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Response of Sugar Beet Plants to Nitrogen and Potassium Fertilization in Sandy Calcareous Soil

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ABSTRACT

This study was conducted during two successive seasons (2004-2005 & 2005-2006) to study the effects of different rates of nitrogen (143, 214 & 285 kg N ha^{-1}) and potassium (0, 57 & 114 kg K_2O ha^{-1}) fertilization on yield, quality and nutrient contents of sugar beet grown on sandy calcareous soil. In this split plot design, the main plots were assigned to levels of N fertilizer and K levels were arranged to random as the sub-plots. The results showed that increasing N and K rates significantly increased root and foliage fresh and dry weight and sugar yield (ton ha^{-1}) of sugar beet plants. Adding the highest level of K (114 kg K_2O ha^{-1}) under different rates of N significantly increased sucrose contents, recoverable sugar yield (ton ha^{-1}) and some quality traits. Adding the highest level of N (285 kg N ha^{-1}) under different rates of K significantly increased sugar loss (ton ha^{-1}) and increased content and uptake of N and K in both root and foliage of sugar beet over two seasons. Increasing N level up to 285 kg N ha^{-1} (under 0.0 kg K_2O ha^{-1}) significantly increased impurities (Na, K & α-amino-N) and sugar loss percentage. In crux, N fertilizer at a level of 285 kg N/fed accompanied with 114 kg K_2O ha^{-1} were the most effective in improving yield, quality and nutritional status of sugar beet grown in a sandy calcareous soil.

Key Words: Sugar beet; Fertilizers; Sandy calcareous soil; Sugar yield; α-amino-N

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is one of the most important crops in Egypt. It is classified as a plant of high potassium (K) requiring crop (Johanson *et al.*, 1971). Fertilizer is considered as a limiting factor for obtaining high yield and quality (Ouda, 2002). Thus, application of suitable fertilizers, such as nitrogen (N) and potassium (K) may be one of the favorable factors for the production of sugar beet. Many investigators have confirmed the role of N and K in increasing the yield and quality of sugar beet by enhancing the biosynthesis of organic metabolites and improving nutritional status (Bondok, 1996; El-Shafai, 2000; O'shea *et al*., 2009). Ibrahim *et al.* (2002) found that the highest sucrose percentage and juice purity were achieved with K application up to 228.5 kg K_2O ha^{-1}. The beneficial effect of K fertilization on growth, yield and quality of sugar beet was emphasized by previous studies (Abd El-Aziz *et al.*, 1992; Sobh *et al.,* 1992; El-Maghraby *et al*., 1998; El-Shafai, 2000; Ouda, 2002). Sugar beet yield and quality are dramatically influenced by the level of available N. Residual and fertilizer N levels allowing adequate top growth and maximize root growth and extractable sucrose concentration are desired. However, sucrose yield decreases by over-fertilizing sugar beet with more N than needed for maximum sucrose production (Hassanin & Elayan, 2000). An adequate supply of N is essential for optimum yield but excess N may result in an increase in yield of roots with lower sucrose content and juice purity. Yield increased with applied but TSS, sucrose%, purity% and recoverable sugar yield per ha were significantly decreased as N level increased (Lauer, 1995; Badawi *et al*., 1995; Salama & Badawi, 1996; El-Hennawy *et al*., 1998). Contrary to this, Horn and Fürstenfeld (2001) showed that the uptake of N by sugar beet plants increased by increasing the application level of N, while the sugar content and juice purity decreased.

The direct effect of K on yield is less marked than of N, which itself constitutes a part of the organic matter synthesized during growth. Also, K uptake is much affected by N level and in most cases, K is more effective at higher N level, which is the case especially to modern high yielding varieties (El-Shafai, 2000; Mäck *et al*., 2007). The interaction between N and K were small at low rates, but became more important at high rates and the best returns from one nutrient were obtained at high rates of others. Root crops especially, have a high K requirement. It is commonly observed that root or tube enlargement is depressed relatively more than leaf development, when K is in short supply (Inal, 1997). In Egypt many investigations revealed that 214-262 kg N ha^{-1} exhibited the highest root quality, technological characters, root and sugar yields and

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minimized sugar losses to molasses (Hassanin & Elayan, 2000; Moustafa & Darwish, 2001; Abo El-Wafa, 2002; Hilal, 2005). The aim of the present study was to determine the effect N and K fertilization on growth root yield and quality as well as nutrient content of sugar beet plant grown on a sandy calcareous soil.

MATERIALS AND METHODS

Two field experiments were conducted at El-Ghorieb Agricultural Experimental and Research Station, Faculty of Agricultural, Assiut University during two successive seasons 2004-2005 and 2005-2006 to study effect of three levels of N (143, 214 & 285 kg N ha^{-1}) and three levels of K (0, 57 & 114 kg K_2O ha^{-1}) on growth, yield, quality and nutrient content of sugar beet plant grown on a sandy calcareous soil. Some physical and chemical properties of a representative soil sample used in the experimental soil were determined before preparation according to Jackson (1958) (Table I).

The recommended dose of phosphorus fertilizer was applied at a level 476 kg calcium superphosphate ha^{-1} (15.5% P_2O_5) during preparation. A split- plot design with three replications was used. The main plots were assigned to 3 levels of nitrogen fertilizer (143, 214 & 285 kg N ha^{-1}) with three potassium levels (0, 57 & 114 kg K_2O ha^{-1}) were arranged at random as the sub-plots. The area of each plot was 10.5 m^2 (3.5 m length x 3 m width), with six ridges 50 apart, 3.5 m in length. Sowing took place on 2^{nd} and 5^{th} November 2004-2005 and 2005-2006, respectively. Seeds of multigerm (Montebianco cv.) were sown in hills 25 cm apart at using 3-4 seeds per hill. Plants were thinned to one plant per hill after 40 days from planting (at 4-6 leaf stage). Nitrogen fertilizer in the form of ammonium nitrate (33.5%N) with the abovementioned levels were added in two equal doses. The first one was applied after thinning and the other one 21 days later. Potassium fertilizer in the form of potassium sulphate (48% K_2O) with the abovementioned levels were applied in one dose after thinning. The other cultural practices were carried out as recommended.

At maturity stage (195 days from sowing), ten plants were taken at random from each plot. The foliage and roots were separated dried at 70°C for 3 days and at 105°C for 2 h in air forced-draft oven, to determine their dry weight. Dry plant samples were ground and chemically analyzed for nutrient content. Total N was analyzed by semi-micro Kjeldahl procedure (Jackson, 1958). Phosphorus and K were wet-digested in a 2:1; nitric: perchloric acid mixture and were determined by colorimetry and flame photometry methods (Jackson, 1958), respectively. Iron and Mn were determined in the digests using a GBC model 300 atomic absorption spectrophotometer.

At harvest (205 days from sowing), plants of each plot were harvest to determine roots and foliage yield (ton ha^{-1}). A sample of 25 kg of roots were taken at random from each plot and sent to the Beet Laboratory at Abo-Korkas Sugar Factory to determine root quality. Alpha amino nitrogen (α-amino N), sodium (Na) and potassium (K) concentrations were estimated according to the procedure of sugar company by auto analyzer described by Cooke and Scott (1993). Sucrose (expressed as Pol %) was estimated in fresh samples of sugar beet root by using Saccharometer according to the method described by A.O.A.C. (1995).

Sugar loss was calculated using the following formula:

Sugar loss % = 0.29 + 0.343 (K + Na) + 0.094 α-amino N.

Sugar recovery % (SR %) was calculated using the following equation according to Cooke and Scott (1993).

Sugar recovery % (SR %) = sucrose % - sugar loss%.

Recoverable sugar yield (ton ha^{-1}) (RSY) was calculated using the following equation of Mohamed (2002):

Recoverable sugar yield = root yield (ton ha^{-1}) X sugar recovery.

Quality index was calculated as (sugar recovery % X 100)/sucrose %.

Gross sugar yield (ton ha^{-1}) = root yield (ton ha^{-1}) X sucrose %.

Sugar loss yield was computed as: root yield (ton ha^{-1}) X sugar loss.

Nutrient uptake was determined as: nutrient concentration X root or foliage dry weight.

The analysis of variance was carried out according to Gomez and Gomez (1984) using MSTAT computer software, after testing the homogeneity of the error according to Bartlett's test. Means of the different treatments were compared using the least significant difference (LSD) test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect of nitrogen fertilization rates. With the application of fertilizers, the roots and foliage fresh and dry weights and sugar yield were significantly increased with increasing N fertilizer rates over two seasons (Table II). The increase of root and sugar yield with N fertilizer may be attributed to increased size and number of leaves, which led to increasing leaf area and photosynthetic activities. This was reflected in greater root and sugar production per unit area (Zalat & Youssif 2001; El-Kholy *et al*., 2006; Malnou *et al*., 2008). Higher rates of N fertilizer (214 & 285 kg N ha^{-1}) had significantly effect on Na and α- amino-N content (mg 100 g^{-1} beet paste) (Table II). These may be due to the reason that high rate of N increased soluble non-sugar in root juice (impurities) and they interfere with sugar extraction. This was reflected by raising the percentage of sugar losses to molasses and consequently reducing sugar recovery.

Table I. Some physical and chemical properties of a representative soil samples in the experimental site before sowing (0-30 cm depth) in 2004-2005 and 2005-2006 seasons

Soil property	2004-2005*	2005-2006*
Partice size distribution		
Sand (%)	85.4	87.2
Silt (%)	8.7	7.2
Clay (%)	5.9	5.6
Texture grade	Sandy	Sandy
EC (1:1 extract) (dS m^{-1})	1.59	1.77
pH (1:1 suspension)	8.12	8.43
Total $CaCO_3$ (%)	19.96	21.15
Organic matter (%)	0.091	0.098
Soluble Cattions		
Ca^{2+} (meq L^{-1})	8.11	8.86
Mg^{2+} (meq L^{-1})	5.49	5.99
Na^{+} (meq L^{-1})	1.97	1.89
K^{+} (meq L^{-1})	0.19	0.21
Soluble Anions		
CO_3^{2-} + HCO_3^- (meq L^{-1})	8.65	7.89
Cl^- + HCO_3^- (meq L^{-1})	7.56	5.99
$NaHCO_3$-extractable P (ppm)	4.87	6.95
NaOAC-extractable K (ppm)	58.65	63.41
Total nitrogen (%)	0.019	0.022
KCl-extractable N (ppm)	31.04	29.16

*Each value represents the mean of three replications

Data presented in Table III indicated that N and K fertilization rates had highly significant effect in sugar beet quality except for sugar loss percentage. The contents and uptake of N and K in the foliage and roots were significantly increased by increasing N fertilizer up to 214 kg N ha^{-1} over two seasons. However, Fe and Mn content of roots and foliage were significantly decreased by increasing of N fertilization rates (Table IV & V). This was expected as high N rate enhanced vegetative growth and consequently the absorption of other nutrients (K) to meet the growth demand. A significant decrease in Fe and Mn content of foliage and roots with increasing of N fertilization rates may be attributed to the dilution caused by the high vegetative growth in the presence of the high N fertilization rates (El-Shahawy *et al*., 2002; Attia, 2004).

Effect of potassium fertilization rates. Application of K fertilizer at the rate of 114 kg K ha^{-1}, significantly increased all growth attributes and sugar yield (Table II), which could be attributed to the stimulatory effect of K on rate of photosynthesis, as well as, transport of the photosynthetic product from the leaves to the storage root (Abdel El-Wahab *et al*., 1996; El-Ramady, 1997; El-Hawary, 1999; Omar *et al*., 2002; Attia, 2004; El-Kholy *et al*., 2006). Most quality characteristics [sucrose percentage, quality index, SR percentage, RSY & sugar loss yield (ton ha^{-1})] of sugar beet were significantly increased by increasing nitrogen fertilization rates, except for sugar loss percentage over two seasons (Table III). The highest sucrose percentage (16.86%) was obtained when 114 kg K_2O ha^{-1} was applied with different rate of N fertilization. Only at the highest level of K fertilization (114 kg K_2O ha^{-1}), Na and α- amino-N content were significant decreased over two seasons (Table II). These results are agreement with those obtained by El-Kishky (1982) and El-Yamani (1999). An increase in recoverable sugar yields might be due to the role of K in nutrients uptake and nutritional balance, which increase the biosynthesis of photosynthates (Milford *et al*., 2000; Attia, 2004).

Data of Tables (IV & V) showed that N and K content and uptake of roots and foliage were significantly increased by increased K fertilization over two seasons. On the other hand, N and K fertilization rates had no effect on P content of roots and foliage over two seasons. The data showed markedly that, the all studied nutrients (N, K, P, Fe & Mn content) of foliage were higher than roots that are related to the essentiality of K to improve photosynthesis. Also, K helps in maintaining a normal balance between carbohydrates and proteins (Moustafa & Darwish, 2001; Monreal *et al*., 2007).

Effect of interaction. Both N and K fertilizers had a highly significant effect on productivity traits of sugar beet i.e., roots and foliage fresh and dry weights yield (ton ha^{-1}) over two seasons. Roots, foliage fresh and dry weights were significantly increased with increasing N and K fertilizers rates over two the seasons. The highest values of root and foliage fresh and dry weights yield (69.35 & 16.15 ton ha^{-1}), (11.32 & 2.78 ton ha^{-1}) were obtained from application of 285 kg N and 114 kg K_2O ha^{-1} over two seasons. Gross sugar yield was increased by increasing both N and K fertilization up to 285 kg N with 114 kg K_2O ha^{-1} over two seasons (Table III). Such effect reflects the response of root yield to N and K fertilizer. The highest sugar yield (10.95 ton ha^{-1}) was obtained with the application of 285 kg N with 114 kg K_2O ha^{-1}. Similar results were obtained by Sharief and Eghbal (1994). The results reveal that the effect of N and K fertilization rates on growth of sugar beet plants (roots & foliage fresh & dry weight) was similar to those effects on sugar yield. The importance of sugar beet is not confined only to the sugar produced from it but also to its byproducts. Foliages of sugar beet are considered a good feed source for livestock. Pectin is also produced from the pulp of sugar beet (Shalaby *et al*., 2002). It could be noticed that increasing N and K fertilizers rates significantly increased root growth and quality. These results appear to be mainly due to the role of N in developing root dimensions by increased cell division and/or elongation. The positive effect of N fertilizer might be due to the increased efficiency of N-fertilization in building up metabolites translocations from leaves to developing roots, thus increases dry matter accumulation (El-Shahawy *et al*., 2002). Increasing N and K fertilization had a significant effect on nutrients content and uptake of roots and foliage over two seasons (table IV &V). Similar results were obtained by Zalat and Youssif (2001). The white sugar yield is an important yield parameter of sugar beet, because it is final useful form of sugar that the consumers use. Most of the quality characters i.e., sucrose percentage, quality index, SR percentage, RSY and sugar loss yield were significantly

Table II. Effect of nitrogen and potassium fertilization rates on yield and impurity components of sugar beet plant grown on a sandy calcareous soil over two seasons

Fertilizer rate ($kg\ ha^{-1}$)		Root fresh weight ($ton\ ha^{-1}$)	Foliage fresh weight ($ton\ ha^{-1}$)	Root dry weight ($ton\ ha^{-1}$)	Foliage dry weight ($ton\ ha^{-1}$)	Na content (mmol 100 g^{-1} beet paste)	K content (mmol 100 g^{-1} beet paste)	α- amino-N (mmol 100 g^{-1} beet paste)
N	K_2O							
143	0.0	48.39	10.44	8.09	1.95	1.44	5.06	3.61
	57	52.28	11.01	9.07	1.99	1.23	5.17	3.41
	114	54.66	11.30	9.43	2.04	1.10	5.24	3.11
214	0.0	55.12	10.73	9.66	2.12	1.84	5.11	4.18
	57	59.83	13.22	10.94	2.41	1.63	5.29	4.00
	114	60.50	13.53	11.10	2.49	1.34	5.41	3.33
285	0.0	63.18	12.25	10.91	2.73	1.89	4.84	4.75
	57	67.99	15.77	11.19	2.79	1.69	4.91	4.25
	114	69.75	16.15	11.32	2.78	1.47	5.01	3.97
Mean of	0.0	55.56	11.14	9.56	2.27	1.72	5.00	4.18
K_2O	57	60.03	13.33	10.40	2.40	1.52	5.12	3.88
	114	61.63	13.65	10.62	2.44	1.30	5.22	3.48
LSD	N	7.11	1.31	1.05	0.42	0.17	0.33	0.39
($P<0.05$)	K	1.44	1.41	0.59	0.13	0.07	0.08	0.06
	N.K	2.50	0.57	0.40	0.23	0.11	0.13	0.10

Table III. Effect of nitrogen and potassium fertilization rates on some quality parameter of sugar beet plants grown on a sandy calcareous soil over two seasons

Fertilizer rate ($kg\ ha^{-1}$)		Sucrose (%)	Sugar loss (%)	Quality index (%)	S.R. (%)	Gross sugar yield ($ton\ ha^{-1}$)	R.S.Y. ($ton\ ha^{-1}$)	Sugar loss yield ($ton\ ha^{-1}$)
N	K_2O							
143	0.0	15.39	2.80	81.81	12.56	7.43	6.26	1.36
	57	16.34	2.80	82.84	13.53	8.54	7.07	1.48
	114	16.86	2.76	83.63	14.09	9.23	7.38	1.50
214	0.0	14.69	3.07	79.13	11.62	8.10	6.41	1.69
	57	15.77	3.19	80.84	12.76	9.43	7.63	1.91
	114	16.03	2.92	81.97	13.25	9.69	8.03	1.76
285	0.0	14.32	3.03	78.81	11.25	9.05	7.10	1.92
	57	15.20	2.95	80.58	12.25	10.33	8.33	2.02
	114	15.68	2.89	81.63	12.85	10.95	9.15	2.01
Mean of	0.0	14.80	2.97	79.92	11.81	8.20	6.60	1.66
K_2O	57	15.77	2.98	81.42	12.85	9.44	7.68	1.80
	114	16.19	2.85	82.41	13.40	9.95	8.18	1.75
LSD	N	0.71	-	1.70	0.63	1.09	0.93	0.30
($P<0.05$)	K	0.46	-	0.58	0.40	0.40	0.37	0.12
	N.K	0.78	-	1.00	0.69	0.69	0.65	0.22

(-) not significant

Table IV. Effect of nitrogen and potassium fertilization rate on the nutrients concentration and uptake by sugar beet roots grown on a sandy calcareous soil over two seasons

Fertilizer rate ($kg\ ha^{-1}$)		Roots nutrients concentration					Roots nutrients uptake				
		N (%)	K (%)	P (%)	Fe ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	N ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	Fe ($g\ ha^{-1}$)	Mn ($g\ ha^{-1}$)
N	K_2O										
143	0.0	0.55	0.75	0.10	52.50	45.00	45.70	60.81	8.10	424.71	364.02
	57	0.59	0.83	0.12	51.65	41.65	52.96	74.85	10.83	468.27	377.59
	114	0.60	0.87	0.11	49.15	38.65	56.53	81.99	10.24	463.27	364.14
214	0.0	0.58	0.90	0.11	49.35	37.35	55.34	86.28	10.59	476.00	360.10
	57	0.66	0.98	0.11	48.35	38.50	71.52	106.63	12.02	528.24	420.78
	114	0.68	1.05	0.10	50.35	41.35	75.45	116.51	11.07	558.47	458.75
285	0.0	0.74	1.03	0.11	48.15	33.50	80.21	112.46	12.02	525.62	365.69
	57	0.78	1.18	0.10	47.00	33.50	87.23	131.97	11.19	525.75	374.85
	114	0.79	1.22	0.09	45.00	31.00	89.49	137.45	10.23	509.32	350.93
Mean of	0.0	0.62	0.89	0.11	50.00	38.60	60.37	86.51	10.24	475.41	363.31
K_2O	57	0.68	1.00	0.11	49.00	37.90	70.57	104.48	11.31	507.42	391.04
	114	0.69	1.05	0.10	48.15	37.00	73.90	111.98	10.05	510.35	391.27
LSD	N	0.05	0.11	-	1.04	1.72	6.94	14.84	0.12	27.00	32.75
($P<0.05$)	K	0.04	0.06	-	0.60	1.16	3.74	2.57	0.09	25.15	11.95
	N.K	0.08	0.18	-	1.43	1.31	5.17	6.65	0.18	43.00	29.28

(-) not significant

Table V. Effect of nitrogen and potassium fertilization rate on the nutrients concentration and uptake by sugar beet foliage grown on a sandy calcareous soil over two seasons

Fertilizer rate ($kg\ ha^{-1}$)		Foliage nutrients concentration					Foliage nutrients uptake				
N	K_2O	N (%)	K (%)	P (%)	Fe ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	N ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	Fe ($g\ ha^{-1}$)	Mn ($g\ ha^{-1}$)
143	0.0	1.96	3.78	0.25	236.50	130.20	38.22	73.66	4.88	461.18	254.07
	57	2.10	3.65	0.28	245.15	122.35	41.69	73.19	5.48	487.85	243.12
	114	2.03	3.31	0.26	243.70	114.20	41.41	67.36	5.36	497.15	232.41
214	0.0	2.07	3.47	0.26	236.80	104.50	43.88	73.19	5.60	502.02	221.46
	57	2.10	3.60	0.24	242.00	112.65	50.49	86.51	5.83	583.22	270.85
	114	2.20	3.71	0.25	245.85	119.15	54.66	92.47	6.19	612.17	296.31
285	0.0	2.23	3.61	0.25	231.65	97.35	60.74	98.28	6.67	632.40	265.37
	57	2.13	3.50	0.23	233.15	96.50	59.29	97.34	6.43	650.49	268.71
	114	2.14	3.63	0.23	218.15	89.15	59.49	101.24	6.31	606.46	248.23
Mean of	0.0	2.09	3.62	0.26	235.00	110.65	47.33	81.76	5.79	533.45	251.18
K_2O	57	2.11	3.58	0.25	240.10	110.50	50.52	85.68	6.00	576.24	265.20
	114	2.13	3.55	0.25	235.90	107.50	51.85	86.99	5.98	575.60	262.30
LSD	N	0.02	0.12	-	5.24	8.72	4.35	6.90	-	12.35	5.23
($P<0.05$)	K	0.02	0.12	-	3.25	2.08	2.47	1.37	-	8.24	3.24
	N.K	0.04	0.70	-	6.42	12.08	3.65	2.58	-	14.23	6.14

(-) not significant

increased by increasing N and K fertilization rates over two seasons. The increased cations contents might be associated with a decrease in the sucrose.

This was further associated with an increase in water content in fresh roots of sugar beet, which diluted the sucrose concentration. Therefore, not only sucrose %, but also juice purity might be expected to increase as the amount of cations decrease (Follett, 1991: Hilal, 2005). Also, El-Kammah (1995) reported that white sugar percentage significant increased by increasing of potassium fertilizer rates.

CONCLUSION

There were significant effects of the N and K fertilization rates on the nutrient uptakes in root and foliage of sugar beet and their highest values were always obtained at the highest N and K fertilizers applied. Moreover, the maximum yield and quality of sugar beet crop obtained with 114 kg K ha^{-1}. These results suggest that the application of both nitrogen and potassium can control impurities components leading to a good quality of sugar.

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