nutrients by the organic colloid of vermicompost. Lower yield in surface application might be due to nutrient stress as a result of higher losses and fixation of nutrients in soil there by reducing nutrient availability and adversely affecting yield attributing parameters and thus the yield.

The results revealed that higher cane yield was obtained with higher fertilizer dose 100 per cent RDF (122.60 and 109.21 t ha^{-1} in plant and ratoon crop) over the lower fertilizer levels. Significantly lower cane yield was observed in absolute control (53.57 and 41.40 t ha^{-1} in plant and ratoon crop). The increment in cane yield of plant and ratoon crop was to the tune of 33.59 and 41.59 per cent and 16.59 and 14.09 per cent over 50 per cent and 75 per cent RDF, respectively. Crop nutrient requirement for attaining higher yield could not be met from native soil fertility as sugarcane producing 100 t ha^{-1} removes 207, 30 and 233 kg N, P_2O_5 and K_2O, respectively (Jagtap *et al*., 2006) thus addition of 100 per cent RDF might have improved the nutrient status in term of nitrogen, phosphorous and potassium in soil. Nitrogen is essential for plant cell division, directly involved in photosynthesis, necessary component of vitamins, aids in production and use of carbohydrates, affects energy reactions in the plant necessary for formation of amino acids and the building blocks of protein. It had direct influence on number of leaves, cane height and number of tillers, which tends to increase with increase in nitrogen levels up to optimum level and in turn affects cane yield. These significant roles played by primary nutrients might have accounted for higher cane and sugar yield.

Sugarcane being a long duration crop with C_4 metabolism produces very heavy biomass and demands large amounts of nutrients and sunlight for its optimum productivity. The present study showed that, significantly higher amount of nutrients were removed in ploughsole method with vermicompost in plant crop (258.15, 27.25 and 216.69 kg NPK ha^{-1}) in ratoon crop, (197.99, 22.75 and 180.48 kg NPK ha^{-1}) than only plough sole method in plant crop (219.27, 22.25 and 204.85 kg NPK ha^{-1}) in ratoon crop, (156.66, 17.56 and 163.26 kg NPK ha^{-1}) as compared to surface application (Table 36, 37). The applied fertilizer along with vermicompost in ploughsole layer was highly effective as it was evidenced by more nitrogen uptake as compared to surface application. On the contrary, due to more volatilization and other losses, less nutrient uptake as observed in surface application method. Simple correlation study indicated that, significant and positive correlation were observed between cane yield and nutrient uptake, nitrogen (r = 0.989, 0.973, respectively) and potassium (r = 0.988, 0.979, respectively). It was also evident by recording higher correlation values of fertilizer use efficiency, agronomic efficiency, and nutrient use efficiencies (Table 40 and 41). The higher nutrient uptake could be attributed to greater in total dry matter production and crop growth rate in plough sole methods with and without vermicompost than surface application. Ploughsole method with vermicompost in plant and ratoon crop recorded higher agronomic efficiency (323.6 and 252.3 kg kg^{-1} N, respectively), FUE (307.4 and 240.1 kg kg^{-1} NPK, respectively) followed by only ploughsole method and surface application method. Ploughsole method in combination of organics (vermicompost) can be a more efficient means of applying fertilizers, particularly nitrogen and potassium, so that nutrient application rates could be reduced by increasing their efficiency in long duration crops. These findings are in close agreement with Jadhav *et al.* (2005) who observed pocket application of fertilizers gives better response over surface application of fertilizers in sugarcane also Stevens *et al*. (2011) in sugarbeet band placement had shown positive response compared to broadcasting.

Improved growth components, yield attributes and yield of sugarcane might be interpreted as the manifestation of higher nutrient uptake by the crop. The Application of higher quantity of nutrients in 100 per cent RDF resulted in significantly higher nutrient uptake (Table 36 & 37) in plant crop (313.22, 33.12 and 284.93 NPK ha^{-1} respectively) and in ratoon crop (212.17, 24.88 and 214.15 kg NPK ha^{-1}, respectively) compared to respective lower fertilizer levels and absolute control. The nutrient uptake is a function of yield and nutrient concentration in plant. It was due to fact that added nutrients increased the N, P and K concentration in sugarcane, by providing balanced nutritional environment inside the plant and higher photosynthetic efficiency, which favored higher dry matter accumulation, resulting in more uptakes of N, P and K by sugarcane. Thus, significant improvement in uptake of nitrogen, phosphorus and potassium might be attributed to their increased concentration in plant under elevated fertility levels. Higher nutrients uptake by crop might be due to the assured supply of balanced nutrition for longer period that led to increased availability of nutrient and with production of higher yield which leads to removal huge quantity of nutrients. These results confirm the findings of Bangar *et al.* (1995), Rana *et al.* (2003), Kumar *et al*. (2004), and Khokar and Nepaliya (2010) in wheat. Total uptake of nutrients in sugarcane also followed the trend similar to uptake by sugarcane.

The improved yield and yield attributes due to good growth attributes are mainly due to higher nutrient uptake (Table 36 and 37). Split application of potassium 50 per cent as basal and 50 per cent at earthing up in plant and ratoon crop recorded higher uptake of nitrogen (232.54 and 167.89 kg ha^{-1}, respectively), phosphorus (24.44 and 19.51 kg ha^{-1} respectively) and potassium (207.32 and 165.73 kg ha^{-1} respectively) over surface application due to continuous supply of required nutrients in larger amounts and higher efficiency of applied nutrients with greater absorption of plant nutrients. Similarly Mandal and Thakur (2010), reported that 80 per cent of sugarcane roots grow up to a depth of 400 mm and 20 per cent go beyond. Therefore, application of fertilizers in differential rate of placements with sub soiling would give greater uptake of nutrients and increased sugarcane yield. Correlation study (Table 53) also indicated positive and significant correlation between cane yield with N and K uptake (r = 0.999 of both plant and ratoon).

Mineral nutrition plays a very important role in growth and productivity of any crop. The differences in cane yield among the treatments were also due to differential uptake of nitrogen and potassium nutrients (r = 0.962, 0.976 and 0.966, 0.980 in plant and ratoon crop, respectively). Significantly higher N uptake (434.72 and 282.15 kg ha^{-1} in plant and ratoon crop, respectively), P (48.26 and 34.47 kg ha^{-1} in plant and ratoon crop, respectively) and K (382.20 and 272.09 kg ha^{-1} in plant and ratoon crop, respectively) were recorded with ploughsole method with vermicompost with 100 per cent RDF and split application of potassium over RPP and other treatment combinations (Table 36 & 37). The higher nutrient uptake in $M_3F_3K_2$ could be attributed to higher plant population and total dry matter production than in $M_1F_1K_1$. Decrease in total NPK uptake was observed in surface application which might have reduced nitrate reductase activity, nitrification and P diffusion through the soil to root surface besides loss of nutrients through leaching and volatilization. Similar results were reported by Shukla *et al*. (2015), Navnit *et al.* (2012) and Kumar (2005).

Table 1: Monthly meteorological data during plant crop in 2014-15 against the normal at Belagavi.

Months	Rainfall (mm)		Maximum temperature (^{0}C)		Minimum temperature (^{0}C)	
	Normal	2014-2015	Normal	2014-2015	Normal	2014-2015
December 2014	4.9	16.5	29.3	26.4	13.9	
January-2015	1.1	0.0	30.1	29.2	14.0	13.3
February-2015	2.1	0.0	32.2	32.8	15.1	14.4
March-2015	10.6	27.2	35.0	33.7	18.0	16.9
April-2015	44.9	19.0	35.7	35.2	19.5	20.3
May-2015	86.4	146.9	34.0	34.6	20.6	21.6
June-2015	157.2	192.1	27.5	29.3	20.6	21.5
July-2015	262.7	79.2	25.2	28.4	19.8	21.2
August-2015	150.3	71.2	25.6	28.4	19.4	20.6
September-2015	103.3	42.1	27.0	30.5	19.0	20.5
October-2015	114.0	105.8	30.1	31.1	18.6	20.2
November-2015	33.3	7.0	29.3	30.7	17.1	18.7
December-2015	4.9	2.3	29.3	29.9	13.9	17.1
Total/Aver	975.7	702.8				

Table 2: Monthly meteorological data during ratoon crop in 2015-16 against the normal at Belagavi.

Months	Rainfall (mm)		Maximum temperature (^{0}C)		Minimum temperature (^{0}C)	
	Normal	2015-2016	Normal	2016	Normal	2016
January-2016	1.1	0.0	30.1	27.9	14.0	16.0
February-2016	2.1	0.0	32.2	25.0	15.1	19.1
March-2016	10.6	23.0	35.0	32.9	18.0	20.7
April-2016	44.9	16.4	35.7	34.3	19.5	21.3
May-2016	86.4	67.2	34.0	31.7	20.6	21.1
June-2016	157.2	180.5	27.5	25.9	20.6	20.1
July-2016	262.7	402.6	25.2	23.5	19.8	19.4
August-2016	150.3	306.4	25.6	23.5	19.4	19.1
September-2016	103.3	123.9	27.0	24.8	19.0	18.7
October-2016	114.0	26.9	30.1	27.0	18.6	18.0
November-2016	33.3	21.3	29.3	27.9	17.1	15.9
Total/Aver	975.7	1168.2				

Table 3: Physical and chemical properties of the soils of the experimental site

Sl No.	Particulars of analysis	Analysi values	Unit	Methodology	Authors	Remarks
	I Mechanical analysis					
1	Coarse sand	44.38	Percentage	International pipette method	(Piper, 1956)	
2	Silt	18.42				
3	Clay	37.20				
	II Chemical analysis					
1	pH (1:2.5)	6.65		pH meter method	(Jackson,1973)	Acidic
2	Electrical conductivity	0.087	(dS m^{-1})	Conductivity bridge	(Jackson, 1973)	Normal
3	Organic carbon	0.41	Percentage	Wet oxidation method	(Walkley and Black, 1934)	Low
4	Available nitrogen	276.23	Kg ha^{-1}	Alkaline permanganate method	(Subbiah and Asija, 1956)	Low
5	Available phosphorus	30.98		Brays No. 1 extracted method	(Jackson, 1973)	Medium
6	Available potassium	244.46		Flame photometric method	(Jackson, 1973)	Medium

Table 4: Cane yield (t ha^{-1}) at harvest in plant and ratoon sugarcane as influenced by methods of fertilizer application, fertilizer levels and split application of potassium

Treatment		Plant crop				Ratoon crop			
Methods	K split	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
M_1	K_1	87.32	97.76	112.40	99.16	68.95	88.66	101.67	86.43
	K_2	89.59	98.20	113.40	100.40	73.19	91.28	104.33	89.60
	Mean	88.46	97.98	112.90	99.78	71.07	89.97	103.00	88.01
M_2	K_1	90.02	98.91	118.92	102.62	76.83	93.50	109.37	93.23
	K_2	90.76	109.73	128.75	109.75	78.77	95.87	111.53	95.39
	Mean	90.39	104.32	123.84	106.18	77.80	94.68	110.45	94.31
M_3	K_1	95.70	111.23	119.26	108.73	80.49	99.89	110.98	97.12
	K_2	97.24	115.09	142.84	118.39	84.61	105.13	117.40	102.38
	Mean	96.47	113.16	131.05	113.56	82.55	102.51	114.19	99.75
Mean of K_1		91.01	102.63	116.86	103.50	75.42	94.02	107.34	92.26
Mean of K_2		92.53	107.67	128.33	109.51	78.86	97.43	111.09	95.79

	Plant crop				Ratoon crop			
Mean (F)	91.77	105.15	122.60		77.14	95.72	109.21	
RPP	129.85				113.22			
Absolute control	53.57				41.40			
Source of variation	S.Em±		C.D. (P = 0.05)		S.Em±		C.D. (P = 0.05)	
Methods	0.32		1.27		0.14		0.57	
Fertilizer levels	0.57		1.74		0.29		0.88	
K splits	0.50		1.47		0.20		0.61	
M X F	0.98		3.02		0.50		1.53	
M X K	0.86		2.55		0.35		1.05	
F X K	0.86		2.55		0.35		1.05	
M X F X K	1.49		4.41		0.61		1.82	
Rest v/s Control	1.37		3.94		0.73		2.08	

Main plot: Method of fertilizer application (M)
M_1= Surface application of fertilizer (Farmers practice)
M_2= Plough sole method of fertilizer application
M_3= Plough sole method with VC (1:1 RDF and VC)

Sub plot: Fertilizer Level (F)
F_1= 50 % RDF (125: 37.5: 95 kg N, P_2O_5, K_2O/ ha) = 258 kg NPK
F_2= 75 % RDF (187.75: 56.25: 142.5 N, P_2O_5, K_2O/ha) = 386 kg NPK
F_3= 100 % RDF (250:75:190 kg N, P_2O_5, K_2O/ ha) = 515 kg NPK

Sub- sub plot: Split application of potassium (K)
K_1= 100 % K at basal
K_2= 50 % K at basal & 50 % K at the time of earthing up (98 DAP)
RPP= Recommended package of practice

Control plots: C_1 = RPP (25 tons FYM/ha and RDF 250:75:190 kg N, P_2O_5, K_2O/ ha); C_2= Absolute control (00:00:00 kg N, P_2O_5, K_2O/ ha); VC = Vermicompost; F_3=515 kg NPK and 515 kg VC

Table 5: pH and EC (d Sm^{-1}) of soil at harvest in plant and ratoon sugarcane as influenced by methods of fertilizer application, fertilizer levels and split application of potassium.

Treatment		Plant crop								Ratoon crop							
		pH				EC				pH				EC			
Methods	K split	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
M_1	K_1	6.51	6.66	6.72	6.63	0.050	0.080	0.102	0.077	5.39	5.49	5.53	5.47	0.056	0.077	0.083	0.072
	K_2	6.57	6.67	6.75	6.66	0.062	0.080	0.109	0.084	5.42	5.49	5.54	5.48	0.062	0.080	0.084	0.075
	Mean	6.54	6.66	6.73	6.64	0.056	0.080	0.105	0.080	5.41	5.49	5.54	5.48	0.059	0.079	0.084	0.074
M_2	K_1	6.62	6.68	6.78	6.69	0.062	0.080	0.113	0.085	5.47	5.51	5.54	5.51	0.062	0.080	0.085	0.076
	K_2	6.63	6.70	6.94	6.76	0.066	0.086	0.121	0.091	5.48	5.51	5.57	5.52	0.064	0.080	0.088	0.077
	Mean	6.63	6.69	6.86	6.72	0.064	0.083	0.117	0.088	5.48	5.51	5.56	5.51	0.063	0.080	0.087	0.077
M_3	K_1	6.64	6.70	6.82	6.72	0.067	0.088	0.115	0.090	5.48	5.51	5.55	5.51	0.066	0.080	0.086	0.077
	K_2	6.65	6.71	7.03	6.80	0.068	0.100	0.144	0.104	5.48	5.52	5.57	5.52	0.067	0.080	0.090	0.079
	Mean	6.64	6.71	6.93	6.76	0.068	0.094	0.130	0.097	5.48	5.52	5.56	5.52	0.067	0.080	0.088	0.078
Mean of K_1		6.59	6.68	6.77	6.68	0.060	0.083	0.110	0.084	5.45	5.50	5.54	5.50	0.061	0.079	0.085	0.075
Mean of K_2		6.62	6.69	6.91	6.74	0.065	0.089	0.124	0.093	5.46	5.51	5.56	5.51	0.064	0.080	0.087	0.077
Mean (F)		6.60	6.69	6.84		0.063	0.086	0.117		5.45	5.51	5.55		0.063	0.080	0.086	
RPP		6.86				0.116				5.55				0.088			
Absolute control		6.40				0.050				5.36				0.050			
Source of variation		S.Em.±		C.D. (P = 0.05)		S.Em.±		C.D. (P = 0.05)		S.Em.±		C.D. (P = 0.05)		S.Em.±		C.D. (P = 0.05)	
Methods		0.006		0.024		0.0005		0.002		0.008		0.031		0.0001		0.0004	
Fertilizer levels		0.006		0.019		0.0004		0.001		0.008		0.025		0.0002		0.0005	
K splits		0.004		0.013		0.0002		0.001		0.006		0.019		0.0001		0.0002	
M X F		0.011		0.033		0.0007		0.002		0.014		0.043		0.0003		0.0009	
M X K		0.008		0.023		0.0003		0.001		0.011		0.033		0.0001		0.0004	
F X K		0.008		0.023		0.0003		0.001		0.011		0.033		0.0001		0.0004	
M X F X K		0.013		0.039		0.0005		0.001		0.019		0.058		0.0002		0.0006	
Rest v/s Control		0.019		0.054		0.0008		0.002		0.058		0.167		0.0007		0.0020	

Main plot: Method of fertilizer application (M)
M_1= Surface application of fertilizer (Farmers practice)
M_2= Plough sole method of fertilizer application
M_3= Plough sole method with VC (1:1 RDF and VC)

Sub plot: Fertilizer Level (F)
F_1= 50 % RDF (125: 37.5: 95 kg N, P_2O_5, K_2O/ ha) = 258 kg NPK
F_2= 75 % RDF (187.75: 56.25: 142.5 N, P_2O_5, K_2O/ha) = 386 kg NPK
F_3= 100 % RDF (250:75:190 kg N, P_2O_5, K_2O/ ha) = 515 kg NPK

Sub- sub plot: Split application of potassium (K)
K_1= 100 % K at basal
K_2= 50 % K at basal & 50 % K at the time of earthing up (98 DAP)
RPP= Recommended package of practice

Control plots: C_1 = RPP (25 tons FYM/ha and RDF 250:75:190 kg N, P_2O_5, K_2O/ ha); C_2= Absolute control (00:00:00 kg N, P_2O_5, K_2O/ ha); VC = Vermicompost; F_3=515 kg NPK and 515 kg VC

Table 6: Organic carbon at harvest in plant and ratoon sugarcane as influenced by methods of fertilizer application, fertilizer levels and split application of potassium

Treatment		Plant crop (OC %)				Ratoon crop (OC %)			
Methods	**K split**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
M_1	K_1	0.33	0.40	0.45	0.39	0.30	0.37	0.42	0.36
	K_2	0.36	0.41	0.45	0.41	0.33	0.38	0.42	0.38
	Mean	0.35	0.41	0.45	0.40	0.32	0.38	0.42	0.37
M_2	K_1	0.37	0.42	0.46	0.42	0.34	0.40	0.43	0.39
	K_2	0.37	0.43	0.49	0.43	0.34	0.40	0.46	0.40
	Mean	0.37	0.43	0.48	0.42	0.34	0.40	0.45	0.40
M_3	K_1	0.38	0.42	0.47	0.42	0.36	0.40	0.44	0.40
	K_2	0.39	0.43	0.51	0.44	0.37	0.40	0.48	0.42
	Mean	0.39	0.43	0.49	0.43	0.37	0.40	0.46	0.41
Mean of K_1		0.36	0.41	0.46	0.41	0.33	0.39	0.43	0.38
Mean of K_2		0.37	0.42	0.48	0.43	0.35	0.39	0.45	0.40
Mean (F)		0.37	0.42	0.47		0.34	0.39	0.44	
RPP		0.48				0.45			
Absolute control		0.32				0.29			
Source of variation		S.Em.±		C.D.(P = 0.05)		S.Em.±		C.D.(P = 0.05)	
Methods		0.002		0.008		0.003		0.013	
Fertilizer levels		0.003		0.008		0.002		0.007	
K splits		0.003		0.008		0.002		0.007	
M X F		0.005		NS		0.004		0.012	
M X K		0.005		NS		0.004		NS	
F X K		0.005		NS		0.004		NS	
M X F X K		0.008		NS		0.007		NS	
Rest v/s Control		0.007		0.021		0.007		0.020	

Main plot: Method of fertilizer application (M)
M_1= Surface application of fertilizer (Farmers practice)
M_2= Plough sole method of fertilizer application
M_3= Plough sole method with VC (1:1 RDF and VC)

Sub plot: Fertilizer Level (F)
F_1= 50 % RDF (125: 37.5: 95 kg N, P_2O_5, K_2O/ ha) = 258 kg NPK
F_2= 75 % RDF (187.75: 56.25: 142.5 N, P_2O_5, K_2O/ha) = 386 kg NPK
F_3= 100 % RDF (250:75:190 kg N, P_2O_5, K_2O/ ha) = 515 kg NPK

Sub- sub plot: Split application of potassium (K)
K_1= 100 % K at basal
K_2= 50 % K at basal & 50 % K at the time of earthing up (98 DAP)
RPP= Recommended package of practice

Control plots: C_1 = RPP (25 tons FYM/ha and RDF 250:75:190 kg N, P_2O_5, K_2O/ ha); C_2= Absolute control (00:00:00 kg N, P_2O_5, K_2O/ ha); VC = Vermicompost; F_3=515 kg NPK and 515 kg VC

Table 7: Nitrogen and Phosphorus uptake (kg ha^{-1}) at harvest in plant and ratoon sugarcane as influenced by methods of fertilizer application, fertilizer levels and split application of potassium

Treatment		Plant crop								Ratoon crop							
		N (kg ha^{-1})				P (kg ha^{-1})				N (kg ha^{-1})				P (kg ha^{-1})			
Methods	**K split**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
M_1	K_1	119.11	148.33	224.99	164.14	12.82	16.97	24.75	18.18	67.22	115.31	161.32	114.62	8.24	14.99	20.06	14.43
	K_2	132.76	158.49	238.14	176.46	14.59	17.83	25.21	19.21	73.13	136.00	170.38	126.50	9.16	17.44	20.24	15.61
	Mean	125.93	153.41	231.56	170.30	13.70	17.40	24.98	18.69	70.18	125.65	165.85	120.56	8.70	16.21	20.15	15.02
M_2	K_1	131.19	189.91	276.22	199.11	13.86	18.57	28.67	20.36	86.82	162.51	197.61	148.98	10.20	17.57	22.67	16.82

	K_2	138.18	201.12	379.01	239.44	15.33	20.52	36.53	24.13	91.90	169.61	231.53	164.35	11.25	19.18	24.48	18.31
	Mean	134.69	195.51	327.62	219.27	14.59	19.55	32.60	22.25	89.36	166.06	214.57	156.66	10.73	18.38	23.58	17.56
M_3	K_1	139.22	238.31	326.25	234.59	13.68	24.48	35.30	24.49	125.63	193.79	230.02	183.15	13.46	21.83	27.33	20.88
	K_2	147.04	263.38	434.72	281.72	14.31	27.45	48.26	30.01	150.93	205.42	282.15	212.84	15.99	23.40	34.47	24.62
	Mean	143.13	250.85	380.49	258.15	13.99	25.97	41.78	27.25	138.28	199.60	256.09	197.99	14.73	22.62	30.90	22.75
Mean of K_1		129.84	192.18	275.82	199.28	13.45	20.01	29.57	21.00	93.22	157.20	196.32	148.92	10.64	18.13	23.36	17.37
Mean of K_2		139.33	207.67	350.62	232.54	14.74	21.94	36.67	24.44	105.32	170.34	228.02	167.89	12.13	20.01	26.40	19.51
Mean (F)		134.58	199.92	313.22		14.10	20.97	33.12		99.27	163.77	212.17		11.38	19.07	24.88	
RPP		361.7				42.26				220.0				28.67			
Absolute control		66.6				8.66				46.52				7.27			
Source of variation		S.Em±		C.D. (P = 0.05)		S.Em±		C.D. (P = 0.05)		S.Em±		C.D. (P = 0.05)		S.Em±		C.D. (P = 0.05)	
Methods		3.09		12.14		0.72		2.85		3.03		11.91		0.93		3.66	
Fertilizer levels		4.46		13.75		0.76		2.34		3.49		10.76		0.60		1.84	
K splits		1.45		4.30		0.34		1.01		1.88		5.57		0.31		0.92	
M X F		7.73		23.82		1.32		4.06		6.05		NS		1.03		NS	
M X K		2.50		7.44		0.59		1.75		3.25		9.65		0.54		NS	
F X K		2.50		7.44		0.59		1.75		3.25		9.65		0.54		NS	
M X F X K		4.34		12.89		1.02		3.04		5.63		16.72		0.93		NS	
Rest v/s Control		8.12		23.24		1.46		4.19		7.01		20.07		1.36		3.88	

Initial available nutrient status N P_2O_5 K_2O 276.23:30.98:244.46 kg ha^{-1}

Main plot: Method of fertilizer application (M)

M_1= Surface application of fertilizer (Farmers practice)

M_2= Plough sole method of fertilizer application

M_3= Plough sole method with VC (1:1 RDF and VC)

Sub plot: Fertilizer Level (F)

F_1= 50 % RDF (125: 37.5: 95 kg N, P_2O_5, K_2O/ ha) = 258 kg NPK

F_2= 75 % RDF (187.75: 56.25: 142.5 N, P_2O_5, K_2O/ha) = 386 kg NPK

F_3= 100 % RDF (250:75:190 kg N, P_2O_5, K_2O/ ha) = 515 kg NPK

Sub- sub plot: Split application of potassium (K)

K_1= 100 % K at basal

K_2= 50 % K at basal & 50 % K at the time of earthing up (98 DAP)

RPP= Recommended package of practice

Control plots: C_1 = RPP (25 tons FYM/ha and RDF 250:75:190 kg N, P_2O_5, K_2O/ ha); C_2= Absolute control (00:00:00 kg N, P_2O_5, K_2O/ ha); VC = Vermicompost; F_3=515 kg NPK and 515 kg VC

Table 8: Potassium uptake (kg ha^{-1}) at harvest in plant and ratoon sugarcane as influenced by methods of fertilizer application, fertilizer levels and split application of potassium

Treatment		**Plant crop**				**Ratoon crop**			
		Fertilizer Levels				**Fertilizer Levels**			
Methods	**K split**	**F_1**	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
M_1	K_1	98.88	126.04	204.44	143.12	63.32	109.82	165.55	112.90
	K_2	109.84	139.69	221.49	157.00	68.39	135.88	178.57	127.61
	Mean	104.36	132.86	212.96	150.06	65.86	122.85	172.06	120.26
M_2	K_1	117.15	174.58	260.79	184.18	86.83	167.22	207.55	153.86
	K_2	125.57	189.92	361.08	225.52	93.30	179.01	245.67	172.66
	Mean	121.36	182.25	310.93	204.85	90.06	173.11	226.61	163.26
M_3	K_1	106.71	195.51	279.59	193.94	102.76	173.96	215.46	164.06
	K_2	115.91	220.20	382.20	239.44	131.16	187.47	272.09	196.91
	Mean	111.31	207.85	330.89	216.69	116.96	180.72	243.77	180.48
Mean of K_1		107.58	165.38	248.27	173.74	84.30	150.33	196.18	143.61
Mean of K_2		117.11	183.27	321.59	207.32	97.62	167.45	232.11	165.73
Mean (F)		112.34	174.32	284.93		90.96	158.89	214.15	
RPP		311.79				208.94			
Absolute control		60.20				49.63			
Source of variation		S.Em±		C.D. (P = 0.05)		S.Em±		C.D. (P = 0.05)	
Methods		5.63		22.09		7.38		28.96	

Fertilizer levels	4.55	14.03	4.13	12.71
K splits	0.89	2.63	1.94	5.76
M X F	7.89	24.31	7.15	NS
M X K	1.53	4.56	3.36	9.97
F X K	1.53	4.56	3.36	9.97
M X F X K	2.66	7.89	5.81	17.28
Rest v/s Control	8.49	24.31	9.20	26.35

Initial available nutrient status N P_2O_5 K_2O 276.23:30.98:244.46 kg ha^{-1}

Main plot: Method of fertilizer application (M)
M_1= Surface application of fertilizer (Farmers practice)
M_2= Plough sole method of fertilizer application
M_3= Plough sole method with VC (1:1 RDF and VC)

Sub plot: Fertilizer Level (F)
F_1= 50 % RDF (125: 37.5: 95 kg N, P_2O_5, K_2O/ ha) = 258 kg NPK
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F_3= 100 % RDF (250:75:190 kg N, P_2O_5, K_2O/ ha) = 515 kg NPK

Sub- sub plot: Split application of potassium (K)
K_1= 100 % K at basal
K_2= 50 % K at basal & 50 % K at the time of earthing up (98 DAP)
RPP= Recommended package of practice

Control plots: C_1 = RPP (25 tons FYM/ha and RDF 250:75:190 kg N, P_2O_5, K_2O/ ha); C_2= Absolute control (00:00:00 kg N, P_2O_5, K_2O/ ha); VC = Vermicompost; F_3=515 kg NPK and 515 kg VC

Table 9: Correlation studies of sugarcane as influenced by methods of fertilizer application, fertilizer levels and split application of potassium.

Parameters	Methods of fertilizer application (M)		Fertilizer levels (F)		Split application of potassium (K)		Interactions (MXFXK)	
	Plant	**Ratoon**	**Plant**	**Ratoon**	**Plant**	**Ratoon**	**Plant**	**Ratoon**
Cane yield (t ha^{-1})	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Number of Tillers at 180 DAP	0.993	0.993	0.998*	0.998*	0.999**	0.999**	0.970**	0.999**
Plant Height (at harvest)	0.998*	0.996	0.990	0.994	0.999**	0.999**	0.953**	0.950**
Cane diameter (at harvest)	0.996	0.999*	0.974	0.993	0.999**	0.999**	0.919**	0.986**
NDVI values (at 240 DAP)	0.955	0.999*	0.968	0.999**	0.999**	0.999**	0.745**	0.999**
Total dry matter production (at harvest)	0.976	0.961	0.999*	0.991	0.999**	0.999**	0.946**	0.970**
Length of internode (at harvest)	0.990	0.998*	0.991	0.989	0.999**	0.999**	0.951**	0.979**
Number of internodes (at harvest)	0.987	0.988	0.999**	0.994	0.999**	0.999**	0.980**	0.902**
Number of millable canes (NMC) (at harvest)	0.995	0.999*	0.999*	0.994	0.999**	0.999**	0.970**	0.997**
Leaf Area Index (At 300 DAP)	0.997*	0.999*	0.999*	0.999*	0.999**	0.999**	0.965**	0.982**
Single cane weight (at harvest)	0.988	0.999*	0.999*	0.996	0.999**	0.999**	0.966**	0.998**
Nitrogen Uptake (at harvest)	0.989	0.973*	0.997*	0.998*	0.999**	0.999**	0.962**	0.976**
Potassium uptake (at harvest)	0.988	0.979	0.998*	0.997*	0.999**	0.999**	0.966**	0.980**
Fertilizer use efficiency (FUE)	0.999*	0.999*	-0.941	-0.995	0.999**	0.999**	-0.609	-0.755**
Agronomic efficiency (AE)	0.999*	0.999*	-0.752	-0.819	0.999**	0.999**	0.199	0.182**
Available Nitrogen (at harvest)	0.965	0.995*	0.999**	0.994	0.999**	0.999**	0.952**	0.988**
Available potassium (at harvest)	0.964	0.998*	0.998*	0.996	0.999**	0.999**	0.953**	0.989**
Sugar yield (t ha^{-1})	0.999*	0.999*	0.999*	0.995*	0.999**	0.999**	0.999**	0.999*

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

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