J. Farm Sci., 31(3): (275-279) 2018

RESEARCH PAPER

Fertilizer placement methods, levels and splitting of potassium in sugarcane to maximize cane yield in Northern Transitional Zone of Karnataka

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(Received: July, 2017 ; Accepted: September, 2018)

Abstract: In plant and ratoon crop, application of fertilizer with plough sole method along with vermicompost organics recorded significantly higher cane yield (113.56 and 99.75 t ha^{-1}), number of millable canes (98.07 and 92.60 thousands ha^{-1}) and other growth parameters compared to farmers practice of surface broadcasting (99.78 and 88.01 t ha^{-1}: 92.80 and 88.81 thousands, respectively). Application of 100 % recommended dose of fertilizers significantly recorded higher cane yield (122.60 and 109.21 t ha^{-1} and NMC (103.24 and 96.58 thousand ha^{-1}) than applying 75 and 50 % recommended dose of fertilizers. Split application of potash 50 % as basal and 50 % as top dressing at earthing up recorded significantly higher cane yield (109.51 and 95.79 t ha^{-1} and NMC 96.47 and 91.54 thousands ha^{-1}) than 100 % as basal application. Among all the treatment combinations, application of 100 % recommended dose of fertilizers along with vermicompost in plough sole method and potassium 50 % as basal and 50 % at earthing up significantly recorded the higher cane yield in plant and ratoon crop (142.84 and 117.40 t ha^{-1}), NMC (108.31 and 99.13 thousands ha^{-1}).

Key words: Fertility levels, Potassium, Split application, Sugarcane

Introduction

Sugarcane is the main source of sugar in India and holds a prominent position as a cash crop. India was the 2nd largest producer of sugar in the world after Brazil in 2014-15. Sugarcane is a renewable, natural agricultural resource because it provides sugar, besides bio fuel, fibre, fertilizer and myriad of byproducts/ co-products with ecological sustainability. Its juice is used for making white sugar, brown sugar (khandsari) and jaggery (gur). It is one of the main crops of earning foreign exchange. The main byproducts of the sugarcane industry are bagasse and molasses. Bagasse is mainly used as a fuel. It is also used for the production of compressed fiber board, paper, plastics and furfural. Molasses is used in distilleries for the manufacture of ethyl alcohol, butyl alcohol, citric acid *etc.* Sugarcane press mud has good potential as organic fertilizer. It being a long duration and huge biomass accumulating crop, removes substantial amount of plant nutrients from the soil, 100 t ha^{-1} exhausts 208 kg N, 53 kg P and 280 kg K besides 3.4 kg Fe, 1.2 kg Mn, 0.6 kg Zn, 0.2 kg Cu and 30 kg S (Lal and Singh, 2002). In India it is grown on an area 5.03 m ha with a production of 356.65 m t and average productivity of 70 t ha^{-1} (Anon., 2015). Generally many fertilizers are imported and costly which are broadcasted by the sugarcane growers with very less nutrient use efficiency due to various losses resulting stagnation in productivity. Placement of fertilizer in bands increases the concentration of nutrients in specific zones which reduces the risk of fixation losses and increases their availability to the plants. Optimizing method of fertilization simultaneously to achieve higher nutrient use efficiency and high crop productivity is necessary in modern agriculture (Cassman *et al.,* 2003). There is a huge regional disparity in fertilizer use and the consumption. All these, point out to a greater opportunity for using more balanced fertilizers in right method for enhancing cane productivity, quality produce and maintaining system sustainability and higher nutrient use efficiencies. Among the macronutrients, potassium plays a vital role in energy transfer and carbohydrates metabolism activating more than 60 enzymes which is the basis for synthesis and accumulation of sugar. At present farmers apply potassium only as basal dose, where some quantity may be fixed by clay colloid and some may be lost leading insufficient availability during later crop growth stages. Hence, the present study was undertaken to study the methods of fertilizer application, fertilizer levels, and split application of potassium on yield and yield parameters.

Material and methods

A field experiment was conducted during the consecutive seasons of 2014-15 and 2015-16 at the Agricultural Research Farm of S. Nijalingappa Sugar Institute (SNSI) Belagavi, which lies in Northern Transitional Zone of Karnataka (Zone-8). The experimental site is located at 15° 46’ 03.8" North latitude and 74° 29` 16.27" East longitudes with an altitude of 534 m above the mean sea level. The soil of the experimental site was medium deep black categorized in 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, respectively. 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	Nitrogen (kg ha^{-1})				
	Basal (10 %)	2nd split (6th week) (20 %)	3rd split (10th week) (30 %)	4th split (14th week) (40 %)	Total (100 %)
F_1	12.5	25.0	37.5	50.0	125.0
F_2	18.7	37.4	56.1	74.8	187.0
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 to be applied in the similar method as applied to plant crop cane. 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 %) after ratoon initiation. 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 covering the soil 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 1). Significantly higher cane yield was recorded in plough sole method with vermicompost in plant (113.56 t ha^{-1}) and ratoon crop (99.75 t ha^{-1}) than plough sole 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. The increase in cane yield was to the extent of 13.81 and 6.41 per cent in plant crop and 13.33 and 7.15 per cent in ratoon crop, respectively over surface application and ploughsole method of fertilizer application. Earlier reports of Serigio *et al.,* 2016 and Mandal and Thakur (2010) also indicated increased cane yield due to

Table 1. 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
Mean (F)		91.77	105.15	122.60	-	77.14	95.72	109.21	-
RPP (C_1)			129.85				113.22		
Absolute control (C_2)			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: 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

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);

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

RPP= Recommended package of practice
VC = Vermicompost; F_3=515 kg NPK and 515 kg VC
RDF: Recommended dose of fertilizer

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. Increased nutrient availability over longer period during later stages of crop growth resulting in better yield attributing characters. 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 number of millable canes is an important yield attribute determining the ultimate cane yield in sugarcane. Survival of tillers to develop into millable canes has a greater influence on higher cane yield. The higher cane yield in ploughsole method with vermicompost and only ploughsole method was attributed to significantly higher yield attributing characters such as number of millable canes.

The effect of precise nutrient management exerted profound influence on the cane yield (Table 1). 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 soil fertility status in terms of nitrogen, phosphorous and potassium. 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. The enhanced fertility status and more tillering which

Table 2. Number of millable canes (NMC) 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			
		NMC (thousand ha^{-1})				NMC (thousand ha^{-1})			
Methods	K split	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
M_1	K_1	84.92	93.48	98.83	92.41	82.17	88.42	94.45	88.35
	K_2	86.28	93.20	100.09	93.19	83.41	89.30	95.10	89.27
	Mean	85.60	93.34	99.46	92.80	82.79	88.86	94.78	88.81
M_2	K_1	87.88	94.36	102.16	94.80	84.76	90.57	95.93	90.42
	K_2	88.35	95.29	106.64	96.76	85.96	91.92	98.35	92.08
	Mean	88.12	94.83	104.40	95.78	85.36	91.25	97.14	91.25
M_3	K_1	90.93	95.67	103.41	96.67	86.87	92.41	96.50	91.93
	K_2	91.92	98.18	108.31	99.47	87.71	92.95	99.13	93.26
	Mean	91.42	96.93	105.86	98.07	87.29	92.68	97.82	92.60
Mean of K_1		87.91	94.50	101.47	94.63	84.60	90.46	95.63	90.23
Mean of K_2		88.85	95.56	105.01	96.47	85.69	91.39	97.53	91.54
Mean (F)		88.38	95.03	103.24	-	85.15	90.93	96.58	-
RPP (C_1)		106.24				97.74			
Absolute control (C_2)		83.38				78.77			

Source of variation	S.Em.±	C.D.(P = 0.05)	S.Em.±	C.D. (P = 0.05)
Methods	0.27	1.06	0.08	0.32
Fertilizer levels	0.63	1.93	0.21	0.66
K splits	0.18	0.52	0.06	0.18
M x F	1.08	NS	0.37	NS
M x K	0.31	0.91	0.11	0.32
F x K	0.31	0.91	0.11	0.32
M x F x K	0.53	1.57	0.19	0.55
Rest v/s Control	1.01	2.90	0.50	1.42

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: 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

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);
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

RPP= Recommended package of practice
VC = Vermicompost; F_3=515 kg NPK and 515 kg VC
RDF: Recommended dose of fertilizer

converting into higher number of millable canes also contributed to more cane yield. The results are in agreement with the findings of Shukla and Ishwar (2011) who also reported that among the fertility levels, significantly highest cane (70.48 t ha^{-1}) were obtained with application of 150, 60 and 60 kg N, P_2O_5 and K_2O ha^{-1}.Whereas, significantly lowest yield parameters were documented under absolute control and ultimately resulted in the lowest cane yield (53.57 and 41.40 t ha^{-1} in plant and ratoon crop, respectively). The significant reduction in cane yield under this treatment was due to severe nutrient stress experienced by crop during all growth stages.

The superiority of 100 per cent RDF over other fertilizer levels in terms of higher cane yield depends on yield parameters. The higher yield levels associated with application of increasing levels were traced back to higher values of yield attributing characters such as number of millable canes. In the present investigation, significantly higher NMC in plant and ratoon crop (103.24 and 96.58 thousands ha^{-1}, respectively) was recorded with 100 per cent RDF (Table 2) compared to 75 per cent (95.03 and 90.93 thousands ha^{-1}, respectively) and 50 per cent RDF (88.38 and 85.15 thousands ha^{-1}, respectively). Higher number of millable canes per unit area with increasing dose of NPK was also observed by Afzal *et al.* (2003) and Sinha *et al.* (2005). More number of millable canes at higher level of NPK might be due to greater availability of nutrients sufficient to meet the requirement of the cane crop per unit area as a result of reduced rate of mortality.

In the present investigation, significant differences were observed due to interaction of fertilizer application methods, fertilizer levels and split application of potassium. Among the interactions, application of 100 per cent RDF in plough sole method along with vermicompost and split application of potash, 50 per cent as basal and 50 per cent at earthing up (Table1) recorded significantly higher cane yield and in plant (142.84 t ha^{-1}) and ratoon crop (117.40 t ha^{-1}) as compared to RPP (129.85 and 113.22 t ha^{-1}) over interaction of $M_1F_1K_1$ (87.32 and 68.95 t ha^{-1}) and absolute control (53.57 and 41.40 t ha^{-1}, respectively) over other interactions. These results are in close agreement with the findings Mushtaq *et al.* (2015) who reported the combined application of nitrogen and biochar showed mean maximum foliage yield (73.42 t ha^{-1}), beet yield (84.12 t ha^{-1}), total biomass yield (145.61 t ha^{-1}) when banded nitrogen was integrated with 50 t ha^{-1} biochar.

Table 3. Number of tillers (thousands ha^{-1}) at 150 days after planting in plant and ratoon sugarcane as influenced by methods of fertilizer application, fertilizer levels and split application of potassium

Treatment		Plant crop				Ratoon crop			
		Number of tillers at 150 days after planting				Number of tillers at 150 days after ratooning			
Methods	K split	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
M_1	K_1	112.83	130.46	137.84	127.04	84.61	97.28	111.21	97.70
	K_2	116.07	132.35	138.59	129.00	89.27	97.23	113.52	100.01
	Mean	114.45	131.41	138.21	128.02	86.94	97.25	112.37	98.85
M_2	K_1	120.84	134.00	139.33	131.39	92.12	98.95	115.23	102.10
	K_2	123.03	134.78	145.46	134.42	92.66	103.20	118.54	104.80
	Mean	121.94	134.39	142.39	132.91	92.39	101.07	116.89	103.45
M_3	K_1	124.93	136.12	140.51	133.85	94.53	104.50	116.68	105.24
	K_2	128.06	136.82	148.09	137.66	94.92	109.61	119.95	108.16
	Mean	126.49	136.47	144.30	135.75	94.73	107.05	118.31	106.70
Mean of K_1		119.53	133.53	139.23	130.76	90.42	100.24	114.38	101.68
Mean of K_2		122.39	134.65	144.04	133.69	92.29	103.35	117.34	104.32
Mean (F)		120.96	134.09	141.64		91.35	101.79	115.86	
RPP (C_1)			142.22				117.75		
Absolute control (C_2)			106.44				84.19		
Source of variation			S.Em.±		C.D. (P = 0.05)		S.Em.±		C.D. (P = 0.05)
Methods			0.19		0.73		0.05		0.21
Fertilizer levels			0.42		1.30		0.37		1.13
K splits			0.20		0.59		0.25		0.75
M x F			0.73		2.25		0.64		1.96
M x K			0.35		1.03		0.44		NS
F x K			0.35		1.03		0.44		NS
M x F x K			0.60		1.78		0.76		NS
Rest v/s Control			1.15		3.31		0.86		2.46

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: 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

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);

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

RPP= Recommended package of practice
VC = Vermicompost; F_3=515 kg NPK and 515 kg VC
RDF: Recommended dose of fertilizer

The yield increment in $M_3F_3K_2$ of plant and ratoon crop was to the tune of 63.58 and 70.25, over $M_1F_1K_1$ and 10.0 and 3.69 per cent over RPP, respectively. Whereas, in two way interactions the yield increment with M_3F_3 was the tune of 47.84 and 60.67 per cent over M_1F_1, M_3K_2 in 19.38 and 18.45 over M_1K_1, F_3K_2 in 41.0 and 47.27 over F_1K_1 respectively. Highest tiller population coupled with efficient conversion of tillers into millable canes at harvest might have contributed to higher cane yield. Since the sugar yield is dependent on cane yield, number of tillers followed the similar pattern as that of cane yield (Table 3). A significant increase in cane yield was observed at higher dose of nitrogen and potassium fertilizers. The higher yields in plough sole method with vermicompost and split application of potassium with 100 per cent RDF may also be resultant of required and continuous availability of nutrients throughout life cycle of the crop in accordance with the demand of crop. Surface application, on the contrary, resulted in considerable wastage plant nutrients due to fixation and losses below root zone which leads to imbalanced soil nutrient environment resulting in declined yield. Increase in sugarcane yield with increase in fertilizer level was also reported by Pahal Singh (2015) and Mandal and Thakur (2010). Further, Navnit *et al.* (2012) reported that application of straight fertilizers such as urea and muriate of potash and DAP were the best alternative source readily available to crop plants and meet the crop requirement to achieve the higher productivity of sugarcane. Among the yield components, number of millable canes (Table 2) was significantly higher in $M_3F_3K_2$ (108.31 thousands ha^{-1} in plant and 99.13 thousands ha^{-1} in ratoon crop) and $M_2F_3K_2$ (106.64 thousands ha^{-1} in plant and 98.35 thousands ha^{-1} in ratoon crop) over other treatments.

Conclusion

Application of 100 per cent recommended dose of fertilizer along with vermicompost in plough sole method and split application of potash 50 per cent as basal and 50 per cent top dressed at the time of earthing up found optimum for higher cane yield reducing the various losses which increased the efficiency of applied plant nutrients compared to farmer's practice of surface broadcasting. Application of fertilizer in plough sole method along with organics can save 25 per cent fertilizers with higher efficiencies.

Acknowledgement

The authors acknowledge the financial and physical support of S. Nijalingappa Sugar Institute, Belagavi for Doctoral research programme in collaboration with UAS, Dharwad.

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