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Response of Sugar Beet Quantity and Quality to Nitrogen and Potasium Fertilization under Sandy Soils Conditions

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ABSTRACT

Sugar beet is a tolerant crop to salinity and wide range of climate, so, it could be economically grown in light textural soils (sandy) such as at the Northern parts of Egypt. Delivering higher quality of sugar beet roots to the factory is determined by the concentration of sucrose and impurities in the root, which, is mainly related to Nitrogen (N) and Potassium (K) fertilizers program. So, the effect of four N levels (105, 141, 176, 211 N kg ha^{-1}) and four K levels (60, 100, 140 and 180 K_2O kg ha^{-1}) on multi germ sugar beet cultivar (Ymer) under sandy soil conditions was studied in North Sinai Governorate, Egypt (31°N and 32°E) during two winter seasons (2009/2010; 2010/2011). Results showed that the highest sugar beet yields of top (15.478 and 17.695 t ha^{-1}), root (41.184 and 49.488 t ha^{-1}) and gross sugar (7.622 and 8.936 t ha^{-1}) were obtained by adding the highest fertilizers rates (211 N kg and 140 K_2O kg per hectare). The maximum sucrose percent (18.64 and 18. 87%) was achieved by adding 100 K_2O kg and 141 N kg ha^{-1}. Gross sugar yield per hactare was positively correlated with yields of sugar beet top (0.974) and roots (0.823) ha^{-1} but negatively correlated with quality index (-0.987). Path analysis indicated that, root yield ha^{-1}, sucrose% and the interaction between root yield and top yield were the most variable contribution of gross sugar yield.

Key words: Sugar beet, nitrogen fertilization, potassium fertilization, correlations study, path analysis, sandy soils

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is one of the most important crops in Egypt as it is well adapted to Egyptian environment especially reclaimed lands and has essential position in winter crop rotation not only in fertile soils but also in poor, sandy, saline alkaline and calcareous soils. Also, it is far better than sugar cane when water use efficiency is concerned; one kilogram of sugar needs about 1.4 and 4.0 m^3 water by sugar beet and sugar cane, respectively (Ouda, 2001). Adding suitable fertilizers, such as macro and/or micro nutrients may be one of the favorable factors for the quantity and quality of sugar beet (Ouda, 2002). So, appropriate nitrogen and potassium fertilizers are essential for high root and sugar yields but an excess of these nutrients decreases juice purity and sugar extractability, in this concern Khan *et al.* (1998) noticed that sugar yield, sucrose and purity percentages of sugar beet increased with increasing N levels from 0 up to 120 kg N ha^{-1} but adding 180 kg N ha^{-1} decreased sucrose percent. Also, Increasing N levels increased root and sugar yields (Ismail, 2002; El-Sayed, 2005), top yield (Ouda, 2002; Osman, 2005) but, decrease sucrose and purity percent (Zalat and Ibrahim, 2002; Azzay, 2004). On the other hand, Abou-Zeid and Osman (2005) reported that there was no evidence for significant differences in the total soluble solids as well as sucrose and purity percentages due to increasing N levels. In Egypt, many investigators study the effect of various levels of N fertilizers on sugar beet grown in clay and/or sandy soils, they concluded that the maximum root, sugar yields, root quality and minimum sugar losses were achieved when N application ranged between 214 and 262 kg N ha^{-1} (Hassanin and Elayan, 2000; Moustafa and Darwish, 2001; Abo El-Wafa, 2002; Hilal, 2005). Increasing nitrogen fertilizer rates up to 120 kg N fed^{-1} and 240 kg N ha^{-1} significantly increased top, root and gross sugar yields per feddan and/or hectare but decreased sucrose% (El-Sarag, 2008; Nasr *et al.*, 2011). Potassium is a very mobile element in plant tissues and moves readily from older tissues to the growing points of the root and foliage. Potassium uptake depends upon N uptake, plant growth, availability of K in the soil and genotype (Carter, 1986). Kasap and Killi (1994) in Turkey and Morrsi (1997) in Egypt, cleared that K fertilization (up to 60 kg K_2O ha^{-1} and 48 kg K_2O/fad.) significantly increased root, top and gross sugar yields/fad as well as root quality parameters in terms of TSS, sucrose and purity percentages. However, the maximum sugar loss (ton ha^{-1}) and sucrose percent were obtained from adding the highest N and K levels (285 kg N and 114 kg K_2O ha^{-1}) (Abdel-Motagally and Attia, 2009). Also, a significant improvement in sugar beet root, top yields and impure sugar percent but not in sugar yield and pure sugar yield were obtained by adding 100 kg K_2O ha^{-1} (Mehrandish *et al.*, 2012). Now, there is no accurate and comprehensive information regard to effect of nitrogen and potassium fertilizer rates on quality and quantity features of sugar beet under sandy soil conditions. So, this research reviews the effect nitrogen and potassium fertilizer levels on top and root yields as well as other quantity and quality features of sugar beet in poor sandy soils conditions.

MATERIALS AND METHODS

Experimental site and treatments: Two field trials were conducted at the experimental farm in Faculty of Environmental Agricultural Sciences (FEAS), Suez Canal University at North Sinai Governorate, Egypt (31°N and 32°E) during winter seasons of 2009/2010 and 2010/2011. The study aimed to examine the effect of nitrogen and potassium fertilizer levels on quantity (top, root and sugar yields) and quality (TSS, Sucrose, Purity and quality index%) of multi germ sugar beet cultivar (Ymer) under sandy soil conditions. Each experiment included 16 treatments which were the combinations of: (i) Four N levels, i.e. 105, 141, 176 and 211 N kg ha^{-1} and (ii) Four K levels, i.e., 60, 100, 140 and 180 K_2O kg ha^{-1}. Mechanical and chemical analysis of experimental site soil in both seasons is presented in Table 1.

Table 1: Mechanical and chemical analysis of the experimental soil

Soil characters	2009/2010	2010/2011
Coarse sand (%)	80.15	79.41
Fine sand (%)	12.04	12.88
Silf (%)	3.00	3.11
Clay (%)	4.81	4.61
Texture	sandy	sandy
O.M.(%)	0.36	0.39
pH	8.62	7.90
Available N (ppm)	11.20	12.50
Available P (ppm)	6.10	5.34
Available K (ppm)	141.20	144

Experimental design: A split plot design with three replicates was used; nitrogen fertilizer levels occupied the main plots and potassium fertilizer levels were assigned randomly to the sub plots. Plot area was 18 m^2 comprised of 6 rows (50 apart×6 m length) and the spacing between hills were 20 cm.

Agricultural practices: In both seasons, the preceding crop was sunflower. Sugar beet seeds were sown on October 25 and 29th in the two respective seasons. The sugar beet plants were thinned to 2 plants $hill^{-1}$ after 30 days from sowing date, then, to 1 plant $hill^{-1}$ l after 10 days later. Calcium super phosphate (15.5% P_2O_5) at a rate of 76 kg P_2O_5 ha^{-1} was added at land preparation. Potassium fertilizer at the studied levels in form of potassium sulphate (48% K_2O) was added in two equal portions; after thinning and 20 days later. The nitrogen fertilizer levels was added in form of urea (46% N) according to each level in three equal doses (1/3 after thinning, 1/ 3 at 70 days from sowing and the rest was applied 25 days later). All other culture practices were carried out as recommended.

Recorded data: At maturity (180 days from sowing), five plants were taken at random from each plot to estimate the root total soluble solids percent (T.S.S.%; using hand refractometer). Sucrose percent% was estimated in fresh samples of sugar beet root by using Saccharometer according to the method described by AOAC (1995). Purity percentage was computed according to the equation:

$$\frac{\text{Sucrose\%}}{\text{T.S.S\%}}\times 100$$

At harvest (205 days from sowing). Three inner rows from each sub plots were harvested to determine top and root yield (ton ha^{-1}). Gross sugar yield (ton ha^{-1}) was calculated by multiplying root yield by sucrose%. A sample of 15 kg of roots were taken at random from each plot and sent to Food Technology Laboratory to determine root quality. Sugar loss was calculated using the following formula: Sugar loss% = 0.29+0.343 (K+Na)+0.094 α-amino N (Reinefeld *et al.*, 1974). Quality index was computed according to Sugar Recovery% (sucrose%-sugar loss) ×100/sucrose%.

Statistical analysis: Data were statistically analyzed for the two seasons and their combined as described by Senecore and Cochran (1981). The mean values were compared using Duncan's multiple range test according to Duncan (1955). All statistical analysis were performed by using analysis of variance technique of (MSTAT) Computer software package.

RESULTS AND DISCUSSION

Effect of K levels: Data presented in Table 2 show that increasing K levels increased significantly root, top yields as well as gross sugar yield in both seasons. In combined analysis, as K levels increased from 60 up to 180 kg K_2O kg ha^{-1}, top, root and gross sugar yields increased from 13.133, 37.104 and 6.811 t ha^{-1} up to 15.478, 41.184 and 7.622 t ha^{-1}, respectively (these increase were by 15.22, 9.91 and 10.55%, respectively). While, the minimum quantity of beet yields (root+sugar)

Table 2: Effect of nitrogen and potassium fertilizer levels on sugar beet quantity (top, root and gross sugar yields; t ha^{-1}) in 2009/2010 and 2010/2011 seasons and combined analysis

	Yields (ton ha^{-1})								
	Top			Root			Gross sugar		
Treatments	2009-10	2010-11	Combined	2009-10	2010-11	Combined	2009-10	2010-11	Combined
K levels (K_2O kg ha^{-1})									
60	16.360^{d}	9.889^{c}	13.133^{d}	40.527^{d}	31.669^{d}	37.104^{d}	8.627^{d}	5.007	6.811^{c}
100	17.567^{c}	10.124^{b}	13.848^{c}	41.257^{c}	32.442^{c}	37.848^{c}	8.841^{c}	5.223	7.033^{b}
140	18.820^{b}	10.683^{b}	14.750^{b}	44.134^{b}	34.712^{b}	40.416^{b}	9.359^{ab}	5.449	7.405^{ab}
180	19.988^{a}	10.925^{a}	15.478^{a}	44.866^{a}	35.482^{a}	41.184^{a}	9.573^{a}	4.665	7.622^{a}
F. test	**	*	**	*	*	**	*	N.S	*
N levels (N kg ha^{-1})									
105	14.450^{d}	6.812^{d}	10.608^{d}	32.757^{d}	22.484^{d}	27 600^{d}	7.053^{d}	3.399^{d}	5.224^{d}
141	17.097 1	9.018^{c}	1 3.056^{c}	41.034^{c}	30.757^{c}	35.904^{c}	8.598^{c}	4.822^{c}	6.712^{c}
176	19.667^{b}	11.970^{b}	15.818^{b}	49.182^{b}	37.878^{b}	43.536^{b}	9.779^{b}	5.219^{b}	7.993^{b}
211	21.563^{a}	13.825^{a}	17.695^{a}	55.814^{a}	43.189^{a}	49.488^{a}	9.972^{a}	6.903^{a}	8 936^{a}
F. (test)	**	**	*	**	**	**	**	**	**
K x N	N.S	N.S	NS	N.S	NS	*	N.S	N.S	N.S

*, ** and NS: Significant at $p<0.05$, 0.01 levels and not significant, respectively, Means with the same letters are not significantly different at 5% level

were obtained when 60 kg K_2O kg ha^{-1} was added. Concerning to sugar beet quality, Table 3 shows there was no significant effect of K levels on T.S.S. and purity % in both seasons. However, the highest sucrose percent (18.64%) was obtained when 100 kg K_2O ha^{-1} was applied. The same trend was observed in sugar loss values, where, the maximum value of sugar loss (2.74 %) was achieved when 60 and/or 100 kg K_2O ha^{-1} was added. An opposite trend was found for quality index, where, it increased with every increment of K addition, which lead to the highest value (84.05%) with the highest K level (180 kg K_2O ha^{-1}).

Effect of N levels: The influence of nitrogen fertilizer application on sugar beet quantity and quality are shown in Table 2 and 3. All sugar beet yield (Top, Root and gross sugar) were affected significantly by N-levels addition, where, each increase in N-level caused significant increase in these yields. Top, Root and Gross sugar yields were increased from 10.608, 27.600 and 5.224 to 17.695, 49.488 and 8.936 t ha^{-1}, respectively (these increases were by 40.05, 44.23, 41.54%, respectively) as N-level increased from 105 up to 211 kg N ha^{-1} in combined analysis. The same trend was observed for sugar beet quality characters, where all of them affected significantly by every addition of N-level, except purity percentage in the 1st season and T.S.S. in combined analysis. There were no significant differences between N application levels of 105 and 141 kg N ha^{-1} on T.S.S. (21.75 and 21.78%) and Sucrose percentages (18.68 and 18.87%), which were superior than the other N-levels. The highest N-level (211 kg N ha^{-1}) gave the maximum sugar loss (3.20%) but the maximum quality index (81.33 and 81.57%) was achieved with the lowest N-level (105 kg N ha^{-1}) in the 1st significant season and combined analysis. This favorable effect of N fertilizer application were rather expected since the soil was sandy poor fertile one (Table 1). In this respect, Ouda (2002), El-Sarag (2008) and Nasr *et al.* (2011) obtained the high and positive response of sugar beet to N rates under sandy soil conditions. The negative effects of high N rates on sucrose concentration reported by Draycott (1993) and Azzay (2004).

Table 3: Effect of nitrogen and potassium fertilizer levels on sugar beet quality (TSS, Sucrose, Purity %, Sugar loss; SL and Quality Index; QI) in 2009/2010 and 2010/2011 seasons and combined analysis

	T.S.S.%			Sucrose%			Purity%			Sugar Loss			Quality Index		
Treatments	2009-10	2010-11	Combined	2009-10	2010-11	Combined	2009-10	2010-11	Combined	2009-10	2010-11	Combined	2009-10	2010-11	Combined
K levels (K_2O kg ha^{-1})															
60	21.15	20.87	21.01	18.53	18.40^{b}	18.47^{b}	87.69	88.29	87.99	2.65	2.83^{a}	2.74^{a}	80.66^{d}	81.83^{d}	81.25^{d}
100	21.23	21.35	21.29	18.64	18.65^{a}	18.64^{a}	87.85	87.46	87.56	2.64	2.83^{a}	2.74^{a}	81.86^{c}	82.67^{c}	82.27^{c}
140	21.35	21.21	21.28	18.59	18.14^{c}	1 8.36^{c}	87.14	85.73	86.44	2.56	2.76^{b}	2.66^{b}	82.65^{b}	83.81^{b}	83.23^{b}
180	21.43	21.69	21.56	18.70	18.38^{b}	18.54^{b}	87.30	84.90	86.10	2.44	2.63^{c}	2.54^{c}	83.44^{a}	84.66^{a}	84.05^{a}
F-test	N.S	NS	N.S	NS	**	**	N.S	N.S	N.S	NS	*	*	**	**	**
N levels (N kg ha^{-1})															
105	21.75^{a}	21.25	21.50	19.07^{a}	18.67	18.68^{a}	87.73	88.06	87.89	2.68^{d}	2.82	2.75^{d}	81.33^{a}	81,81	81.57^{a}
141	21.78^{a}	21.08	21.42	18.97^{a}	18.40	18. 87^{a}	87.25	87.45	87.35	3.07^{c}	3.09	3.08^{c}	79.13^{b}	79.26	79.19^{b}
176	20.82^{b}	21.79	21.31	18.24^{b}	18.60	18.42^{ab}	87.65	85.45	86.55	3.11^{b}	3.13	3.12^{b}	78.66^{c}	78.81	78.74^{c}
211	20.8.1^{b}	21.00	20.92	18.17^{b}	17.90	18.04^{b}	87.35	85.43	86.39	3.18^{a}	3.22	3.20^{a}	77.34^{d}	77.65	77.49^{d}
F. (test)	*	NS	N.S	**	N.S	**	N.S	N.S	N.S	**	NS	**	**	NS	**
K x N	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	**

*, ** and NS:Significant at $p<0.05$, 0.01 levels and not significant, respectively, Means with the same letters are not significantly different at 5% level

Interaction effect: Figure 1, 2 and 3 shows the significant interaction effects between N and K fertilizer levels on quantity (top+root yields) and quality (QI) (combined data) on sugar beet grown under sandy soil conditions. Application of 211 kg N and 180 kg K_2O ha^{-1} gave the highest top and root yields (19.21 and 50.59 t ha^{-1}) while, the lowest quantities of sugar beet top and root (9.71 and 25.43 t ha^{-1}) were achieved by adding 105 kg N and 60 kg K_2O ha^{-1}. However, application of 105 kg N and 180 kg K_2O ha^{-1} surpassed all the other treatments in quality index

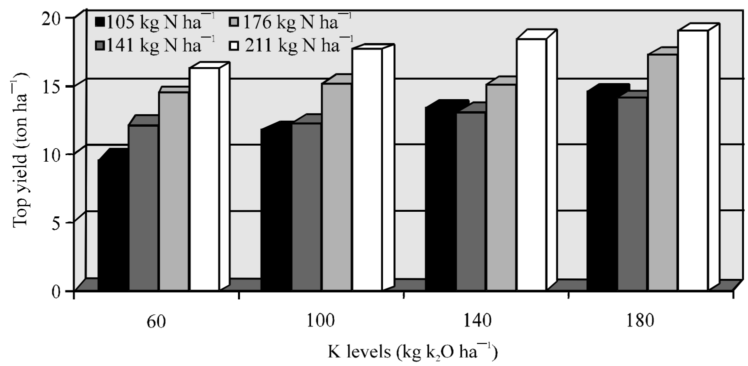

Fig. 1: Sugar beet top yield (t ha^{-1}) as affected by N and k levels (kg ha^{-1}) interaction n combined

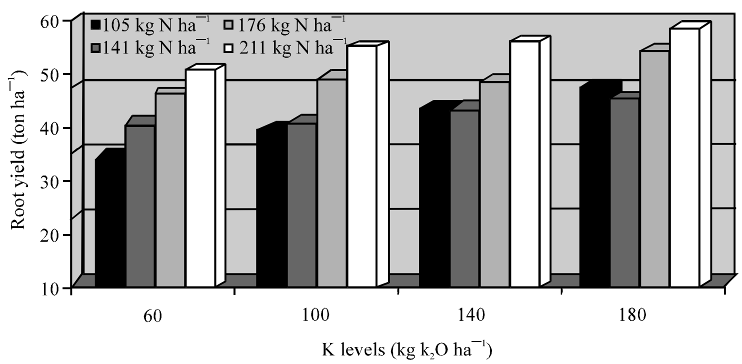

Fig. 2: Sugar beet root yield (t ha^{-1}) as affected by N and k levels (kg ha^{-1}) interaction n combined

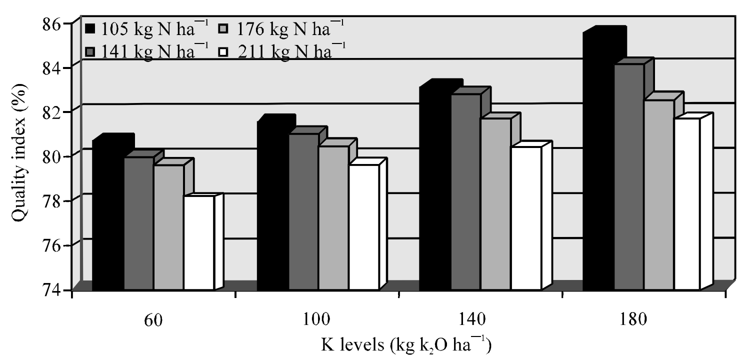

Fig. 3: Sugar beet quality index (%) as affected by N and k levels (kg ha^{-1}) interaction in combined analysis

(85.63%). These results may refer to the more effective response of potassium under high nitrogen levels for beet yields and under low nitrogen levels for quality characters, which reflects in sucrose percent (Table 3).

Yield analysis

Correlation coefficient: The correlation coefficients in Table 4 show relationships between gross sugar yield and each of root, top yields, sucrose, T.S.S., purity and quality index%. Positive and highly significant correlations were obtained between gross sugar yield and each of root yield ha^{-1} (r = 0.974**) and top yield ha^{-1} (r = 0.823*). Also, positive and highly significant correlation coefficients were seen between root and top yields (r = 0.825*) as well as quality index% (r = 0.856**). However, the root yield ha^{-1} was negatively and highly significantly correlated with sucrose% (r = -0.396**). Also, T.S.S.% was negatively and highly significantly correlated with purity (r = -0.476**). Finally, quality index was negatively and highly significantly correlated with sugar yield (-0.987**) but positively with root yield (0.856**). Also, sucrose percent correlated negatively but significantly (0.675*) with quality index. All the other components were correlated non significantly to quality index. Similar results were obtained by several workers among them Rady *et al.* (2000), Assey *et al.* (2005) and Nasr *et al.* (2011).

Path analysis: The method of path coefficients included the three yield components i.e. root yield, top yield and sucrose%. Path analysis was practiced in order to find the relative importance of these three characters in contributing to gross sugar yield variation. The effects of direct and indirect path coefficients were computed by partitioning the simple correlation coefficient into its components (Fig. 4). Root yield ha^{-1} proved to have a high direct effects on gross sugar yield

Table 4: Correlation coefficients between sugar yield (t ha^{-1}) and its components

Character	1	2	3	4	5	6
Y-Gross sugar yield (t ha^{-1})	0.974**	0.823**	0.170^{ns}	-0.108^{ns}	-0.080^{ns}	-0.987**
1- Root yield (t ha^{-1})		0.825**	-0.396*	-0.318*	-0.065^{ns}	0.856**
2- Top yield (t ha^{-1})			-0.214^{ns}	-0.141^{ns}	-0.113^{ns}	-0.324^{ns}
3- Sucrose%				0.841**	-0.006^{ns}	-0.675*
4- T.S.S.					-0.476**	-0.322^{ns}
5- Purity						0.413^{ns}
6- Quality index						--

*, ** and ns: Significant at p<0.05, 0.01 levels and not significant, respectively

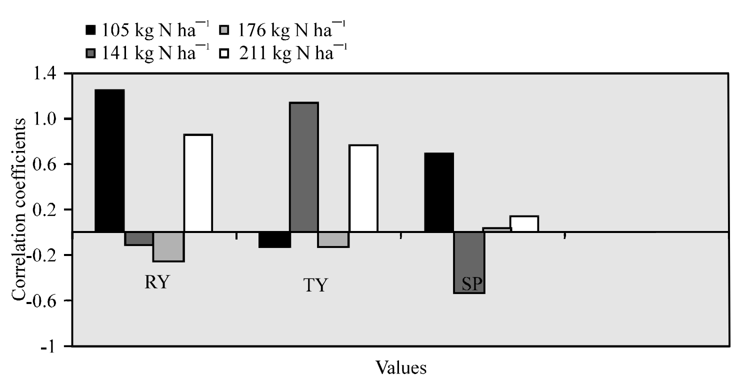

Fig. 4: Protoning of Simple correlation coefficients between gross sugar yield (t ha^{-1}) and its components (RY: Root yield, Ty: Top yield and Sp: Sucroses percent) of sugar beet

Table 5: Direct and joint effects of gross sugar yield (t ha^{-1}) components presented as a percentage of variation of sugar beet

Sources	C.D.	Percentage
Root yield (t ha^{-1})	0.3552	45.53
Top yield (t ha^{-1})	0.0044	0.54
Sucrose (%)	0.1234	11.34
Root yield (t ha^{-1})×Top yield (t ha^{-1})	0.0721	8.21
Root yield (t ha^{-1})×Sucrose (%)	0.0118	1.08
Top yield (t ha^{-1})×Sucrose (%)	0.0115	1.05
R^2	0.6785	67.75
Residual	0.3235	32.25
Total	1.0000	100.00

C.D.: Coefficient of determination, %: Percentage contributed

followed by sucrose% compared to top yield. The superiority of root yield ha^{-1} in its contribution on gross sugar yield was also reported by Geweifel (1982) and Nasr *et al.* (2011). The relative importance in contributing gross sugar yield presented as percentage of variation for yield component and their interaction are shown in (Table 5). It is clear that, root yield ha^{-1}, sucrose% and the interaction between root yield and top yield contributed more gross sugar yield variation, since R2 reached 67.75% of the total yield variation. Finally, it is of interest to note that root yield ha^{-1} greatly affected the yield variation, where the path coefficient was 0.4553 and together with its interaction with top yield caused 53.74 of the total variation. These results are supported by Assey *et al.* (2005).

CONCLUSION

It can be recommended from the obvious field traits and technological analysis of sugar beet grown in sandy soils, that maximizing root, gross sugar yield (t ha^{-1}) and quality index could be obtained by adding 180 kg K_2O and 211 kg N per hectare, which could minimize sugar loss. From path analysis, it was clear that root yield ha^{-1} proved to have a high direct effects on gross sugar yield followed by sucrose% compared to top yield.

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