Assessment of Salinity Tolerance of some Wheat Genotypes Irrigated with Saline Waters

Aboushal A. A. and I. I. Mahmoud
Soil, Water, and Environ. Res. Inst., Soil Salinity Lab., Alexandria.

ADDITIONAL INDEX WORDS: Wheat (*Triticum aestivum L.*), saline water irrigation, salt tolerance.

ABSTRACT

A great concern is needed to sustain high wheat production in irrigated salt effected areas through the use of salt-tolerant wheat genotypes. Therefore, a greenhouse pot experiment was conducted at the Soil Salinity Lab. of Alexandria, Egypt to study the salt tolerance variability among six wheat genotypes with check variety Sakha 8. Treatments included five levels of irrigation water salinity: tap water (control treatment of 320 mg/L) artificially salinized with commercial NaCl and $CaCl_2$ salts (1:1 by weight) to get the other treatments, i.e., 3000, 6000, 9000, and 12000 mg/L water salinity. The corresponding electrical conductivities of irrigation waters (EC_i) were 0.50, 4.69, 7.50, 11.25, and 15.0 dS/m. At harvesting, chemical properties of soil were determined. Moreover, biological yield, grain yield, and yield components were recorded and statistically analyzed.

The results revealed a straight-line relationship between soil salinity EC_s and irrigation water salinity EC_i with a highly significant correlation coefficient. Soil salinity was increased proportionally by 1.24 dS/m for each increasing unit of applied water. At maturity, increasing salinity of irrigation water up to 15.0 dS/m significantly reduced ($P \leq 0.05$) grain yield, biological yield, spikes weight, number of tillers/pot, number of spikes/pot, number of kernels /spike, 1000-kernels weight, and plant height. The decreased grain yield due to salinity could be attributed to the reduction of spikes weight, 1000-kernel weight and number of spikes/pot, rather than the reduction of number of tillers/pot or number of kernels/spike.

Over all salinity levels, Sakha 8 gave the highest grain yield, biological yield, spikes weight, number of tillers per pot and number of spikes per pot. However, Geno.6 produced the lowest biological yield, spikes weight and ranked after Geno.1 for grain yield. The heaviest 1000-kernels weight was recorded for Geno.1, while Geno.4 had the lowest value. Finally, Geno.6 was the tallest genotype, while Geno.4 was the shortest.

Data of salinity x genotypes interactions indicated significantly that the check variety Sakha 8 insisted to be the highest for grain yield, biological yield, and spikes weight either at non-saline or at the highest salinity level (0.50 and 15.0 dS/m, respectively). At the highest salinity level, Sakha 8 had the lowest reduction percentage in grain yield (35.31%), followed by Geno.2 (44.51%). Otherwise, Geno.6, Geno.5 and Geno.4 produced the greatest reduction percentages (54.51, 51.56, and 51.36 %, respectively).

The estimated values of EC_{50} index overall genotypes for grain and biological yields were 18.65 ± 0.90 and 21.40 ± 1.27 dS/m, respectively showing that biological yield was more tolerant to salinity than grain yield. The values of the parameter EC_{50} of tolerance of grain yield to salinity were 26.24, 22.10, 19.02, 17.29, 17.18, 17.13 and 15.95 dS/m for Sakha 8, Geno.2, Geno.1, Geno.3, Geno.4, Geno.5 and Geno.6, respectively. Accordingly, Sakha 8 and Geno.2 were the most tolerant genotypes, whereas the geno.6 was the most salt sensitive. Although, Geno.2 produced relatively lower yield potential than Geno.5 at non-saline treatment, it ranked the second as salt tolerant genotype after Sakha 8. Moreover, Geno.6 had the lowest yield potential at non-saline conditions and was the most salt sensitive.

INTRODUCTION

Wheat (*Triticum aestivum L.*) is considered a strategic cereal crop in Egypt for its importance in the Egyptian diet. Wheat provides more than one-third of the daily calorie intake of consumers and 45 percent of their total daily protein consumption (Rowntree 1993; Abdel Ghaffar 1994), and is occupying about 38 percent of the total winter crop area (2.7 million feddan). Wheat self-sufficiency is often cited as a goal of government wheat policy as its production for the agricultural season 2007 reached 7.4 million tons. Egypt ranked second among the world countries in importing wheat (7 million tons for season 2006/2007).

Recently, a great attention of several investigators has been directed to increase the productivity of wheat to minimize the gap between the Egyptian production and consumption by increasing wheat production through increasing unit land area productivity and increasing cultivated area, particularly the salt affected ones (El Ashtar 2005; Nabila *et al.* 2007; Ragab, *et al.* 2008).

Due to deficiency in supplies of high quality water, water availability could be enhanced for irrigation through judicious and proper use of low quality water. The entire water requirement in Egypt totals 71-73 milliard m^3 per year. However, the combined water resources of the Nile, groundwater and drainage water recycling add up to only 63 milliard m^3 (Bishay,1993; Attia *et al.*, 1995; FAO, 1997; Abdel-Hafez *et al.*, 1999), and there is no possibility of accessing additional water resources (Anonymous, 1995; Seckler and Altaf, 1997).

Saline water can be applied by cyclic or blending strategy to grow crops without detrimental long-term consequences to crop or soil (Grattan and Rhoades, 1990). In this concern, salt-sensitive and salt-tolerant crops are grown in particular rotations with saline and nonsaline waters. Otherwise, the blending strategy is introduced to combine saline water with nonsaline ones in proportions to produce different water qualities suitable for the different crops under consideration. Thus, salt tolerance studies should be focused on major crops of great importance like wheat crop. Wheat is a moderately salt-tolerant crop with threshold without yield loss at 6 dS/m and with yield 50% loss at 13 dS/m (Mass and Hoffman, 1977; Allen *et al.*, 1998).

Considerable research has been conducted annually at Soil Salinity Laboratory, Egypt on the salt tolerance of some Egyptian varieties and cross wheat (*Triticum aestivum L.*). This would help to select the suitable varieties and cross for certain soil contained known amount of salts or where high quality water is not available. This study was conducted to determine the salt tolerance performance of six local wheat genotypes namely; Geno.1, Geno.2, Geno.3, Geno.4, Geno.5, Geno.6, and the check variety Sakha 8 grown under five salinity levels.

MATERIALS AND METHODS

A greenhouse pot experiment was carried out at the Soil Salinity Laboratory. Alexandria, Agricultural Research center, using plastic pots with a hole in the bottom (32 cm diameter and 45 cm height) filled with 37 kg calcareous loam soil (*Typic Calciorthents*) to 1.38 g/cm^3 bulk density, leaving 10 cm free at the top for irrigation practices. Some physical and chemical properties of the used soil were conventionally determined according to Page *et al.* (1982) and are shown in Table 1.

Table 1. Some physical and chemical characteristics of the studied soil.

Soil property	Mean value	Soil property	Mean value
EC, dS m^{-1}	1.80	Mechanical analysis, %	
†pH	8.29	Sand	45.00
SAR	5.13	Silt	32.50
Soluble ions, meq/L		Clay	22.50
Ca^{2+}	4.35	Texture, loam	
Mg^{2+}	3.32	‡ Moisture characterization	
Na^{+}	10.05	Saturation, %	47.00
K^{+}	0.40	Field capacity, %	23.60
Cl^{-}	9.37	P.Wilting point, %	11.10
HCO_3^{-}	2.72	$CaCO_3$, %	32.10
SO_4^{2-}	6.05	$NaHCO_3$-P, mg/kg	10.00
Organic carbon, %	0.28	Total N, %	0.50

† Measured in 1:2.5 soil to water suspension ‡ On volumetric basis

Certified seeds of six wheat (*Triticum aestivum L.)* genotypes (namely, Geno.1, Geno.2, Geno.3, Geno.4, Geno.5, and Geno.6), and Sakha 8 were supplied by the Wheat Research Department, Field Crops Research Institute, Agriculture Research Center. These genotypes were selected from screening trials performed in the past years by Wheat Research Department (Table 2). Sakha 8 is used as a standard variety (the check reference) for the salt tolerance test of wheat genotypes at this study. Wheat genotypes were planted on November 26, 2005. Three weeks later, thinning was conducted to maintain five seedlings/pot until maturity.

Table 2. Name and Pedigree of 7 wheat genotypes tested for salt tolerance in the study.

Genotype No.	Name and Pedigree
1	Vee"S"/Swm6525/4/Trm//Kal/Bb/3/Corp"S"/Piy"S"
2	Vee"S"7/6/Kvz/4/1171/3/Maia"S"/Bb//Inia/Lgm/5/Sakha8
3	Achtar/5/Bb/Kal//Alo"S"/3/7C/4/Furg
4	Tevee"S"/Kauze
5	4777(2)//Fkn/Gb/3/Vee"S"/4/Buc"S"/Pvn"S"15/Maya"S"/Mon"S"//CMH74A
6	KAUZ//ALTAR84/AO5/3/KAUZ CMBW89Y00785-OTOP M-3Y-OLOM-OLOM-OY
7	Sakha 8

All pots received the recommended doses of mineral fertilization as follows: single super phosphate fertilizer (15% P_2O_5) was added at a rate of 30 kg P_2O_5/feddan (1 feddan = 0.42 hectare) mixed thoroughly with the soil sample before cultivation, nitrogen fertilizer as ammonium nitrate (33.5%N) was broadcasted at a rate of 90 kg N/feddan in three equal doses applied at seedling, tillering and heading stage and potassium sulphate (48% K_2O) was added at a rate of 48 K_2O/feddan three weeks after sowing. All other cultural practices were applied as recommended.

The pots were irrigated with tap water equal to soil field capacity for three weeks (emergence stage). Thereafter, the seedlings were thinned to 5 seedlings/pot and irrigated with different saline waters having electrical conductivities (EC_i) of 4.69, 7.50, 11.25 and 15.0 dS/m besides tap water (0.50 dS/m) as a control treatment. The salinization was accomplished by adding equal weights of NaCl and $CaCl_2$ to tap water. Taking into account that the salts used were commercial materials and contained some other elements. The final analysis of the prepared irrigation water treatments is shown in Table 3. The experimental pots were arranged on greenhouse benches in a randomized complete block design consisting of five salinity treatments (0.50, 4.69, 7.50, 11.25 and 15.0 dS/m) and seven wheat genotypes (Table 2). Each treatment was replicated four times.

Table 3. Compositions of irrigation waters used in the experiment.

TDS†, mg/L	EC_w, dS/m	Soluble cations, meq/L				Soluble anions, meq/L			SAR‡
		Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	SO_4^{2-}	
320	0.50	1.94	1.10	1.67	0.15	1.84	0.30	2.69	1.35
3000	4.69	25.54	6.59	16.38	0.51	41.29	0.51	7.53	4.20
6000	7.50	40.12	9.62	29.63	0.72	68.62	0.57	10.77	5.94
9000	11.25	52.56	15.13	44.32	1.14	94.75	1.03	17.14	7.62
12000	15.00	80.96	19.27	59.55	1.50	137.47	1.27	22.32	8.41

† TDS = total dissolved solids.
‡ SAR = $Na^+/[(Ca^{2+} + Mg^{2+})/2]^{1/2}$, all concentrations are expressed in meq/L.

During the growing season, all pots were irrigated whenever needed in addition to 15% more as leaching fraction to prevent any risky salt accumulation in the pots. At harvest, 165 days after planting, wheat biological (straw + spikes weight), grain yields (g/pot), weight of spikes/pot, number of tillers/pot, number of spikes/pot, number of kernels/spike, 1000-kernel weight (g) and plant height (cm) were recorded. The significant differences among all the resultant means were identified statistically using SAS-GLM procedure (SAS, 1992). Soil samples were taken after harvest from each pot and analyzed for EC_s, pH, and soluble cations and anions.

Salinity tolerance index:

Crop salt tolerance data have traditionally been analyzed with the concept of EC_{50} index, where EC_{50} is a parameter which describes the degree of salt tolerance of various crops. The relationship between grain/biological yield and salinity were established for each wheat genotype by a sigmoidal response model [option 12 of the SALT program described by van Genuchten (1983)]:

$$\mathbf{Y_r = 1\ /\ [1 + (EC / EC_{50})^{P}]} \qquad (1)$$

where Y_r is the relative yield of a test crop ($Y_r = Y/Y_m$), Y and Y_m are the values of the yield parameters studied for a given EC and for non-saline conditions, respectively. EC_{50} is the salinity of the soil saturation extract (EC) that reduces the value of the parameter by 50% and *P* is a parameter that determines the steepness of the curve, identified as an approximate estimate of the absolute value of the mean dY_r/dEC. The parameters EC_{50}, *P*, and Y_m are calculated by the program.

RESULTS AND DISCUSSION

Irrigation water salinity versus soil salinity:

The analysis of the investigated irrigation waters given in Table 3 showed that tap water is characterized by low salinity (EC_i=0.50 dS/m) and low sodicity (SAR=1.35). The 3000 and 6000 mg/L saline water were classified as moderately saline water class and the other tested waters 9000 and 12000 mg/L were classified into highly saline water class according to Rhoades (1982). The compositions of the used irrigation waters (Table 3) showed that the actual Na concentration was less than Ca due to the presence of other cations such as Mg and K in the commercial NaCl salt. Consequently, their SAR values amounted to a maximum value of only 8.41 and they may be described as nonsodic waters. Such waters are in ample supply in many irrigated land and have good potential for selected crop production (FAO, 1993).

Consistent increase in soil salinity EC_s was marked for all the treatments due to the used irrigation water salinity (Table 4). The average soil salinity EC_s was consistently and significantly correlated with the irrigation water salinity EC_i (r=0.995) as shown in Fig.1. The best fit straight line equation that expresses this relationship is:

$$\mathbf{EC_s = 0.436 + 1.212\, EC_i \qquad 0.50 \le EC_i \ge 15.0 \qquad (2)}$$

Table 4. Chemical properties of the studied soil after crop harvesting.

EC_i, dS/m	EC_s, dS/m	EC_s/ EC_i	pH	Soluble cations, meq/L				Soluble anions, meq/L			SAR†	ESP‡
				Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	SO_4^{2-}		
0.50	0.70	1.40	8.30	1.82	0.94	3.97	0.34	5.22	1.28	0.53	3.38	3.59
4.69	6.50	1.39	8.35	22.52	10.79	31.56	0.92	57.02	2.91	5.74	7.73	9.21
7.50	9.50	1.27	8.32	33.06	17.05	45.31	0.82	80.01	3.09	12.77	9.05	10.79
11.25	13.95	1.24	8.19	60.34	17.51	61.95	1.31	114.56	4.51	20.97	9.93	11.81
15.00	18.45	1.23	8.05	67.83	31.07	85.90	1.58	145.98	6.93	33.70	12.22	14.35

† SAR = $Na^+ / [(Ca^{2+} + Mg^{2+})/2]^{1/2}$, all concentrations are expressed in meq/L.

‡ ESP = Exchangeable sodium percentage.

Equation 2 recalculated (EC_s = 1.242 EC_i) by forcing the intercept to zero value. Moreover, it may be concluded also from Table 4 that the salinization ratio, as presented by EC_s / EC_i tended to decrease as EC_i increased (Aragues *et al.*, 1999). The highest salinization ratio (1.40) was recorded for 0.50 dS/m water treatment (EC_i) and gradually decreased with increasing irrigation water salinity till it reached its minimum value (1.23) for the 15.0 dS/m water treatment. Recently, the results presented by Aboushal, (2000) and Elkhatib, (2003) showed a very good accordance with the obtained results using wider ranges of water salinity from 0.45 up to 17.0 dS/m. Soluble cations and anions in addition to SAR values exhibited the same tendency as salinity of saturated soil extract (EC_s).

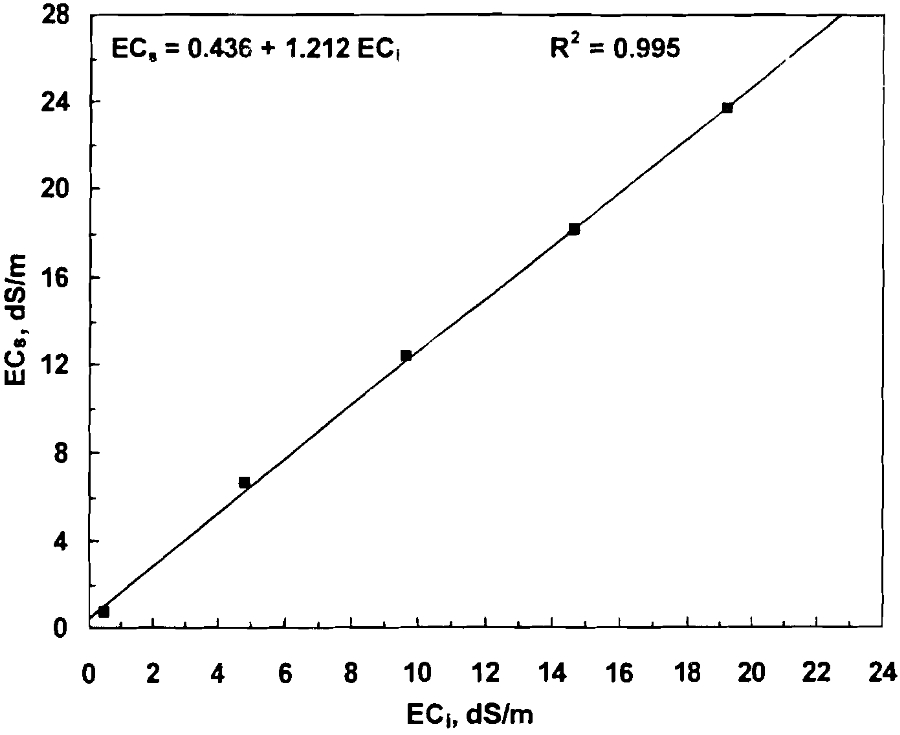

Fig.1. Electrical conductivity of soil saturation extract as a function of the electrical conductivity of irrigation water.

Salinity effects on yield parameters:

Data of grain yield, yield components and growth over the seven wheat genotypes as a function of salinity of irrigation water are given in Table 5. Over all wheat genotypes, increasing salinity of irrigation water significantly reduced ($P \leq 0.05$) the yield of all the studied traits. Data revealed that increasing salinity of irrigation water significantly decreased grain yield by 8.27, 21.30, 37.48 and 47.50% at saline water of 4.69, 7.50, 11.25 and 15 0 dS/m, respectively, as compared with the control treatment. This finding was in accordance with that obtained by El Ashtar (2005) and El-Haddad and Mostafa (2007). Similar and consistent reductions of 43.39 and 41.73% were found for biological yield and spikes weight/pot at the highest salinity level (15.0 dS/m), respectively. Harvest index, the ratio of grain yield to biological yield, was slightly reduced as salinity increased in all irrigation treatments with a reduction value of 13% at the highest salinity treatment (15.0 dS/m).

The reported means of grain and biological yields given in Table 5 were calculated in relative values (Y_r) and depicted in Figure 2 against average soil salinity after crop harvesting. The best fit straight line equations for this relationship are:

$$\mathbf{Y_r,\ Grain = 105.12 - 2.85\ EC_s \qquad 0.70 \leq EC_i \geq 18.45} \qquad \mathbf{(3)}$$

$$\mathbf{Y_r,\ Biological = 104.55 - 2.48\ EC_s \qquad 0.70 \leq EC_i \geq 18.45} \qquad \mathbf{(4)}$$

The depression for biological yield with increasing salinity of irrigation water was less than that of grain yield as illustrated form the slope of equations 3 and 4. The reduction of grain yield: biological yield ratio was found to be 1: 0.87 as calculated by dividing the slopes of equations 3 and 4. This finding was confirmed by calculating the EC_{50} index overall genotypes for grain and biological yields. The estimated values of EC_{50} for grain and biological yields were 18.65 ± 0.90 and 21.40 ± 1.27; respectively showing that biological yield was more tolerant to salinity than grain yield. In addition, the plants submitted to the highest irrigation salinity (15.0 dS/m) were 6.48% shorter than those of the control treatment at maturity stage.

Table. 5. Means of grain yield, yield components and growth of wheat as affected by genotypes and saline irrigation water treatments.

Treatments	Grain yield g/pot	Bio. Yield g/pot	Spikes weight g/pot	Tillers No. / pot	Spikes No. / pot	1000-kernels wt., g	Kernels No./ spike	Harvest Index %	Plant height, cm
Salinity (S), dS/m:									
0.50	70.88	155.89	98.43	41.14	35.89	48.55	44.11	45.90	74.43
4.69	65.02	144.14	90.57	38.04	32.86	47.03	43.69	45.26	73.29
7.50	55.78	125.32	79.86	37.61	31.61	41.94	43.81	45.10	71.96
11.25	44.32	111.32	68.54	36.50	30.21	36.45	41.16	43.19	70.82
15.00	37.21	88.25	57.36	33.68	26.61	34.86	41.52	39.93	69.61
L.S.D.$_{0.05}$ (S)	2.65	6.03	3.87	1.50	1.63	2.07	2.09	1.82	1.88
Genotypes (V):									
Geno.1	49.47	116.75	71.90	36.60	31.60	48.09	32.35	41.94	74.90
Geno.2	53.10	115.20	71.85	40.00	33.55	46.81	33.92	46.15	71.45
Geno.3	51.35	116.80	73.30	33.50	26.50	39.55	48.87	44.11	70.20
Geno.4	54.94	119.95	78.05	37.15	31.40	36.30	48.38	45.67	63.85
Geno.5	56.22	118.30	77.70	35.00	28.60	39.84	49.60	47.88	68.75
Geno.6	46.85	112.65	67.85	34.70	27.40	40.31	42.05	41.26	78.25
Sakha 8	70.57	175.25	112.00	44.80	41.00	41.48	32.35	40.11	76.75
L.S.D.$_{0.05}$ (V)	3.14	7.14	4.58	1.85	1.94	2.45	3.78	2.15	2.23
Interaction (S x V):									
L.S.D.$_{0.05}$	7.03	15.96	10.23	4.32	4.34	N.S.	6.46	4.81	4.98

N.S. = Not significant Bio. = Biological Geno. = Genotype

Among the yield components, number of kernels/spike and number of tillers/pot were less sensitive to salinity, being reduced by 5.87 and 18.13%, respectively at saline water of 15.0 dS/m compared with 41.73% for spikes weight, 28.21% for 1000-kernel weight, and 25.87% for number of spikes/pot. As a result, the decreased grain yield due to salinity could be attributed to the reduction of spikes weight, 1000-kernel weight and number of spikes/pot, rather than the reduction of number of tillers/pot or number of kernels/spike. These results are in consistent with those obtained by earlier investigators (Francois *et al.*, 1986, and 1988; El-Haddad *et al.*, 1993; El-Haddad and Mostafa., 2007).

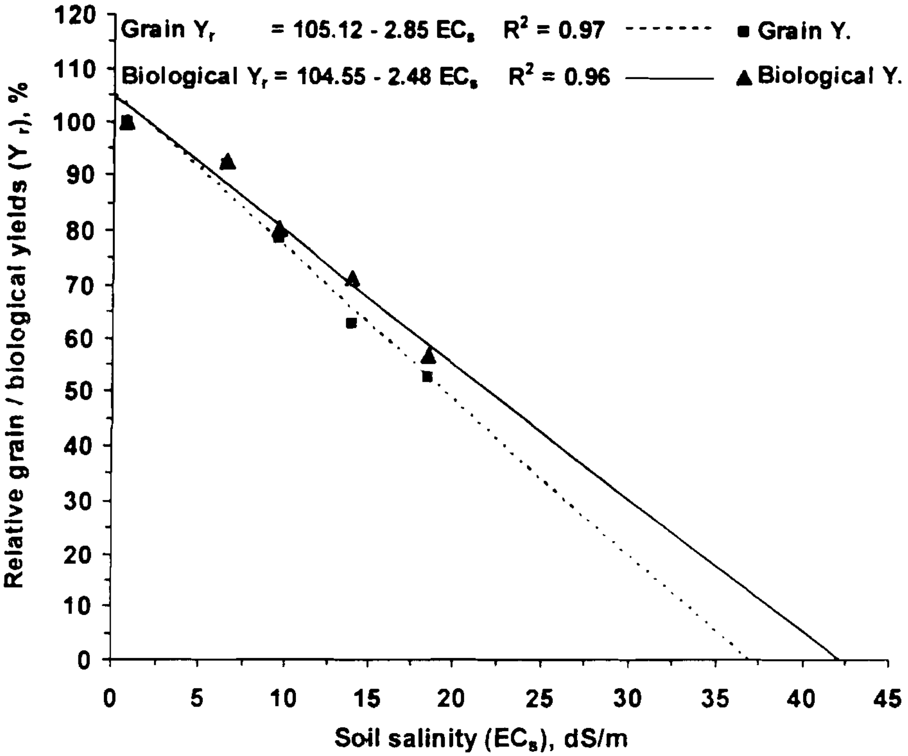

Fig.2. Relative grain and biological yields of wheat genotypes as a function of increasing soil salinity.

Genotypes effects on yield parameters:

The results in Table 5 and Figure 3 indicated a significant difference ($P \leq 0.05$) among genotypes and Sakha 8 (the check reference) over all salinity treatments for all studied parameters.

Sakha 8 was significantly higher than the other genotypes given grain yield of 70.57 g/pot. At the same time, Geno.1 and Geno.6 illustrated the lowest grain yield (49.47 and 46.85 g/pot, respectively) The reduction percentage of grain yields were 29.89, 24.76, 27.23, 22.14, 20.34 and 33.62% for Geno.1, Geno.2, Geno.3, Geno.4, Geno.5 and Geno.6, respectively as compared with Sakha 8.

All tested genotypes showed a significant decrease in biological yield comparing with Sakha 8, but there were insignificant differences among them. The reduction percentages were 33.38, 34.27, 33.35, 31.55, 32.50 and 35.72% for Geno.1, Geno.2, Geno.3, Geno.4, Geno.5 and Geno.6, respectively. The reduction in biological yield may be attributed to deficiency in water uptake caused by osmotic stress, imbalance in nutrition induced by ion excess or a combination (El-Haddad *et al*., 1993, and El Etreiby, 2002).

Moreover, Sakha 8 surpassed the other genotypes in spikes weight, number of tillers per pot and number of spikes per pot over all levels of salinity (Table 5). On the other hand, Figure 3 demonstrates that Geno.6 produced the lowest grain yield, biological yield and spikes weight.

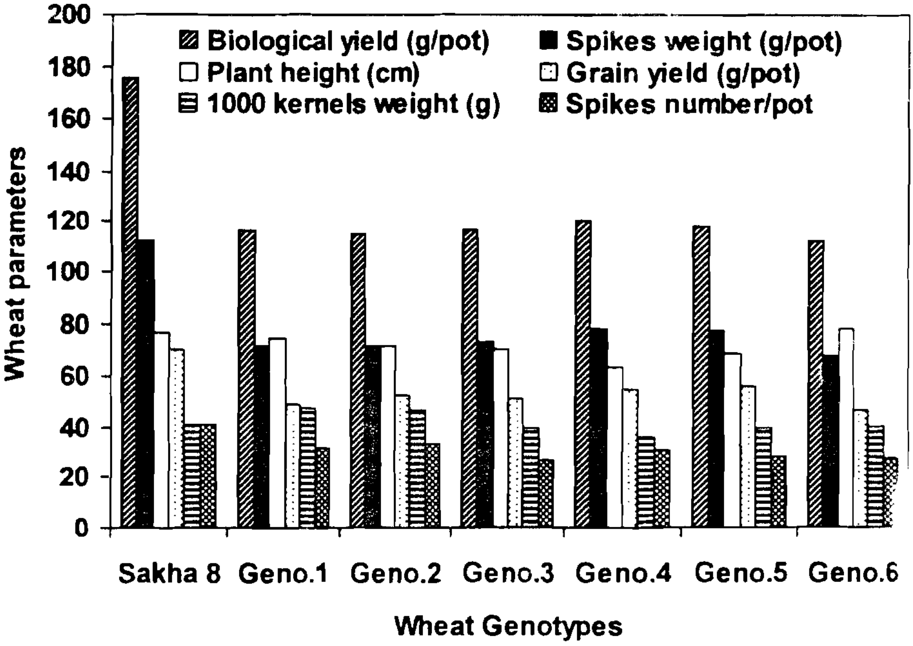

Fig.3. Means of grain yield, yield components and plant height of wheat genotypes as affected by different salinity levels.

Harvest index% was the highest for Geno.5 followed by Geno.2 (47.9, 46.2%, respectively). Genotypes 1 and 2 were superior in the 1000-kernel weight where Geno.1 gave the heaviest 1000-kernels weight (48.09 g) followed by Geno.2 (46.81 g), while Geno.4 had the lowest value. Higher number of kernels per spike for genotypes 5, 3 and 4 revealed a wide gape to the other genotypes. Finally, Genotype 6 showed to be the tallest genotype followed by Sakha 8 (78.25, and 76.75 cm, respectively).

Salinity x genotypes interaction:

The significant interaction between salinity of irrigation water and wheat genotypes were noticed for grain yield, biological yield, spikes weight, number of tillers/pot, number of spikes/pot, number of kernels/spike, harvest index and plant height at maturity. The data of those parameters and L.S.D$_{05}$ for interaction are listed in Table 6 and depicted in Figure 4.

Data of salinity x genotypes interactions indicated that, for each cultivar under this study increasing salinity of irrigation waters from 0.50 to 15.0 dS/m decreased all characters of wheat genotypes. Moreover, the check variety Sakha 8 insisted to be the highest for grain yield, biological yield, and spikes weight either at non-saline or at the highest irrigation salinity level (0.50 and 15.0 dS/m, respectively).

Grain yield of Sakha 8 and Geno.5 were the greatest under non-saline conditions giving 80.44 and 74.57 g/pot, respectively. Increasing salinity level up to 4.69 dS/m induced 8.51% increase in grain yield of Sakha 8 and then yield declined with increasing salinity (Table 6). At the highest irrigation salinity (15.0 dS/m), Sakha 8 presented the highest grain yield (52.04 g/pot) and Geno.6 provided the lowest grain yield (30.38 g/pot), although, grain yields of the other cultivars were statistically similar to one another.

No significant differences among the six new genotypes were recorded at 0.50 dS/m for biological yield and spikes weight and for the later at 15.0 dS/m. Number of tillers/pot was the highest for Sakha 8 at the control salinity level, while Sakha 8, Geno.2, Geno.1 and Geno.4 were statistically similar to each other at the highest salinity level. Moreover, Sakha 8, Geno.1 and Geno.2 exhibited the same behavior in number of spikes/pot at the highest salinity level. The genotypes number 6 and 4 offered the lowest harvest index at non-saline water treatment, while Geno.5 produced the highest harvest index at 15 dS/m irrigation salinity level (Table 6). Finally, Sakha 8 followed by Geno.6 was the tallest at the lowest salinity level. However, a reverse order was observed at the highest salinity level followed by Geno.1

Table 6. Means of grain yield, yield components and growth of wheat as influenced by the interaction between genotypes and each of salinity levels.

Genotypes	Salinity levels (dS/m)					Salinity levels (dS/m)				
	0.50	4.69	7.50	11.25	15.0	0.50	4.69	7.50	11.25	15.0
		Grain yield (g/pot)					Biological yield (g/pot)			
Geno.1	66.88	56.00	48.88	40.74	34.8	145.0	125.5	116.2	107.0	90.00
Geno.2	70.78	56.70	53.33	45.41	39.2	142.5	130.5	105.0	104.5	93.50
Geno.3	67.62	64.37	50.75	39.84	34.1	147.0	141.0	123.7	100.0	72.25
Geno.4	69.11	67.94	61.89	42.16	33.6	153.7	137.5	128.5	103.7	76.25
Geno.5	74.57	68.24	58.42	43.72	36.1	148.5	142.5	129.5	103.0	68.00
Geno.6	66.78	54.61	45.33	37.15	30.3	152.0	128.2	100.5	102.2	80.25
Sakha 8	80.44	87.29	71.90	61.19	52.0	202.5	203.7	173.7	158.7	137.5
L.S.D. $_{0.05}$			7.03					15.96		
		Spikes weight (g/pot)					Tillers number/pot			
Geno.1	93.50	77.50	71.50	63.25	53.7	40.00	38.75	35.25	34.50	34.50
Geno.2	93.75	75.75	70.25	65.00	54.5	43.00	42.25	39.50	40.25	35.00
Geno.3	91.50	88.25	73.75	59.25	53.7	35.00	33.25	34.50	32.50	32.25
Geno.4	94.50	92.25	86.25	66.25	51.0	42.00	34.50	37.50	38.00	33.75
Geno.5	98.00	94.25	81.25	61.75	53.2	36.25	36.00	36.00	35.50	31.25
Geno.6	91.50	76.00	62.25	60.50	49.0	39.50	34.00	37.00	31.25	31.75
Sakha 8	126.2	130.0	113.7	103.7	86.2	52.25	47.50	43.50	43.50	37.25
L.S.D. $_{0.05}$			10.23					4.32		
		Spikes number/pot					Kernels number /Spike			
Geno.1	36.75	33.25	31.25	28.25	28.5	34.46	31.61	33.45	32.97	29.28
Geno.2	37.25	36.75	34.00	31.75	28.0	36.44	28.92	33.22	35.09	35.91
Geno.3	28.75	27.25	26.25	25.00	25.2	51.95	51.94	48.65	49.37	42.45
Geno.4	38.00	29.75	30.25	32.75	26.2	42.88	52.94	58.41	41.83	45.86
Geno.5	30.75	29.50	30.00	29.75	23.0	48.12	54.07	53.38	43.03	49.43
Geno.6	32.00	28.75	29.25	24.00	23.0	45.68	42.20	37.51	44.16	40.69
Sakha 8	47.75	44.75	40.25	40.00	32.2	35.13	44.19	42.04	41.69	47.00
L.S.D. $_{0.05}$			4.34					6.46		
		Harvest index (%)					Plant height (cm)			
Geno.1	46.12	44.62	42.04	38.07	38.7	75.00	75.50	74.00	76.75	73.25
Geno.2	49.67	43.45	50.79	43.46	42.0	74.00	71.50	72.00	70.75	69.00
Geno.3	46.00	45.65	41.01	39.84	47.3	76.75	68.25	68.75	71.00	66.25
Geno.4	44.95	49.41	48.17	40.63	44.0	63.25	67.00	65.50	62.75	60.75
Geno.5	50.22	47.89	45.11	42.44	53.1	71.75	68.00	71.00	67.50	65.50
Geno.6	43.93	42.58	45.10	36.33	37.8	78.50	80.00	78.50	76.25	78.00
Sakha 8	39.72	42.84	41.38	38.54	37.8	81.75	82.75	74.00	70.75	74.50
L.S.D. $_{0.05}$			4.81					4.98		

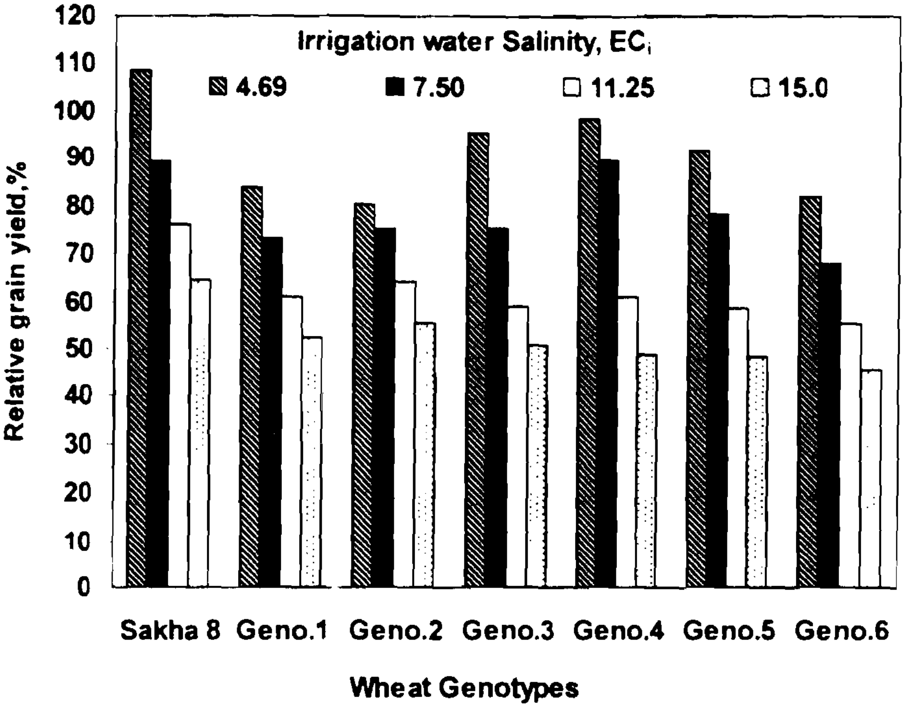

Fig.4. Salt tolerance of grain yield of seven wheat genotypes as a function of increasing salinity.

Assessment of salt tolerance:

To compare salinity tolerance, a number of models for the response of genotypes to salinity have been defined. Survival and absolute yield under saline conditions have been used in some cases, but have a number of drawbacks when comparisons need to be made. The absolute yield of the wheat crop on saline soils is one of the criteria for appraising salt tolerance. On this basis, grain yield of Sakha 8 and Geno.2 were the greatest under the highest salinity level, while Geno.6 and Geno.4 provided the lowest grain yield compared to the other genotypes (Table 6).

The use of relative yield compared to a control under saline conditions is another criterion allows for comparisons between wheat genotypes for salt tolerance (U.S. Salinity Laboratory Staff, 1954). The tolerance can be described by plotting the yield or relative yield as a continuous function of soil salinity. It was found that the check variety Sakha 8 had the highest relative grain yield (64 69%) among the other genotypes and had the lowest reduction percentage in grain yield (35.31%) at irrigation salinity level of 15.0 dS/m (Figure 4). At the same time, Geno.2 was next to Sakha 8 in its salt tolerance giving relative grain yield of 55.49% and had reduction percentage of 44.51% compared by the control treatment. Whereas, Geno.6, Geno.5 and Geno.4 produced the lowest relative yields among the other cultivars (45.59, 48.44, and 48.64%, respectively), and the yield reduction percentage at the highest salinity level were the greatest (54.51, 51.56, and 51.36 %, respectively).

van Genuchten (1983) described a computer program (SALT) to fit the unknown coefficients of different models to experimental data, using a non-linear least squares fit which can handle data sets with few experimental measurements:

$$Y_r = 1 \;/\; [1 + (EC / EC_{50})^p]$$

where EC_{50} is the salinity that reduces yield by 50% and *p* is an empirical constant affecting the form of the sigmoid curve, with the curve becoming steeper as the value of *p* increases.

The criteria of using EC_{50} as an index of genotypes tolerance would seem sufficient for comparing the salinity tolerance of different genotypes. The values of the parameter EC_{50} of tolerance of grain yield to salinity were 26.24, 22.10, 19.02, 17.29, 17.18, 17.13 and 15.95 dS/m for wheat genotypes Sakha 8, Geno.2, Geno.1, Geno.3, Geno.4, Geno.5 and Geno 6, respectively. Accordingly, the data indicate that Sakha 8 and Geno.2 were the most tolerant genotypes, whereas the geno.6 was the most salt sensitive. The EC_{50} has been shown to be a suitable parameter to evaluate salt tolerance (U.S. Salinity Laboratory Staff, 1954; van Genuchten and Hoffman, 1984; van Genuchten and Gupta, 1993; Steppuhn *et al.* 2005 a, b, Ould Ahmed *et al.* 2007).

Previous studies have shown that high yielding wheat cultivars are more salt sensitive to stress than cultivars with low yield potential. In this context, Geno.5 for instance, was the second after Sakha 8 (the check reference) producing higher yield up to 4.69 dS/m (Table 6), but in the same time was comparatively lower in salt tolerance. Although, Geno.2 produced relatively lower yield potential than Geno.5 at non-saline treatment, it ranked the second as salt tolerant genotype after Sakha 8.

Moreover, Geno.6 had the lowest yield potential at non-saline conditions and was the most salt sensitive. However, the importance of improving both salt tolerance and high yield needs to be recognized in any selection and breeding program. This strategy makes the evaluation and selection become very difficult, and might create a problem in cultivars selection for salt tolerance.

REFERENCES

Abdel Ghaffar, A. (1994). The producing, pricing, and marketing policies of wheat in the Government of Egypt. Cairo. Mimeo.

Abdel-Hafez, S. A., S. H. Abou-Khadra, F.A. Sorour, and A. Z. El-Bably. (1999). Influence of water stress on some water relations and calculation of potential evapotranspiration when estimating water requirements. Irrigation management and saline conditions. Proceedings of regional symposium. Just, Irbid, Jordan, June1999. 60-78.

Aboushal, A.A. (2000). Guar crop performance under different levels of salinity. Alex. J. Agric. Res. 45:39-56.

Allen, R.G., L.S. Pereira, D. Raes and M. Smith, (1998). Crop evapotranspiration: Guideline for computing crop water requirements. FAO No.56.

Anonymous (1995). Reuse of drainage water in the Nile Delta: monitoring Modeling and analysis. Final Report Reuse of Drainage Water Project. The Netherlands.

Aragues R., E. Playan, R.Ortiz, and A. Royo. (1999). A new-irrigation system for crop salt tolerance evaluation. Soil. Sci. Soc. Am. J. 63:1398-1404.

Attia, B., M. Andjelic, and W. Klohn. (1995). River Nile monitoring. Forecasting and simulation project. Use of remote sensing techniques in irrigation and drainage. Water Reports, FAO 1995.

Bishay, A. (1993). The deserts. of Egypt: desert development systems. (In the Agri culture of Egypt, G. M. Graig (ed). G. M., pp. 16 -38. Oxford University Press.

El Ashtar, A. (2005). Effect of saline irrigation waters on some soil properties and salt tolerance of new wheat genotypes. Alex. Sci. Exch. J. 26:106-112.

El Etreiby, F. (2002). Effect of high saline irrigation waters on some soil properties and wheat cultivars. Alex. Sci. Exch. J. 23:77-91.

El-Haddad, E. H., M.A. Amer, and M. A. Moustafa. (1993). Effect of salinity on the growth yield of three wheat cultivars grown in calcareous soil. Menofiya J. Agric. Res. 18:1669-1683.

El-Haddad, E.H., and M.A. Mostafa. (2007). Salt tolerance variability among 12 Egyptian wheat cultivars. J. Adv. Agric. Res. 12:35-49.

Elkhatib, H.A. (2003). Growth and yield response of salt stressed Radish. Alex. Sci. Exch. 24:299-311.

FAO. (1993). The use of saline waters for crop production. J.D. Rhoades, A. Kandiah, and A.M. Mashali. Irrigation and Drainage paper 48, Rome.

FAO. (1997). Irrigation in the Near East region in figures. Water Reports 9 (87-94). ISSN. 1020 –1203. FAO, Rome.

Francois, L. E., E. V. Mass, Mass, T. J. Donovan, and V. L. Youngs. (1986). Effect of salinity on grain yield and quality, vegetative growth, and germination of semi-dwarf and durum wheat. Agron. J. 78:1053-1058.

Francois, L. E., T. J. Donovan, E. V. Mass, and G. L. Rubenthaler. (1988). Effect of salinity on grain yield and quality, vegetative growth, and germination of triticale. Agron. J. 80:642-647.

Grattan S.R. and J.D. Rhoades. (1990). Irrigation with saline groundwater and drainage water. In: Agricultural Salinity Assessment and Management Manual.ASCE, New York.

Mass, E.V., and G.J. Hoffman. (1977). Crop salt tolerance: current assessment. J. Irrig. Drainage Div. ASCE 103:115-134.

Nabila, M. Z., M.S. Hassanein, and K. M. Gamal El-Din. (2007). Growth and yield of some wheat cultivars irrigated with saline water in newly cultivated land as affected by biofertilization. J. Appl. Sci. Res..3:1121-1126

Ould Ahmed, B.A., T. Yamamoto, and M. Inoue. (2007). Response of drip irrigated sorghum varieties growing in dune sand to salinity levels in irrigation water. J. Applied Science. 7:1061-1066.

Page, A. L., R. H. Miller, and D. R. Keeny. (1982). Methods of soil analysis. Part 2, 2nd ed. Agronomy Monograph . 9. Madison, WI: ASA and SSSA, USA.

Ragab A.A.M., F.A. Hellal and M. Abd El-Hady. (2008). Water salinity impacts on some soil properties and nutrients uptake by wheat plants in sandy and calcareous soil. Aust. J. Basic & Appl. Sci., 2:225-233.

Rhoades, J.D. (1982). Reclamation of salt-affected soils after drainage. Proc. First Annual Western Provincial Conf. Lethbridge, Alberta, Canada.

Rowntree, J. (1993). Marketing channels and price determination for agricultural commodities. In The agriculture of Egypt, ed. E. M. Craig. Oxford, U.K.: Oxford University Press.

SAS Institute. (1992). SAS/ STAT (1992). User's guide: Statistics. Version 6.03, Cary, NC. USA.

Seckler, D. and Z. Altaf. (1997). Use and productivity of the Nile water in Egypt. International Irrigation Management Institute. Colombo, Sri Lanka. Annual report 1997. 12-21.

Steppuhn, H., M. Th. van Genuchten, and C. M. Grieve. (2005a). Root-zone salinity: I. Selecting a product–yield index and response function for crop tolerance. Crop Sci. 45:209–220.

Steppuhn, H., M. Th. van Genuchten, and C. M. Grieve. (2005b). Root-zone salinity: II. Indices for tolerance in agricultural crops. Crop Sci. 45:221–232.

van Genuchten, M.Th. (1983). Analyzing crop salt tolerance data: Model description and user's manual. UDSA, ARS, U.S. Salinity Lab. Research Report No. 120. 50 pp. U.S. Gov. Printing Office, Washington, DC.

van Genuchten, M.Th., and G.J. Hoffman. (1984). Analysis of crop salt tolerance data. p. 258–271. *In* I. Shainberg and J. Shalhevet (ed.) Soil salinity under irrigation–Process and management. Ecological Studies 51. Springer-Verlag, New York.

van Genuchten, M.Th., and S.K. Gupta (1993). A reassessment of the crop tolerance response function. J. Indian Soc. Soil Sci. 41:730-737

U. S. Salinity Laboratory Staff. (1954). Diagnosis and improvement of saline and alkali soils: U S. Dept. Agric. Handbook 60, p. 1-160.

الملخص العربي

تقييم تحمل الملوحة لسلالات قمح مروية بمياه ملحية

أحمد عبد الرازق أبوشال ، إبراهيم إسماعيل محمود

معهد بحوث الأراضى والمياه والبيئة – قسم بحوث الأراضى الملحية والقلوية بالإسكندرية

يتطلب الحفاظ على إنتاجية عالية للقمح في المناطق المروية والمتأثرة بالأملاح اهتماما كبيرا لاستخدام سلالات القمح المتحملة للملوحة. لذلك أجريت هذه الدراسة فى صوبة زجاجية بمعمل بحوث الأراضى الملحية بالإسكندرية بهدف دراسة الاختلاف فى التحمل للملوحة لستة سلالات جديدة من القمح (Geno.1 ، Geno.2 ، Geno.3 ، Geno.4 ، Geno.5 ، Geno.6) مقارنة بالصنف سخا ٨ تحت ظروف الرى بماء متدرج فى الملوحة باستخدام نسب وزنيه متساوية من كل من ملحى كلوريد الصوديوم و كلوريد الكالسيوم للحصول على خمسة مستويات لملوحة مياه الرى وهى: معاملة المقارنة (ماء الصنبور ذات تركيز كلى للأملاح الذائبة قدرة ٣٢٠ مجم/لتر) ، ٣٠٠٠، ٦٠٠٠، ٩٠٠٠، ١٢٠٠٠ مجم/لتر. وكانت قيم التوصيل الكهربائى المقابلة هى: ٠,٥٠، ٤,٦٩ ، ٧,٥٠ ، ١١,٢٥ ، ١٥,٠٠ ديسيمنز/م. عند الحصاد تم تقدير الخواص الكيميائية للأرض بالإضافة إلى أن بيانات المحصول

البيولوجى ومحصول الحبوب ومكوناته قد سجلت وتم تحليلها بالطرق الإحصائية.

وقد أوضحت هذه الدراسة ما يلى :

١- وجود علاقة خط مستقيم ذات معامل ارتباط مرتفع المعنوية بين ملوحة مياه الرى EC_i ,ملوحة الأرض EC_e فى نهاية الموسم. وقد تناسبت الزيادة فى ملوحة الأرض طرديا مع زيادة ملوحة مياه الرى حيث ازدادت بمعدل ١,٢٤ ديسيسمنز/م لكل وحدة زيادة فى ملوحة ماء الرى.

٢- فى مرحلة تمام النضج أدى ارتفاع ملوحة مياه الرى إلى ١٥,٠ ديسيسمنز/م إلى حدوث انخفاضا معنويا فى محصول الحبوب ، المحصول البيولوجى ، وزن السنابل ، عدد السنابل/أصيص ، عدد الأفرع /أصيص ، عدد الحبوب/سنبلة ، وزن ١٠٠٠ حبة ، وأخيراً طول النبات. ويعزى النقص فى محصول الحبوب نتيجة زيادة الملوحة بصفة رئيسية إلى انخفاض وزن السنابل ، وزن ١٠٠٠ حبة ، عدد السنابل/أصيص ، بالمقارنة إلى النقص فى مكونات المحصول الأخرى وهى عدد الأفرع /أصيص أو عدد الحبوب/سنبلة.

٣- بصرف النظر عن معاملات الملوحة كان هناك اختلافات معنوية بين السلالات المختبرة والصنف المقارن سخا ٨ حيث تفوق الصنف سخا ٨ فى محصول الحبوب ، المحصول البيولوجى ، وزن السنابل ، عدد الأفرع /أصيص ، عدد السنابل/أصيص ، بينما كانت السلالة ٦ هى الأقل فى المحصول البيولوجى ، وزن السنابل ، والأقل فى محصول الحبوب بعد السلالة١. وفى حين حققت السلالة ١ أعلى قيمة معنوية لوزن ١٠٠٠ حبة ، أعطت السلالة ٤ القيمة الأقل. وأخيرا كانت السلالة ٦ هى أطول الأصناف والسلالة ٤ الأقصر بين السلالات المختبرة.

٤- أظهرت النتائج وجود تفاعل معنوى بين مستويات الملوحة والسلالات المختبرة ، حيث تبين النتائج تفوق الصنف سخا ٨ على السلالات المختبرة فى محصول الحبوب ، المحصول البيولوجى ، وزن السنابل سواء فى معاملة المقارنة (٠,٥٠ ديسيسمنز/م) أو المعاملة الأعلى للملوحة (١٥,٠ ديسيسمنز/م) والتى عندها أبدى الصنف سخا ٨ أقل انخفاض نسبى فى محصول الحبوب (٣٥,٣١%) ، تلاه السلالة ٢ (٤٤,٥١%) ، بينما السلالات ٦ ، ٥ ، ٤ أعطت أعلى انخفاض نسبى فى محصول الحبوب (٥٤,٥١ ، ٥١,٥٦ ، ٥١,٣٦% على التوالى).

٥- بغض النظر عن السلالات فإن القيم المقدرة للدالة EC_{50} (ملوحة مستخلص الأرض المشبعة التى يحدث عندها نقص فى محصول الحبوب بنسبة ٥٠%) لمحصول الحبوب والمحصول البيولوجى كانت ١٨,٦٥ ± ٠,٩ ، ٢١,٤٠ ± ١,٢٧ ديسيسمنز/م على التوالى ، مما يوضح أن المحصول البيولوجى كان أكثر تحملا للملوحة عن محصول الحبوب. وقد كانت القيم المقدرة لدالة النقص EC_{50} فى محصول الحبوب هى: ٢٦,٢٤ ، ٢٢,١٠ ، ١٩,٠٢ ، ١٧,٢٩ ، ١٧,١٨ ، ١٧,١٣ ، ١٥,٩٥

ديسيسمنز/م للصنف المقارن سخا ٨ ، السلالة ٢ ، السلالة ١ ، السلالة ٣ ، السلالة ٤ ، السلالة ٥ ، السلالة ٦ على التوالى. وعلية فإن الصنف سخا ٨ والسلالة ٢ هما الأكثر تحملا للملوحة عن باقى السلالات الأخرى ، بينما السلالة ٦ كانت الأكثر حساسية للملوحة. ورغم أن السلالة ٥ سجلت محصولا مطلقا أعلى من السلالة ٢ فى معاملة المقارنة (بدون تمليح) فإن الأخيرة رتبت الثانية فى التحمل للملوحة بعد الصنف سخا ٨. ومن ناحية أخرى أنتجت السلالة ٦ أقل محصول مطلق فى معاملة المقارنة وكذلك كانت السلالة الأكثر حساسية لتحمل الملوحة.