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Effect of Different Levels of Potassium on Agronomic Traits, Productivity and Quality of Sugarcane (*Saccharum officinarum* L.)

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Abstract: Effect of applied K on agronomic traits and productivity of sugarcane was studied by applying potassium levels of 0, 50, 100, 150 and 200 kg K_2O ha^{-1} with a basal dose of 220 kg N and 120 kg P_2O_5 ha^{-1}. Early stalk population increased with increasing potash levels. Number of tillers per hectare, at early growth stages, were minimum and significantly low in plots where K was not applied. Application of K increased millable canes significantly. K did not affect total soluble solids (Brix %) during October and at the start of November. However, during December total soluble solids (Brix %) were significantly higher in K applied plots than the control. Stalk height was increased with K application. It was minimum in control plots (250.33 cm) and maximum (310 cm) at 150 kg K_2O ha^{-1}. Stalk diameter also followed a similar trend which was minimum (27.40 mm) in control and was maximum (31.75 mm) at 150 kg K_2O ha^{-1}. Cane yield increased with K application and it was maximum (155 t ha^{-1}) with the application of 150 kg K_2O ha^{-1}. Sugar recovery was also higher in applied K treatments and it was maximum (11.6 %) with the application of 150 kg K_2O ha^{-1}. P, K, Mg, B and Zn contents of the leaf sheath were also increased significantly with the application of K. Economic analysis of the study showed that each incremental application of K increased net profit and it was maximum (Rs. 20,200 ha^{-1}) with the application of 150 kg K_2O ha^{-1}.

Key words: Sugarcane, potassium, productivity, quality, agronomic traits

Introduction

Sugarcane is an important cash crop in Pakistan and is grown on more than one (>1) million hectares. Besides providing a regular cash flow to farmers, it also supplies fodder for animals during the winter months when there is shortage of fodder due to severe cold. Although there had been vast expansion in the sugar industry and the area under sugarcane, yet the productivity of cane is relatively very low in Pakistan. Improving the cane productivity per unit area has always been a challenge for researchers, extension workers and farmers. There is no doubt that the improved high yielding varieties and production technology is available and relatively higher yield is being achieved at research stations and progressive growers' farms, however, the national average cane yield is very low. Many factors are responsible for the low productivity of sugarcane. One of the most important factors responsible for low cane yield is the imbalanced and inadequate use of fertilizer (Akhtar, 1998; 1999). Most of the cane growers in the country use only N and P with an imbalanced combination. There are only 4 % of the cane growers in the Punjab those use NP and K in their cane crop (Akhtar, 1998; 1999).

Sugarcane absorbs very high amounts of K from soil. Therefore, K available in many sugarcane growing areas may not be sufficient for the best economic yields, hence adequate use of balanced fertilizers, including, K is required. It has been reported that a yield of 100 t cane ha^{-1} would remove about 340 kg of K_2O, 130 kg N and 90 kg P_2O_5 from the soil (Akhtar *et al.*, 1997). It is important to note that sugarcane growth is usually expressed in terms of elongation of stalks, increase in dry matter, as well as increased weight and size (Van Dillewijn, 1952). The main role of K in plants is that of an activator (Fileo, 1985). This nutrient is absorbed in the form of K^+ and is the most abundant plant cell cation accumulating in the cell sap. In sugarcane, K is essential for cellular structure for C assimilation as well as synthesis and translocation of nitrogenous compounds (Hartt, 1934) and K deficiency exerts negative effect on photosynthesis. Humbert (1963) reported that Potassium deficiency in sugarcane plants affects photosynthesis and carbohydrate transport (Hart, 1970 and Alexendar 1973). It is also reported that K application helps plants in maintaining water balance under low moisture conditions and resistance against insect pests and diseases as K increases cuticle thickness (Van Dillewijn, 1952). Keeping these facts in view balanced nutrition of cane crop is a must, including potassium, for obtaining maximum economic cane and sugar yield per unit area.

As application of potassium to cane crop in Pakistan is negligible, it is very important to assess the need of K for sugarcane and to revisit the earlier findings. Therefore, present experiment was planned to study the effect of K on agronomic traits and productivity of sugarcane.

Materials and Methods

The experiment was conducted during the years 1996-98 at the National Agricultural Research Centre, Islamabad to find out the impact of various K levels on agronomic traits and productivity of sugarcane. Soil samples were taken from the field at various depths for physico-chemical analysis (USDA, 1954 and Winkleman *et al.*, 1990), prior to planting the experiment (Table 1). A promising exotic sugarcane variety RB 72-454 was planted at a row spacing of 1 meter with two budded double setts placed end to end. There were six rows of sugarcane measuring eight m each in treatment plot. The experiments were planted during September and harvested during the month of December the next year. Five levels of 0, 50, 100, 150 and 200 kg K_2O ha^{-1} were tested in the study. All K and a basal dose of 120 kg P_2O_5 ha^{-1} was applied at the time of planting to all the treatments. Nitrogen was applied @ 220 kg ha^{-1} in four equal splits i.e., at planting, at the end of March, end of April and during the 1st week of June. Fertilizer used in the study were Urea, DAP and MOP. Gesapax combi (80 WP) was applied as pre-emergence herbicide @ 3.75 kgs ha^{-1}. Data on tillering were collected at early growth stages to see the tiller development and their mortality from central two rows i.e., from an area of 12 m^2. Plant tissue samples (Clements, 1980) were collected during the month of August to determine (Jones and Case, 1990) the nutrient content of the cane plants.

Data on millable canes, stalk height and diameter and cane yield were recorded. Brix readings were taken during October, November and December with the help of hand refractometer. Representative stalks were taken from the harvested canes to measure the stalk height and diameter. Similar stalks were used to measure the girth. Stalk girth was measured from the centre, 25 cm above the basal node and 25 cm below the top most node and then averaged. Harvested stalks were also used for the estimation of sugar recovery. Sugar recovery was calculated on the basis of Winter- Crap formula (Geerlings, 1904) as given below:

Sugar recovery (SR) = [POL in juice – (Brix-POL in juice) x 0.4]

Commercial cane sugar (CCS) t ha^{-1} was calculated as follows:

CCS = Cane yield t ha^{-1} x sugar recovery.

The data collected were statistically analyzed with PC SAS (SAS Inc., 1986) using analysis of variance technique and LSD to determine the difference between treatment means at a probability level of 5 %.

Results and Discussion

Sugarcane is a heavy feeder of nutrients that takes up and exports high amounts of K from soil. Usually K available in soil in many cane growing areas is inadequate to meet the requirements of the crop for maximum economic yield. As stated earlier, K plays very important role in improving cane yield. In the present study, data regarding effect of different K levels on selected agronomic characters were collected, analyzed and are being presented.

Nutrient status of the experimental site: The experimental site was normal, having low organic matter, N, P and K extractable levels. It belongs to Gujranwala soil series, a non calcareous, fine silty clay loam, mixed, hyperthermic Udic Haplustalf. The nutrient status is low (Table 1). The soil nutrient standards presently used are of general nature, mainly based on soil test calibrations for wheat and no work has been done for sugarcane. However, it is clear that sugarcane needs much more nutrients as compared to wheat, because it generates a large volume of biological material, hence for maximum economic yield the soils would require substantial amount of N, P and K fertilizers is a balanced ratio.

Early tiller development and millable stalks at harvest: Data collected on tiller development at early growth stages indicate that application of K significantly increased the number of tillers ha^{-1}. Number of tillers ha^{-1}. increased as the K level was increased till July. It started declining afterward with competition for light under canopy cover and nutrients. The number of tillers ha^{-1} decreased on July 25 as compared to earlier dates, however the difference between No-K and K-applied plots was significant (Table 2).

Millable stalks at harvest were significantly higher in applied-K plots as compared to the control. It indicates that K needs of cane plants were adequately fulfilled with applied K. It is important to note that millable canes at harvest are the main factor contributing towards cane yield.

Total soluble soils (Brix%) at different stags: Brix content of sugarcane in different treatments was measured with the help of hand refractor meter at various maturity stages till harvest. The data indicate that the Brix content were significantly higher in plots where K was applied compared to the control. Total soluble solids increased in all treatments as the cane crop reached to maturity. Brix content was maximum at the time of harvest and significantly higher in K applied plots as compared to control. The maximum Brix of 18.80 % was found in plots where 150 kg K_2O ha^{-1} was applied (Table 2)

Stalk height, stalk diameter, cane yield and sugar recovery: Stalks were significantly taller in plots where K was applied compared to those without K. The tallest stalks (310 cm) were found in plots where K was applied @150 kg K_2O ha^{-1}. Stalk diameter followed a similar trend as that of stalk height. Significantly thicker stalks were produced with the application of K. Stalk diameter was maximum (31.35 mm) in plots where K was applied @ 150 kg K_2O ha^{-1}(Table 3). When K is deficient in sugarcane fields plant growth would be retarded, internodes are shorter, stalks are slender and shorter than normal plants. (Van Dillewijn 1952; Humbert, 1963; Barres, 1964).

Cane yield was significantly increased with the application of K. Maximum cane yield (155.00 tons ha^{-1}) was recorded in plots where K was applied @ 150 kg k_2O ha^{-1}, whereas, minimum cane yield (119.00 t ha^{-1}) was produced in the control plots. Potassium plays a significant role as an enzyme activator (Fileo, 1985) and is the most abundant plant cell cation, accumulated in the cell sap. Hartt (1934) observed that K was essential in sugarcane to assure cellular structure for C assimilation and for syntheses and translocation location of proteins. Humbert (1963) indicated that

Table 1: Chemical characteristics of the experimental site

Depth (cm)	pH	EC_e (dS m^{-1})	NO_3-N (mg kg^{-1})	P	K	Ca + Mg (m eq l^{-1})	Cl
0-30	7.6	0.44	0.18	1.26	114	4.5	0.35
30-45	7.8	0.43	0.62	1.36	126	4.33	0.45
45-60	7.9	0.57	0.85	2.12	96	4.2	0.60
60-90	7.9	0.60	1.25	2.04	82	3.9	1.75

Organic matter = 0.5 %

Table 2: Effect of different k levels on tillering and brix percentage TSS (Total Soluble Solids) of sugarcane

	Number of tillers (000 ha $^{-1}$)				TSS (%)			
K_2O (kg ha^{-1})	June 15	July 04	July 25	Dec 14	Oct 20	Nov. 02	Nov. 24	Dec. 14
0	109.47	119.47	111.13	090.67	16.57	17.27	17.00	17.63
50	192.23	193.30	171.67	123.57	16.23	17.00	18.30	18.87
100	149.6	161.70	164.43	124.13	16.67	17.67	18.77	18.73
150	157.80	165.00	150.00	122.50	16.23	17.10	18.40	17.80
200	168.63	169.77	146.43	120.77	16.30	16.57	18.53	18.70
LSD (0.05)	48.5	041.47	021.63	006.49	NS	NS	01.12	00.35

NS non- significant

Table 3: Effect various K levels on stalk height, stalk diameter, cane yield and sugar recovery

Treatments K_2O (kg ha^{-1})	Stalk height (cm)	Stalk diameter (mm)	Cane yield (t ha^{-1})	Sugar recovery (%)
0	250.33	27.40	119.00	10.70
50	304.00	30.47	125.50	11.40
100	304.67	31.60	148.00	11.30
150	310.00	31.75	155.00	11.60
200	304.33	31.50	154.50	11.50
LSD (0.05)	013.65	01.93	006.83	00.45

Table 4: Effect of different potash levels on nutrient concentration in sugarcane

Fertilizer treatments (K_2O kgs ha^{-1})	Nutrient contents in sugarcane leaf sheath (First year)				
	K (%)	P (%)	Mg (mg kg^{-1})	Zn (mg kg^{-1})	B (mg kg^{-1})
0	0.23b	2.14b	2820d	05.3d	07.5d
50	0.25a	2.41a	2960c	08.5c	08.3c
100	0.27a	2.41a	3035b	16.5b	09.4b
150	0.28a	2.41a	3221a	20.6a	12.1a
200	0.28a	2.41a	3252a	22.5a	12.4a
Adequacy range	0.20-0.30	1.10-1.80	0.10-0.35 %	20.100ppm	04.0-30ppm
LSD (0.0 5)	0.02	0.04	36.0	01.9	00.5

Means with different letters differ from each other at 5% levels of probability

Table 5: Economics of potash application in sugarcane

K_2O (kg ha^{-1})	MOP Bags (ha^{-1})	Cane Yield (t ha^{-1})	Cane yield increase due to K over control (t ha^{-1})	Cost of K_2O and additional expenses on increased cane yield (Rs. ha^{-1})	Income from additional cane yield (Rs. ha^{-1})	Net income over control (Rs ha^{-1})
0	-	119.00	-	-	-	-
50	1.67	125.50	06.50	(918+1544) = 2462	5687	3225
100	3.3	148.00	29.00	(1815+6887)=8702	25375	16673
150	5.0	155.00	36.00	(2750+8550)=11300	31500	20200
200	6.67	154.50	35.50	(3668+8431)=12099	31062	18963

MOP= Rs. 550 per bag Sugarcane price = Rs. 35 per 40 kgs.
Additional expenditure (cane harvesting + cleaning + transportation to mill) = Rs. 9.50 per 40 kgs.

K deficiency exerted a negative effect on photosystem and ultimately carbohydrate transport was affected (Hartt, 1930; Alexander, 1973) in K deficient sugarcane plants and vice versa. Application of K also improved sugar recovery. It was significantly higher in K applied plots compared to the control. Sugar recovery was maximum in plots where K was applied @ 150 kg k_2O ha^{-1} (Table 3) .

Nutrient contents of cane plant tissue: The results of plant tissue samples, analyzed in the laboratory, indicate that P content of leaf sheath was higher in plants where K was applied. However, the difference in P contents of plants at various K levels were non-significant. Similarly K contents were significantly higher in plants where K was applied. Zinc, Mg and B content of plant tissue also increased significantly with increasing K levels upto 150 kg K_2O ha^{-1} (Table 4). Since potash application has improved the plant metabolism, the plants were able to absorb nutrients more efficiently. The effect observed in this experiment seems to be the consequence of better root growth, water balance and nitrogen metabolism (Tisdale *et al.*, 1997).

Economics of potash application in sugarcane: Economics of K application in sugarcane was calculated on the basis of bags of MOP applied per hectare, additional cane yield obtained due to K application, cost of K_2O applied and harvesting, loading and transportation charges of additional cane yield to the mill. Income from additional cane yield was calculated by subtracting expenses on additional yield from the income of additional cane yield and net income was calculated (Table 5).
Data presented in Table 5 shows that application of five (5) bags of MOP ha^{-1} (150 kg K_2O ha^{-1}), adding an additional expenditure of Rs. 11300 ha^{-1}, resulted in a net benefit of Rs. 20200 ha^{-1} over control (Table 5).

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