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Effect of Potassium Application on Yield, Nutrient Uptake and Quality of Sugarcane and Soil Health

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Abstract

Potassium (K), being an essential major nutrient, is critical for sustenance of crop yields. Removal of K by crops is either equal to or more than that of nitrogen (N). Balanced nutrition, comprising of application of N, phosphorus (P) and K in optimum proportions holds key to the maximization of crop productivity. Scant or non-application of K fertilizer has exhausted soils of their native K and is coming in the way of realizing the potential yields. Sugarcane crop, because of its high K requirements, must be fertilized with K to produce an optimum yield of the millable canes and also get the quality cane juice. Field experiments with sugarcane variety Co 0238 were conducted on the alluvial soil of National Sugar Institute, Kanpur during 2015-16 and 2016-17 using N and K fertilizers in different combinations. Data emanating from these experiments on several physico-chemical and nutritional parameters of sugarcane such as length, diameter, number of leaves, weight, millable canes, yield, available N, P & K, brix, pol per cent cane, purity and benefit: cost ratio showed that the treatment comprising of 240 kg N + 120 kg K_2O ha^{-1} maximized the economic yields and produced the best quality cane. Results indicate that the application of K in the range of 120 or 180 kg K_2O ha^{-1} along with N can provide higher cane yield and improve further the cane quality attributing characteristics and benefit: cost ratio and sustain the soil health.

Key words: Sugarcane yield, cane quality, potash fertilization and soil health

Introduction

Sugarcane is the main source of sugar in India and contributes significantly to the national economy. Being an important agro-based industry, sugar industry plays a substantial role in the socio-economic development of the country and provides direct employment to approximately 7.5% of its rural population.

Burgeoningly rising country's population has been a driving force for production of more agricultural products including sugar. With increase in the crop productivity, nutrient removal from the soil also increases. Unless the nutrients removed or mined from the soil are replenished, crop yields will become highly unsustainable. It is for this reason that the soil fertility management is crucial in increasing crop productivity and improving nutritional security, while maintaining soil health and environmental quality (Prasad and Power, 1997; Sanyal et al., 2014).

Global sugar production is approximately 170-180 million tonnes (Mt), with about 25% of it produced from sugar beet. Demand for sugar at the global level is expected to be around 255 Mt by 2050. In India, 359.66 Mt of sugarcane is produced on 5.14 million hectares (Mha) area (ISMA, 2012). Present situation of cane productivity and sugar recovery as well as sugarcane as a feedstock for producing bio-ethanol calls for a judicious use of the available resources to meet the projected requirements of 2050.

Potassium, though being an essential nutrient for cane production as well as for other quality parameters, has often been ignored by the farmers in states like Uttar Pradesh. Quite often, farmers tend to apply excessive quantities of N fertilizer which often leads to wastage of this costly nutrient intimately linked with climate change and environmental quality, deterioration in cane and juice quality, lodging of the canes, and soil health. Keeping this in view, present field trials were conducted at Kanpur for 2 years to standardize the doses of N and K fertilizers for achieving higher cane yields and improving the cane quality.

Materials and Methods

Experiments were conducted for two consecutive years (2015-16 and 2016-17) at the Agriculture Farm of National Sugar Institute, Kanpur. The experimental soil, a true representative of the

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Table 1. Treatment details for the experiment

Treatment details	Rate of nutrients applied in kg ha^{-1} in the year	
	2015-16	2016-17
T_1- N_1K_1	$N_{120} + K_2O_{60}$	$N_{120} + K_2O_{80}$
T_2- N_1K_2	$N_{120} + K_2O_{120}$	$N_{120} + K_2O_{140}$
T_3- N_1K_3	$N_{120} + K_2O_{180}$	$N_{120} + K_2O_{200}$
T_4-N_2K_1	$N_{180} + K_2O_{60}$	$N_{180} + K_2O_{80}$
T_5- N_2K_2	$N_{180} + K_2O_{120}$	$N_{180} + K_2O_{140}$
T_6-N_2K_3	$N_{180} + K_2O_{180}$	$N_{180} + K_2O_{200}$
T_7-N_3K_1	$N_{240} + K_2O_{60}$	$N_{240} + K_2O_{80}$
T_8- N_3K_2	$N_{240} + K_2O_{120}$	$N_{240} + K_2O_{140}$
T_9-N_3K_3	$N_{240} + K_2O_{180}$	$N_{240} + K_2O_{200}$
T_{10}- Farmers' fertilizer practice (FFP)	$N_{200} + P_{75} + K_2O_0$	$N_{200} + P_{75} + K_2O_0$

Indo-Gangetic Alluvial Plains, had pH 8.49, electrical conductivity (EC) 0.25 dS m^{-1} and Walkley-Black organic carbon 0.45% available N, P and K at the start of the experiment were 225.0, 16.0 and 104.0 kg ha^{-1}, respectively. Experiment was laid out in a randomized block design with ten treatments. Details of the treatments are given in **Table 1**. Three replications were taken for each treatment. Sugarcane variety Co 0238 was raised following standard package of practices. Measurement of the different parameters was done during the cropping season. After the harvest of the crop, cane yield was recorded and the cane juice obtained from each treatment was subjected to chemical analysis. Data was subjected to analysis of variance technique to assess the influence of K fertilizer on the different parameters. Economics of K application was computed taking into account the value of produce and the cost of fertilizer used.

Results and Discussion

Cane Growth and Yield Parameters

Application of N and K in various combinations increased the cane length, diameter and number of leaves per plant over T_1 (N_{120} K_2O_{60}) during both the years (**Table 2**). Significant increase in the cane length was noted up to T_7 (N_{240} K_2O_{60}). Length of cane was more responsive to N doses than K. It might be due to the fact that the vegetative growth is more pronounced with N application as the experimental field was low in the available N (225 kg ha^{-1}). Diameter of cane varied from 2.65 to 3.48 cm; it was minimum under T_1 and maximum under T_8. Similar response of N and K combinations was noted on the number of leaves per plant. Response on length, diameter and leaves number to K application was significant, which implies that the higher levels of K might have further increased these parameters.

Higher K doses during second year had at par response on these growth parameters. Cane weight, millable canes and yield increased under different N and K combinations over their lowest dose.

Table 2. Effect of treatments on length, diameter and number of leaves per plant of sugarcane

Treatment details	Length (cm)		Diameter (cm)		Number of leaves plant^{-1}	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1- N_1K_1	159.4	158.1	2.65	2.52	21	21
T_2- N_1K_2	162.3	162.4	2.76	2.70	21	21
T_3- N_1K_3	162.3	163.0	2.90	2.82	21	21
T_4-N_2K_1	175.8	174.6	3.10	2.98	22	22
T_5- N_2K_2	175.9	176.6	3.25	3.18	22	22
T_6-N_2K_3	176.1	176.0	3.28	3.25	22	22
T_7-N_3K_1	185.4	184.3	3.40	3.25	24	24
T_8- N_3K_2	187.0	188.1	3.48	3.40	24	24
T_9-N_3K_3	187.2	188.5	3.48	3.38	24	24
T_{10}- FFP	175.1	177.1	3.20	3.12	22	23
S.E. of difference	1.3	1.4	0.09	0.10	0.2	0.2
CD (P = 0.05)	2.8	3.0	0.19	0.21	0.5	0.5

Table 3. Effect of treatments on cane weight, millable canes and yield of sugarcane

Treatment details	Cane weight (g)		Millable canes (numbers ha^{-1})		Yield (t ha^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1- N_1K_1	771	740	65,230	68,610	50.26	50.80
T_2- N_1K_2	798	780	70,360	70,590	56.15	55.10
T_3- N_1K_3	799	800	74,228	71,200	59.32	58.00
T_4-N_2K_1	868	860	79,520	77,110	69.02	67.20
T_5- N_2K_2	882	870	84,830	82,826	75.82	73.80
T_6-N_2K_3	895	882	88,000	85,480	78.60	77.00
T_7-N_3 K_1	1012	992	94,100	90,760	92.23	90.30
T_8- N_3K_2	1070	1020	96,390	95,890	103.14	98.70
T_9-N_3K_3	1066	1030	97,110	96,822	103.42	100.50
T_{10}- FFP	995	990	95,120	91,800	94.66	90.60
S.E. of difference	21	23	934	1,075	0.56	1.08
CD (P = 0.05)	45	48	1,948	2,236	1.16	2.24

Data in **Table 3** indicates that the cane yield varied from minimum of 50.26 t ha^{-1} under T_1 (N_{120} K_2O_{60}) to maximum of 103.42 t ha^{-1} under T_9 (N_{240} K_2O_{180}). Higher doses of K during the second year with various N doses were at par with lower K doses during the first year. Observed increase in the cane yield is in accordance with the essential role played by K in the processes namely, photosynthesis, water relationships and requirements for K in at least 60 different enzyme systems within the plant. Results showing the benefits of K on crop yield have also been reported by Khosa (2002) and Singh et al. (2008).

Cane Quality Parameters

Quality like Brix, purity and per cent pol are used for evaluation of the juice quality of the sugarcane. Brix (refractometer Brix) of a solution is defined as the concentration of the total dissolved solids in solution (in g of solute per 100 g of solution). The pol (polarisation) is the concentration (in g of solute per 100 g of solution) of a solution of pure sucrose in water having the same optical rotation as the sample at a specified temperature. Brix, purity and per cent pol of cane increased significantly under various N and K combinations over their respective lower doses (**Table 4**). Maximum Brix and purity noted were 23.04 and 90.88 in T_9 and T_7, respectively during second year of experimentation. Increasing dose of K during second year with various N doses significantly increased these parameters. Pole percent of cane also increased significantly under various N and K combinations compared to the previous year of lower K doses. Per cent reducing sugar decreased

Table 4. Effect of treatments on total soluble solids (TSS), purity percentage, pol percentage in cane, and percentage of reducing sugar in the sugarcane juice

Treatment details	TSS (°Brix)		Purity (%)		Pol in cane (%)		Reducing sugar content (%)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1- N_1K_1	19.00	23.04	83.35	90.42	12.68	14.97	1.037	1.021
T_2- N_1K_2	19.50	23.52	83.63	88.93	13.99	14.10	1.008	1.012
T_3- N_1K_3	19.70	22.56	85.65	77.62	14.85	14.78	0.885	0.992
T_4-N_2K_1	19.60	22.62	85.50	91.52	14.55	14.66	0.880	0.980
T_5- N_2K_2	19.58	23.35	86.62	90.29	14.59	14.44	0.785	0.822
T_6-N_2K_3	19.62	22.29	86.81	87.99	14.29	14.40	0.780	0.800
T_7-N_3 K_1	20.10	22.96	84.54	90.88	13.50	13.60	0.898	0.910
T_8- N_3K_2	20.26	22.12	87.98	90.02	14.59	14.70	0.750	0.790
T_9-N_3K_3	20.58	23.04	88.41	88.35	14.45	14.59	0.750	0.792
T_{10} - FFP	19.50	23.06	86.08	91.06	13.64	13.77	0.986	1.031
S.E. of difference	0.13	0.15	0.42	0.37	0.10	0.13	0.02	0.03
CD (P = 0.05)	0.28	0.31	0.88	0.77	0.21	0.27	0.04	0.06

Table 5. Effect of treatments on N, P and K uptake by sugarcane crop

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1- N_1K_1	122.7	124.0	14.58	14.73	134.3	137.2
T_2- N_1K_2	144.9	142.2	16.84	16.53	160.0	159.8
T_3- N_1K_3	153.0	149.6	17.20	16.82	175.0	174.0
T_4-N_2K_1	162.8	172.0	19.32	18.82	186.4	181.4
T_5- N_2K_2	212.3	205.9	23.50	22.88	219.9	221.4
T_6-N_2K_3	223.2	218.7	23.58	23.10	234.2	238.7
T_7-N_3K_1	280.9	275.4	29.51	28.90	253.6	252.8
T_8- N_3K_2	304.3	302.0	33.00	31.58	300.1	296.1
T_9-N_3K_3	308.2	307.5	36.19	35.17	307.2	301.5
T_{10}- FFP	265.0	261.9	35.97	34.31	288.7	234.8
S.E. of difference	3.4	3.6	0.61	0.65	1.2	1.2
CD (P = 0.05)	7.0	7.4	1.27	1.35	2.6	2.5

with increasing doses of N and K, which might be due to the antagonistic effect of N and K on reducing sugar.

Nutrient Uptake and Benefit: Cost Ratio

With increase in the rates of N and K application, uptake of N, P and K registered an increase (**Table 5**). Uptake of these nutrients increased significantly under various N and K treatment combinations over the lowest dose of N_{120} K_2O_{60} (T_1). This might be basically due to the increase in yield obtained under various treatment combinations of N and K. Higher biomass led to the increased removal of nutrients by sugarcane. Ng Kee Kwong (2000), Bokhtiar et al. (2011), Hunsigi (2010) and Shukla et al. (2008) have also reported similar results.

Positive effects of various treatment combinations recorded on yield were economical in terms of improved benefit: cost ratio of sugarcane (**Table 6**). Highest benefit: cost ratio of 15.5:1 was noted under T_8 (N_{240} K_2O_{120}) during the first year (2015-16).

Available Nutrient Status in the Post-Harvest Soil

Effect of application of different combinations on N and K was determined on the available N, P and K content of soil after each crop harvest. Available N and K status of the soil was directly linked to the respective rates of their

Table 6. Effect of treatments on response and benefit: cost ratio over 60 kg K applications in sugarcane crop

Treatments	Cost of fertilizer (Rs. ha^{-1})	Yield (t ha^{-1})	Response over 60 kg K_2O ha^{-1} dose (t ha^{-1})	Benefit due to additional application of K (Rs. ha^{-1})	Benefit: cost ratio (Rs. Re^{-1})
T_1- N_1K_1	1950	50.26	-	-	-
T_2- N_1K_2	3900	56.15	5.89	16492	8.46:1
T_3- N_1K_3	5850	59.32	9.06	25368	6.50:1
T_4-N_2K_1	2868	69.02	-	-	-
T_5- N_2K_2	4818	75.82	6.8	19040	9.76:1
T_6-N_2K_3	6768	78.6	9.58	26824	6.88:1
T_7-N_3K_1	3786	92.23	-	-	-
T_8- N_3K_2	5756	103.14	10.91	30548	15.5:1
T_9-N_3K_3	7686	103.42	11.19	31332	8.03:1
T_{10}-FFP	3062	94.66	2.43	6804	2.22:1

Rate of fertilizer : Urea Rs. 6.96 kg^{-1}, DAP Rs. 23.82 kg^{-1}, MOP Rs. 19.50 kg^{-1}
Price of sugarcane : 2015-16 - Rs. 2800 t^{-1}, 2016-17 - Rs. 3100 t^{-1},

Table 7. Effect of treatments on the available N, P and K content at the harvest of sugarcane crop

Treatments	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_1- N_1K_1	225.8	252.1	27.6	29.80	110.0	118.2
T_2- N_1K_2	244.8	265.1	27.8	30.12	122.1	132.1
T_3- N_1K_3	257.2	270.1	28.2	31.10	136.5	145.8
T_4-N_2K_1	284.8	280.3	28.0	32.20	117.9	120.1
T_5- N_2K_2	298.5	285.0	28.2	32.80	129.1	135.0
T_6-N_2K_3	306.2	288.4	28.5	32.88	138.5	142.2
T_7-N_3 K_1	313.6	305.8	28.5	33.10	115.8	118.9
T_8- N_3K_2	319.9	307.0	28.8	33.10	130.2	135.6
T_9-N_3K_3	332.4	310.1	28.8	33.60	139.8	140.3
T_{10}- FFP	288.5	282.1	29.1	33.10	142.5	142.3
S.E. of difference	2.3	2.2	0.5	0.6	1.0	1.2
CD (P = 0.05)	4.7	4.5	1.0	1.2	2.1	2.4
Initial soil test value	225.0		16.0		104.0	

application (**Table 7**). Build-up of K was generally more at the end of second year of experimentation because of the cumulative additions.

Conclusion

On the basis of two years' experimentation on low K alluvial soil of Kanpur, it is concluded that the conjoint application of N_{240} K_2O_{120} is optimum and economical for obtaining higher sugarcane yield of better quality. Improvement in the available N, P and K status under this treatment is indicative of sustenance of soil health.

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