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Response of Wheat (*Triticum aestivum L.*) to Irrigation Water Salinity: II. Effect on Ion Concentration and Protein Content

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استجابة القمح لأجهاد الملوحة: ٢ تركيز الأيونات والبروتين

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خلاصة: تمت دراسة ١٣ صنفا من الأصناف المقاومة للملوحة مع الصنف المحلي وادي قريات ١٦٠ وذلك لمدى استجابتها لخمس مستويات من ملوحة ماء الري (٢(الشاهد) ، ٤ ، ٨ ، ١٢ و١٦ ديسيسمين/م) خلال الموسم الشتوي في ٩٦-١٩٩٧ و ٩٧-١٩٩٨م وذلك في قصارى تحتوي على تربه رمليه طمييه. أشارت النتائج الى أن تأثير المواسم والملوحة والأصناف كان معنويا بالنسبة إلى البروتين والبوتاسيوم K والكلوريد Cl ونسبة البوتاسيوم للصوديوم K/Na. كانت جميع التداخلات ذات تأثير معنوي عالٍ ما عدا التداخل الثالث (المواسم×الملوحة×الأصناف) وذلك بالنسبة للصوديوم Na بينما كانت جميعها غير معنوية للفسفور P . كانت هناك علاقة متبادلة معنوية وايجابيه بين الملوحة مع الصوديوم Na (+٠,٧٢٢** و+٠,٦٦١**) في كلتا السنتين غير أن الارتباطات كانت معنوية وقويه بالتساوي ولكنها سالبه بين الملوحة وكل من الفوسفور P (-٠,١٥٩**و-٠,٢٣٤**) والبوتاسيوم K (-٠,٥٢١** و-٠,٦٣٣**) والبوتاسيوم على الصوديوم) K/Na (-٠,٨١٦** و-٠,٦٥٤**). كانت العلاقات المتبادلة السلبية معنوية للبروتين (-٠,١٤٦**) والكلور يد (-٠,٢٧٧**) مع الملوحة خلال ٩٦-١٩٩٧ و٩٧-١٩٩٨م على التوالي. وجد أن الأصناف متباينة في طبيعة تجمع البروتين والأيونات المختلفة عند مستويات الملوحة المختلفة. وجد أن الصنفان Sakha-٦٩ وSids-٩ كانا الأعلى مقاومة للملوحة استنادا إلى البوتاسيوم K العالي والصوديوم Na والكلوريد Cl المنخفضان والنسبة العالية للبوتاسيوم K على الصوديوم Na (K/Na) .

ABSTRACT: Thirteen salt tolerant wheat genotypes along with a local cultivar, WQS 160, were investigated for their response to five levels of irrigation water salinity viz. Control (2 dSm^{-1}), 4, 8, 12 and 16 dSm^{-1} consecutively during two winter seasons. The results indicated that the effects of year, salinity, genotypes and their interactions were highly significant with respect to K^+, Cl^-, K^+/Na^+ ratio and protein. All the ANOVA components except three factor interaction viz. year x salinity x genotypes were highly significant for Na^+ while all these components were not significant for P. There was strong and significant positive correlation of salinity with Na^+ (+0.722** and +0.661**) in both years while the associations were equally strong and significant but negative between salinity and P (-0.159* and -0.234**), K^+ (-0.521** and -0.633**) and K^+/Na^+ (-0.816** and -0.654**). The negative correlations of protein (-0.146**) and Cl^- (-0.277**) with salinity were significant only during Year 2 and Year 2, respectively. Differential nature of accumulation of different ions and protein at varying levels of salinity was found among the genotypes. The genotypes Sakha-69 and Sids-9 were assessed to be tolerant based on high K^+, low Na^+ and Cl^-, and high K^+/Na^+ ratio.

Keywords: salt tolerant, wheat, irrigation water, ion concentration, protein content.

Salinity stress has been an important constraint on agricultural production worldwide especially in the area of irrigation. Although soil and water management have been used with some success in lessening the impact of this problem, it continues to cause increasingly serious economic losses (Gale, 1982; Mashali, 1991). Research is in progress on the alteration of important crop plants to increase their salt tolerance by utilizing salt tolerant genotypes in irrigated agriculture (Shannon, 1985; Wyn Jones and Gorham, 1986; Gorham, 1991; Qualset and Corke, 1991). The adverse effect of salinity has been established on different growth and yield characters right from seedlings (Rashid *et al.*, 1999) to adult stages of wheat (Kelman and Quaslet, 1991; Ashraf and Oleary, 1996 and 1999; Steppuhn *et al.*, 1996; Steppuhn and Wall, 1997). The salinity effect is known to take place either by saline water deficit, ion toxicity or nutrient imbalance (Greenway and Munns, 1980). Several workers have regarded imbalance in ionic contents such as Na^+, Cl^-, K^+, N, and P to disfavor growth and development of wheat (El-Agrodi *et al.*, 1988a; Chhipa

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as Na^+, Cl^-, K^+, N, and P to disfavor growth and development of wheat (El-Agrodi *et al.*, 1988a; Chhipa and Lal, 1995; Leidi *et al.*, 1991). It has also been established that there is a differential response of genotypes to salinity within a species with respect to ionic contents (El-Agrodi *et al.*, 1988b; Chhipa and Lal, 1992; Rashid *et al.*, 1999) and protein (Ashraf and Oleary, 1999). Recently, we have discussed differential response of wheat to varying levels of irrigation water salinity in respect of some agronomic attributes, yield components, grain yield and dry biomass (Nadaf *et al.*, 2000) based on the investigations carried out consecutively for two years utilizing salt tolerant wheat genotypes. In this paper we investigate the effects of irrigation water salinity on ion concentration and protein content of wheat.

Materials and Methods

The genotypes under study belonged to two groups viz. mono-or di-culm genotypes having one or two tillers, comprised ones with No. 1 to 7 (Sids-4, Sids-5, Sids-6, Sids-7, Sids-8, Sids-9 and Sids-10 from Egypt) and multi-culm types having more than two tillers comprised the genotypes with No. 8 to 14 (Sakha-8, Sakha-69, Sakha-92, Sahil-1 and Giza-164 from Egypt, S-24 from Pakistan and a local cultivar, WQS-160). The physical and chemical characteristics of the experimental soil, and the chemical characteristics of irrigation water treatments are presented in Tables 1 and 2, respectively.

TABLE 1

Values of physical and chemical characteristics of experimental soil.

Characteristics	Experimental Soil
Physical	
Gravel	2.10
Coarse sand (%)	0.80
Fine sand (%)	60.30
Silt (%)	26.60
Clay (%)	12.30
Texture	Sandy loam
Chemical	
EC (dSm^{-1})	2.07
PH	7.50
Soluble cations ($mmol_c/l$)	
Ca	12.70
Mg	7.20
Na	2.68
Soluble anions ($mmol_c//l$)	
CO_3	0.20
HCO_3	2.70
Cl	2.50
N (%)	0.24
P (%)	0.002
K ($mmol_c/100$ g)	0.88

TABLE 2

Values of chemical characteristics of irrigation water treatments.

Ionic Contents	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}
Cations ($mmol_c/l$)					
Ca	1.50	3.00	4.00	5.00	6.00
Mg	6.80	12.00	21.00	27.00	34.00
Na	7.20	34.00	52.50	66.20	76.20
K	0.60	2.20	3.20	4.80	6.20
Anions ($mmol_c/l$)					
HCO_3	2.20	2.40	2.30	2.40	2.70
CO_3	0.40	0.20	0.20	0.20	Traces
Cl	15.00	32.50	69.50	112.00	150.50

The trial was laid in a two factor completely randomized design with three replications using fourteen genotypes under five levels of irrigation water salinity viz. Control (2 dSm^{-1}), 4, 8, 12 and 16 dS m^{-1} in pots of 20 cm diameter under shade house conditions. In both years, fresh soil initially collected from the same land was used. Four plants grown in each pot were fertilized with the recommended dose of 150 kg N/ha, 90 kg P_2O_5/ha and 60 kg K_2O/ha in the form of urea, triple super phosphate and potassium sulphate, respectively.

The entire quantities of potassium and phosphate fertilizers along with one quarter of the nitrogen fertilizer were applied before planting while the remaining nitrogen was applied in three equal splits subsequently one week after planting, at heading and milky grain stages, respectively. The pots of each genotype were frequently irrigated with water corresponding to levels of salinity lightly till their germination and later three times a week till a week prior to harvest. Sea water of electrical conductivity 48.5 $\pm$ 2 dSm^{-1} was used as a source of salinity as it incorporates several salt compositions commonly encountered in saline soils, namely high concentrations of sodium, chloride, sulphate and boron and a low calcium to magnesium ratio. The salinity treatments were prepared in 100 liter plastic drums by diluting the sea water with control water. Protective measures against pests and diseases were taken whenever necessary. The genotypes were harvested at maturity stage.

A destructive plant sample in each treatment was analyzed for ionic concentrations viz. N, P, K^+, Na^+ and Cl^- at harvest during Year 2 (i.e., 1996-97) and at 100% heading stage during Year 2 (i.e., 1997-98), and protein content was computed from N (AOAC, 1984; Chapman and Pratt, 1961). The data on above ionic concentrations, protein and K/Na ratio were subjected to statistical analysis according to the methods of Gomez and Gomez (1984) using MSTAT computer program. Simple correlation coefficients (r) of salinity vs ionic concentrations and protein were computed from the raw data irrespective of salinity levels, genotypes and replications.

Results and Discussion

The results indicated that the effects of planting year, salinity, genotypes and the interactions were highly significant with respect to K^+, K^+/Na^+ ratio, Cl^- and protein content ($p<0.01$). All the ANOVA components except three factor interaction viz. year x salinity x genotypes were highly significant ($p<0.01$ for Na^+ while all these components were not significant ($p>0.05$) for P. The figures of ion concentrations and protein content determined for the samples of Year 2 were invariably higher than those of Year 2. This was attributed to different growth stages at which plants were sampled in the two cropping years (Gorham *et al.*, 1986).

CHARACTER ASSOCIATION - SALINITY VS ION CONCENTRATION AND PROTEIN: There was strong and significant ($p<0.01$) positive correlation of salinity with Na^+ (+0.722** and +0.661**) in both years (Table 3) while the associations were equally strong and significant ($p<0.05$) but negative between salinity and P (-0.159* and -0.234**), K^+ (-0.521** and -0.633**) and K^+/Na^+ (-0.816** and -0.654**). The negative correlations of protein (-0.146**) and Cl^- (-0.277**) with salinity were significant ($p<0.01$) only during Year 2 and Year 2, respectively.

TABLE 3

Correlation coefficients between salinity and ion concentration and protein in wheat.

Ion Concentration/	Correlation Coefficients (r)	
	Year 2	Year 2
K^+	-0.521**	-0.633**
Na^+	0.722**	0.661**
K^+Na^+	-0.816**	-0.654**
Cl^-	-0.024	-0.277**
P	-0.159*	-0.234*
Protein	-0.146*	-0.131

K^+, NA^+ CONCENTRATIONS AND K^+/NA^+ RATIO: There was gradual and significant decrease ($p<0.05$) in the concentration of K^+ with increasing level of salinity in both years (Table 4). The mean K^+ decrease was from 3.90% to 2.49 % in Year 2 and from 1.83 % to 1.21% in Year 2 from control (2 dSm^{-1}) to 16 dSm^{-1}. Higher mean K^+ across salinity treatments was found in Giza-64, Sakha-8 and Sakha-69 in Year 2 and in Sakha-92 and WQS-160 in Year 2 among multi-culm genotypes. Among mono or di-culm genotypes, Sids-8, Sids-9 and Sids-10 had high mean K^+ in both years. Similarly, higher accumulation of K^+ in tolerant genotypes in comparison with susceptible ones was also noticed in the studies of El-Agrodi *et al.* (1988b) and Chhipa and Lal (1992).

TABLE 4

Mean Potassium (K^+) concentration (%) of wheat genotypes under different levels of salinity.

Sl.† No.	Year 2						Year 2					
	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean
1	3.13	2.89	2.85	2.62	2.11	2.72	1.66	1.66	1.49	1.38	0.99	1.44
2	4.01	3.63	3.23	2.98	2.28	3.23	1.66	1.57	1.53	1.24	0.95	1.39
3	4.05	3.64	3.02	2.98	2.86	3.31	1.60	1.48	1.36	1.09	1.11	1.33
4	3.91	3.97	2.96	2.75	2.65	3.25	1.58	1.53	1.35	1.08	1.15	1.34
5	4.28	4.17	3.45	3.54	3.66	3.82	1.87	1.55	1.45	1.64	1.24	1.55
6	4.41	4.21	3.76	3.36	3.54	3.86	1.83	1.72	1.54	1.36	1.37	1.56
7	4.05	3.74	4.16	3.08	2.72	3.55	1.96	1.64	1.70	1.50	1.26	1.61
8	4.25	3.51	2.93	2.83	2.62	3.23	1.86	1.61	1.56	1.55	1.29	1.57
9	3.68	3.28	2.99	2.91	2.20	3.01	1.99	1.88	2.22	1.87	1.58	1.91
10	3.14	2.37	2.46	1.65	1.46	2.22	1.95	1.90	2.10	2.00	1.31	1.85
11	3.92	3.73	2.72	2.54	2.22	3.03	1.91	1.70	1.52	1.66	1.24	1.61
12	4.41	3.83	3.13	2.63	2.58	3.32	1.89	1.81	1.56	1.66	1.03	1.59
13	3.66	2.80	2.35	2.09	1.96	2.57	1.84	1.88	1.95	1.41	1.24	1.66
14	3.75	2.80	2.25	2.10	1.96	2.57	2.01	1.87	1.89	1.80	1.23	1.76
Mean	3.90	3.47	3.02	2.72	2.49		1.83	1.70	1.66	1.52	1.21	

Statistical parameters:

	F-test	LSD (5%)
Year	**	0.03
Salinity	**	0.04
Year x Salinity	**	0.06
Genotypes	**	0.07
Year x Genotypes	**	0.10
Salinity x Genotypes	**	0.16
Year x Salinity x Genotypes	**	0.22

**- Significant at 0.01 level of probability

† 1. Sids-4; 2. Sids-5; 3. Sids-6; 4. Sids-7; 5. Sids-8; 6. Sids-9; 7. Sids-10; 8. Sakha-8; 9. Sakha-69; 10. Sakha-92; 11. Sahil-1; 12. Giza-164; 13. S-24; 14. WQS-160

TABLE 5

Mean Sodium (Na^+) concentration (%) of wheat genotypes under different levels of salinity.

Sl.† No.	Year 2						Year 2					
	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean
1	0.83	1.33	1.51	1.64	2.00	1.46	0.75	0.95	1.24	1.21	1.46	1.12
2	0.83	0.87	1.07	1.15	1.02	0.99	0.78	0.87	0.74	1.21	1.37	0.99
3	0.91	1.21	1.37	1.79	1.80	1.42	0.96	0.97	1.03	1.13	1.37	1.09
4	0.89	1.34	1.44	1.57	1.94	1.44	1.10	0.85	0.96	1.21	1.37	1.10
5	0.87	1.15	1.15	1.24	1.58	1.20	0.76	0.80	0.94	1.25	1.40	1.03
6	0.82	1.14	1.02	1.06	1.62	1.13	0.70	0.73	0.78	0.86	1.22	0.86
7	0.85	1.47	1.06	1.10	2.00	1.30	0.70	0.75	0.78	0.96	1.26	0.89
8	0.91	0.91	1.32	1.12	1.70	1.19	0.70	0.85	0.90	0.95	1.35	0.95
9	0.84	0.84	0.87	1.09	1.40	1.01	0.62	0.66	0.82	0.84	1.06	0.80
10	0.74	0.71	0.83	0.96	1.68	0.98	0.70	0.85	0.98	1.00	1.41	0.99
11	0.67	0.99	1.11	0.94	1.40	1.02	0.75	0.82	0.88	1.15	1.39	1.00
12	0.91	1.11	1.00	1.11	1.62	1.15	0.84	0.98	1.04	1.24	1.71	1.16
13	0.94	0.90	1.12	1.34	1.88	1.24	0.74	0.84	0.98	1.28	1.48	1.06
14	0.65	0.90	1.07	1.10	1.88	1.12	0.51	0.89	1.04	1.11	1.48	1.01
Mean	0.83	1,06	1.14	1.23	1.68		0.76	0.84	0.94	1.10	1.38	

Statistical parameters:

	F-test	LSD (5%)
Year	**	0.02
Salinity	**	0.03
Year x Salinity	**	0.05
Genotypes	**	0.06
Year x Genotypes	**	0.08
Salinity x Genotypes	**	0.13
Year x Salinity x Genotypes	NS	-

**- Significant at 0.01 level of probability; NS - Nonsignificant

† 1. Sids-4; 2. Sids-5; 3. Sids-6; 4. Sids-7; 5. Sids-8; 6. Sids-9; 7. Sids-10; 8. Sakha-8; 9. Sakha-69; 10. Sakha-92; 11. Sahil-1; 12. Giza-164; 13. S-24; 14. WQS-160

The Na^+ concentration showed a progressive and significant increase ($p<0.05$) from the control to higher salinity levels in both years (Table 5). The mean Na^+ concentration across genotypes increased significantly from 0.83 % to 1.68 % in Year 2 and from 0.76 % to 1.38 % in Year 2 from control to 16 dSm^{m-1}. Among the multi-culm types, Sakha-69, Sakha-92 and Sahil-1 had low concentrations of Na^+ in both years. Sids-5 in Year 2 and Sids-5, Sids-9 and Sids-10 in Year 2 had low amount of Na^+ among mono- or di-culm types. Such restricted uptake of Na^+ in tolerant genotypes was noticed also in the studies of El-Agrodi *et al.* (1988 b) and Chhipa and Lal (1992).

The K^+/Na^+ ratio showed a gradual and significant decrease ($p<0.05$) from the control to higher salinity levels in both years (Table 6). The mean K^+/Na^+ ratio across genotypes decreased significantly from 4.73 % to 1.53 % in Year 2 and from 2.51 % to 0.90 % in Year 2 from control to 16 dSm^{-1}. Among the multi-culm types, Sakha-69, Sahil-1 and Giza-164 in Year 2 and Sakha-69, WQS-160 and Sakha-92 in Year 2 had maintained high mean K^+/Na^+ ratios across the salinity levels. While among mono- or di-culm types, Sids-9, Sids-8 and Sids-5 in Year 2 and Sids-9 and Sids-10 in Year 2 had high K^+/Na^+ ratios. The greater degree of salt tolerance of a genotype could be related to its low accumulation of Na^+ and maintenance of higher K/Na ratio (Chhipa and Lal, 1995 and Ashraf and Oleary, 1996).

Cl^- CONCENTRATION: The accumulation of Cl^- was significant ($p<0.05$) but not consistent with increasing levels of salinity. However, there was low accumulation of Cl^- at 16 dSm^{-1} (Table 7). The association between salinity and Cl^- content was negative and significant ($p<0.01$) only in Year 2 (Table 3) in contrast to the findings of Al-Saadi *et al.* (1982) and El-Agrodi *et al.* (1988a). This was attributed to the genetic constitution of the salinity tolerant genotypes studied in this investigation, which were expected to contain low concentrations of Cl^- in plant tissues (Bilski, 1988). A lower mean Cl^- concentration across the salinity treatments was found in S-24 and Sakha-92 during Year 2 and in Sakha-69, Sakha-8 and Sahil-1 during Year 2 among multi-culm genotypes. Among mono or di-culm genotypes, Sids-8, Sids-6 and Sids-4 during Year 2 and only Sids-4 and Sids-5 during Year 2 had low mean Cl^-. A lower accumulation of Cl^- in tolerant genotypes as compared to susceptible ones was also noticed in the studies of El-Agrodi *et al.* (1988b) and Bilski (1988).

P CONCENTRATION: Neither the effects of year, salinity, genotypes or their interactions were significantly different ($p > 0.05$) for P. This indicates that P was not or least affected by salinity in both years in all the genotypes studied (Table 8). Similarly, water salinity treatment had no significant effect on P content in wheat grain in the studies by El-Agrodi *et al.* (1988a).

TABLE 6

Mean K^+/ (Na^+) of wheat genotypes under different levels of salinity.

Sl. † No.	Year 2						Year 2					
	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean
1	3.77	2.17	1.89	1.60	1.06	2.10	2.20	1.75	1.20	1.14	0.68	1.40
2	4.83	4.17	3.02	2.59	2.24	3.37	2.13	1.81	2.07	1.03	0.70	1.55
3	4.45	3.01	2.20	1.66	1.59	2.58	1.66	1.53	1.32	0.96	0.81	1.26
4	4.39	2.96	2.06	1.75	1.37	2.51	1.44	1.80	1.40	0.89	0.84	1.27
5	4.92	3.63	3.00	2.85	2.32	3.34	2.46	1.94	1.55	1.31	0.88	1.63
6	5.38	3.69	3.69	3.17	2. 19	3.62	2.62	2.36	1.97	1.58	1.12	1.93
7	4.76	2.54	3.92	2.80	1.36	3.08	2.80	2.19	2.18	1.56	1.00	1.95
8	4.67	3.86	2.22	2.53	1.54	2.96	2.66	1.89	1.73	1.64	0.95	1.77
9	4.37	3.90	3.44	2.67	1.57	3.19	3.20	2.85	2.71	2.23	1.49	2.50
10	4.24	3.34	2.96	1.72	0.87	2.63	2.79	2.24	2.14	2.00	0.93	2.02
11	5.85	3.77	2.45	2.70	1.59	3.27	2.54	2.08	1.73	1.45	0.89	1.74
12	4.85	3.45	3.13	2.37	1.59	3.08	2.25	1.84	1.50	1.34	0.60	1.51
13	3.90	3.11	2.10	1.56	1.04	2.34	2.49	2.24	1.99	1.10	0.84	1.73
14	5.77	3.11	2.10	1.91	1.04	2.79	3.94	2.10	1.82	1.62	0.83	2.06
Mean	4.73	3.34	2.73	2.28	1.53		2.51	2.04	1.81	1.42	0.90	

Statistical parameters:

	F-test	LSD (5%)
Year	**	0.06
Salinity	**	0.09
Year x Salinity	**	0.13
Genotypes	**	0.15
Year x Genotypes	**	0.21
Salinity x Genotypes	**	0.34
Year x Salinity x Genotypes	**	0.48

**Significant at 0.01 level of probability

† 1. Sids-4; 2. Sids-5; 3. Sids-6; 4. Sids-7; 5. Sids-8; 6. Sids-9; 7. Sids-10; 8. Sakha-8; 9. Sakha-69; 10. Sakha-92; 11. Sahil-1; 12. Giza-164; 13. S-24; 14. WQS-16

TABLE 7

Mean Chloride (Cl^-) of wheat genotypes under different levels of salinity.

Sl. † No.	Year 2						Year 2					
	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean
1	3.83	2.83	2.53	2.40	2.70	2.86	0.59	1.48	1.18	0.89	0.89	1.01
2	2.37	2.50	2.50	3.10	4.40	2.97	0.74	1.18	0.89	1.04	0.89	0.95
3	3.40	2.83	1.20	2.97	3.60	2.80	0.89	1.63	0.89	0.89	1.18	1.10
4	2.37	3.10	2.37	3.10	3.67	2.92	1.18	2.07	0.89	0.89	1.33	1.27
5	2.70	2.83	2.10	2.70	3.10	2.69	1.48	1.18	1.18	0.89	1.33	1.21
6	4.47	3.13	2.70	3.87	2.70	3.37	0.89	1.48	1.04	0.74	1.33	1.10
7	3.43	1.80	3.57	3.60	3.10	3.10	1.63	1.33	1.04	0.59	1.33	1.18
8	2.50	2.20	3.73	2.83	2.70	2.79	1.48	1.04	1.18	1.04	1.18	1.18
9	2.80	1.30	3.27	2.80	2.70	2.57	1.33	1.08	1.33	0.89	1.18	1.16
10	3.00	1.60	2.40	3.01	0.90	2.18	1.78	2.22	1.48	1.04	1.33	1.57
11	2.23	3.27	3.57	1.80	0.90	2.35	1.48	1.48	1.04	0.89	1.33	1.24
12	3.00	4.40	2.40	2.67	4.90	3.47	2.37	1.18	1.33	1.18	1.04	1.42
13	2.43	1.25	1.32	1.45	1.63	1.62	2.37	1.04	1.18	1.19	1.33	1.42
14	2.70	1.80	2.80	2.20	1.80	2.26	1.78	1.18	0.89	1.33	1.48	1.33
Mean	2.95	2.49	2.60	2.75	2.77		1.43	1.40	1.11	0.96	1.23	

Statistical parameters:

	F-test	LSD (5%)
Year	**	0.04
Salinity	**	0.07
Year x Salinity	**	0.10
Genotypes	**	0.12
Year x Genotypes	**	0.17
Salinity x Genotypes	**	0.26
Year x Salinity x Genotypes	**	0.37

**Significant at 0.01 level of probability.

† 1. Sids-4; 2. Sids-5; 3. Sids-6; 4. Sids-7; 5. Sids-8; 6. Sids-9; 7. Sids-10; 8. Sakha-8; 9. Sakha-69; 10. Sakha-92; 11. Sahil-1; 12. Giza-164; 13. S-24; 14. WQS-16

TABLE 8

Mean Phosporous (P) concentration (%) of wheat genotypes under different levels of salinity.

Sl.† No.	Year 2						Year 2					
	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean
1	0.15	0.18	0.27	0.31	0.04	0.19	0.26	0.24	0.23	0.31	0.22	0.25
2	0.28	0.13	0.10	0.13	0.07	0.14	0.27	0.26	0.27	0.23	0.21	0.25
3	0.25	0.15	0.24	0.12	0.10	0.17	0.25	0.24	0.28	0.25	0.20	0.25
4	0.21	0.15	0.26	0.32	0.03	0.19	0.21	0.24	0.26	0.27	0.19	0.23
5	0.13	0.33	0.31	0.13	0.02	0.18	0.29	0.27	0.31	0.23	0.18	0.26
6	0.31	0.25	0.46	0.26	0.03	0.26	0.30	0.29	0.33	0.26	0.21	0.28
7	0.21	0.27	0.45	0.21	0.03	0.24	0.28	0.31	0.28	0.29	0.24	0.28
8	0.21	0.32	0.34	0.24	0.04	0.23	0.18	0.19	0.21	0.24	0.14	0.19
9	0.15	0.15	0.24	0.04	0.05	0.13	0.23	0.22	0.24	0.23	0.17	0.22
10	0.15	0.17	0.18	0.06	0.05	0.12	0.17	0.17	0.23	0.22	0.16	0.19
11	0.10	0.17	0.35	0.10	0.03	0.15	0.22	0.23	0.31	0.19	0.15	0.22
12	0.23	0.17	0.19	0.08	0.15	0.16	0.20	0.22	0.28	0.24	0.16	0.22
13	0.15	0.07	0.18	0.09	0.14	0.13	0.21	0.21	0.22	0.21	0.15	0.20
14	0.16	0.18	0.19	0.19	0.19	0.18	0.16	0.18	0.19	0.19	0.19	0.18
Mean	0.19	0.19	0.27	0.16	0.07		0.23	0.23	0.26	0.24	0.18	

Statistical parameters:

	F-test
Year	NS
Salinity	NS
Year x Salinity	NS
Genotypes	NS
Year x Genotypes	NS
Salinity x Genotypes	NS
Year x Salinity x Genotypes	NS

† 1. Sids-4; 2. Sids-5; 3. Sids-6; 4. Sids-7; 5. Sids-8; 6. Sids-9; 7. Sids-10; 8. Sakha-8; 9. Sakha-69; 10. Sakha-92; 11. Sahil-1; 12. Giza-164; 13. S-24; 14. WQS-16

TABLE 9

Mean protein content (%) of wheat genotypes under different levels of salinity.

Sl.† No.	Year 2						Year 2					
	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	Control	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean
1	15.17	16.90	16.04	16.65	16.19	16.19	12.02	13.52	10.15	13.10	11.25	12.01
2	14.48	17.17	18.02	17.27	19.44	17.28	12.58	13.90	11.77	10.73	10.06	11.81
3	18.77	17.13	15.98	17.65	15.25	16.95	11.73	12.19	11.58	12.23	10.23	11.59
4	15.44	20.33	17.50	12.65	17.06	16.60	11.25	11.65	12.08	11.67	10.13	11.35
5	16.13	20.25	16.96	15.75	17.50	17.32	14.56	12.40	12.27	12.31	10.10	12.33
6	18.60	20.63	13.94	18.27	19.44	18.18	11.98	12.27	11.04	13.13	10.15	11.71
7	18.19	20.88	19.69	13.63	17.13	17.90	11.58	12.19	11.54	11.85	11.38	11.71
8	18.94	15.75	14.83	14.40	16.75	16.13	8.75	10.29	9.71	12.08	8.08	9.78
9	15.33	15.00	15.00	15.67	13.31	14.86	11.35	10.27	9.71	11.50	9.98	10.56
10	13.94	17.19	11.63	11.33	11.31	13.08	8.48	10.17	10.02	9.25	8.75	9.33
11	13.06	18.08	19.52	15.60	14.56	16.17	8.60	9.35	12.77	9.75	8.50	9.80
12	18.29	20.46	14.96	12.19	14.25	16.03	7.56	10.54	12.31	9.48	8.71	9.72
13	15.56	9.06	14.81	12.79	13.31	13.11	8.98	11.23	11.48	11.15	8.00	10.17
14	10.90	8.75	10.40	10.38	11.08	10.30	10.90	7.54	10.46	10.38	11.08	10.07
Mean	15.91	16.97	15.66	14.59	15.47		10.74	11.25	11.21	11.33	9.74	

Statistical parameters:

	F-test	LSD (5%)
Year	**	0.32
Salinity	**	0.50
Year x Salinity	**	0.71
Genotypes	**	0.84
Year x Genotypes	**	1.19
Salinity x Genotypes	**	1.89
Year x Salinity x Genotypes	**	2.67

**Significant at 0.01 level of probability.

† 1. Sids-4; 2. Sids-5; 3. Sids-6; 4. Sids-7; 5. Sids-8; 6. Sids-9; 7. Sids-10; 8. Sakha-8; 9. Sakha-69; 10. Sakha-92; 11. Sahil-1; 12. Giza-164; 13. S-24; 14. WQS-16

In other studies, however, P of grain and straw decreased with increasing level of salinity (Chhipa and Lal, 1992).

PROTEIN CONTENT: There was significant ($p<0.05$) but inconsistent accumulation of protein with increasing levels of salinity indicating no specific trend (Table 9). Differential response of genotypes in the magnitude of accumulation of protein to higher levels of salinity was also apparent not only within the year but also between the years. Higher mean protein across salinity treatments was found in Sahil-1, Sakha-8 and Giza-164 during Year 2 and in Sakha-69, S-24 and WQS-160 during Year 2 among multi-culm genotypes. Among mono- or di-culm genotypes, Sids-9, Sids-10, Sids-8 and Sids-5 during Year 2 and Sids-8, Sids-4, Sids-5 and Sids-9 and Sids-6 during Year 2 had high mean protein contents. Similarly, El-Agrodi *et al.* (1988b) and Chhipa and Lal (1992) also observed a differential response in accumulating a high concentration of N by tolerant genotypes as compared to susceptible ones.

The nature of accumulation of different ions associated with plant nutrition and salinity predominated by Na^+ and or Cl^- in both saline tolerant and susceptible genotypes of wheat have also been observed with either saline water (El-Agrodi *et al.*, 1988a and b) or soils (Al-Saadi *et al.*, 1982; Bilski, 1988; Ashraf and Oleary, 1996). Further, the quantity of ionic content of a genotype was associated with its tolerance (El-Agrodi *et al.*, 1988 b; Bilski, 1988; Chhipa and Lal ,1995 and Ashraf and Oleary, 1996).

Many workers reported variability in salt tolerance within species (Shannon, 1985; Kelmen and Qualset, 1991; Gonzales, 1996) but the criteria of selection for salt tolerance have not been consistent among the investigators (Shannon, 1985; Rawson *et al.*, 1988; Kelmen and Qualset, 1991). Recently, we have assessed the salinity tolerance of genotypes using the concepts of both stress susceptibility index at each higher salinity level in relation to control and mean value over the salinity treatments with respect to each character and selected the most tolerant genotypes considering the information of agronomic traits with yield (Nadaf *et al.*, 2001. Among all the genotypes tested, the salinity tolerance of S-24, a multi-culm type of Pakistan developed as salt tolerant genotype and Sids-6 of Egypt, a mono-or di-culm type was of higher degree and more consistent (Nadaf *et al.*, 2001).

In the present study, the genotypes of Egypt viz. Sakha-69 among multi-culm types and Sids-9 among mono-or di-culm types were assessed to be tolerant as they had high K^+ and low Na^+ besides maintaining high K^+/Na^+ ratio. In addition, Sakha-69 had low Cl^-. This indicates that there existed differential nature of saline tolerant genotypes to express growth or yield attributes and accumulate different ions concerning salinity depending on their genetic architecture. The pattern of ion accumulation was also found to be inconsistent among the genotypes in relation to their degree of salt tolerance (Ashraf and Oleary, 1996). The genes having a major effect on varietal responses to edaphic stress factors have been reported for many crops (Devine, 1982). These are especially the ones controlling uptake/ utilization of nutrients or exclusion of toxic ions. Hence, ionic contents like Na^+, K^+ and Cl^- could be used to confirm the tolerance of selected genotypes from a large germplasm pool and from segregating or advanced generation material to suit to the required salinity conditions.

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