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Effect of Nitrogen and Potassium on Growth, Development and Sugar Accumulation in Tropical Sugarbeet

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ABSTRACT

A field experiment was conducted at the Agronomy R esearch Farm, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh from November 2012 to April 2013 with four levels of nitrogen viz., 0, 50, 100 and 150 kg N ha^{-1} in combination with four levels of potassium viz., 0, 60, 120 and 180 kg K ha^{-1} to findout the optimum doses of nitrogen and potassium for optimum growth, development and sugar accumulation in tropical sugarbeet in Bangladesh. Plant height, number of leaves per plant, LAI and crop growth rate (CGR) significantly increased with the increase in nitrogen level but not significant with increased potassium level. The combination of 150 kg N and 180 kg K ha^{-1} resulted in the highest number of leaves per plant and LAI. Increasing nitrogen levels led to decrease in TSS content in juice and sucrose content in root. The TSS content increased with increasing potassium level up to 120 kg K ha^{-1}. The combination of nitrogen and potassium levels did not show any significant effect on sucrose content in root. Increasing nitrogen and potassium levels caused reduction in juice purity. For optimum growth, development and sugar accumulation in tropical sugarbeet in Bangladesh the nitrogen and potassium requirement of the crop is 150 kg N and 180 kg K ha^{-1}.

Key words: Nitrogen, potassium, growth, development, sugar accumulation, tropical sugarbeet

INTRODUCTION

Nitrogen is one of the most important nutrient elements of those supplied to sugarbeet in fertilization. It causes desirable effect on sugarbeet growth and developments. In New Zealand, sugar yields were optimal when nitrogen was applied at the rate of 200 kg N ha^{-1}, (Smit *et al.,* 1995). The increase in root and sugar yield with N fertilizer is attributed to increased size and number of leaves, which lead to increased leaf area and photosynthetic activities. An adequate supply of N is essential for optimum yield but excess of it may result in an increase in yield of roots with lower sucrose content and juice purity. High rates of N fertilizer (214 kg and 285 kg N ha^{-1}) significantly increase the Na and ?- amino-N content in root juice (Abdel-Motagally *et al.*, 2009). The high rate of N increases soluble non-sugar impurities in root juice and the percentage of sugar losses to molasses and consequently reduces sugar recovery. El-Shahawy *et al.* (2002) and Attia,

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(2004) found significant decrease in Fe and Mn content in foliage and roots with high rate of N fertilization. Sugar beet is a high potassium (K) requiring crop. Ibrahim *et al.* (1998) found the highest sucrose percentage and juice purity with K application up to 228.5 kg K_2O ha^{-1}. The beneficial effect of K fertilization on growth, yield and quality of sugarbeet was emphasized by previous studies (Sobh *et al.*, 1992; El-Shafai, 2000). It is commonly observed that root enlargement is depressed more than leaf development, when K is in short supply. El-Shafai (2000) and O'shea *et al.* (2009) found that nitrogen and potassium fertilization significantly influences the sugarbeet quality. Hence, the present research work was undertaken to findout the optimum doses of nitrogen and potassium fertilizer for growth, development and sugar accumulation in tropical sugar beet under Bangladesh condition.

MATERIALS AND METHODS

The experimental site was belongs to Madhupur Tract (AEZ 28) that characterized by a sub-tropical climate. The experiment was carried out from November 2012 to April 2013. The experimental land was prepared thoroughly by ploughing. As sugar beet prefers alkaline soil dolomite was applied @ 1500 kg ha^{-1} (Islam *et al.*, 2010). During final land preparation cow dung @ 15 t ha^{-1} was incorporated into the soil. A fertilizer dose of 120 kg N, 105 kg P, 150 kg K, 18 kg S, 3.5 kg Zn and 1.2 kg B ha^{-1} was applied in the form of urea, TSP, MOP, Gypsum, $ZnSO_4$ and Boric acid, respectively. All fertilizers and 1/3 of urea were applied during final land preparation. The remaining amount of urea was applied as two top dressing 55 and 90 DAS. The experiment was laid out in a strip plot with three replications. The unit plot size was 3m x 2m. The experiment comprised of following treatments:

Factor A: Four levels of nitrogen viz., 0, 50, 100 and 150 kg N ha^{-1}

Factor B: Four levels of potassium viz., 0, 60, 120 and 180 kg K ha^{-1}

Seeds of tropical sugar beet genotype (Shubhra) were sown in lines on 01 November, 2012 with the spacing of 50 x 20 cm. Light irrigation was done immediately after sowing to ensure uniform emergence. To ensure optimum soil moisture irrigation was done twice in a week up to maturity till April. Intercultural operations were done uniformly in each plot to ensure normal growth of the crop. Weeding and mulching were done simultaneously in the experimental plots at 20, 40 and 60 DAS. Plant was thinned out keeping one plant per hill during the second weeding. Earthing up was done at 55 and 90 DAS after top dressing of nitrogen. Dithane M 45 @ 2.2 kg ha^{-1}, Tilt 1ml/L of water and Score 250 EC 0.5 ml/L of water were used to control damping off, sclerotium root rot and cercospora leaf spot diseases. Durshban @ 2.5 ml/L of water was applied for controlling cut warm, tobacco caterpillar and army warm. Data regarding number of leaves, leaf area index, crop growth rate, relative growth rate, net assimilation rate, total soluble solid, sucrose content and sucrose yield were collected, analyzed and interpreted. Beets were harvested calculated (kg m^{-2} and t ha^{-1}) and statistically analyzed with the help of MSTAT-C Program with LSD Test at 5% level of significance.

Following formulae were used to calculate different growth parameters

$$\text{LAI} = \frac{\text{Total leaf area of three plants (cm}^2\text{)}}{\text{Ground area covered by three plants (cm}^2\text{)}}$$

Crop Growth Rate

$$CGR = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2} \text{ day}^{-1}$$

Relative Growth Rate

$$RGR = \frac{(\ln W_2 - \ln W_1)}{T_2 - T_1} \text{ (mg g}^{-1}\text{day}^{-1}\text{)}$$

Where,

W_1 = dry weight at time T_1 (g), W_2 = dry weight at time T_2 (g) and
GA = ground area (m^2) or Land area (m^2)

RESULTS AND DISCUSSION

Plant height, number of leaves per plant and leaf area index (LAI)

It was found that the plant height, number of leaves per plant and LAI increased rapidly up to 120 DAE and thereafter followed a slower rate. The general trend was an increase in plant height, number of leaves per plant and LAI with the increase in nitrogen level. Plant height is an important morphological character that might affect yield. Nitrogen is responsible for rapid growth of a plant. The height of a plant depends on nutrient availability especially on nitrogen. The variations in plant height over time are illustrated in Figure1 reveals that different levels of nitrogen fertilizer exerted significant influence on plant height throughout the growth periods. Irrespective of treatments plant height increased rapidly up to 120 DAE and thereafter a slower rate was found. During the growth periods at 120 DAE the tallest plant (41.67 cm) was obtained at 150 kg N ha^{-1} and the shortest (29.08 cm) was at 0 kg N ha^{-1}.

Combination effects of nitrogen and potassium levels on number of leaves per plant in tropical sugar beet started functioning significantly from 90 DAE (Table1). The highest number of leaves (36.00 $plant^{-1}$) was recorded in combination of 150 kg N ha^{-1} and 180 kg K ha^{-1} at 150 DAE followed by the 150 kg N ha^{-1} and 0-120 kg K ha^{-1}, 150 kg N ha^{-1} and 0-120 kg K ha^{-1} and 150 kg N ha^{-1} and 100 kg K ha^{-1}at same DAE which were statistically identical, while the lowest number of leaves was recorded at 0 kg N ha^{-1} with 0 kg K ha^{-1} (31.67 $plant^{-1}$). It was revealed that 150 DAE was the turning point of leaf induction because older leaves dropped. However, Watson *et al.* (1972) found that the number of leaves in sugarbeet is relatively unaffected by cultural practices or environmental factors. At 165 DAE, the leaves counted were less than those at 150 DAE, and the highest number of leaves retained in the treatment combination of 100-150 kg N ha^{-1} with 120-180 kg K ha^{-1}. Therefore, after assessing the data it may be concluded that sugarbeet genotype shubhra performs the best with the treatment combination of 100-150 kg N ha^{-1} x 120 kg K ha^{-1} to have the highest number of leaves per plant.

Leaf area index of tropical sugarbeet genotype shubhra over time was significantly influenced by different levels of nitrogen (Figure 2). Irrespective of nitrogen levels, the LAI increased sharply after emergence up to 90 DAE then gradually attained a peak at 120 DAE and thereafter decreased gradually. This increase was due to the production of higher number of functioning leaves, which increased total photosynthetic area. Similar trend was also reported by Theurer (1979) in sugarbeet. Different nitrogen levels strongly influenced the LAI at 60, 90, 120, 150 and 165 DAE. At 120 DAE, the highest LAI (3.47) was obtained with 150 kg N ha^{-1} followed by 100 kg N ha^{-1} (2.75) and 50 kg N ha^{-1} (1.90) and the lowest LAI (1.53) was found when no nitrogen was applied.

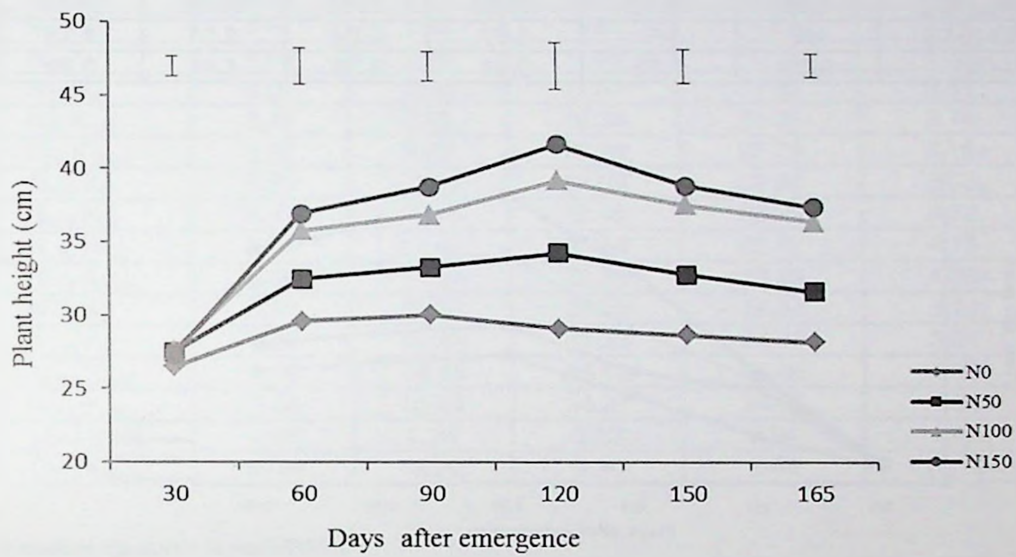

Figure 1. Plant height in tropical sugar beet genotype shubhra over time as influenced by different levels of nitrogen application. Vertical bar indicates LSD 0.05.

Table 1. Number of leaves per plant in tropical sugarbeet genotype shubhra over time

Treatment (N×K)	Number of leaves per plant					
	30 DAE	60 DAE	90 DAE	120 DAE	150 DAE	165 DAE
$N_0 K_0$	6.33	13.00	19.33	30.33	31.67	29.67
$N_0 K_{60}$	6.33	13.67	19.33	31.00	32.00	30.33
$N_0 K_{120}$	6.33	14.33	19.67	31.67	32.00	30.00
$N_0 K_{180}$	6.33	14.00	19.33	31.00	32.00	30.00
$N_{50} K_0$	6.66	14.33	20.67	32.00	33.33	31.67
$N_{50} K_{60}$	6.33	14.33	20.67	32.00	33.67	31.67
$N_{50} K_{120}$	6.33	14.33	21.00	32.67	34.00	32.00
$N_{50} K_{180}$	6.66	14.00	21.00	32.67	34.33	32.67
$N_{100} K_0$	6.33	14.33	21.33	33.33	34.67	32.00
$N_{100} K_{60}$	6.33	14.67	21.67	33.00	35.00	32.33

(Contd.)

Treatment (N×K)	Number of leaves per plant					
	30 DAE	60 DAE	90 DAE	120 DAE	150 DAE	165 DAE
N_{100} K_{120}	6.66	15.00	21.67	33.67	35.33	32.67
N_{100} K_{180}	6.66	15.33	22.00	33.67	35.33	33.67
N_{150} K_0	6.33	14.33	22.00	33.67	35.67	32.67
N_{150} K_{60}	6.33	15.00	22.33	33.33	35.67	33.00
N_{150} K_{120}	6.66	15.00	22.33	33.67	35.67	33.67
N_{150} K_{180}	6.66	15.33	22.67	33.67	36.00	33.67
LSD (0.05)	NS	NS	1.37	2.04	2.51	1.75
CV (%)	9.00	7.10	3.91	3.75	4.41	3.29

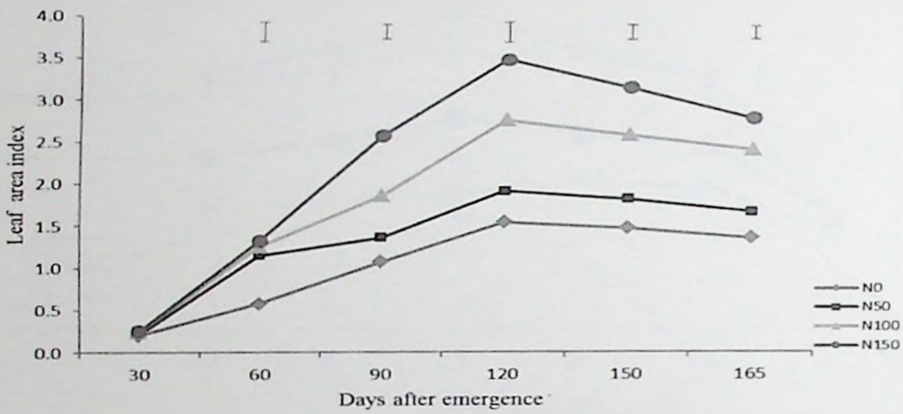

Figure 2. Leaf area index in tropical sugar beet genotype shubhra over time as influenced by different levels of nitrogen application. Vertical bar indicates LSD 0.05.

Crop Growth Rate

Nitrogen and potassium exerted significant effects on crop growth rate. The tropical sugarbeet showed the highest CGR (24.91 g $m^{-2}day^{-1}$) with the combination levels of 150 kg N ha^{-1} and 180 kg K ha^{-1} followed by (24.83 g $m^{-2}day^{-1}$) 150 kg N ha^{-1} and 120 kg K ha^{-1} and 100 kg N ha^{-1} and 180 kg K ha^{-1} which are statistically identical. Lower rate of fertilizer combination resulted in lower crop growth rate throughout the growth period which ultimately lowered the yield of tropical sugarbeet. The CGR gradually increased with each increase in nitrogen and potassium combination levels over time. The increase in CGR due to raising nitrogen and potassium fertilizer levels may be attributed to their role in increasing LAI and dry matter accumulation in root and foliage. So that 100 - 150 kg N ha^{-1} and 0 -180 kg K ha^{-1} will be the suitable combination for sugarbeet cultivation.

Table 2. Combination effect of nitrogen and potassium levels on crop growth rate in tropical sugarbeet genotype shubhra over time

Treatment (N×K)	Crop growth rate (g m^{-2} day^{-1})				
	30 -60 DAE	60 -90 DAE	90-120 DAE	120-150 DAE	150-165 DAE
N_0 K_0	3.26	8.28	12.64	10.99	2.71
N_0 K_{60}	3.31	8.48	12.29	11.84	2.73
N_0 K_{120}	3.50	8.75	13.61	11.95	2.65
N_0 K_{180}	3.47	8.68	13.81	12.23	3.18
N_{50} K_0	4.99	9.56	17.43	21.11	3.38
N_{50} K_{60}	5.07	9.63	17.57	21.80	3.59
N_{50} K_{120}	5.46	9.86	18.28	22.25	3.74
N_{50} K_{180}	5.52	9.93	18.48	22.29	3.13
N_{100} K_0	6.29	11.11	22.09	22.84	3.02
N_{100} K_{60}	6.41	11.44	22.45	23.29	3.22
N_{100} K_{120}	6.57	11.49	22.84	23.77	4.15
N_{100} K_{180}	6.66	11.50	22.89	23.99	4.38
N_{150} K_0	6.97	13.54	24.29	24.32	3.74
N_{150} K_{60}	7.08	13.94	24.33	24.36	3.94
N_{150} K_{120}	7.14	14.93	24.83	24.38	4.36
N_{150} K_{180}	7.16	15.14	24.91	24.87	4.82
LSD (0.05)	1.38	2.24	3.23	2.94	1.43
CV (%)	14.94	12.22	9.90	8.64	14.19

Relative Growth Rate (RGR)

Relative growth rate of tropical sugarbeet over time did not significantly differ either by nitrogen levels nor by potassium levels. Irrespective of nitrogen levels, the RGR was high in early growth period and showed similar decreasing trend as the crop advanced in age. The decline in RGR towards maturity might be due to lower photosynthetic efficiency of older leaves as well as leaf senescence. The decline in RGR was also due to the decrease in net assimilation rate. Rao and Mitra (1988) and Singh *et al.* (1998) also reported the similar results in groundnut and in mungbean, respectively.

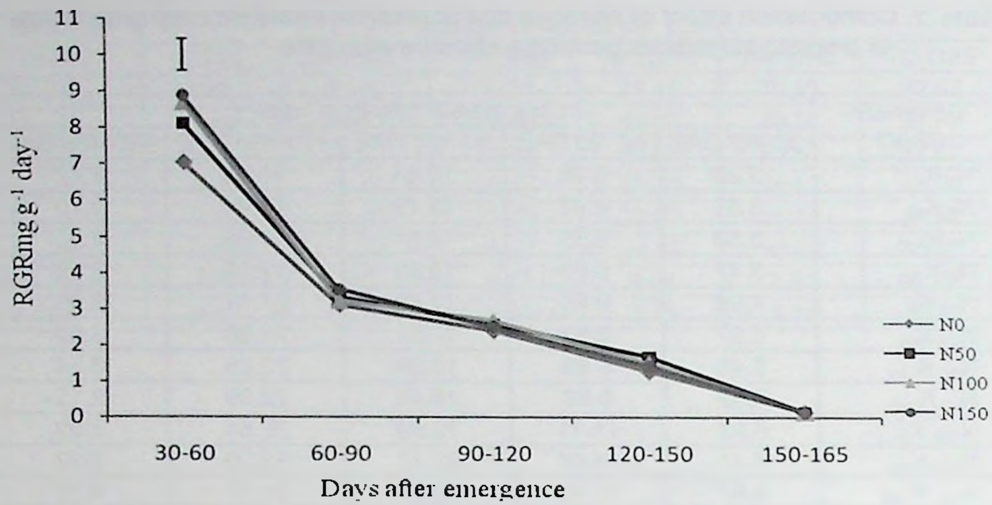

Figure 3. Relative growth rate (mg $g^{-1}day^{-1}$) in tropical sugarbeet genotype shubhra over time as influenced by nitrogen levels.

Table 3. Combination effect of nitrogen and potassium levels on TSS %, sucrose%, apparent purity % and sugar yield in tropical sugarbeet genotype shubhra at maturity

Treatment (N×K)	TSS %	Sucrose %	Apparent purity %	Sugar Yield (t ha^{-1})
N_0 K_0	23.12	15.57	67.23	6.90
N_0 K_{60}	22.94	15.60	67.61	7.63
N_0 K_{120}	23.15	15.68	67.57	7.52
N_0 K_{180}	23.27	15.76	67.46	7.52
N_{50} K_0	23.02	15.42	66.76	8.53
N_{50} K_{60}	23.08	15.45	66.92	9.47
N_{50} K_{120}	22.75	15.40	67.42	9.45
N_{50} K_{180}	22.67	15.30	67.53	9.44
N_{100} K_0	22.30	15.03	67.31	10.58
N_{100} K_{60}	22.31	15.18	67.32	11.14
N_{100} K_{120}	22.35	15.20	67.42	12.49
N_{100} K_{180}	22.44	15.21	67.42	12.55
N_{150} K_0	22.10	14.83	66.92	11.43
N_{150} K_{60}	22.12	14.95	66.76	12.17
N_{150} K_{120}	22.33	15.00	66.14	12.74
N_{150} K_{180}	22.23	14.98	66.39	13.07
LSD (0.05)	ns	0.52	ns	1.60
CV (%)	2.99	3.07	1.62	9.44

Total soluble solids (TSS)

Nitrogen and potassium levels did not exert significantly differed on TSS at maturity Table 3. The results showed that the higher percentages of total soluble solids were obtained at lower levels of nitrogen and potassium combinations. The TSS was reduced with highest nitrogen and potassium combination levels. The decrease in TSS content due to excessive nitrogen or potassium application can be ascribed to their role in increasing root weight, root diameter, tissue water content. This result confirms the findings of Sobh *et al.* (1992) and Sultan *et al.* (1999).

Sucrose content

Nitrogen and potassium combination levels significantly influenced the sucrose content in roots of tropical beet. It was observed that each increase in nitrogen and potassium combination levels from 0 kg N ha^{-1} and 0 kg K ha^{-1} to 150 kg N ha^{-1} and 180 kg K ha^{-1} was associated with gradual decrease in sucrose content. The maximum sucrose content in beet roots was recorded from low levels of nitrogen and potassium combination. On the contrary, the lowest one was recorded from application of 150 kg N ha^{-1} and 180 kg K ha^{-1}. The decrease in sucrose content owing to increasing nitrogen fertilizer levels can be attributed to its role in increasing non-sucrose substances such as proteins and alpha amino acid, and hence decreasing sucrose content in roots. Similar results were obtained by Sultan *et al.* (1999).

Sugar yield

Sucrose yield is the most important parameter in sugarbeet. Nitrogen and potassium levels had significant effect on sugar yield in tropical sugar beet. Remarkable increase in sugar yield was noticed as a result of increased nitrogen and potassium combination levels from 0 kg N and 0 kg K $ha^{-1}$to 150 kg N and 180 kg K ha^{-1}. The nitrogen and potassium combination, which produced the highest sugar yield (13.07 t ha^{-1}) was 150 kg N and 180 kg K ha^{-1} followed by 150 kg N and 120 kg K ha^{-1} (12.74 t ha^{-1}), 100 kg N and 180 kg K ha^{-1} (12.55 t ha^{-1}) and 100 kg N and 120 kg K ha^{-1} (12.49 t ha^{-1}). However, excess nitrogen application might not be desirable, because it reduces the most quality parameters and sugar yield. The increase in gross sugar yield per unit area due to application of nitrogen and potassium fertilizers can be explained through the fact that nitrogen and potassium play a vital role in improving all growth attributes and root weight per plant as well as sucrose content in root, consequently increasing gross sugar yield per unit area. These results agree with those stated by EL-Hawary (1999), Sultan *et al.* (1999) and EL-Zayat (2000).

Apparent purity percentage

Apparent purity percentage of tropical sugarbeet was influenced by nitrogen, potassium and their combination levels. Increasing nitrogen fertilizer levels from 0 to 50, 100 and 150 kg N ha^{-1} tended to decrease juice purity from 67.18 to 67.15, 67.15 and 67.08 %, respectively. Similar results were obtained by Abd EL-Moneim (2000), Kandil *et al.* (2002b) and Ramadan *et al.* (2003). Increasing potassium fertilizer levels from 0 to 60, 120 and 180 kg K ha^{-1} tended to increase juice purity from 66.58 to 67.49, 67.78 and 67.98%, respectively. Similar trend was obtained by Kandil *et al.* (2002a). Increasing nitrogen and potassium combination levels from 0 kg N ha^{-1} and 0 kg K ha^{-1} to 150 kg N ha^{-1} and 180 kg K ha^{-1} caused reduction in juice purity in all cases. The reduction in juice purity owing to increased nitrogen fertilizer levels can be attributed to its role in increasing impurity substances such as proteins and alpha amino acid, and hence decreasing juice purity. Similar results were reported by Abou-Amou *et al.* (1996).

From the experimental results in the field, it may be concluded that for optimum growth, development and sugar accumulation in tropical sugarbeet in Bangladesh. The nitrogen and potassium requirement of the crop seems to more than 150kg N and 180kg K ha^{-1}. Hence, excess nitrogen application not desirable, because it reduces the most quality parameters and sugar yield. The increase in gross sugar yield per unit area due to application of nitrogen and potassium play a vital role in improving all growth attributes and root weight per plant as well as sucrose content in root, consequently increasing gross sugar yield per unit area.

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