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YIELD AND QUALITY OF SUGARCANE AS INFLUENCED BY DIFFERENT DOSES OF POTASH AND ITS TIME OFAPPLICATION

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The present study was conducted to determine the role of potassium in split application on yield and quality of sugarcane. Experiment was carried out at the Farm Area, Sugarcane Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan in a randomized complete block design having three replications with a net plot size of 6m × 8m. The results revealed significant differences among all the treatments means except for fiber percent. The maximum stripped cane yield (116 & 107 t ha^{-1}during 2006 and 2007, respectively) was recorded with the application of 168 kg K_2O ha^{-1} in two splits; 84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 days after planting, while the highest brix (20.4 and20.8% during 2006 and 2007, respectively), sucrose (17.5 and 18.2% during 2006 and 2007, respectively) and commercial cane sugar (12.95 and 13.60% during 2006 and 2007, respectively) were obtained with the application of 224 kg K_2O ha^{-1} in two splits;112 kg K_2O ha^{-1} at planting+ 112kg K_2O ha^{-1} at 90 days after planting. The same results were also supported by Contrasts' analysis. It was concluded that the maximum stripped cane yield, NFB and BCR were obtained with the application of 168 kg K_2O ha^{-1} in two splits; 84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP in the moderately fertile soil.
Keywords: Potassium, sugarcane, split application, sugar yield

INTRODUCTION

Sugarcane, a complex hybrid of *Saccharum* spp. is being planted in 104 countries of the world. Pakistan ranks 5th with respect to area and production, while 8th with regards to sugar production (FAO, 2012). Sugarcane is one of the important cash crops of Pakistan which not only provides main stay to sugar industry but also raw material to many allied industries for alcohol and chip board manufacturing and thus plays a vital role both in agricultural and industrial economy of the country (Sajjad *et al.*, 2012). It is grown on an area of 1.001 million hectares with a total annual stripped cane production of 61 million tones giving an average stripped cane yield of 55.49 t ha^{-1} (Anonymous, 2012).

Sugarcane is a long duration and exhaustive crop that requires high quantity of nutrients. Moreover, continuous planting of sugarcane in the same field depletes the soil nutrients drastically. The crop having yield of 100 t ha^{-1} removes 207kg N, 30kg P_2O_5 and 233kg K_2O from the soil (Jagtap *et al.*, 2006). K influences water use efficiency (Quampah *et al*. 2011). Therefore, these elements must be added in adequate quantities for attaining higher yield.

Potassium is one of the major plant nutrients. Although it is not a part of plant or plant product, yet it is very important for the life process of plant (Haji *et al.*, 2011). The major role of potassium is energy transfer and carbohydrates metabolism. It is required for maintaining cell turgidity, photosynthesis, root development, tolerance to drought and resistance to certain pests and diseases (Saleem and Akhtar, 1996). It also increases the percentage of brix for plant and ratoon crops (De Boer, 1999).

A big gap exists between attainable cane yield potential (300 t ha^{-1}) and the average national harvested yield (49 t ha^{-1}) of existing cane varieties (Majid, 2007). Higher productivity of the cane and sugar depends on the genetic potential of the cultivars and proper management of the crop including application of fertilizer at appropriate rate and time. In Pakistan, use of K is around 0.73 kg ha^{-1} as against 85 kg ha^{1} of nitrogen and 21 kg ha^{-1} of P_2O_5 (Anonymous, 2003) which seems to be inadequate and imbalanced to explore the production potential of the crop. Pakistan soils have developed from micaceous alluvium and the irrigation water has high K contents, the crop is well supplied with the element (Iqbal *et al.*, 1998), so it is generally presumed that crops will not positively respond to K (Arain*et al.*, 2000) and only N and P are applied. However, with the introduction of high yielding varieties and intensive agronomic practices sugarcane crop is becoming more responsive (Khan *et al.*, 2005) to higher levels of K fertilizer than recommended rates. Very less research work has been done regarding the time of K application as it is applied often at the time of planting. Keeping this all in view, the present study was planned with the hypothesis that application of potassium in high amounts and at different times will improve sugarcane yield and quality.

MATERIALS AND METHODS

A field experiment was carried out at the Farm Area, Sugarcane Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan in a randomized complete block design having three replications with a net plot size of 6m x 8m. The physico-chemical properties of experimental soil are given in Table 1 which indicates that soil is moderately fertile with respect to available K.

Table 1.Physico-chemical properties of the soil (0-15 cm)

Properties	2006	2007
Texture	Loam	Loam
pH	7.90	7.90
EC (dS m^{-1})	0.37	1.40
Organic matter (%)	0.87	0.87
Available N (%)	0.044	0.044
Available P (ppm)	7.50	7.50
Available K (ppm)	116.00	108.00

The sugarcane variety HSF-240 was planted on 5^{th} of March 2006 for first year and 7^{th} of March 2007 for second year. The seed rate used was 75000 DBS (double budded setts) ha^{-1} and was placed end to end in two parallel rows 1.2 m apart trenches. The N and P_2O_5 fertilizer levels were kept constant (@168 and 112 kg ha^{-1}), respectively and were applied in trenches in the form of urea (46% N) and Single Super Phosphate (18% P_2O_5).Whole of the phosphorus and one third of the nitrogen was applied at the time of planting and remaining two third nitrogen was applied in two equal splits i.e. at completion of germination, 45 days after planting (DAP) and at the time of earthing up (90 DAP) while potash was applied in the form of sulphate of potash (SOP 50% K) as per treatment (No potash, 112 kg K_2O ha^{-1} at planting, 112 kg K_2O ha^{-1}at 90 DAP, 56 kg K_2O ha^{-1} at planting + 56 kg K_2O ha^{-1} at 90 DAP, 168 kg K_2O ha^{-1} at planting, 168 kg K_2O ha^{-1} at 90 DAP, 84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP, 224 kg K_2O ha^{-1} at planting, 224 kg K_2O ha^{-1} at 90 DAP and 112 kg K_2O ha^{-1} at planting + 112 kg K_2O ha^{-1} at 90 DAP). All other agronomic practices were kept normal and uniform for all the treatments. The crop was harvested manually at its physiological maturity on 16^{th} and 18^{th} of December, 2006 and 2007, respectively. Meteorological data for growing periods of the crop were collected from the Observatory, Pakistan Agricultural Research Council (PARC) unit, Ayub Agricultural Research Institute, Faisalabad, Pakistan (Fig.1).All stripped canes of each plot (28.8 m^2) were weighed in kilograms and then transformed to t ha^{-1}.

(a)

(b)

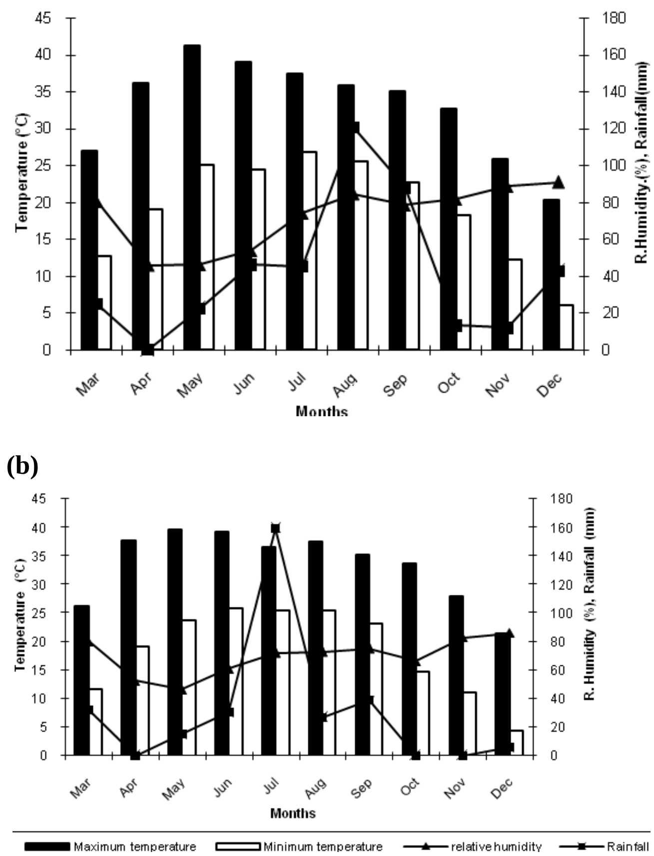

Figure 1. Meteorological data at AARI, Faisalabad, Pakistan, (a) 2006 and (b) 2007

Ten canes per plot were randomly collected and passed through a power crusher for juice extraction. Juice was collected in the glass jars. Temperature of the juice was noted. Then the brix percent reading was recorded by Brix hydrometer. The recorded brix values were corrected by using the Schmitz's table (Spancerand Meade, 1963).

Pol reading of extracted juice for each treatment was noted with the help of polarimeter. Cane juice sucrose content was calculated using the Schmitz's table described by Spancerand Meade (1963).

Cane juice purity was determined as described by Spancerand Meade (1963).

$$\text{Cane juice purity (\%)} = \frac{\text{Pol}}{\text{Brix}} \times 100$$

Commercial cane sugar (CCS percent) was calculated by using the method of Spancerand Meade (1963).

$$CCS\% = \frac{3P}{2}\left(1 - \frac{F+5}{100}\right) - \frac{B}{2}\left(1 - \frac{F+3}{100}\right)$$

P = Pol percent in juice

B = Brix percent in juice

F = Fiber percent in juice

Total sugar (t ha^{-1}) was determined by the following formula:

$Total\ sugar\ (t\ ha^{-1}) =$ ▯ EMBED Equation.3 ▯▯▯

The collected data was analyzed by using Fisher's analysis of variance technique. Duncan's New Multiple Range (DNMR) test at 5% probability was applied to compare the significance among the treatments' means (Steel *et al.*, 1997).

RESULTS

Statistical analysis of data regarding yield and quality parameters presented in Table 2 revealed significant differences among the treatments' means at different K_2O level and time of its application except for fiber percent. The maximum stripped cane yield (116& 107 t ha^{-1} during 2006 and 2007, respectively) was recorded at T_7 (84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP) which were at par with all other treatments except T_1in 2006,and $T_1$and T_3 in 2007. Year effect on stripped cane yield was observed non-significant. Analysis of contrast revealed non-significant effect in all meaningful orthogonal contrasts except C_1 (K_2OVS no K_2O) and C_2 (112 kg K_2O ha^{-1}VS 168 kg K_2O ha^{-1}) which were significant in 2006 and 2007, while C_3 (112 kg K_2O ha^{-1}VS 224 kg K_2O ha^{-1}) was significant only during 2007.

Effect of K_2O level and time of its application on brix percentage over control was significant while no difference was observed between levels during both the years. The maximum brix percentage (20.4& 20.8% during 2006 and 2007, respectively) was noted in T_{10} (112 kg K_2O ha^{-1} at planting + 112 kg K_2O ha^{-1} at 90 DAP) while minimum (17.5& 17.9% during 2006 and 2007, respectively) at T_1 where noK_2O was applied. Year effect on brix percent was significant. All meaningful orthogonal contrasts were

Table 2. Effect of K_2O level and time of its application on yield and quality of sugarcane

Treatment	Stripped cane yield (t ha^{-1})		Brix (%)		Sucrose (%)		Purity (%)		Fiber (%)		Commercial cane sugar (%)		Sugar yield (t ha^{-1})	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T_1	77 b	70 c	17.5 b	17.9 b	14.2 b	14.8 b	81.3 b	82.5 b	13.9	13.8	9.94 b	10.52 b	7.7 b	7.4 b
T_2	102 a	94 ab	19.6 a	19.9 a	16.5 a	17.1 a	84.5 a	85.8 a	13.6	13.5	12.07 a	12.59 a	12.3 a	11.8 a
T_3	99 a	93 b	19.6 a	20.1 a	16.6 a	17.3 a	84.3 a	86.3 a	13.9	13.5	11.96 a	12.78 a	11.9 a	11.8 a
T_4	104 a	95 ab	19.7 a	20.0 a	16.7 a	17.3 a	84.7 a	86.1 a	13.8	13.7	12.14 a	12.71 a	12.6 a	12.1 a
T_5	110 a	102 ab	20.0 a	20.2 a	17.1 a	17.5 a	85.4 a	86.7 a	13.8	13.6	12.47 a	12.93 a	13.7 a	13.2 a
T_6	106 a	100 ab	19.8 a	20.1 a	17.0 a	17.4 a	85.9 a	86.8 a	13.7	13.6	12.51 a	12.94 a	13.3 a	13.0 a
T_7	116 a	107 a	20.0 a	20.3 a	17.2 a	17.6 a	85.9 a	86.8 a	13.6	13.5	12.64 a	13.04 a	14.7 a	13.9 a
T_8	107 a	100 ab	20.1 a	20.4 a	17.3 a	17.9 a	86.2 a	87.2 a	13.6	13.4	12.78 a	13.42 a	13.7 a	13.4 a
T_9	106 a	99 ab	19.9 a	20.4 a	17.2 a	17.9 a	86.3 a	87.7 a	13.5	13.3	12.68 a	13.36 a	13.4 a	13.2 a
T_{10}	109 a	104 ab	20.4 a	20.8 a	17.5 a	18.2 a	86.0 a	87.6 a	13.3	13.2	12.95 a	13.60 a	14.1 a	14.1 a
LSD	18.20	15.97	01.85	1.94	1.47	1.57	2.25	2.10	NS	NS	1.17	1.12	4.4.10	4.20
Year mean	104	96	19.7 b	20.0 a	16.7 b	17.3 a	85.1 b	86.4 a	13.7	13.5	12.21b	12.79 a	12.7	12.4
LSD	NS		0.42		00.55		1.25		NS		0.56		0.25	
Meaningful orthogonal contrasts														
C_1	**	**	**	**	**	**	**	**	NS	NS	**	**	**	**
C_2	*	*	NS	NS	NS	NS	*	*	NS	NS	NS	NS	*	*
C_3	NS	*	NS	NS	NS	NS	**	**	NS	NS	NS	NS	*	*
C_4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C_5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C_6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C_7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

T_1: No potash, T_2: 112 kg K_2O ha^{-1} at planting, T_3: 112 kg K_2O ha^{-1} at 90 DAP, T_4: 56 kg K_2O ha^{-1} at planting + 56 kg K_2O at 90 DAP, T_5: 168 kg K_2O ha^{-1} at planting, T_6: 168 kg K_2O ha^{-1} at 90 DAP, T_7: 84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP, T_8: 224 kg K_2O ha^{-1} at planting, T_9: 224 kg K_2O ha^{-1} at 90 DAP, T_{10}: 112 kg K_2O ha^{-1} at planting + 112 kg K_2O ha^{-1} at 90 DAP.
C_1: K_2O VS no K_2O, C_2: 112 kg K_2O ha^{-1} VS 168 kg K_2O ha^{-1}, C_3: 112 kg K_2O ha^{-1} VS 224 kg K_2O ha^{-1}, C_4:168 kg K_2O ha^{-1}VS 224 kg K_2O ha^{-1}, C_5: All K_2O at planting VS all K_2O at 90 DAP, C_6: All K_2O at planting VS in two splits, C_7: All K_2O at 90 DAP VS in two splits.

Means in a column not sharing the same letters differ significantly from each other at 5% probably level as per DNMR.LSD = Least signifiant différence

NS = Non-signifiant, * Significant at 5% probability level, ** Significant at 1% probability level observed non-significant except for C_1 (K_2OVS no K_2O), which was significant during 2006 and 2007. Statistically equal sucrose content was recorded between K_2O level and time of its application while significant effect of K_2O level over control was noted during both the years. The maximum sucrose percentage (17.5 & 18.2% during 2006 and 2007, respectively) in cane juice was recorded at T_{10} (112 kg K_2O ha^{-1} at planting + 112 kg K_2O ha^{-1} at 90 DAP) while minimum was given by T_1 with no K_2O application during both the years. Effect of year on sucrose percent in cane juice was observed significant. All meaningful orthogonal contrasts were non-significant except C_1 (K_2OVS no K_2O), which was significant during 2006 and 2007.

The maximum cane juice purity (86.3&87.7% during 2006 and 2007, respectively) was recorded at T_9 (224 kg K_2O ha^{-1} at 90 DAP) which was statistically at par with all other treatments except for T_1 (no K_2O) where minimum (81.3& 82.5% during 2006 and 2007, respectively) cane juice purity was noted. Year effect on cane juice purity percent was noted significant. All meaningful orthogonal contrasts were non-significant except C_1 (K_2OVS no K_2O), C_2 (112 kg K_2O ha^{-1}VS 168 kg K_2O ha^{-1}) and C_3 (112 kg K_2O ha^{-1}VS 224 kg K_2O ha^{-1}), which were significant during both the years. Cane fiber percentage ranged between 13.3-13.9 and 13.2-13.8, minimum in T_{10} and maximum in T_1 during 2006 and 2007, respectively. Year effect on cane fiber percent was also non-significant. Commercial cane sugar percentage (CCS percent) data given in Table 2 indicated significant effects of different levels of K_2O and time of its application over T_1 (no K_2O) during both the years. The maximum CCS percent (12.95& 13.60 during 2006 and 2007, respectively) was recorded at T_{10} (112 kg K_2O ha^{-1} at planting + 112 kg K_2O ha^{-1} at 90 DAP) and it was statistically at par with all other treatments where potash was applied while minimum CCS percent (9.94 & 10.52 during 2006 and 2007, respectively) was associated with T_1 (no K_2O). Year effect on CCS percent was observed significant. All meaningful orthogonal contrasts were non-significant except C_1 (K_2OVS no K_2O), which was significant during 2006 and 2007.

Significant effect of different K_2O level and time of its application on total sugar yield (t ha^{-1}) of sugarcane was observed in 2006 and 2007. In 2006, the maximum sugar yield (14.7 t ha^{-1}) was recorded at T_7 (84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP) while in 2007, the maximum sugar yield (14.1 t ha^{-1}) was produced by T_{10} (112 kg K_2O ha^{-1} at planting + 112kgK_2O ha^{-1} at 90 DAP) and

Table 3. Economic analysis

A)

Treatments	Benefit Cost Ratio			Dominance Analysis	
	Total cost ($Rs.ha^{-1}$)	Gross income ($Rs.ha^{-1}$)	Benefit cost Ratio	Cost that vary ($Rs.ha^{-1}$)	Net field benefit ($Rs.ha^{-1}$)
T_1	72684	111000	1.53	20350	90650
T_2	84694	147000	1.74	31810	112190
T_3	84144	144000	1.71	32360	114640
T_4	85003	148500	1.75	32669	115831
T_5	89599	159000	1.77	36440	118060
T_6	88774	154500	1.74	37265	121735
T_7	91300	168000	1.84	38966	129034
T_8	91754	156000	1.70	39145	115355D*
T_9	91479	154500	1.69	39420	116580 D
T_{10}	92372	159000	1.72	40038	118962 D

*D = Dominated

B)

Treatments	Marginal Analysis				
	Cost that vary ($Rs.ha^{-1}$)	Marginal cost ($Rs.ha^{-1}$)	Net field benefit ($Rs.ha^{-1}$)	Marginal net benefit ($Rs.ha^{-1}$)	Marginal rate of return (%)
T_3	31810	-	112190	-	-
T_2	32360	550	114640	2450	445
T_4	32669	309	115831	1191	385
T_6	36440	3771	118060	2229	59
T_5	37265	825	121735	3675	445
T_7	38966	1701	129034	7299	429

T_1: No potash, T_2: 112 kg K_2O ha^{-1} at planting, T_3: 112 kg K_2O ha^{-1} at 90 DAP, T_4: 56 kg K_2O ha^{-1} at planting + 56 kg K_2O at 90 DAP, T_5: 168 kg K_2O ha^{-1} at planting, T_6: 168 kg K_2O ha^{-1} at 90 DAP, T_7: 84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP, T_8: 224 kg K_2O ha^{-1} at planting, T_9: 224 kg K_2O ha^{-1} at 90 DAP, T_{10}: 112 kg K_2O ha^{-1} at planting + 112 kg K_2O ha^{-1} at 90 DAP.

both these were statistically at par with all other treatments except T_1 where no K_2O was applied and gave minimum (7.7 &7.4 t ha^{-1} during 2006 and 2007, respectively). Analysis of contrast revealed non-significant differences among all meaningful orthogonal contrasts except C_1 (K_2OVS no K_2O), C_2(112 kg K_2O ha^{-1}VS 168 kg K_2O ha^{-1}) and C_3 (112 kg K_2O ha^{-1} VS 224 kg K_2O ha^{-1}) during 2006 and 2007, which were significant.

Economic analysis was calculated on the basis of average data of 2006 and 2007. Sugarcane grown with T_7 (84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP) gave the maximum net field benefit (NFB) of Rs. 129034 ha^{-1} and benefit cost ratio (BCR) of 1.84 (Table 3-A). The treatmentsT_8, T_9 and T_{10} had NFB that was less than those with lower cost. Consequently these treatments got dominated (D). The remaining un-dominated treatments were further considered in the marginal analysis. Marginal analysis of un-dominated treatments (Table 3-B) indicated that T_2 (112 kg K_2O ha^{-1} at planting) and T_5 (168 kg K_2O ha^1 at planting) gave the maximum and equal marginal rate of return (MRR) of 445 percent.

DISCUSSION

Maximum stripped cane yield at T_7 (84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP) might be attributed due to higher values of yield contributing parameters like number of millable canes, cane length and cane girth due to more LAI, LAD and CGR with the same treatment (data not shown).Significant increase in stripped cane yield up to an optimal level of K_2O had already been reported by Kumar *et al.* (2003). Contrary to that Ramesh and Varghese (2003) and Patel *et al.* (2004) reported non-significant difference in cane yield at different doses of K_2O while Gawander *et al.* (2004) registered statistically same stripped cane yield at varied levels of potassium on sites having high K status and significant effect on soils with low exchangeable K. Although brix percent increased linearly with each increment in K_2O level from 0-224 kg ha^{-1} but this addition in brix percent was non-significant between K_2O level and time of its application, while significant over no K_2O application. These results are in consonance with the findings of Ahmad (2012) who recorded that K-fertilization increased the percentage of brix for plant and ratoon crops. There was also a linear increase in sucrose percent with increasing dose of $K_2O$was perhaps due to melassigenic behavior of potassium as one atom of K holds one sucrose atom (Gupta and Prasad, 1968). These findings are in accordance with Khosa (2002) who recorded increase in sucrose percent with increasing rate of K_2O. Significantly higher cane juice purity in treatments with applied K_2O over control and statistically at par between K_2O levels was ascribed to more sucrose percent in cane juice in treatments where K_2O was applied. There was non-significant difference in fiber content at varied levels of K_2O and time of its application over control and among K_2O levels. This might be due to genetic characteristics of variety that responded equally in all the treatments. These findings are in concurrence with Elamin *et al.* (2007). The low CCS percentage in control treatment was ascribed to less value of brix percent, sucrose percent and purity percent and high fiber percent. These results are in conformity with those of Kumar *et al.* (2003) and Kumar (2005) who reported significantly low CCS percentage at 0, 25 and 50 kg K_2O ha^{-1}. More brix, sucrose in cane juice, cane juice purity and CCS percentage in later year might be due to dry climatic conditions at the time of maturity of cane crop (Fig.1). The maximum sugar yield (t ha^{-1}) obtained in T_7 and $T_{10}$was due to higher stripped cane yield and CCS percentage. The results are in corroboration with Gawander *et al.* (2004) who recorded maximum sugar yield with increasing rate of K_2O. Contrasts' analysis revealed that sugarcane yield and quality parameters were significantly improved by applying potash even though our soils had built in K. The NFB and BCR were maximum at T_7 (84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP) while the MRR was highest and equal in T_2 (112 kg K_2O ha^{-1} at planting) and T_5 (168 kg K_2O ha^{-1} at planting). As the variable cost was more in T_5 so, T_2 where 112 kg K_2O ha^{-1} was applied at sowing is considered an appropriate and economical level of K_2O for spring planted sugarcane.

***Conclusion*:** It was concluded that the maximum stripped cane yield, NFB and BCR were obtained with the application of 168 kg K_2O ha^{-1} in two splits; 84 kg K_2O ha^{-1} at planting + 84 kg K_2O ha^{-1} at 90 DAP in the moderately fertile soil.

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