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Nutrient Uptake of Sugar Beet as Affected by NPK Fertilization and Soil Salinity Levels

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IN A POT experiment, the growth of sugar-beet (*Beta vulgaris* L.) cv. kawamira on clay loam soil was studied. An imitation of natural salinity, prevailing in Egyptian saline soils, was performed by using the salt crust, which was applied in the pots before sowing to reach 4000, 6000 and 8000 ppm, as well as control. Salinity and NPK fertilizers were applied to the pot-experiment, according to a split-split design. The obtained results can be summarized as follows:

1-Root length, root and top yields (g/pot), as well as nutrient upakes (N,P,K and Na), were significantly decreased by increasing soil salinity levels. Root/top ratio showed positive response to salt concentration increased during both seasons.
2-Application of N-fertilizer at the rate of 100 mg/kg soil increased significantly the root diameter and its length, root and top yields (g/pot), as well nutrient uptakes (mg/pot). Root/top ratio was increased significantly at the rate of 50-mg N/kg soil only.
3-Application of P and /or K-fertilization affected positively yield and yield components, as well nutrient uptakes, except for root diameter and its length and the absorbed amount of sodium by sugar beet plants during both seasons.
4-The interaction effect of SxN and SxPK-treatments had significant effects on the root dry yield (g/pot). Maximum root dry yield/pot was produced with the addition of 100 mg N/kg soil or with 20 mg P_2O_5 + 50 mg K_2O/kg soil at 2000 ppm soil salinity level.

Key words : Sugar beet, NPK fertilization, Salt affected soils.

Sugar beet in Egypt has a considerably higher sugar content and long growth period compared with sugar cane. Furthermore, consumed water by sugar beet to prorduce one ton of sucrose is aboout 1300 m^3, whereas sugar cane needs about 4000 m^3 of water to produce the same quantity of sucrose. Sugar beet is widely grown in areas with salinity problems. Salinity reduces growth and productivity due to the rising osmotic potential of soil solution and consequently leads to a deficiency of moisture and nutrient availability (Eisa, 1997).

Recently (in Egypt), great attention was paid possibly to increase sugar beet productivity on salt affected soils via fertilization practices. This can be done by increasing the efficiency of added NP and K-fertilizers under saline conditions. NPK-fertilization of sugar beet has been investigated by many workers (Badawi , 1989; Draycott ,1995 and Neamatt-Alla, 1997). They found that there was an increase in yield components with increasing N-fertilization. Lielah and Taha (1992) reported that 60 N+30 P_2O_5+24 K_2O kg/fed. was recommended for enhancing root and top yields of sugar beet. Ghonema and Sarhan (1994) found that increasing NPK-fertilizers rate up to 75 N+15.5P_2O_5+ 24K_2O kg/fed. gave the highest root and top yields/fed). Khan *et al.* (1990) concluded that 120 kg N and 60-90 kg P_2O_5 were optimal for high yields of sugar beet in saline-sodic soils and they concluded that P-content in roots and leaves increased with increasing N-and P-rates.

The objective of the present study was to determine the optimal NPK fertilization rates for obtaining the highest yield of sugar beet cv. Kawamira under saline conditions.

Material and Methods

Two similar pot experiments were set up outdoors at the agricultural experiment station of Mansoura Univ.during the successive growing seasons of 1994/95-1995/96, to investigate the influence of salinity and NPK-fertilization on yield and its components and nutrient uptakes by sugar beet plants, cv. Kawamira.

The experiment was layed out in plastic containers (35 cm diameter and 45 cm height). Each container was filled with 25 kg of disturbed clay loam soil, sieved through 2mm. The soil was taken from the upper layer (0-15 cm) of Agric. Exp. Sta., Mansoura Univ. Farm. Some physical and chemical properties of the experimental soil are illustrated in Table 1.

TABLE 1. Some physical and chemical properties of soil sample.

Soil character	Particle size distribution				Texture	$CaCO_3$ %	pH 1:2.5	EC ppm	Available nutrients		
	Clay %	Silt %	CS %	FS %					N ppm	P ppm	K ppm
	38.3	27.8	2.41	32	Clay loam	4.12	7.83	2000	1700	4.97	203

A split-split plot design with three replicates was adopted. The main plots were assigned to the four salinity levels (S_1, S_2, S_3 and S_4). The sub-plots were occupied by the three nitrogen levels (N_0, N_1 and N_2), while the sub-sub plots were assigned to the different combinations of two phosphorus levels (P_0 and P_1) and two potassium levels (K_0 and K_1). The total number of these trails were [SxNxPxK (4x3x2x2 =48 treatments)]. Each treatment was replicated 3 times to give a total of 144 containers. The potted non-saline soil was artificially salinized by dissolving the salt crust (NaCl is the most dominant salt) in a quantity of tap water equivalent to the water holding capacity to achieve the studied salinity treatment, *i.e.* 4000, 6000 and 8000 ppm, as well as the control (natural soil) in both seasons. Salinity of origfinal soil (2000 ppm) was taken into consideration when preparing the required degree of salinity . On November 9^{th}, 1994 and November 1^{st} 1995, ten seeds were selected of Kawamira variety and sown in each container, which had 60% moistre of water holding capacity at equal depth and distances.

Nitrogen fertilizer levels (0,50 and 100 mg/kg soil) were added in the form of ammonium nitrate (33.5%) and at two equal doses, *i.e.* 45 and 75 days from sowing. Potassium rates (0 and 50 mg/kg soil) were added as potassium sulfate (50% K_2O) and phosphorus levels (0 and 20 mg/kg soil) were applied as super phosphate (16% P_2O_5). Potassium fertilizer was applied in one dose after 45 days from sowing date with the first dose of N-fertilizer. Phosphorus fertilizer was applied prior to sowing. Sugar beet plants were thinned after the appearance of the first foliage leaf to one seedling per container and were harvested when the outside leaves of these plans turn yellow (after 180 days from sowing). Total nitrogen was determnined colorimetrically at a wavalength of 420 nm by the Nessler's method as described by Jackson (1967) and phosphorus was determined colorimetrically at a wavelength of 725 nm using zeiss spectrophotometer (spekol) as described by Jackson (1967). Potassium and sodium were determined using Gallen Kamp flame-photometer.

All data were statisitcally analyzed according to the technique of analysis of variance (ANOVA) and the new L.S.D. method, mentioned by Gomez and Gomez (1984) .

Results and Discussion

The overall means of yield, yield components and nutrient uptake of sugar beet, as affected by soil salinity , N and PK fertilization and their interactions are presented in Tables 2-7.

Effect of soil salinity levels

Results presented in Table 2 show that means of root length (cm), fresh and dry yields of root and top (g/pot) of sugar beet decreased very significantly, due to the increase of the concentrations of salts during 1994/95 and 1995/96 seasons. However , root diameter was affected insignificantly by the soil salinity levels .

The highest salinity level (S4 =8000 ppm) caused 60 and 28 % reduction in the top and root fresh yields per pot in the first season, while in the second season it caused 61 and 25% reductions in the top and root fresh yields per pot respectively , as compared to the natural soil. The deterious effect of salinity on plant growth may be attributed to its effect on water stress, ion toxicity , ion imbalance or combination of all these factors (Salama, 1991). These results are in harmony with those of Kandil (1985); Shehata (1989) and Mostafa (1996).

Concerning nutrient uptakes , Table 3 shows that the amounmt of nutrient elements significantly decreased by increasing salinity . The higher the concentration of salts, the greater the decrease in total uptake of N, P, K and Na (mg/pot). This indicates that excessive concentration of Na and Cl ions in the growth media are inhibitory to the uptake and possibly also the translocation process of essential nutrients (Eisa, 1997). These findings are in coincidence with those obtained by David and Goswami (1986); Mostafa (1996) and Eisa (1997) They reported that increasing salinity affected plant growth, which reflects the metabolic status of plants and consequently the accumulation of nutrients.

TABLE 2. Yield and yield components of sugar beet plants as affected by soil salinity levels (ppm) during 1994/95 and 1995/96 seasons.

Salinity levels (ppm.)	Root diameter (cm)		Root length. (cm)		Top fresh yield (g/pot)		Top dry yield (g/pot)		Root fresh yield (g/pot)		Root dry yield (g/pot)		Root/top ratio	
	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96
2000	11.7	11.3	31.4	31.2	161.9	160.3	41.5	38.6	1230.0	1227.0	397.5	401.3	9.57	9.68
4000	10.6	10.7	29.8	29.2	109.0	109.1	28.1	30.1	988.5	984.0	356.4	361.3	12.67	12.25
6000	11.3	11.4	26.3	26.2	96.7	97.6	20.6	20.5	1010.0	1001.0	334.2	328.1	16.2	16.3
8000	10.6	10.8	25.7	25.8	65.2	63.4	18.1	17.0	881.3	915.9	301.7	296.1	16.7	16.5
L.S.D. 5%	--	--	1.7	1.6	10.2	10.4	1.98	2.0	75.1	71.4	32.8	30.5	2.3	2.2
L.S.D. 1%	--	--	3.0	2.5	15.5	15.7	2.9	3.3	93.7	89.3	51.4	--	--	3.4

TABLE 3. Total uptake of N, P, K and Na (mg/pot) of sugar beet plants as affected by soil salinity levels (ppm) during both seasons .

Salimnty levels (ppm)	Total N- Uptake (mg/pot)		Total K- Uptake (mg./pot)		Total P- Uptake (mg/pot)		Total Na - Uptake (mg/pot)	
	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96
2000	2017	2054	254	263	6966	6710	5841	5444
4000	1623	1599	232	217	5752	5909	5226	5363
6000	1314	1444	166	169	5390	4867	5388	5091
8000	1062	1135	137	142	4474	4437	4782	4758
L.S.D. 5%	75	73	11	11	89	84	81	79
L.S.D. 5%	83	--	--	--	--	--	--	--

Effect of N and PK-fertilization

N-Fertilization effects

In both seasons, root diameter, root length as well as fresh and dry yields of top anu root very significantly increased as N-fertilizer levels increased from zero up to the highest rate (100 mg/kg soil), (Table 4). These increments may be due to the role of nitrogen in increasing photosynthetic activities, which resulted in increasing photosynthetic gains and , consequently , in improving root dimensions by increasing division and elongation of cells. Similar results were obtained by Emara (1990), Besheit *et al.* (1995) and Neamatt-Alla (1997). Root/top ratio increased with raising nitrogen fertilizer levels from zero to 50 mg/kg soil, while a higher dose (100mg/kg soil) caused a decrease. This decrease in root/top ratio at the highest level of N fertilizer may be due to the role of nitrogen to stimulate leaf growth more than root growth (Table 4). It is evident from the data in Table 5 that a progressive increase in accumulated nutrients N, P, K and Na (mg/pot) in sugar beet plants occurred as the result of additional doses of N-fertilizer up to 100 mg/kg soil during both seasons. This may have occured due to the increase in yield of dry matter (Table 4). These results are in agreement with those obtained by Tisdale *et al.* (1985), who found that the addition of nitrogen tends to increase nutrients uptake by plants. Saif (1991) and Abou-Amou *et al.* (1996) came to the same conclusion.

PK-Fertilization effects

Data in Table 4 show that root diameter and its length were slightly affectea due to the application of P and / or K fertilizer during both seasons. On the contrary, yield and yield components were influenced significantly due to the same additional rates. The treatment with 50 mg/kg soil gave the highest fresh and dry values of sugar beet tops, meanwhile application of 20 mg P_2O_2 + 50 mg K_2O caused the highest fresh and dry values of beet roots, compared to other treatments during both seasons. This enhancement in the yield and yield components can be explained by the fact that P is a constituent of many compounds in plants and it is important in most plant metabolic processes (Russell, 1988). Moreover, K is a co-factor (enzyme-activator) for different enzymes and it helps to maintain electro-neutrality in plant cells (Russell, 1988). Similar findings are reported by Emara (1990) and Metwally *et al.* (1997). It is

TABLE 4. Yield and yield components of sugar beet plants as affected by N and PK-fertilization during 1994/95 and 1995/96 seasons.

Characters / Treatments	Root diameter (cm)		Root length (cm)		Top fresh yield (g/pot)		Top dry yield (g/pot)		Root fresh yield (g/pot)		Root dry yield (g/pot)		Root/Top ratio	
	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96
N-levels (ma/kgsoil)														
0	9.29	9.24	26.95	25.51	75.12	76.38	18.62	18.90	512.9	528.8	208.1	214.1	11.18	11.33
50	11.60	11.69	30.69	30.54	110.5	109 8	28.92	30.00	1205.0	1200.0	406.6	400.1	14.06	13.33
100	12.69	12.19	31.52	31.26	138.9	136.7	33.69	34.31	1365.0	1310.0	427.6	423.1	12.69	12.25
New L.S.D. 5%	0.40	0.34	2.02	1.83	10.89	10.13	3.21	3.11	63.29	68.38	31.14	30.13	2.80	2.60
New L.S.D. 1%	0.51	0.47	2.80	2.15	15.07	16.11	4.30	4.81	73.17	80.00	48.31	45.12	3.87	—
PK-levels (mg/ks soil)														
0 0	11.23	11.14	29.91	29.37	106.5	110.3	23.61	24.00	1029.0	1017.0	343.4	330.4	14.11	13.73
20 0	11.15	11.37	28.64	27.13	99.42	103.1	26.84	27.71	1023.0	1053.0	349.0	340.1	13.01	12.00
0 50	10.53	10.03	27.78	26.38	114.7	120.1	31.67	29.00	997.39	988.0	347.3	335.1	10.97	11.48
20 50	10.96	11.00	26.88	26.00	109.4	105.7	26.19	27.93	1085.0	1090.0	350.1	344.3	13.18	12.64
New L.S.D. 5%	0.47	0.45	1.54	1.63	---	—	3.50	3.10	56.31	60.31	29.72	27.13	2.54	2.08
New L.S.D. 1%	—	-	-	--	--	—	4.11	4.20	--	—	43.48	45.18	—	—

TABLE 5. Total uptake of N, P, K and Na (mg/pot) of sugar beet plants as affected by N and PK fertilization (mg/kg soil) during both 1994/95 and 1995/96 seasons .

Characters / Treatments	Total N-uptake (mg/pot)		Total P-uptake (mg/pot)		Total K-uptake (mg/pot)		Total Na-uptake (mg/pot)	
	94/95	95/96	94/95	95/96	94/95	95/96	94/95	95/96
N-levels (mg/kg soil)								
0	565.1	630.13	129.35	140.85	2846.15	2729.83	2767.00	3086.16
50	1854.4	1760.14	218.17	231.81	6912.20	6812.13	6437.78	6123.45
100	2324.2	2181.21	230.13	236.13	7669.10	7548.80	7561.41	6938.18
NewL.S.D. 5%	76.4	71.83	11.00	14.31	74.00	76.06	78.60	76.32
NewL.S.D. 1%	85.1	82.45	—	—	—	—	—	—
PK-levels (mg/kg soil)								
0 0	1399.1	1463.2	171.60	180.98	5146.15	5183.02	5434.18	5260.42
20 0	1535.7	1516.4	207.54	218.41	5428.91	5372.53	5506.66	5490.86
0 50	1621.5	1645.8	189.01	183.05	5906.21	5741.99	5354.06	5160.18
20 50	1415.3	1500.4	209.43	202.73	5722.80	5613.05	5217.37	5174.51
New L.S.D. 5%	71.1	68.1	10.06	9.80	63.00	72.00	—	—
NewL.S.D. 1%	—	—	—	—	-	-	—	—

obvious, from data collected in Table 5, that there was a significant and relative increase in the absorbed amount of N,P and K by sugar beet plants due to the applied doses of phosphorus with or without potassium fertilizer, whereas the absorbed amount of Na by plant tissues was influenced insignificantly under the same treatments in comparison with the control. These results can be attributed to the role of P and K in stimulating the plant growth and the increasing dry matter accumulation in sugar beet tissues. Khan *et al.* (1990) and Abou Amou *et al.* (1996) came to the same findings.

Interaction effect

Data of the interaction effects between soil salinity levels, N and PK-fertilization, on dry yield (g/pot) are presented in Tables 6&7.

TABLE 6. Means of dry root yield (g/pot) of sugar beet plants as affected by the interaction between salinity levels and N-treatments in both seasons .

Salinity levels (ppm).	N-treatments (mg/kg soil)					
	1994/95			1995/96		
	0	50	100	0	50	100
2000	231.8	420.2	516.7	250.3	450.0	520.1
4000	218.5	408.3	460.4	230.1	398.4	471.2
6000	224.0	379.7	358.7	216.2	232.3	381.2
8000	180.1	206.9	163.6	168.4	213.9	142.0
New L.S.D. 5%	36.32			34.66		
New L.S.D. 1%	--			45.00		

TABLE 7. Means of dry root yield of sugar beet plants as affected by the interaction between soil salinity levels and PK-treatments in both seasons .

Salinity levels (ppm)	PK-treatments (mg/kg soil)							
	1994/95				1995/96			
	P_0K_0	P_1K_0	P_0K_1	P_1K_1	P_0K_0	P_1K_0	P_0K_1	P_1K_1
2000	408.2	393.5	375.78	418.7	406.7	389.4	372.7	420.3
4000	297.6	385.4	379.3	365.6	298.1	381.5	383.2	365.8
6000	381.0	340.6	348.1	317.2	332.2	341.3	345.8	319.4
8000	326.9	278.7	286.7	283.8	323.5	276.9	286.6	308.5
New L.S.D. 5%	43.34				36.4			
New L.S.D. 1%	–				48.0			

From Table 6, it clearly appears that there was a significant interaction effect between the two factors of study on dry yield during both seasons. The maximum dry root yield means (516.7 and 250.1 g/pot) in the first and second seasons, respectively, were obtained from the treatment of 2000 ppm salinity level with 100 mg N/kg soil. Meanwhile, at the highest soil salinity level (8000 ppm) applying 100 mg N/kg soil gave the lowest means of dry root yield (163.6 and 142.0 g/pot), respectively, compared to the control. This reduction may be ascribed to Cl, competing very strongly with NO_3 for binding sits on the plasma membrane and it can suppress the transport of NO_3 from the external solution, (Cutin *et al.,* 1993).

Results presented in Table 7 reveal that the interaction effects of soil salinity levels and PK treatments on dry root yield per pot of sugar beet were significant in both seasons. At the highest soil salinity level (8000 ppm), application of the 20 mg P_2O_2 + 50 mg K_2O / kg soil produced the lowest dry root yields (283.8 and 308.5 g/pot), respectively, as compared to unfertilized treatment under the same soil salinity level during both 1994/95 and 1995/96 seasons. This reduction may be due to a substitution mechanism of Na^+ for K^+ and / or an antigonistic state between Na and other nutrients in the soil solution and in the plant tissues (Salama, 1991). These findings are in correspondence with those obtained by El-Hawary (1994).

Conclusion

Generally, it can be concluded that application of the 100 N + 20 P_2O_5 + 50 K_2O mg/ kg soil led to optimum root yields (g/pot) and increased the efficiency of applied N, P and K fertilizer, due to the increase of these accumulated nutrients and to the inhibition of Na effects on soils and plant growth under saline conditions.

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امتصاص بنجر السكر للعناصر الغذائية تحت تأثير التسميد النيتروجيني والفوسفاتي والبوتاسي ومستويات ملوحة التربة

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أجريت تجربة أصص تحت الظروف الحقلية خلال موسمى ٩٤ / ٩٥ ، ٩٥ / ٩٦ لمحصول بنجر السكر صنف (كواميرا). وفى محاولة للحصول على تربة ملحية طبيعياً مماثلة للأراضى الملحية المصرية تم اضافة ملح تجارى إلى الأصص قبل الزراعة للوصول إلى التركيزات ٤٠٠٠ ، ٦٠٠٠ ، ٨٠٠٠ جزء فى المليون بالإضافة إلى الكنترول (أرض عادية) . ولقد تم إضافة الأملاح والأسمدة النيتروجينية والفوسفاتية والبوتاسية إلى أصص التجارب باستخدام تصميم القطع المنشقة مرتين ذات مكررات وقد أوضحت النتائج الآتى :

١- أشارت النتائج إلى وجود انخفاض معنوى فى كل من طول الجذر ومحصول العرش والجذور (جم / أصيص) بالإضافة إلى الممتص من العناصر الغذائية (ن ، فو ، بو ، ص) (ملجم / أصيص) نتيجة الزيادة فى مستويات الملوحة بينما أظهرت نسبة الجذر / العرش استجابة واضحة تحت تأثير الزيادة فى مستويات الملوحة خلال موسمى النمو .

٢- لقد أدت إضافة السماد النيتروجيني بمعدل (١٠٠ ملجم / كجم تربة) إلى زيادة معنوية في طول وقطر الجذر بالإضافة إلى محصول الجذور والعرش (جم / أصيص) وكذلك الممتص من النيتروجين والفوسفور والبوتاسيوم والصوديوم بينما أدت إضافة المعدل الثاني من السماد النيتروجيني (٥٠ ملجم / كجم تربة) إلى زيادة معنوية في نسبة الجذر / العرش.

٣- أدت إضافة الفوسفور منفرداً أو مع البوتاسيوم إلى تأثير إيجابي على المحصول ومكوناته بالإضافة الى محتوى المحصول من العناصر الغذائية (ملجم / أصيص) فيما عدا قطر الجذر وطوله ومحتوى المحصول من الصوديوم في كلا الموسمين .

٤- كما أثر التفاعل (ملوحة مع نيتروجين) وكذلك الملوحة مع الفوسفور والبوتاسيوم تأثيراً معنوياً على المحصول الجاف للجذر لكل أصيص . ولقد وجد أن إضافة المعدل السمادي ١٠٠ ملجم نيتروجين + ٢٠ ملجم فوسفور + ٥٠ ملجم بوتاسيوم لكل كجم تربة أدت إلى الحصول على أعلى محصول من الوزن الجاف تحت ظروف الأرض العادية (الكنترول) خلال الموسمين .