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Response of Wheat (*Triticum aestivum* L.) to Irrigation Water Salinity: I. Effect on Agronomic and Yield Attributes

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استجابة القمح لاجهاد الملوحة: ١ الصفات الفلاحية والوزن البيولوجي للمحصول

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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 ((٢الشاهد) ، ٤ ، ٨ ، ١٢ و١٦ ديسيسمين/م) خلال المواسم الشتوي في ٩٦-١٩٩٧ و ٩٧-١٩٩٨م وذلك في قصارى تحتوي على تربه رمليه طمييه تحت ظروف المظلات الزراعية. أشارت النتائج إلى أن تأثير المواسم والملوحة والأصناف كان من معنويا الى عالي المعنوية بالنسبة لجميع الصفات التي تمت دراستها، أما بالنسبة للتداخلات فقد كان تأثير تداخل المواسم والملوحة معنويا عاليا بالنسبة لطول الأوراق وعدد الأوراق والوزن الجاف. كان تأثير تداخل المواسم مع الأصناف والملوحة على الأصناف قد تراوح بين معنوي إلى معنوي عالي للصفات التالية: عدد الأوراق وطول الأوراق وامتداد السنبلة ووزن الحبوب/للنبات ومعامل الحصاد والوزن الجاف. كان تأثير تداخل المواسم مع الأصناف معنويا إلى عالي المعنوية بالنسبة لجميع الصفات ما عدا عدد الأوراق بينما كان تأثير تداخل الملوحة مع الأصناف معنويا بالنسبة لجميع الصفات ما عدا طول النبات ومعامل الحصاد. كان تأثير تداخل المواسم مع الملوحة على الأصناف معنويا أيضا بالنسبة لعدد الأيام لبداية التزهير وطول السنبلة ووزن الحبوب/للنبات. كان التأثير السلبي للملوحة ظاهرا على كل صنف في جميع الصفات. وكانت مقاومة الأصناف للملوحة قد قيمت على أساس معامل مقاومة الإجهاد لكل مستوى من الملوحة وعلاقته بالشاهد ، وكذلك على متوسط قيم النمو والانتاج لمعاملات الملوحة بالنسبة لكل صفة. وجد أن الصنفان S٢٤ و٦-Sids كانا الأعلى والأكثر استقرارا في مقاومتهما للملوحة. هذا وقد تمت اختيارهما لاستغلالهما في برنامج التربية الذي سوف يستغل الأصناف المحلية في التحسين الوراثي. تفاوتت بقية الأصناف في مدى استجابتها للمستويات المختلفة من الملوحة.

ABSTRACT: Thirteen salt tolerant wheat genotypes along with 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} during two winter seasons. The wheat was grown in pots containing sandy loam soil under shade house conditions. The results indicated that the effects of the years, salinity and genotypes were significant to highly significant ($p < 0.01$ to 0.05) with respect to all the characters studied. Among the interactions, the effect of year x salinity was highly significant ($p < 0.01$) for number of leaves, leaf length, spike exsertion, grain weight, harvest index and dry biomass. Interaction effects of year x genotype were significant to highly significant ($p < 0.01$ to 0.05) with respect to all the characters except number of leaves while the effect of salinity x genotype was also significant ($p < 0.01$) for all the characters except plant height and harvest index. Interaction effect of year x salinity x genotype was significant only in case of days to heading initiation ($p < 0.01$), spike length ($p < 0.05$) and grain weight/plant ($p < 0.01$). Adverse effect of salinity was evident in the genotypes for all characters. Salinity tolerance of genotypes was assessed using the concepts of both stress susceptibility index at each higher salinity level in relation to control (lowest salinity level) and mean value over the salinity treatments with respect to each character. Among all the genotypes tested, S-24 and Sids-6 were found to have a consistently high degree of salinity tolerance. These two genotypes were proposed for utilization in breeding program involving local cultivars.

Keywords: salinity, irrigation water, wheat, agronomic, yield.

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Irrigation is the key to agricultural productivity in arid and semi-arid regions. Recently, these regions have been affected either by soil salinity due to poor irrigation practices or by water salinity especially near the coast due to seawater intrusion. Under such conditions, there is a need to seek saline tolerant genotypes of crops. These can then be subjected to crop improvement for high yield and quality. Plant breeders along with physiologists are now modifying crop plants to suit adverse saline soil or irrigation water conditions while maintaining reasonable and reliable yields (Shannon, 1985; Wyn Jones and Gorham, 1986; Gorham, 1991; Qualset and Corke, 1991). Wheat (*Triticum aestivum* L.) grain yields are dependent directly upon yield contributing traits like spike length, spike exsertion, and harvest index although agronomic growth attributes like plant height, number of tillers, leaf length and leaf number would also influence yield indirectly. Salinity, drought and other environmental stresses can greatly affect development of these characters. Several workers indicated the effect of salinity on different growth and yield characters right from seedling (Rashid *et al.*, 1999) to adult (Kelman and Quaslet, 1991; Ashraf and Oleary, 1996 and 1999; Steppuhn *et al.*, 1996; Steppuhn and Wall, 1997) stages of wheat. This paper discusses the effects of different levels of irrigation water salinity on agronomic and yield attributes, and dry biomass of wheat.

Materials and Methods

The present investigation was conducted for two consecutive years, from 1996-97 to 1997-98, utilizing salt tolerant wheat genotypes at Agriculture Research Center, Rumais, Oman. 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 check, WQS-160). The physical and chemical characteristics of the experimental soil and the chemical characteristics of the irrigation water treatments are presented in Tables 1 and 2, respectively.

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 dSm^{-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, 90 kg P_2O_5 and 60 kg K_2O/ha in the form of urea triple super phosphate and potassium sulphate,

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

respectively. The entire quantities of potassium and phosphate fertilizers along with ¼ nitrogen fertilizer were applied before planting while the remaining nitrogen was applied in three splits of ¼ N each 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 till their germination and later thrice a week till a week prior to harvest. Seawater 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 seawater by control water. Protective measures against pests and diseases were taken whenever necessary.

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 observations on plant height, tillers/plant, number of leaves/plant, leaf length, days to heading initiation, spike length (cm), spike exsertion (cm), grain weight/plant (g), straw weight/plant (g) were recorded at appropriate stages of crop growth. The harvest index was computed in percentage as a ratio of grain yield to biological yield [grain weight/(grain weight + straw weight)]. One plant in each treatment was analyzed for dry biomass. The data on above characters were subjected to statistical analysis according to the methods of Gomez and Gomez (1984) using MSTAT computer program. A stress susceptibility index, S for the genotypes was determined on the basis of each character in the high salinity irrigation treatment relative to the control (Fischer and Maurer, 1978; Kelman and Qualset, 1991). The S is defined as: $S = [1- (Y_{ij} / Y_{ic})] / [1- (Y_j / Y_c)]$, where Y_{ij} = character expression of ith genotype in the jth saline treatment, Y_{ic} = character expression of the same genotype in the control treatment, Y_j = mean character expression of all genotypes in the jth saline treatment, and Y_c = mean character expression of all the genotypes in the control treatment. Low S values indicate low susceptibility or high tolerance to environmentally induced stress.

Results and Discussion

The results indicated that the effects of the years, salinity and genotypes were significant to highly significant ($p<0.01$ to 0.05) with respect to all the characters studied. Among the interactions, the effect of year x salinity was highly significant ($p<0.01$) for number of leaves, leaf length, spike exsertion, grain weight, harvest index and dry biomass. Interaction effects of year x genotype were significant to highly significant ($p<0.01$ to 0.05) with respect to all the characters except number of leaves while the effect of salinity x genotype was also significant ($p<0.01$) for all the characters except plant height and harvest index. Interaction effect of year x salinity x genotype was significant only in case of days to flowering initiation ($p<0.01$), spike length ($p<0.05$) and grain weight/ plant ($p<0.01$). Adverse effect of salinity was evident in genotypes for all the characters. However, stress susceptibility index values were found to vary for each character among the genotypes with different levels of salinity.

PLANT HEIGHT: Although there was significant reduction in mean plant height with increased level of salinity ($p<0.05$) in both years, the decrease in plant height from control to 4 dSm^{-1} was not significant in Year 2 (Table 3). It was 4.09% in Year 1 and 1.82% in Year 2. The decrease from control to 8 dSm^{-1} was 9.12% in Year 1 and 11.68% in Year 2 while the reduction in plant height was to the extent of 26% in Year 1 to 30% in Year 2 at 16 dSm^{-1} as compared to control. In Year 1, Giza-164 (76.74 cm) recorded highest mean plant height followed by Sakha-8 (71.20 cm) and Sahil-1 (70.84 cm) among multi-culm types while Sids-6 (70.96 cm) and Sids-7 (70.21 cm) were significantly taller among mono- or di-culm types. In Year 2, Giza- 164 (75.21 cm) and Sahil-1 (73.27 cm) were also significantly taller among multi-culm types while Sids-7 (61.22 cm), Sids-6 (61.11 cm) and Sids-10 (61.00 cm) recorded highest mean plant height among mono- or di-culm types. Stress susceptibility index values of Giza- 164 and S-24 among multi-culm types and that of Sids-6, Sids-7 and Sids-10 among mono-culm types were low and consistent in both years at all higher levels of salinity in relation to control, indicating their superiority in tolerance to salinity.

NUMBER OF TILLERS/PLANT: It is shown in Table 4 that the genotypes no. 1 to 7 are mostly mono- or di-culm types. They rarely showed two tillers under control or 4 dS/m^{-1}. However, under high salinity levels of 8 dSm^{-1} or more, they survived with only one tiller. In general, number of tillers decreased gradually and significantly from control to subsequent levels of salinity in both years ($p<0.05$). All the multi-culm genotypes were reduced to either mono or di- or tri-tiller ones under high salinity levels. Sakha-92 (4.80 and 4.47), S-24 (3.20 and 4.54) and WQS-160 (4.00 and 3.80) recorded high mean tillers in both years as compared to other genotypes. S-24 and WQS-160 among multi-culm types and Sid-4, Sids-5 and Sids-6 among mono-culm types showed low stress susceptibility index values in both years at all higher levels of salinity in relation to control.

NUMBER OF LEAVES/PLANT: The reduction in number of leaves/plant was mainly due to decrease in number of tillers especially in multi-culm types (Table 5). Decrease in mean number of leaves was significant ($p<0.05$) in subsequent levels of salinity from control (29.43 and 28.21) to 16 dSm^{-1} (11.05 and 13.57) in both years. Sakha-92 (44.67 and 43.33), WQS-160 (38.93 and 43.13) and S-24 (37.57 and 41.27) among the multi-culm types and Sids-10 (9.20 and 9.60) and Sids-7 (8.40 and 8.60) recorded high mean number of leaves in both the years as compared to other genotypes. In respect of stress susceptibility index, Sakha-69, Sakha-92 and S-24 among multi-culm types and Sids-5, Sids-6 and Sids-10 among mono-culm types scored low values at all salinity levels in both years.

LEAF LENGTH: Leaf length was reduced significantly ($p<0.05$) with increasing salinity levels from control in both years (Table 6). The decrease in leaf length from control to 4 dSm^{-1} was 5.34 % in Year 1 while it

TABLE 3

Mean plant height (cm) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on plant height.

Sl. † No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	75.20	73.40	64.97	54.90	52.27	64.15	60.50	62.33	59.00	45.63	38.63	53.22	0.59	1.49	1.59	1.16	-1.67	0.21	1.21	1.19
2	76.80	70.50	67.07	65.33	56.33	67.21	66.83	65.80	61.17	51.67	44.27	57.95	2.01	1.39	0.88	1.02	0.85	0.73	1.12	1.11
3	76.80	76.57	76.47	68.17	56.80	70.96	65.83	72.67	63.57	58.33	45,17	61.11	0.07	0.05	0.66	0.99	-5.72	0.29	0.56	1.03
4	76.27	73.83	74.40	66.67	59.990	70.21	68.33	69.77	62.67	56.23	49.10	61.22	0.78	0.27	0.74	0.82	-1.16	0.71	0.87	0.93
5	70.93	69.77	67.20	62.57	49.60	64.01	64.33	66.10	57.17	50.33	43.17	56.22	0.40	0.58	0.69	1.15	-1.51	0.95	1.07	1.08
6	76.33	67.52	63.67	55.37	50.67	62.71	59.93	59.60	55.00	48.50	42.23	53.05	2.82	1.82	1.61	1.28	0.31	0.70	0.94	0.97
7	72.67	72.33	68.33	61.25	60.00	66.92	70.50	69.77	60.17	57.33	47.23	61.00	0.11	0.65	0.92	0.67	0.57	1.25	0.92	1.09
8	87.63	75.73	69.50	64.30	58.83	71.20	79.80	71.17	65.83	57.83	59.00	66.73	3.32	2.27	1.57	1.25	5.96	1.50	1.36	0.86
9	77.80	77.63	74.00	64.67	59.77	70.77	75.67	72.83	70.00	57.40	52.33	65.65	0.05	0.54	0.99	0.89	2.06	0.64	1.19	1.02
10	73.87	69.73	61.50	59.00	50.57	62.93	80.00	67.33	58.67	53.17	49.33	61.70	1.37	1.83	1.18	1.20	8.72	2.28	1.66	1.26
11	79.47	77.37	70.63	69.63	57.10	70.84	85.83	81.00	68.17	69.00	62.33	73.27	0.65	1.22	0.73	1.07	3.10	1.76	0.97	0.90
12	83.67	82.57	82.07	72.07	63.33	76.74	83.20	85.80	75.63	72.17	59.27	75.21	0.32	0.21	0.82	0.93	-1.72	0.78	0.65	0.95
13	65.23	63.87	63.67	62.17	55.17	62.02	55.83	55.33	54.67	50.67	44.00	52.10	0.51	0.26	0.28	0.59	0.49	0.18	0.46	0.70
14	71.63	69.87	63.60	57.17	55.17	63.49	77.67	76.67	66.33	64.67	56.50	68.37	0.60	1.23	1.19	0.88	0.71	1.25	0.83	0.90
Mean	76.02	72.91	69.08	63.09	56.11	-	71.02	69.73	62.72	56.64	49.47	-								

Statistical Parameters:

	F-test	LSD (5%)
Year	**	0.86
Salinity	*	1.35
Year x Salinity	NS	-
Genotypes	**	2.27
Year x Genotypes	**	3.21
Salinity x Genotypes	NS	-
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

TABLE 4

Mean number of tillers of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on number of tillers.

Sl. † No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	1.00	1.00	1.00	1.00	1.00	1.00	1.67	1.33	1.33	1.00	1.00	1.27	0.00	0.00	0.00	0.00	0.92	0.60	0.88	0.74
2	1.00	1.33	1.00	1.00	1.00	1.07	1.67	1.33	1.33	1.00	1.00	1.27	-1.67	0.00	0.00	0.00	0.92	0.60	0.88	0.74
3	1.00	1.00	1.00	1.00	1.00	1.00	1.67	1.33	1.33	1.00	1.00	1.27	0.00	0.00	0.00	0.00	0.94	0.60	0.88	0.75
4	1.33	1.00	1.33	1.00	1.00	1.13	2.00	1.00	1.00	1.00	1.00	1.20	1.25	0.00	0.58	0.47	2.30	1.50	1.10	0.93
5	1.67	1.33	1.00	1.00	1.00	1.20	2.00	1.67	1.33	1.00	1.00	1.40	1.00	1.44	0.93	0.75	0.76	1.00	1.10	0.93
6	1.33	1.00	1.00	1.00	1.00	1.07	2.00	1.67	1.33	1.00	1.00	1.81	1.25	0.90	0.58	0.47	0.76	1.00	1.10	0.93
7	1.67	1.00	2.33	1.00	1.00	1.40	1.67	1.33	1.33	1.00	1.00	1.27	2.00	-1.44	0.93	0.75	0.92	0.60	0.88	0.74
8	5.33	3.67	3.00	3.00	2.00	3.40	4.33	3.67	2.67	2.33	1.67	2.93	1.56	1.58	1.01	1.17	0.71	1.15	1.02	1.15
9	4.67	4.00	3.67	3.33	1.33	3.40	4.67	3.67	2.67	2.67	2.00	3.13	0.71	0.77	0.66	1.34	0.99	1.28	0.94	1.06
10	8.00	5.67	4.33	3.00	3.00	4.80	6.00	5.00	4.67	3.33	3.33	4.47	1.46	1.65	1.45	1.17	0.77	0.66	0.98	0.83
11	3.00	3.00	2.33	1.33	1.00	2.13	4.67	3.33	3.33	2.67	1.33	3.07	0.00	0.80	1.29	1.25	1.32	0.86	0.94	1.33
12	3.33	2.33	2.33	1.33	1.00	2.07	4.33	3.00	2.33	1.67	1.00	2.47	1.50	1.08	1.39	1.31	1.42	1.38	1.35	1.43
13	4.67	3.67	3.33	2.33	2.00	3.20	5.33	5.00	4.67	4.05	3.67	4.54	1.07	1.03	1.16	1.07	0.29	0.37	0.53	0.58
14	5.33	4.67	3.67	3.33	3.00	4.00	5.33	4.67	3.33	3.00	2.67	3.80	0.62	1.12	0.87	0.82	0.58	1.12	0.96	0.93
Mean	3.10	2.48	2.24	1.76	1.45	-	3.50	2.74	2.33	1.91	1.62									

Statistical Parameters:

	F-test	LSD (5%)
Year	*	0.11
Salinity	**	0.17
Year x Salinity	NS	-
Genotypes	**	0.29
Year x Genotypes	*	0.41
Salinity x Genotypes	**	0.65
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

TABLE 5

Mean number of leaves of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on number of leaves.

Sl. † No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	9.00	7.00	6.67	6.33	6.67	7.13	12.33	10.67	9.33	6.67	5.67	8.93	0.86	0.60	0.59	0.42	1.10	0.99	1.01	1.04
2	9.00	7.67	7.00	6.67	6.67	7.40	9.67	8.67	8.33	6.67	7.33	8.13	0.57	0.51	0.52	0.42	0.84	0.56	0.68	0.47
3	7.67	7.20	7.20	7.00	7.00	7.21	12.00	10.33	9.67	7.33	7.00	9.27	0.24	0.14	0.17	0.14	1.13	0.79	0.85	0.80
4	11.00	9.33	7.67	7.00	7.00	8.40	12.67	8.00	7.67	7.67	7.00	8.60	0.59	0.70	0.73	0.58	3.00	1.61	0.86	0.86
5	9.67	8.67	7.00	7.00	6.00	7.67	13.00	10.67	8.00	6.00	6.33	8.80	0.40	0.64	0.55	0.61	1.46	1.57	1.18	0.99
6	9.00	7.67	7.00	6.00	6.33	7.20	13.00	10.00	8.00	6.33	6.00	8.67	0.58	0.51	0.67	0.47	1.88	1.57	1.12	1.04
7	13.33	11.67	7.00	7.00	7.00	9.20	12.00	10.33	11.33	7.33	7.00	9.60	0.48	1.10	0.95	0.76	1.13	0.23	0.85	0.80
8	47.67	29.67	22.67	19.33	11.67	26.20	42.33	37.17	29.00	19.00	14.67	28.43	1.47	1.21	1.19	1.21	0.99	1.28	1.21	1.26
9	32.00	26.33	19.00	19.00	8.33	20.93	31.33	30.33	18.67	16.33	17.33	22.80	0.69	0.94	0.81	1.18	0.26	1.65	1.05	0.86
10	65.00	53.33	42.67	34.33	28.00	44.67	59.00	49.00	43.33	33.67	31.67	43.33	0.70	0.79	0.94	0.91	1.38	1.08	0.94	0.89
11	34.33	28.33	19.67	16.00	8.00	21.27	35.33	29.33	32.67	25.00	14.33	27.33	0.68	0.99	1.07	1.23	1.38	0.31	0.64	1.15
12	34.00	21.67	17.67	11.67	8.33	18.67	34.67	27.00	20.33	12.00	8.67	20.53	1.41	1.11	1.31	1.21	1.80	1.69	1.43	1.45
13	56.00	48.33	32.67	28.54	22.33	37.57	52.33	51.33	41.00	31.00	30.67	41.27	0.53	0.96	0.98	0.96	0.16	0.88	0.89	0.80
14	74.33	39.00	30.00	30.00	21.33	38.93	55.33	53.67	50.67	29.67	26.33	43.13	1.85	1.38	1.19	1.14	0.24	0.34	1.02	1.01
Mean	29.43	21.85	16.71	14.71	11.05	-	28.21	24.75	21.29	15.33	13.57									

Statistical Parameters:

	F-test	LSD (5%)
Year	*	1.24
Salinity	**	1.96
Year x Salinity	**	2.77
Genotypes	*	3.27
Year x Genotypes	NS	-
Salinity x Genotypes	**	7.32
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

TABLE 6

Mean leaf length (cm) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on leaf length.

Sl. † No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	35.00	30.13	28.93	19.27	18.97	26.46	32.00	31.13	25.83	21.17	15.93	25.21	2.60	1.51	1.79	1.47	0.33	1.05	1.16	1.29
2	36.13	34.54	30.50	24.67	20.43	29.25	32.47	31.33	31.33	24.50	23.13	28.55	0.82	1.36	1.26	0.84	0.42	0.19	0.84	0.74
3	36.10	34.17	33.33	29.73	22.63	31.19	36.07	33.00	31.83	26.93	19.90	29.55	1.00	0.67	0.70	1.31	1.02	0.64	0.87	1.15
4	36.67	35.83	32.00	25.47	20.37	30.07	39.30	35.50	31.33	26.67	21.40	30.84	0.43	1.11	1.22	1.33	1.16	1.11	1.10	1.17
5	33.80	33.63	26.40	26.50	21.50	28.37	37.27	35.33	27.30	25.33	21.17	29.28	0.09	1.91	0.86	1.26	0.63	1.46	1.10	1.11
6	34.67	31.37	30.50	23.00	21.90	28.29	34.40	33.13	28.37	27.07	21.77	28.95	1.78	1.05	1.34	1.07	0.44	0.96	0.73	0.94
7	37.17	34.14	31.73	24.13	19.80	29.39	37.17	36.50	30.70	26.97	22.50	30.77	1.53	1.28	1.40	1.15	0.22	0.95	0.94	1.01
8	36.60	35.37	34.20	26.87	26.20	31.85	24.47	20.90	20.83	17.27	17.67	20.23	0.63	0.57	1.06	0.81	1.76	0.81	1.01	0.71
9	34.13	31.40	30.90	26.60	24.13	29.43	32.63	29.23	27.67	23.33	19.83	26.54	1.50	0.83	0.88	1.15	1.25	0.83	0.98	1.00
10	33.70	32.58	32.03	29.53	27.10	30.99	25.17	23.17	20.67	18.43	15.50	20.59	0.62	0.43	0.49	1.12	0.96	0.97	0.92	0.98
11	36.10	34.30	32.50	31.03	27.03	32.19	23.33	20.67	19.67	18.81	18.60	20.22	0.93	0.87	0.56	0.59	1.37	0.86	0.66	0.52
12	38.43	36.13	36.30	32.60	30.40	34.77	30.50	22.67	21.33	20.40	19.33	22.85	1.12	0.48	0.60	1.07	3.09	1.64	1.14	0.94
13	32.00	31.13	25.83	21.17	19.13	25.85	19.90	18.83	16.33	13.67	12.73	16.29	0.51	1.68	1.35	1.42	0.65	0.98	1.07	0.92
14	34.80	34.13	33.53	30.37	26.40	31.85	28.17	25.47	20.33	16.13	14.50	20.92	0.36	0.32	0.51	1.05	1.15	1.52	1.47	1.24
Mean	35.38	33.49	31.33	26.50	23.29	-	30.92	28.35	25.25	21.91	18.85	-								

Statistical Parameters:

	F-test	LSD (5%)
Year	**	0.44
Salinity	**	0.70
Year x Salinity	**	0.98
Genotypes	**	1.16
Year x Genotypes	**	1.65
Salinity x Genotypes	**	2.60
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

was 8.31 % in Year 2. The decrease from control to 8 dSm^{-1} was 11.45 % in Year 1 and it was 18.34 % in Year 2. Similarly, the reduction in leaf length was to the extent of 34.17 % in Year 1 to 39.04 % in Year 2 at 16 dSm^{-1} as compared to control. Most of the mono or di-culm types have significantly longer leaves than multi-culm types. Sakha-69 (29.43 and 26.54 cm), Sahil-1 (32.19 and 20.22 cm) and Giza-164 (34.77 and 22.85 cm) among muti-culm types and Sids-6 (31.19 and 29.55 cm), Sids-7 (30.07 and 30.84 cm) and Sids-10 (29.39 and 30.77 cm) among mono-culm types had significantly longer leaves in both years. Sakha-92 and Sahil-1 among multi-culm types and Sids-5 and Sids-6 among mono-culm types had consistently low stress susceptibility index values in both years.

DAYS TO HEADING INITIATION: Salinity gradually delayed the time of initiation of heading by three to four days from control to 16 dSm^{-1}, the highest level of salinity, in both years (Table 7). The delay from control to each higher level of salinity and between levels of salinity was statistically significant ($p<0.05$). However, the time difference for heading initiation from control to 4 dSm^{-1} and between each interval of higher levels of salinity was within a day and a half. Differential response of genotypes to higher levels of salinity was apparent not only within the year but also between the years. Sahil-1 seemed to have been affected negligibly at 4 dSm^{-1} from control in both years (64.33 d to 64.67 d in Year 1 and 68.67 d in Year 2). While there was no effect on heading initiation for Sakha-69 (58.00 d) and Sakha-92 (69 d) from control to 4 dSm^{-1} in Year 1, their initiation was delayed by a day in Year 2. Similar response was also noticed in other genotypes except S-24 and WQS-160, whose response was inconsistent. This is attributed to genetic make up of the genotypes expressing this quantitative trait differentially under stress in two years.

SPIKE LENGTH: There was gradual and significant ($p<0.05$) decrease in spike length at subsequent higher levels of salinity from control (Table 8). The reduction in spike length was 7.79 % during Year 1 and 4.70 % during Year 2 at 4 dSm^{-1} from control while it was to the extent of 52.37 % during Year 1 and 25.27 % during Year 2 at 16 dSm^{-1}. S-24 recorded highest spike length of 14.03 cm during Year 1 followed by Giza-164 (10.57 cm) and Sakha-69 (10.29 cm) while Giza-164 had the highest spike length (15.11 cm) during Year 2 followed by S-24 (14.33 cm), WQS-160 (13.75 cm) and Sakha-8 (13.75 cm) among multi-culm types. Among mono- or di-culm types, Sids-7 (12.57 cm), Sids-6 (11.60 cm) and Sids-4 (11.11 cm) during Year 1 and Sids-10 (9.01 cm), Sids-6 (8.97 cm) and Sids-5 (8.85 cm) during Year 2 had high spike length. From viewpoint of stress susceptibility index, WQS-160 and S-24 among multi-culm types and Sids-6, Sids-7 and Sids-9 among mono- or di-culm types had low values in both years, indicating their superiority in tolerance with respect to spike length.

SPIKE EXSERTION: Panicle or spike exsertion has been used as the marker trait in many cereal crops like rice to indicate tolerance to any stress condition (Pandey and Gupta, 1993; IRRI, 1994; Sthapit *et al.*, 1995) where spike exsertion would be long and least affected in case of tolerant genotypes. In the present study, there was gradual and significant ($p<0.05$) reduction in spike exsertion under subsequent higher salinity levels from control to 16 dS m^{-1} in both years (Table 9). Among multi-culm types, Giza-164 (10.43 cm), Sahil-1 (9.15 cm) and Sakha-69 (8.89 cm) during Year 1 and Sakha-69 (8.38 cm), Giza-164 (7.53 cm) and Sahil-1 (6.78 cm) during Year 2 had long mean spike exsertion while among mono-culm types Sids-7 (12.04 cm), Sids-6 (11.57 cm) and Sids-10 (11.17 cm) during Year 1 and Sids-7 (10.81), Sids-10 (10.17 cm) and Sids-5 (10.09 cm) during Year 2 had long mean spike exsertion. In respect of stress susceptibility index, Sakha-69, Giza-164 and S-24 among multi-culm types and Sids-5, Sids-6, Sids-7 and Sids-10 among mono-culm types scored low values at all salinity levels in both years.

GRAIN WEIGHT/PLANT: Grain weight showed progressive and significant decrease ($p<0.05$) in trend from the control to higher salinity levels in both years (Table 10). Grain weight was reduced significantly by 18.93% in Year 1 and insignificantly by just 8.59% in Year 2 at 4 dSm^{-1} from control. It was further reduced significantly by 45.06% in Year 1 and 42.18% in Year 2 at 8 dSm^{-1} from control. Further decrease was more than 60% from control. In general, multi-culm types produced significantly more grain weight than the mono- or di-culm types due to more number of spike bearing tillers. Sakha-92 (4.09 and 2.07 g/plant), Sahil-1 (3.99 and 2.12 g/ plant) and S-24 (4.09 and 2.01 g/plant) among multi-culm types and Sids-8 (2.11 and 1.48 g/plant), Sids-9 (2.28 and 1.54 g/plant) and Sids-10 (2.51 and 1.29 g/plant) among mono-culm types had given significantly high grain yield in both years. However, in respect of stress susceptibility index, Sids-5, Sids-6 and Sids-9 among mono-culm types and S-24 among multi-culm types scored very low values at all salinity levels indicating their consistency in tolerance in respect of yield under stress conditions.

STRAW WEIGHT/PLANT: Straw weight also showed progressive and significant decrease ($p<0.05$) with increasing salinity levels in both years (Table 11). Straw weight was reduced significantly by 23.48 % in Year 1

TABLE 7

Meandays to flowering initiation of wheat genotypes under different levels of salinity.

Sl. † No.	Year 1						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	45.00	45.67	46.33	47.00	47.33	46.27	42.00	43.33	44.33	45.00	45.67	44.07
2	48.33	51,33	52.00	52.67	53.67	51.60	44.00	45.67	45.33	45.33	47.00	45.47
3	48.67	50.67	52.00	52.33	53.33	51.40	45.33	45.67	46.33	47.00	47.00	46.27
4	50.00	54.67	54.67	54.67	55.00	53.80	45.33	45.67	46.00	47.33	47.67	46.40
5	52.00	53.67	54.00	55.00	55.00	53.93	46.00	46.33	47.67	48.33	49.33	47.53
6	49.00	51.00	53.33	53.67	54.00	52.20	44.33	44.67	45.67	46.33	46.67	45.53
7	51.33	52.33	53.67	53.67	53.67	52.93	45.67	46.33	47.00	47.33	47.67	46.80
8	60.00	63.33	64.33	65.33	65.33	63.66	71.67	72.00	72.67	73.00	73.33	72.53
9	58.00	58.00	58.33	59.67	61.33	59.07	57.00	58.33	59.67	61.00	61.67	59.53
10	69.00	69.00	70.00	71.67	74.00	70.73	70.33	71.33	71.67	72.67	75.33	72.27
11	64.33	64.67	65.00	65.67	65.67	65.07	68.67	68.67	69.33	70.67	71.67	69.80
12	63.00	65.00	65.67	66.67	67.00	65.47	67.67	71.00	71.67	72.33	73.00	71.13
13	74.57	75.83	76.17	80.33	81.00	77.58	75.67	74.33	75.00	76.67	77.00	75.73
14	75.67	74.33	75.00	76.67	77.00	75.73	81.83	84.00	84.00	85.33	89.67	84.97
Mean	57.78	59.25	60.04	61.07	61.67	-	57.54	58.38	59.02	59.88	60.91	

Statistical Parameters:

	F-test	LSD (5%)
Year	**	0.16
Salinity	**	0.25
Year x Salinity	NS	-
Genotypes	**	0.42
Year x Genotypes	**	0.60
Salinity x Genotypes	**	0.94
Year x Salinity x Genotypes	**	1.34

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

TABLE 8

Mean spike length (cm) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on spike length.

Sl.† No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	14.50	13.33	11.13	9.80	6.80	11.11	9.27	9.27	8.47	6.00	5.40	7.68	1.04	0.98	0.89	1.01	0.00	0.70	2.16	1.65
2	12.57	11.23	10.54	9.53	5.63	9.90	10.23	9.67	9.83	8.03	6.50	8.85	1.37	0.68	0.67	1.05	1.16	0.31	1.32	1.44
3	13.70	13.50	13.07	10.63	7.10	11.60	10.83	9.77	9.40	8.13	6.73	8.97	0.19	0.19	0.62	0.92	2.09	1.07	1.53	1.50
4	14.87	14.83	13.10	12.03	8.00	12.57	10.30	9.30	8.53	7.30	6.30	8.35	0.03	0.50	0.53	0.88	2.06	1.39	1.79	1.54
5	12.83	12.00	9.72	8.87	5.00	9.68	10.00	9.47	8.27	6.80	6.13	8.13	0.83	1.02	0.85	1.17	1.13	1.40	1.96	1.53
6	11.54	11.40	8.63	7.50	5.83	8.98	9.27	9.23	8.47	7.67	6.43	8.21	0.16	1.06	0.96	0.94	0.08	0.70	1.06	1.21
7	16.17	12.80	9.95	9.37	7.17	11.09	11.33	10.33	8.33	8.30	6.73	9.01	2.67	1.62	1.16	1.06	1.88	2.14	1.64	1.61
8	14.10	13.63	8.17	5.67	5.53	9.42	14.67	14.17	13.80	13.53	12.60	13.75	0.43	1.77	1.65	1.16	0.72	0.48	0.48	0.56
9	13.57	12.07	9.93	8.06	7.80	10.29	9.47	9.33	8.67	8.47	7.73	8.73	1.42	1.13	1.12	0.81	0.31	0.68	0.65	0.73
10	17.03	15.03	8.70	6.33	2.7	9.93	12.83	12.70	12.33	12.30	11.33	12.30	1.51	2.05	1.73	1.62	0.22	0.32	0.25	0.46
11	12.77	11.20	10.07	6.97	4.73	9.15	15.00	14.10	13.33	13.10	12.67	13.64	1.58	0.89	1.25	1.20	1.28	0.90	0.78	0.61
12	14.33	13.33	11.20	7.67	6.30	10.57	16.60	15.70	12.63	16.00	14.60	15.11	0.90	0.92	1.28	1.07	1.15	1.94	0.22	0.48
13	15.03	13.67	13.70	13.97	13.77	14.03	15.50	14.50	14.30	13.87	13.50	14.33	1.17	0.37	0.20	0.16	1.37	0.63	0.65	0.51
14	9.27	9.27	8.47	6.00	5.40	7.68	15.03	14.57	14.00	13.67	11.50	13.75	0.00	0.36	0.97	0.80	0.66	0.56	0.56	0.93
Mean	13.73	12.66	10.46	8.74	6.54	-	11.91	11.35	10.44	9.97	8.90	-								

Statistical Parameters:

	F-test	LSD (5%)
Year	**	0.17
Salinity	**	0.26
Year x Salinity	NS	-
Genotypes	**	0.44
Year x Genotypes	**	0.62
Salinity x Genotypes	**	0.98
Year x Salinity x Genotypes	*	1.39

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

TABLE 9

Mean spike exertion (cm) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on spike exertion.

Sl. † No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	13.33	11.40	11.13	9.80	6.80	10.49	12.70	11.80	11.67	7.00	3.57	9.35	2.10	0.63	0.68	0.88	0.74	0.48	1.53	1.32
2	12.57	11.23	9.33	9.53	5.63	9.66	12.30	11.90	11.17	9.37	5.70	10.09	1.54	0.99	0.62	0.99	0.34	0.54	0.81	0.99
3	13.70	13.33	13.07	10.63	7.10	11.57	11.63	10.53	10.70	9.33	5.97	9.63	0.39	0.18	0.57	0.86	0.98	0.47	0.67	0.89
4	13.73	15.13	11.30	12.03	8.00	12.04	13.40	12.57	11.27	9.17	7.67	10.81	-1.48	0.68	0.32	0.75	0.64	0.93	1.08	0.79
5	12.83	12.00	9.20	9.07	5.00	9.62	11.13	8.20	9.00	8.43	4.67	8.29	0.94	1.09	0.75	1.09	2.74	1.12	0.83	1.07
6	11.37	7.77	8.63	7.50	5.83	8.22	10.33	9.67	9.07	8.23	5.17	8.49	4.59	0.92	0.87	0.87	0.67	0.72	0.69	0.92
7	12.80	17.50	9.00	9.37	7.17	11.17	12.77	11.57	11.17	9.30	6.07	10.17	-5.32	1.14	0.69	0.79	0.98	0.74	0.93	0.96
8	14.10	10.30	8.17	5.67	4.67	8.58	10.73	8.53	6.83	6.70	4.57	7.47	3.91	1.61	1.53	1.20	2.13	2.13	1.28	1.06
9	12.07	11.33	9.90	6.50	4.67	8.89	10.00	9.80	9.00	8.50	4.60	8.38	0.89	0.69	1.18	1.10	0.21	0.59	0.51	0.99
10	7.03	5.03	2.40	1.93	1.53	3.59	8.20	7.93	4.57	3.37	1.67	5.15	4.12	2.53	1.86	1.40	0.34	2.60	2.01	1.46
11	12.77	11.20	10.07	6.97	4.73	9.15	8.27	7.43	6.97	6.70	4.53	6.78	1.78	0.81	1.16	1.13	1.05	0.92	0.65	0.83
12	13.67	13.30	11.20	6.30	7.67	10.43	9.67	8.90	7.83	6.77	4.47	7.53	0.39	0.69	1.38	0.79	0.83	1.12	1.02	0.99
13	8.30	7.87	4.13	1.67	2.13	4.82	6.87	6.97	5.90	5.70	4.33	5.95	0.76	1.93	2.05	1.33	-0.16	0.83	0.58	0.68
14	6.03	5.67	4.00	3.33	1.57	4.12	1.67	0.53	0.73	0.13	0.70	0.75	0.87	1.29	1.15	1.32	7.07	3.29	3.13	1.07
Mean	11.74	10.93	8.68	7.16	5.18	-	9.98	9.02	8.28	7.05	4.55	-	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00

Statistical Parameters:

	F-test	LSD (5%)
Year	**	0.25
Salinity	**	0.40
Year x Salinity	**	0.56
Genotypes	**	0.67
Year x Genotypes	**	0.94
Salinity x Genotypes	**	1.49
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

TABLE 10

***Mean grain weight/plant (g) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on grain weight* per se.**

Sl.† No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	2.05	1.36	1.31	1.24	0.27	1.25	1.60	1.50	1.33	0.67	0.37	1.09	1.78	0.80	0.63	1.10	0.73	0.40	0.97	1.00
2	3.09	2.36	2.25	1.21	0.44	1.87	1.95	1.90	1.33	0.83	0.57	1.32	1.25	0.60	0.96	1.09	0.30	0.75	0.95	0.92
3	2.62	2.33	1.64	1.46	0.61	1.73	2.13	2.03	0.97	0.77	0.50	1.28	0.58	0.83	0.70	0.97	0.55	1.30	1.06	0.99
4	2.77	2.56	1.97	0.47	0.64	1.68	2.20	1.93	0.67	0.73	0.50	1.21	0.40	0.64	1.31	0.98	1.41	1.65	1.11	1.00
5	3.85	3.04	1.64	1.45	0.56	2.11	2.25	2.17	1.30	1.13	0.53	1.48	1.11	1.27	0.99	1.09	0.41	1.00	0.83	0.99
6	3.28	3.12	2.56	1.22	1.24	2.28	2.23	2.00	1.77	1.23	0.47	1.54	0.26	0.49	0.99	0.79	1.20	0.49	0.74	1.03
7	4.83	2.73	2.33	1.66	1.02	2.51	2.77	1.73	0.83	0.73	0.40	1.29	2.30	1.15	1.04	1.00	4.35	1.66	1.22	1.11
8	6.80	5.22	3.04	2.68	2.02	3.95	2.40	2.33	1.03	0.70	0.37	1.37	1.23	1.23	0.96	0.89	0.34	1.35	1.18	1.10
9	5.96	5.17	2.43	1.91	0.94	3.28	2.47	2.33	1.30	1.07	0.90	1.61	0.70	1.31	1.08	1.07	0.66	1.12	0.94	0.83
10	6.13	5.42	3.98	3.75	1.17	4.09	3.17	2.53	2.17	1.27	1.20	2.07	0.61	0.78	0.61	1.03	2.34	0.75	1.00	0.81
11	8.84	5.79	2.23	1.58	1.51	3.99	3.13	3.07	2.57	1.00	0.83	2.12	1.82	1.66	1.30	1.06	0.23	0.42	1.13	0.95
12	5.57	4.51	3.06	1.66	0.86	3.13	3.63	3.50	1.90	1.77	0.43	2.25	1.01	1.00	1.11	1.08	0.42	1.13	0.85	1.14
13	6.10	5.92	4.45	2.30	1.70	4.09	3.03	2.87	2.17	1.30	0.67	2.01	0.16	0.60	0.99	0.92	0.61	0.67	0.95	1.01
14	6.12	5.68	4.45	2.48	1.55	4.06	2.90	2.85	1.40	1.03	0.53	1.74	0.38	0.61	0.94	0.95	0.20	1.23	1.07	1.06
Mean	4.86	3.94	2.67	1.79	1.04	-	2.56	2.34	1.48	1.02	0.59									

Statistical Parameters:

	F-test	LSD (5%)
Year	**	0.14
Salinity	**	0.23
Year x Salinity	**	0.32
Genotypes	**	0.38
Year x Genotypes	**	0.54
Salinity x Genotypes	**	0.86
Year x Salinity x Genotypes	**	1.21

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

TABLE 11

***Mean straw weight/plant (g) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on straw weight* per se.**

Sl.† No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	2.85	2.08	1.52	1.79	0.93	1.83	3.17	2.83	1.67	1.37	0.40	1.89	1.15	1.06	0.62	0.88	0.41	0.92	0.83	1.02
2	4.49	3.07	3.35	2.65	0.95	2.90	5.77	4.70	4.77	1.17	0.67	3.41	1.35	0.58	0.68	1.03	0.72	0.34	1.16	1.04
3	3.73	3.56	2.43	2.24	1.19	2.63	4.73	4.10	3.03	1.37	0.57	2.76	0.19	0.79	0.66	0.89	0.52	0.70	1.03	1.03
4	3.72	3.69	2.99	1.99	1.20	2.72	4.77	2.40	1.63	1.80	0.87	2.29	0.03	0.45	0.77	0.88	1.92	1.27	0.90	0.96
5	4.88	4.59	2.95	2.87	1.76	3.41	3.97	2.73	1.70	1.40	0.77	2.11	0.25	0.90	0.68	0.83	1.20	1.11	0.94	0.95
6	4.91	4.25	3.64	2.31	1.70	3.36	6.40	3.80	2.77	1.17	0.63	2.95	0.57	0.59	0.88	0.85	1.57	1.10	1.19	1.06
7	3.94	3.95	2.94	1.55	1.11	2.70	5.43	3.33	1.87	1.60	0.63	2.57	-0.01	0.58	1.00	0.94	1.50	1.27	1.02	1.04
8	11.63	7.01	4.15	3.73	2.87	5.88	18.43	13.67	7.53	6.63	2.93	9.84	1.69	1.46	1.12	0.98	1.00	1.15	0.93	0.99
9	8.22	7.82	6.99	4.35	2.00	5.88	18.30	11.63	5.47	4.43	2.47	8.46	0.21	0.34	0.78	0.99	1.41	1.36	1.10	1.01
10	12.29	10.18	6.10	5.48	1.97	7.20	19.53	12.97	8.37	5.90	3.40	10.03	0.73	1.15	0.92	1.10	1.30	1.11	1.01	0.97
11	15.42	8.61	5.47	3.42	2.02	6.99	16.63	14.43	8.43	5.87	2.00	9.47	1.88	1.47	1.29	1.13	0.51	0.96	0.94	1.03
12	10.41	7.93	6.43	2.74	1.79	5.86	11.73	8.57	5.47	3.70	1.33	6.16	1.01	0.87	1.22	1.08	1.04	1.04	0.99	1.04
13	11.30	8.84	6.55	4.29	3.16	6.83	12.43	10.58	9.50	5.17	2.10	7.96	0.93	0.96	1.03	0.94	0.58	0.46	0.85	0.97
14	12.48	8.84	6.40	4.29	3.16	7.03	10.73	9.54	6.52	2.70	2.10	6.32	1.24	1.11	1.09	0.97	0.43	0.76	1.09	0.94
Mean	7.88	6.03	4.42	3.12	1.84		10.14	7.52	4.91	3.16	1.49									

Statistical Parameters

	F-test	LSD (5%)
Year	**	0.48
Salinity	**	0.77
Year x Salinity	NS	-
Genotypes	**	1.08
Year x Genotypes	**	1.81
Salinity x Genotypes	**	2.87
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

and by 25.83 % in Year 2 at 4 dSm^{-1} from control. It was further reduced significantly by 43.90 % in Year 1 and 51.58 % in Year 2 at 8 dSm^{-1} from control. Further decrease was 60% or more from control. Among multi-culm types, Sakha-92 (7.20 and 10.03 g/plant), Sahil-1 (6.99 and 9.47 g/plant), Sakha-8 (5.88 and 9.84 g/plant) and S-24 (6.83 and 7.96 g/plant) and among mono- or di-culm types, Sids-5 (2.90 and 3.41 g/plant), Sids-9 (3.36 and 2.95 g/plant), Sids-8 (3.41 and 2.11 g/plant) and Sids-6 (2.63 and 2.76 g/plant) produced more straw weight than others in both years. However, Sids-6 among mono-or di-culm types and S-24 of multi-culm types had low values of stress susceptible index in both years.

HARVEST INDEX (%): The response of wheat genotypes to salinity was inconsistent in respect of harvest index (Table 12). During Year 1, the average harvest index of the genotypes at 4 dSm^{-1} (39.96 %) or 8 dSm^{-1} (38.43 %) was on par with that at control (39.80 %) while it decreased significantly at 12 dSm^{-1} and 16 dSm^{-1}. During Year 2, there was significant increase in harvest index at high salinity levels from control (>20.16 %). Among multi-culm types, Sakha-8 recorded highest harvest index of 40.99 % followed by S-24 (37.10 %) and Sakha-92 (37.08 %) during Year 1 while Giza-164, which had the highest harvest index (27.05 %) followed by WQS-160 (21.94 %) and S-24 (20.76 %) during Year 2. Sids-10 recorded highest harvest index of 47.95 % among mono- or di-culm types, followed by Sids-9 (40.07 %) and Sids-6 (38.90 %) during Year 1 while Sids-8 had the highest harvest index (41.90 %) followed by Sids-4 (38.64 %), Sids-9 (38.61 %) and Sids-6 (34.24 %) during Year 2. Sakha-8, Giza-164, S-24, Sakha-92 and WQS-160 among multi-culm types and Sids-4, Sids-6 and Sids-10 among mono or di-culm types had low values of stress susceptibility index in both years.

DRY BIOMASS: Dry biomass also showed progressive and significant ($p<0.05$) decrease in trend from the control to higher salinity levels in both years (Table 13). Dry biomass was reduced significantly by 30.84% in Year 1 and by 22.30% in Year 2 at 4 dSm^{-1} from control. It was further reduced significantly by 43.49% in Year 1 and 41.43% in Year 2 at 8 dSm^{-1} from control. Further decrease was 60% or more from control. Among multi-culm types, WQS-160 (9.07 and 5.83 g/plant), S-24 (6.97 and 8.09 g/plant) and Sakha-92 (6.44 and 10.17 g/plant) and among mono- or di-culm types, Sids-5 (1.46 and 4.50 g/plant) and Sids-9 (1.35 and 4.16 g/plant) produced dry biomass more than others in both years. However, Sids-6 and Sids-7 among mono or di-culm types and Sakha-8, Sakha-69 and S-24 among multi-culm types had low values of stress susceptible index in both years indicating their relative tolerance to salinity with respect to biomass.

Adverse effects of salinity on growth of wheat plants have also been observed earlier due to reduction not only in traits like plant height (Kelmen and Qualset, 1991; Steppuhn and Wall, 1997), number of tillers (Holloway and Alston, 1992; Maas *et al.*, 1994), leaf number (Sharma and Garg, 1985; Grieve *et al.*, 1993; Grieve *et al.*, 1994), leaf area (Sharma and Garg, 1985) but also grain yield (El-Agrodi *et al.*, 1988; Kelmen and Qualset, 1991; Holloway and Alston, 1992; Soliman, *et al.*, 1994; Steppuhn *et al.*, 1996; Steppuhn and Wall, 1997), straw yield (Francois *et al.*, 1994; Soliman, *et al.* 1994) and yield associated traits like spike length (Grieve *et al.*, 1992), spike weight (Grieve *et. al.*, 1992) and harvest index (Kelmen and Qualset, 1991), and biomass (Kelmen and Qualset, 1991; Hollowway and Alston, 1992; Soliman *et al.*, 1994). The present study considered spike exsertion to assess the salinity tolerance of the genotypes as applied in other investigations concerning biotic stresses like diseases (Sthapit *et al., 1995*) or insects (IRRI, 1994) and abiotic stresses like cold (Pandey and Gupta, 1993) and drought (IRRI, 1994) in rice where tolerant genotypes show longer exsertion of the panicle from the boot. Also, in the present study the nature of salinity effect on heading initiation was investigated for the first time.

Many scientists reported variability in salt tolerance within species (Shannon, 1985; Kelmen and Qualset, 1991; Gonzales, 1996) but criteria of selection for salt tolerance have not been consistent among the investigators. Salinity tolerance of a crop plant can be assessed either in terms of its physiology as a small relative growth reduction due to salinity or on absolute plant basis as revealed by high growth rate in or out of salinity (Rawson *et al.*, 1988). On the other hand, Shannon (1985) discussed salinity tolerance in terms of either relative tolerance or by mean productivity between saline and non-saline environments or across a range of saline environments with their merits and demerits in respect of both low yielding and high yielding lines. Later, Kelmen and Qualset (1991) applied the concept of relative tolerance for selection of a genotype using its stress susceptibility index with reference to particular character in high saline environment relative to low saline environment. In the present study, we have assessed the salinity tolerance of genotypes using the concepts of stress susceptibility index at each higher salinity level in relation to a control and the mean value over the salinity treatments with respect to each character. The most tolerant genotypes were selected considering the information of all the characters under study. Among all the genotypes

TABLE 12

Mean harvest index (%) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on harvest index.

Sl.† No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	41.84	39.53	46.29	40.92	22.50	38.22	33.56	34.62	44.38	32.79	47.85	38.64	-13.69	-3.09	0.23	3.87	0.08	1.04	-0.05	0.67
2	40.77	43.46	40.20	31.32	31.65	37.48	25.57	28.79	21.81	41.65	45.95	32.69	16.46	0.40	2.44	1.87	0.36	-0.44	1.46	1.29
3	41.26	39.56	40.29	39.41	34.00	38.90	31.08	33.15	24.18	35.94	46.86	34.24	-10.26	0.68	0.47	1.47	0.17	-0.72	0.35	0.80
4	42.68	40.96	39.72	19.11	34.78	35.45	31.58	44.61	29.00	28.94	36.58	34.14	-10.03	2.02	5.82	1.55	1.06	-0.26	-0.19	0.25
5	44.10	39.84	35.73	33.56	24.14	35.48	36.19	44.26	43.33	44.73	41.00	41.90	-24.02	5.51	2.52	3.79	0.57	0.64	0.53	0.21
6	40.05	42.31	41.29	34.56	42.16	40.07	25.84	34.48	38.95	51.31	42.45	38.61	14.05	-0.90	1.44	-0.44	0.86	1.64	2.21	1.01
7	55.07	40.87	44.21	51.71	47.89	47.95	33.74	34.21	30.82	31.42	38.72	33.78	-64.16	5.73	0.64	1.09	0.04	-0.28	-0.15	0.23
8	36.89	42.68	42.28	41.79	41.31	40.99	11.52	14.57	12.06	9.55	11.12	11.76	39.05	-4.25	-1.40	-1.00	0.68	0.15	-0.38	-0.05
9	42.03	39.80	25.80	30.51	31.97	34.02	11.89	16.69	19.20	19.41	26.73	18.78	-13.20	11.22	2.89	2.01	1.03	1.98	1.42	1.96
10	33.28	34.74	39.50	40.63	37.26	37.08	13.95	16.33	20.57	17.68	26.09	18.92	10.95	-5.43	-2.33	-1.00	0.44	1.53	0.60	1.37
11	36.45	40.22	28.96	31.60	42.74	35.99	15.84	17.53	23.36	14.56	29.40	20.14	25.73	5.97	1.40	-1.45	0.27	1.53	-0.18	1.35
12	34.86	36.25	32.24	37.70	32.45	34.70	23.63	29.00	25.79	32.32	24.52	27.05	9.87	2.18	-0.86	0.58	0.58	0.29	0.83	0.06
13	35.06	40.10	40.44	34.89	35.00	37.10	19.60	21.34	18.59	20.09	24.19	20.76	35.73	-4.46	0.05	0.02	0.23	-0.17	0.06	0.37
14	32.90	39.12	41.01	36.63	32.91	36.52	21.28	23.00	17.68	27.61	20.15	21.94	46.99	-7.16	-1.19	0.00	0.21	-0.55	0.67	-0.08
Mean	39.80	39.96	38.43	36.02	35.05		20.16	28.04	26.41	29.14	32.97									

Statistical Parameters

	F-test	LSD (5%)
Year	**	1.34
Salinity	**	2.11
Year x Salinity	NS	2.99
Genotypes	**	3.54
Year x Genotypes	**	5.00
Salinity x Genotypes	NS	-
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

†† Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (dS), low salinity treatment.

TABLE 13

***Mean dry biomass/plant (g) of wheat genotypes and their stress susceptibility indexes (S_{ij}) based on dry biomass* per se.**

Sl.† No.	Means												Stress Susceptibility Indexes††							
	Year 1						Year 2						Year 1				Year 2			
	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	2 dSm^{-1}	4 dSm^{-1}	8 dSm^{-1}	12 dSm^{-1}	16 dSm^{-1}	Mean	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$	$S_{2.4}$	$S_{2.8}$	$S_{2.12}$	$S_{2.16}$
1	2.75	1.93	1.63	1.00	0.85	1.63	3.53	3.30	1.90	1.60	0.93	2.25	0.96	0.93	1.06	0.94	0.29	1.11	0.86	0.91
2	2.00	1.83	1.53	1.20	0.73	1.46	7.93	6.90	4.23	2.17	1.27	4.50	0.28	0.54	0.67	0.86	0.58	1.13	1.15	1.04
3	1.83	1.70	1.43	1.30	0.73	1.40	4.60	3.97	3.13	1.93	1.27	2.98	0.24	0.51	0.49	0.82	0.61	0.77	0.91	0.90
4	1.87	1.53	1.40	0.97	1.03	1.36	4.17	4.03	3.30	1.97	0.97	2.89	0.59	0.58	0.81	0.61	0.15	0.50	0.83	0.95
5	1.57	1.50	1.05	1.00	0.83	1.19	6.03	4.77	2.87	2.20	1.13	3.40	0.14	0.76	0.61	0.64	0.94	1.27	1.00	1.00
6	1.90	1.77	1.27	1.10	0.70	1.35	7.23	4.47	4.13	2.73	2.23	4.16	0.22	0.77	0.70	0.86	1.71	1.04	0.98	0.85
7	1.53	1.40	1.33	1.03	0.60	1.18	7.53	3.47	3.10	2.20	1.13	3.49	0.28	0.30	0.54	0.83	2.42	1.42	1.12	1.05
8	3.95	3.87	3.20	2.97	1.33	3.06	9.10	6.47	6.00	4.33	2.03	5.59	0.07	0.44	0.42	0.90	1.30	0.82	0.83	0.96
9	5.17	5.07	3.88	3.47	1.63	3.84	6.10	6.03	4.63	3.20	1.73	4.34	0.06	0.57	0.55	0.93	0.05	0.58	0.75	0.89
10	11.53	8.97	5.37	4.07	2.27	6.44	20.53	13.67	9.33	5.10	2.20	10.17	0.72	1.23	1.08	1.09	1.50	1.32	1.19	1.10
11	6.67	3.77	3.37	2.57	1.93	3.66	7.67	7.60	5.37	3.10	1.30	5.01	1.41	1.14	1.03	0.96	0.04	0.72	0.94	1.03
12	5.67	3.47	3.13	2.93	1.17	3.27	10.40	10.10	7.87	5.67	1.03	7.01	1.26	1.03	0.81	1.08	0.13	0.59	0.72	1.11
13	11.33	9.00	7.53	3.83	3.15	6.97	12.90	11.20	8.83	4.00	3.50	8.09	0.67	0.77	1.10	0.98	0.59	0.76	1.09	0.90
14	20.80	8.47	8.30	4.00	3.80	9.07	11.60	6.70	5.23	3.53	2.10	5.83	1.92	1.38	1.35	1.11	1.89	1.33	1.10	1.01
Mean	5.61	3.88	3.17	2.25	1.48		8.52	6.62	4.99	3.12	1.63									

Statistical Parameters

	F-test	LSD (5%)
Year	**	0.24
Salinity	**	0.38
Year x Salinity	**	0.54
Genotypes	**	0.64
Year x Genotypes	**	0.90
Salinity x Genotypes	**	1.43
Year x Salinity x Genotypes	NS	-

*Significant at 0.05 level of probability; ** Significant at 0.01 level of probability; NS – Non significant.

†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.

††Stress susceptibility index of 'j" (dS), high salinity treatment relative to 'i' (d S), low salinity treatment.

tested, the salinity tolerance of S-24, a multi-culm type of Pakistan developed salt tolerant genotype (Ashraf and Oleary, 1999) was of higher degree and more consistent as it scored low values of stress susceptible index under high salinity levels in respect of all the characters except leaf length. It also had high mean values for as many as seven out of eleven characters viz. number of tillers, number of leaves, spike length, spike exsertion, straw weight, harvest index and dry biomass. Sids-6 from Egypt, mono-or di-culm type, also depicted its tolerance on the basis low stress index scores at higher levels of salinity with respect to all the characters while it had high mean values only with respect to six characters viz. plant height, leaf length, spike length, spike exsertion, straw weight and harvest index. All other genotypes, however, responded differentially to different levels of salinity for different characters.

Plant biomass has been frequently used as an indicator of salinity tolerance of genotypes (Kingsbury and Epstein, 1984; Dvorak and Ross, 1986; Richards *et al.*, 1987; Kelvin and Quaslet, 1991) while yield related traits have been seldom used to assess the effect of salinity on the genotypes (Grieve *et al.*, 1992 and Kelmen and Qualset, 1991). However, grain yield being an ultimate economic product has been considered for assessing salinity tolerance by many investigators like Shannon (1985) and Kelvin and Quaslet (1991) for breeding genotypes for salt tolerance. In the present study, S-24 and Sids-6 were superior in tolerance to salinity with respect to both agronomic and yield attributes on the basis of mean value across salinity treatments and low salinity stress indices. These genotypes could be used in breeding programs with local genotypes in order to develop high yielding elite genotypes tolerant to a range of salinity levels or to a desired level of salinity under field conditions.

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