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Response of selected barley genotypes to different levels of irrigation water salinity

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Abstract. Four nationally recommended barley genotypes namely, J-51, J-54, J-58 and J-98 along with exotic variety, Dictator and international check, Beecher were investigated for their response to six levels of irrigation water salinity viz. control (1 dSm^{-1}), 3, 6, 9, 12 and 15 dSm^{-1} consecutively for two years during winter seasons of 2007-2008 and 2008-2009 (November to March) under field conditions. The results indicated that the effects of salinity, genotypes and their interaction were highly significant ($p < 0.01$) for plant height, leaf length, leaf width, number of tillers and dry matter % in both years. The main effects of salinity and genotypes were highly significant only in respect of green matter and dry matter yields ($p < 0.01$) at harvest in both years. However, only the effect of salinity was significant ($p < 0.05$) for chlorophyll content. Adverse effect of salinity was observed in all the genotypes for all characters. Salinity tolerance of barley genotypes was assessed applying the concepts of lower stress susceptibility indexes at each higher salinity level in relation to control and higher meanvalues over the salinity treatments with respect to each character for selecting the most tolerant genotypes. Among all the genotypes tested, the salinity tolerance of J-58 was of higher order and consistency as it scored high mean values across salinity environments (levels) for all the characters except leaf width, followed by J-51 which also scored higher mean values across salinity environments (levels) in respect of six out of eight characters viz. plant height, leaf length, leaf width and green and dry matter yields. The values of stress susceptibility index, however, were found inconsistent to provide any clue for comparative salinity tolerance of the genotypes, studied. Beecher and J-98 were assessed in general as moderately tolerant whereas Dictator and J-98 were sensitive to salinity.

Keywords: Salinity, irrigation water, tolerance, growth, yield, barley.

INTRODUCTION

Since couple of decades, arid and semi-arid regions of the world have been suffering from either soil salinity due to improper irrigation practices or by water salinity all along their coasts due to sea water intrusion. These conditions have adversely affected the production, productivity and quality in several crops that are grown (Flowers and Yeo, 1995; Chinnusamy et al., 2005). Under such conditions, instead of using reclamation methods that further add to costs of cultivation, there is need of research to seek salt tolerant varieties of crops grown in the region which can be subsequently used in crop improvement for high yield and quality through breeding. Both plant breeders and physiologists are now developing salt tolerant varieties in different crops (Chinnusamy et al., 2005; Colmer et al., 2006; Babu et al., 2007). The criteria of assessment and selection of varieties for salt tolerance adapted are not consistent among the researchers (Nadaf et al., 2001 in wheat and Taghipour and Salehi, 2008 and Shafi et al., 2013 in barley). Some authors considered overall means over salinity environments (Shannon et al., 1985; Abdennaceur et al., 2012; Shafi et al., 2013) while others relied on indexes based on computations using values of performance in salinity and control environments (Fischer and Maurer, 1978; Rawson et al., 1988; Kelman and Qualset, 1991; Nadaf et al., 2001). Barley (*Hordeum vulgare* L.) forage yields are dependent upon agronomic growth attributes like plant height, number of tillers/ plant, leaf length and leaf width etc. Abiotic stresses like salinity and drought are known to adversely affect development of these characters. Several workers indicated the effect of salinity on different growth and yield characters at different stages of growth (Nadaf et al., 2001; Nadaf et al., 2008; Taghipour and Salehi, 2008; Bakht et al., 2011). Keeping in view of the above information, the present investigation was conducted to study the effects of different levels of irrigation water salinity on agronomic traits, dry matter % and dry matter weight of six barley genotypes/varieties under field conditions.

MATERIALS AND METHODS

The trial was conducted in two consecutive winter seasons of 2007-2008 and 2008-2009 under drips in modified two-factor RCBD with three replications during winter season (November to March) using six genotypes of barley viz. J-51, J-54, J-58, J-98, Dictator and Beecher under six levels of irrigation water salinity viz. Control (1 dSm^{-1}), 3, 6, 9 , 12 and 15dSm^{-1} on a sandy soil site at Rumais Research Station located in the coastal line of Al-Batinah governorate of Oman. The physical and chemical characteristics of the experimental soil and the chemical characteristics of the irrigation water treatments determined during two cropping seasons are presented in Tables 1(a and b) and 2 (a and b), respectively (Chapman and Pratt, 1961)

Available ground water of electrical conductivity 36.5 ± 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 low calcium to magnesium ratio. The salinity treatments were prepared in separate water tanks by diluting the available ground water by control water (1 ± 0.20 dS m^{-1}) for supply of irrigation water of desired level of salinity to respective salinity blocks having plots of test barley cultivars.

In each salinity block, two seeds per spot were planted at plant to plant spacing of 10 cm in 5-drip rows / genotype that were 25 cm apart. All the crop husbandry practices were followed as per national recommendations. The plots were fertilized with 100 kg N/ha, 90 kg P_2O_5/ha and 60 kg K_2O/ha in the form of urea (200 kg/ha), triple super phosphate (180 kg/ha) and potassium sulphate (120 kg/ha). 1/3 of nitrogen and all of phosphate and potash were applied before sowing. The rest of nitrogen was applied in two further splits, 1/3 after two weeks of sowing (after germination) and the last 1/3 after one month of planting. The fertilizers were applied manually at 8 to 10 cm distance from the plants. The crops were irrigated through drips very gently till germination and later at two-day intervals till soil attained near to a stage of field capacity. Barley genotypes attained 50 % blooming between 90 and 100 days after planting and were harvested for green forage after 100 days of planting.

Recording of observations on growth and yield parameters was made at harvest. The observations on plant height (cm), number of tillers /m^2, leaf length (cm), leaf width (cm) and leaf chlorophyll content (SPAD value) were recorded. Leaf chlorophyll was recorded in the field by using Chlorophyll Meter SPAD-502 on three sample sites of a leaf prior to the top leaf at 30 and 60 days after planting and of a leaf prior to the flag leaf at 50 % flowering (70 days after planting) which gives a value called SPAD value that corresponds to the amount of chlorophyll present in the leaf sample. Green matter weight (kg) was recorded from the plants of middle 1 m length of any one of three rows selected at random. Plant samples of all replications were taken to the laboratory for estimating dry matter percent for each genotype. Green matter weights per meter-row length were transformed into yields/ha. Dry matter weights/ha were computed using dry matter %. The data were subjected to statistical analyses considering salinity and genotypes as factors adapting ANOVA having only one error component according to the methods of Gomez and Gomez (1984) using MSTAT-C. Stress susceptibility index, S for each genotype 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

Tables 1a and 1b present the values of physical characters of experimental soils of two winter seasons 2007-2008 and 2008-2009, respectively. The physical characters indicated that the soils of experimental sites were sandy in nature comprising more than 69% of fine sand with variable % of gravel, coarse sand and clay in both the years. However, 1.8 to 4.8% of silt was found in the soils of 2008-2009 at different salinity levels. In general, salinity (ECe) of experimental soil at top depth (0 to 15 cm) was found higher than that at lower depth (15 to 30 cm) in both the years whereas it was opposite in respect of pH (Tables 1a and b). All the soluble cations

Table 1a. Values of physical and chemical characteristics of experimental soil before planting during winter 2007-2008.

Characteristics	Control (<1 dSm^{-1})		3 dSm^{-1}		6 dSm^{-1}		9 dSm^{-1}		12 dSm^{-1}		15 dSm^{-1}	
Soil depth (cm)	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
Physical												
Gravel (%)	11.10	12.40	7.60	7.20	7.00	8.30	8.90	8.00	7.80	7.90	11.80	11.30
Coarse sand (%)	19.80	16.20	13.60	17.10	13.40	15.10	14.30	13.30	17.00	14.40	14.50	17.70
Fine sand (%)	89.70	74.30	76.90	74.40	78.10	77.40	78.20	77.20	76.50	79.10	76.00	75.80
Silt (%)	3.80	3.80	3.80	4.80	3.80	1.80	2.80	3.80	1.80	1.80	3.80	2.80
Clay (%)	5.70	5.68	5.70	3.70	4.70	5.70	4.70	5.70	4.70	4.70	5.70	3.70
Texture	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy
Chemical												
ECe (dSm^{-1})	1.95	1.28	1.32	2.64	2.11	1.46	2.62	1.64	4.19	2.92	3.57	1.88
pH	8.5	8.7	8.5	8.4	8.3	8.5	8.3	8.5	8.3	8.4	8.3	8.4
Soluble cations ($mmol_c/L$)												
Ca	3.60	2.00	1.80	3.20	2.80	1.60	5.80	3.20	10.00	3.20	8.00	5.60
Mg	2.40	1.20	4.60	5.20	4.00	1.20	11.40	6.00	10.00	8.40	12.00	8.40
Na	6.40	7.20	6.00	5.80	5.60	6.20	5.60	6.50	6.80	7.90	30.70	29.00
Soluble anions ($mmol_c/L$)												
CO_3	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
HCO_3	3.60	3.20	3.00	2.00	2.60	2.40	2.20	2.40	1.40	2.20	2.00	1.80
Cl	7.00	9.00	8.00	6.00	12.00	10.00	22.00	10.00	28.00	14.00	32.00	20.00
N (%)	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.02
P (%)	26.00	22.00	46.00	20.00	14.00	16.00	15.00	23.00	15.00	32.00	15.00	23.00
K ($mmol_c$/100 g)	20.70	17.80	13.80	16.20	23.20	22.10	11.60	16.10	13.10	14.30	20.30	20.10

viz. Ca, Mg and Na and anions like HCO_3 and Cl were found to be higher in top soil than at lower depth whereas in respect of other elements, concentrations were in-consistent with soil depth. The values of chemical characteristics of irrigation water at different salinity levels indicated all the cations viz. Ca, Mg, Na and K and anions like Cl were higher in concentration as levels of salinity increased whereas contents of other anions were not consistent with increase or decrease in salinity levels (Tables 1a and b). Similar observations were made by Nadaf et al*.* (2001b)

In respect of chemical contents in irrigation water, all the cations viz. Ca, Mg, Na and K and anions like Cl were found to be increased at higher levels of salinity as compared to control in both the years. However, contents of HCO3 and values of Sodium Adsorption Ratio (SAR) were inconsistent at higher levels of salinity as compared to control without showing any definite trend (Tables 2a and b).

Tables 3 and 4 present the means of characters of six barley genotypes and their stress susceptibility indices ($S_{c.j}$) based on characters at harvest (100^{th} day) during winter seasons of 2007-2008 and 2008-2009, respectively. The results indicated that all the effects of salinity, genotypes and their interaction were highly significant ($p< 0.01$) for plant height, leaf length, leaf width, number of number of tillers and dry matter %.

Table 1b. Values of physical and chemical characteristics of experimental soil before planting during winter 2008-2009.

Characteristics	Control (<1 dSm^{-1})		3 dSm^{-1}		6 dSm^{-1}		9 dSm^{-1}		12 dSm^{-1}		15 dSm^{-1}	
Soil depth (cm)	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
Physical												
Gravel (%)	11.40	10.50	11.50	10.00	10.70	11.60	11.40	10.10	10.40	9.80	11.40	12.00
Coarse sand (%)	18.60	14.00	16.90	16.70	23.20	15.30	28.90	13.80	22.20	15.40	22.00	16.60
Fine sand (%)	74.80	76.50	76.50	74.80	71.80	77.20	66.10	75.70	69.20	78.10	71.40	75.90
Clay (%)	5.00	5.70	5.00	3.70	4.60	4.70	4.60	5.70	5.00	4.70	5.00	4.70
Texture	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy
Chemical												
ECe (dSm^{-1})	3.19	3.54	7.13	5.80	10.81	9.96	10.97	9.20	12.42	12.35	20.40	19.46
pH	7.9	8.1	7.6	7.6	7.5	7.6	7.4	7.4	7.6	7.7	7.5	7.6
Soluble cations (mmol$_c$/L)												
Ca	4.26	5.26	7.58	7.60	15.40	14.20	15.60	17.00	12.60	8.92	27.00	25.50
Mg	4.36	5.58	14.28	11.74	24.56	31.70	33.06	34.70	29.76	22.52	59.46	60.44
Na	16.96	13.91	22.17	20.87	24.35	42.17	44.35	56.09	45.22	44.35	65.22	44.78
Soluble anions (mmol$_c$/L)												
CO_3	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace	trace
HCO_3	4.06	4.64	3.74	4.08	5.16	3.78	5.34	3.84	2.76	3.08	5.58	5.48
Cl	26.90	27.90	62.90	50.30	125.00	162.40	152.20	117.90	133.90	182.60	237.20	241.50
N (%)	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.02
P (%)	26.00	22.00	46.00	20.00	14.00	16.00	15.00	23.00	15.00	32.00	15.00	23.00
K (mmol$_c$/100 g)	50.00	50.00	40.00	40.00	40.00	40.00	30.00	40.00	40.00	40.00	60.00	60.00

The main effects of salinity and genotypes were highly significant only in respect of green matter and dry matter yields ($p < 0.01$) at harvest in both years. However, only the effect of salinity was significant ($p < 0.05$) for chlorophyll content. Adverse effect of salinity was observed in all the genotypes depending on the their salt sensitiveness for all characters (Abdennaceur et al., 2012; Shafi et al., 2013) due to which stress susceptibility index values were found to vary for each character among the genotypes with different levels of salinity in both years (Nadaf et al., 2001a)

In respect of plant height, in both years, there was significant reduction in mean plant height with increased level of salinity ($p < 0.05$). However, decrease in plant height from control to 3 dS m^{-1}and from 9 dS m^{-1} to 12 and 15 dS m^{-1}and from 12 dS m^{-1} to 15 dS m^{-1} was not significant in 2007-2008 (Table 3) whereas in 2008-09 decrease was not significant only between 9 dS m^{-1} to 12 and between 12 dS m^{-1} to 15 dS m^{-1} (Table 4). The decrease from control to 3 dS m^{-1} was 8.75% in 2007-2008 and 9.17% in 2008-2009 while the reduction in plant height was to the extent of 22.10% in 2008-2009 to 23.45% in 2007-2008 at 6 dS m^{-1} as compared to control. Further decrease in plant height at higher salinity levels was drastic to over 70% in both the years. In both the years, J 58 (57.89 and 55.23 cm) recorded highest mean plant height followed by J 51 (52.88 and 52.54 cm) and Dictator (47.69 and 46.83 cm) among the varieties.

Table 2a. Values of chemical characteristics of irrigation water treatments during winter 2007- 2008.

Ionic contents	Control (<1 dSm^{-1})	3 dSm-1	6 dSm^{-1}	9 dSm^{-1}	12 dSm^{-1}	15 dSm-1
Cations (mmolc/L)						
Ca	0.40	2.60	5.60	8.20	12.40	14.40
Mg	0.60	10.00	21.80	34.20	46.80	59.20
Na	7.70	26.30	37.40	45.90	54.10	62.80
K	0.10	0.30	0.50	0.70	0.80	1.00
Anions (mmolc/L)						
HCO3	0.70	0.80	0.70	0.70	0.90	0.90
CO3	trace	trace	trace	trace	trace	trace
Cl	7.00	28.00	56.00	83.00	113.00	123.00
SAR	11.00	10.52	10.11	9.98	9.94	10.36

Table 2b. Values of chemical characteristics of irrigation water treatments during winter 2008-2009.

Ionic contents	Control (<1 dSm^{-1})	3 dSm^{-1}	6 dSm^{-1}	9 dSm^{-1}	12 dSm^{-1}	15 dSm^{-1}
Cations ($mmol_c$/L)						
Ca	1.58	3.30	7.84	9.42	11.24	14.10
Mg	2.42	12.00	28.70	34.66	42.06	56.42
Na	6.74	11.78	55.22	66.96	76.52	78.70
K	0.10	0.23	0.49	0.56	0.72	0.87
Anions ($mmol_c$/L)						
HCO3	0.52	0.64	0.92	0.90	0.94	1.10
CO3	trace	trace	trace	trace	trace	trace
Cl	3.20	8.80	74.60	92.00	116.80	148.80
SAR	4.77	4.26	12.92	14.26	14.82	13.25

Stress susceptibility index values of J-58 and J-51 were low and consistent in both years at all higher levels of salinity in relation to control, indicating their superiority in tolerance to salinity (Tables 3 and 4).

In general, number of tillers was found to have decreased gradually and significantly from control to subsequent levels of salinity in both years ($p < 0.05$). The reduction was drastic at salinity levels of 12 and 15 dS m^{-1} (Tables 3 and 4). J 98 (128.78 and 128.07), J 58 (125.78 and 125.03) and J 51 (101.44 and 101.27) recorded higher number of tillers in both years as compared to other genotypes. Similar observations were made earlier by several workers (Abdennaceur et al., 2012). J 98 and J 54 showed low stress susceptibility index values in both years at all higher levels of salinity in relation to control.

Leaf length was reduced significantly ($p < 0.05$) with increasing salinity levels from control in both years (Tables 3 and 4). The decrease in leaf length from control to 3 and 6 dS m^{-1} was about 8% and less in both the years while at 15 dS m^{-1} it was 27.75 % in 2007-2008 and 28.92% in 2008-2009. J 58 and J 51 had longest leaf length of over 20 cm in both the years. Leaf width was seen decreased significantly ($p < 0.05$) with increasing salinity levels from control in both years (Tables 3 and 4). The decrease in leaf width from control to 3 and 6 dS m^{-1} was less than 10% in both the years while it was 39.16% and more in subsequently higher levels of salinity in both the years. Beecher and Dictator recorded higher leaf width of 1.4 cm and above as compared to other varieties in both the years. J 51 had consistently low stress susceptibility index values in both years in respect of both these characters followed by J 54 for leaf length and J 58 for leaf width. Similar observations were made earlier by several workers (Taghipour and Salehi, 2008; Abdennaceur et al., 2012).

There was gradual and significant decrease in chlorophyll content ($p < 0.05$) with increasing salinity levels from control in both years (Tables 3 and 4). The decrease was gradual from control till 15 dS m^{-1} to the extent of 17 % in 2007-2008 and 25 % in 2008-2009. This is also observed by Khalaf and Salih (2013). Beecher recorded highest contents of chlorophyll (40.41 and 39.25) followed by J 98 (37.94 and 38.74) in both the years. However, J 98 and J 51 had consistently low stress susceptibility index values in both years.

Both green and dry matter yields also showed progressive and significant ($p < 0.05$) decrease in trend at

Table 3. Means of agronomic characters of barley genotypes at different salinity levels and their stress susceptibility indexes (S_{ij}) based on respective characters during winter 2007-2008.

Characters	Genotypes	Control	3 dSm^{-1}	6 dSm^{-1}	9 dSm^{-1}	12 dSm^{-1}	15 dSm^{-1}	Mean	Sc3	Sc6	Sc9	Sc12	Sc15
Plant height (cm)	J 51	92.80	83.70	67.40	29.17	22.27	21.93	52.88	1.12	1.17	0.95	0.99	0.98
	J 54	75.80	63.53	56.07	18.30	16.03	15.07	40.80	1.85	1.11	1.05	1.02	1.03
	J 58	101.27	93.83	73.13	29.67	24.63	24.83	57.89	0.84	1.18	0.98	0.98	0.97
	J 98	74.97	71.80	62.07	23.43	17.77	17.70	44.62	0.48	0.73	0.95	0.99	0.98
	Beecher	74.57	65.37	56.67	21.30	21.83	21.10	43.47	1.41	1.02	0.99	0.92	0.92
	Dictator	86.57	83.47	71.93	17.37	14.17	12.63	47.69	0.41	0.72	1.10	1.09	1.10
	Mean	84.33	76.95	64.55	23.21	19.45	18.88						
Tiller No./m^2	J 51	164.67	141.33	121.33	76.00	66.00	39.33	101.44	1.45	1.06	2.09	1.07	1.02
	J 54	114.00	103.33	78.00	126.00	72.00	40.00	88.89	0.96	1.27	-0.41	0.66	0.87
	J 58	205.33	196.00	128.00	122.67	62.67	40.00	125.78	0.46	1.52	1.57	1.25	1.08
	J 98	178.67	158.67	158.00	167.33	71.33	38.67	128.78	1.14	0.47	0.25	1.08	1.05
	Beecher	135.33	110.00	98.67	93.33	68.67	42.00	91.33	1.91	1.09	1.21	0.88	0.93
	Dictator	122.00	120.67	107.33	98.00	66.00	34.67	91.45	0.11	0.48	0.76	0.82	0.96
	Mean	153.33	138.33	115.22	113.89	67.78	39.11						
Leaf length (cm)	J 51	23.23	22.40	22.90	22.31	19.93	17.47	21.37	0.55	0.16	0.28	0.58	0.89
	J 54	16.63	16.63	15.91	15.37	13.47	13.63	15.27	0.00	0.50	0.53	0.77	0.65
	J 58	25.40	23.53	22.83	22.57	19.37	19.93	22.27	1.14	1.17	0.78	0.96	0.78
	J 98	20.90	18.77	18.57	17.97	15.47	14.77	17.74	1.58	1.29	0.98	1.05	1.06
	Beecher	24.67	21.80	20.23	18.13	17.14	17.10	19.85	1.81	2.08	1.86	1.24	1.11
	Dictator	18.67	18.03	17.83	14.63	12.11	10.63	15.32	0.53	0.52	1.52	1.42	1.55
	Mean	21.58	20.19	19.71	18.50	16.25	15.59						
Leaf width (cm)	J 51	1.60	1.60	1.50	0.98	0.97	0.97	1.27	0.00	0.86	0.99	0.93	0.88
	J 54	1.27	1.20	1.20	0.83	0.83	0.77	1.02	1.31	0.76	0.88	0.82	0.88
	J 58	1.57	1.53	1.47	0.93	0.93	0.93	1.23	0.60	0.88	1.04	0.97	0.91
	J 98	1.67	1.57	1.57	0.97	0.93	0.87	1.26	1.42	0.83	1.07	1.05	1.07
	Beecher	2.03	1.93	1.77	1.21	1.13	1.10	1.53	1.17	1.77	1.03	1.05	1.03
	Dictator	1.83	1.70	1.70	1.13	0.97	0.87	1.37	1.68	0.98	0.98	1.11	1.18
	Mean	1.66	1.59	1.54	1.01	0.96	0.92						
Chlorophyll	J 51	39.57	39.16	37.80	35.19	34.03	31.61	36.23	0.23	0.58	0.91	0.82	1.10
	J 54	39.68	38.20	35.62	33.54	31.27	30.82	34.86	0.81	1.33	1.27	1.24	1.22
	J 58	38.43	33.81	33.07	32.34	30.52	30.17	33.06	2.62	1.81	1.30	1.20	1.18
	J 98	41.18	40.91	40.44	39.62	33.96	31.52	37.94	0.14	0.23	0.31	1.02	1.28

Table 3. Contd.

	Beecher	46.14	42.31	39.88	38.83	38.23	37.09	40.41	1.81	1.76	1.30	1.00	1.07
	Dictator	38.54	38.01	37.97	34.35	33.81	37.83	36.75	0.30	0.19	0.89	0.72	0.10
	Mean	40.59	38.73	37.46	35.65	33.64	33.17						
Green matter yield (t/ha)	J 51	14.86	11.97	5.30	2.15	2.34	1.49	6.35	-7.42	1.57	1.02	0.98	1.02
	J 54	5.75	8.61	3.83	1.71	1.25	1.51	3.78	18.97	0.81	0.84	0.91	0.84
	J 58	11.53	12.54	9.85	3.01	2.18	1.72	6.81	3.34	0.35	0.88	0.94	0.97
	J 98	11.26	9.77	7.09	1.42	1.06	1.33	5.32	-5.05	0.90	1.04	1.05	1.00
	Beecher	12.81	12.40	6.73	1.23	1.50	1.21	5.98	-1.22	1.16	1.08	1.03	1.03
	Dictator	10.12	12.79	6.33	1.22	1.03	0.85	5.39	10.06	0.91	1.05	1.05	1.04
	Mean	11.06	11.35	6.52	1.79	1.56	1.35						
Dry matter yield (t/ha)	J 51	7.02	4.90	2.10	0.88	1.00	0.44	2.72	5.71	1.53	0.98	0.95	1.02
	J 54	2.36	2.74	1.51	0.37	0.24	0.51	1.29	-3.05	0.79	0.95	1.00	0.85
	J 58	5.35	4.57	4.20	1.04	0.85	0.59	2.77	2.76	0.47	0.90	0.94	0.97
	J 98	4.72	4.88	2.93	0.37	0.23	0.38	2.25	-0.64	0.83	1.04	1.06	1.00
	Beecher	5.42	5.71	2.99	0.28	0.44	0.30	2.52	-1.01	0.98	1.07	1.02	1.03
	Dictator	4.62	5.13	2.27	0.28	0.21	0.12	2.11	-2.09	1.11	1.06	1.06	1.06
	Mean	4.92	4.66	2.67	0.54	0.50	0.39						

Statistical parameters

ANOVA	Plant height		No. of tillers/m		Leaf length (cm)		Leaf width (cm)		Chlorophyll		Green matter weight (t/ha)		Dry matter %		Dry matter weight (t/ha)	
	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%
Rep	NS	-	NS	-	**	1.36	**	0.07	NS	-	NS	-	*	0.84	NS	-
Salinity	**	3.58	**	17.33	**	1.92	**	0.09	*	3.58	**	1.62	**	1.19	**	0.26
Genotypes	**	3.58	**	17.33	**	1.92	**	0.09	NS	-	**	1.62	**	1.19	**	0.26
Salinity × Variety	**	8.81	**	42.45	**	4.71-	**	0.23	NS	-	NS	-	**	2.92	NS	-
CV (%)	11.47		25.36		15.74		11.12		14.84		43.76		5.22		32.15	

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

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

higher salinity levels in both years (Tables 3 and 4). However, both mean green and dry matter yields were not different in 3 dS m^{-1} as compared to control in 2007-2008 ($p > 0.05$) while it was found significantly decreased in 2008-2009 ($p < 0.01$). The decrease in green and dry matter yields were highly significant at 6 dS m^{-1} to the extent 41% in 2007-2008 and 47% in 2008-2009 whereas it was 87.79 % in 2007-2008 and 90.03%

Table 4. Means of agronomic characters of barley genotypes at different salinity levels and their stress susceptibility indexes (S_{ij}) based on respective characters during winter 2008-2009.

Characters	Genotype	Control	3 dSm^{-1}	6 dSm^{-1}	9 dSm^{-1}	12 dSm^{-1}	15 dSm^{-1}	Mean	Sc3	Sc6	Sc9	Sc12	Sc15
Plant height (cm)	J 51	91.69	82.68	65.39	27.16	26.03	22.27	52.54	1.07	1.30	0.98	0.95	0.99
	J 54	73.69	62.41	54.06	18.30	16.03	15.07	39.93	1.67	1.21	1.04	1.04	1.04
	J 58	99.43	82.73	71.11	28.66	24.83	24.63	55.23	1.83	1.29	0.99	1.00	0.98
	J 98	69.81	64.86	60.04	22.39	17.68	16.76	41.92	0.77	0.63	0.94	0.99	0.99
	Beecher	63.55	63.34	54.66	21.62	21.28	21.10	40.93	0.04	0.63	0.91	0.89	0.87
	Dictator	84.56	82.45	70.83	16.35	14.16	12.63	46.83	0.27	0.74	1.12	1.11	1.11
	Mean	80.46	73.08	62.68	22.41	20.00	18.74						
No. of tillers/m	J 51	164.33	141.66	121.00	76.33	65.00	39.28	101.27	1.47	1.15	1.69	1.07	1.02
	J 54	125.47	113.86	103.00	77.87	71.34	39.26	88.47	0.99	0.78	1.20	0.76	0.92
	J 58	203.22	194.67	127.96	121.66	62.64	40.02	125.03	0.45	1.62	1.27	1.23	1.07
	J 98	176.65	158.56	157.23	166.30	71.22	38.46	128.07	1.09	0.48	0.19	1.06	1.05
	Beecher	135.12	109.87	98.56	93.22	68.55	41.89	91.20	2.00	1.18	0.98	0.87	0.92
	Dictator	121.06	120.56	106.36	97.88	64.76	34.26	90.81	0.04	0.53	0.61	0.82	0.96
	Mean	154.31	139.86	119.02	105.54	67.25	38.86						
Leaf length (cm)	J 51	23.67	23.12	22.85	22.37	19.63	17.42	21.51	0.37	0.34	0.38	0.69	0.91
	J 54	16.90	16.61	16.59	15.34	13.61	13.43	15.41	0.27	0.18	0.64	0.78	0.71
	J 58	25.39	23.83	22.57	22.53	19.83	19.36	22.25	0.97	1.09	0.78	0.88	0.82
	J 98	20.88	18.87	18.76	18.55	15.46	14.74	17.88	1.52	1.00	0.77	1.05	1.02
	Beecher	24.66	21.79	20.21	18.11	17.38	17.00	19.86	1.84	1.77	1.84	1.19	1.07
	Dictator	18.76	17.81	16.02	14.60	12.02	10.61	14.97	0.80	1.43	1.54	1.45	1.50
	Mean	21.71	20.34	19.50	18.58	16.32	15.43						
Leaf width (cm)	J 51	1.58	1.56	1.47	0.94	0.94	0.88	1.23	0.34	0.63	0.98	0.82	0.81
	J 54	1.25	1.18	1.16	0.81	0.76	0.62	0.96	1.51	0.65	0.85	0.80	0.92
	J 58	1.76	1.56	1.52	0.93	0.92	0.91	1.27	3.07	1.23	1.14	0.97	0.89
	J 98	1.66	1.56	1.50	0.92	0.90	0.86	1.23	1.63	0.87	1.08	0.93	0.88
	Beecher	2.02	1.90	1.76	1.10	1.08	1.01	1.48	1.60	1.16	1.10	0.95	0.92
	Dictator	1.89	1.82	1.68	1.11	0.96	0.86	1.39	0.65	1.06	0.96	1.09	1.10
	Mean	1.69	1.60	1.52	0.97	0.93	0.86						
Chlorophyll	J 51	38.14	38.11	37.60	35.14	32.03	30.40	35.24	0.02	0.24	0.65	0.98	0.81
	J 54	41.82	39.66	37.20	36.42	34.62	23.51	35.54	1.31	1.84	1.07	1.05	1.74
	J 58	40.17	39.52	38.81	33.43	33.34	32.07	36.22	0.41	0.56	1.40	1.04	0.80
	J 98	41.36	41.12	40.62	39.44	35.96	33.94	38.74	0.15	0.30	0.39	0.80	0.71

Table 4. Contd.

	Beecher	46.09	39.88	39.14	38.21	36.13	36.05	39.25	3.41	2.51	1.42	1.32	0.87
	Dictator	38.41	37.97	37.82	33.79	33.54	28.16	34.95	0.29	0.26	1.00	0.77	1.06
	Mean	41.00	39.38	38.53	36.07	34.27	30.69						
	J 51	14.68	11.79	5.27	2.33	2.13	1.46	6.28	1.26	1.36	0.99	0.98	1.00
	J 54	8.41	5.57	3.62	1.69	1.49	1.14	3.65	2.15	1.21	0.94	0.94	0.96
	J 58	12.44	11.43	9.58	2.89	2.15	1.62	6.69	0.52	0.49	0.90	0.95	0.97
Green matter yield (t/ha)	J 98	11.24	9.67	7.06	1.39	1.21	1.02	5.27	0.89	0.79	1.03	1.02	1.01
	Beecher	12.72	12.38	6.53	1.37	1.13	1.11	5.87	0.17	1.04	1.05	1.04	1.01
	Dictator	12.76	10.08	6.23	1.18	1.01	0.82	5.35	1.34	1.09	1.07	1.05	1.04
	Mean	12.04	10.15	6.38	1.81	1.52	1.20						
	J 51	6.92	5.02	2.15	0.94	0.84	0.43	2.72	1.18	1.25	0.97	0.96	0.99
	J 54	3.44	2.19	1.23	0.53	0.32	0.22	1.32	1.57	1.16	0.95	0.99	0.99
	J 58	5.76	4.86	3.71	1.05	0.74	0.55	2.78	0.68	0.65	0.92	0.95	0.95
Dry matter yield (t/ha)	J 98	5.60	4.04	2.90	0.39	0.31	0.22	2.24	1.20	0.87	1.04	1.03	1.02
	Beecher	5.85	5.49	2.76	0.40	0.28	0.25	2.51	0.27	0.96	1.04	1.04	1.01
	Dictator	5.81	4.04	2.23	0.27	0.20	0.12	2.11	1.31	1.12	1.07	1.05	1.04
	Mean	5.57	4.27	2.50	0.60	0.45	0.30						

Statistical parameters

ANOVA	Plant height (cm)		No. of tillers (m)		Leaf length (cm)		Leaf width (cm)		Chlorophyll		Green matter weight (t/ha)		Dry matter (%)		Dry matter weight (t/ha)	
	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%	F-test	LSD 5%
Rep	NS	-	NS	-	**	1.34	**	0.05	NS	-	NS	-	*	0.81	NS	-
Salinity	**	3.56	**	16.22	**	1.88	**	0.07	*	3.56	**	1.53	**	1.16	**	0.21
Genotypes	**	3.56	**	16.22	**	1.88	**	0.07	NS	-	**	1.53	**	1.16	**	0.21
Salinity × genotype	**	8.79	**	40.46	**	4.69	**	0.21	NS	-	NS	-	**	2.92	NS	-
CV%																

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

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

in 2008-2009 at 15 dS m^{-1} in green matter yield while this decrease at 6 dS m^{-1} was 45.73% in 2007-2008 and 55.12% in 2008-2009. Among the varieties, J 58 (6.81 and 6.69 t/ha of green matter yield in 2007-2008 and 2008-2009, respectively and 2.77 and 2.72 t/ha of dry matter yield in 2007-2008 and 2008-2009, respectively) and J 51 (6.69 and 6.28 t/ha of green matter yield in2007-2008 and 2008-2009, respectively and 2.78 and2.72 t/ha of dry matter yield in 2007-2008 and 2008-2009, respectively) significantly ($p < 0.01$) out yielded rest of the varieties in respect of mean performance over salinity levels. However, in respect of stress susceptible index, J-51, J-98 and J-58 had low values in both years indicating their relative tolerance to salinity with respect to both green and dry matter yields.

In the present study, salinity tolerance of barley varieties was evaluated considering their lower values of stress susceptibility index at higher salinity levels in comparison with control and higher mean values over the salinity treatments with respect to all the characters (Nadaf et al., 2001a and b). Among all the genotypes tested, the salinity tolerance of J-51 and J-58 was of higher degree and more consistent as they scored high mean values across salinity environments (levels) for at leastfour characters viz. plant height, leaf length, green and dry matter weights, out of seven charactersstudied. The values of stress susceptible index of J-51 and J-58, however, were lower but inconsistent indicating their superiority in salinity tolerance to other genotypes, studied. All other genotypes, however, responded differentially to different levels of salinity for different characters. Beecher and J-98 were moderately tolerant whereas Dictator and J-98 were sensitive to salinity.

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