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Full Length Research Paper

Evaluation of bread wheat genotypes for salinity tolerance under saline field conditions

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In two consecutive seasons (2007-08 and 2008-09), field experiments were conducted at Soil Salinity Research Institute, Pindi Bhattian and Biosaline Agricultural Research Station, Pakka Aana, Pakistan. During 2007-08, 103 wheat landrace genotypes were evaluated for salinity tolerance. During 2008-09, 47 selected genotypes were evaluated at the same locations. Combined analysis of both locations during both years revealed that genotypes differed significantly for plant height, dry biomass m^{-2}, fertile tillers plan^{-1}, spike length, grain spike^{-1}, 1000 seed weight and yield m^{-2}. Grain yield had strong positive correlation with plant height, dry biomass, spike length, spikelets spike^{-1}, grain spike^{-1} and 1000 grain weight. Due to this positive correlation, yield can be used as a selection criterion under saline field conditions. Accessions 10807 (Pak), 11299 (Pak), 11917 (Iran) and cultivars Pavon (Pak) performed better during both years. These genotypes could be effectively used as new sources of salt tolerance.

Key words: Genetic divergence, bread wheat, field evaluation, salinity tolerance.

INTRODUCTION

Salinity is a major abiotic stress limiting crop production in many agricultural regions of the world (Katerji et al., 2009). Over 800 million hectares of land are affected by salt worldwide (Munns, 2005). Some of the most serious examples of salinity occur in the arid and semiarid regions. In Pakistan, more than 10 million hectares are affected by salt (FAO, 2008). A low level of salinity may not reduce grain yield, although shoot biomass is reduced, which is reflected in a harvest index. Wheat yield is substantially reduced as the soil salinity level rises to 100 mM NaCl (Munns et al., 2006).

Screening large population for salinity tolerance in the field is difficult due to tremendous heterogeneity of saline soils (Richards, 1983). However, various statistical techniques have been used to tackle similar problems, e.g. by blocking, particularly the use of small blocks (Bartlett, 1978). These have reduced error variations and increased detection of varietal differences, and can be adapted to cope with the high heterogeneity of saline fields. Most of the experiments are carried out under controlled conditions where plants are not exposed to those conditions that prevail in salt affected field conditions such as spatial and temporal heterogeneity of soil chemical and physical properties (Munns and James, 2003). Therefore, salt tolerance of genotypes under field conditions needs to be evaluated particularly as a function of yield that is considered as a foremost target of the plant breeder (Yamaguchi and Blumwald, 2005).

Kingsbury and Epstein (1984) evaluated 5000 accessions of bread wheat in 50% seawater and identified 29 accessions that produced seed. Jafari-Shabestari et al. (1995) evaluated 400 Iranian wheat genotypes in irrigated field conditions in California and identified numerous accessions that were consistently high for grain yield in both low and high salinity treatments. Ahmad et al. (2005) studied six wheat varieties in salt affected soils and reported that salt tolerant varieties

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Abbreviations: EC_e, Electrical conductivity; SAR, sodium absorption ratio; SSRI, soil salinity research institute; BARS, Biosaline Agricultural Research Station; RSCw, residual sodium carbonate.

Table 1 Physico-chemical analysis of the soils sampled from site 1 (BARS) and site 2 (SSRI).

Season		2007-2008		2008-2009	
Parameter	**Unit**	**Site 1**	**Site 2**	**Site 1**	**Site 2**
pH	–	8.1	8.3	8.2	8.4
EC_e	dS m^{-1}	16.9	13.4	17.8	14.6
SAR	–	1.72	14.32	5.49	16.45
$CaCO_3$	%	1.42	1.23	1.39	1.21
OM	%	0.70	0.30	0.69	0.29
N	%	0.03	0.04	0.03	0.02
Extractable P	mg kg^{-1}	4.12	3.47	3.75	2.10
Extractable K	mg kg^{-1}	33.5	54.6	35.4	55.5
Sand	%	42.7	12.5	-	-
Silt	%	37.2	34.2	-	-
Clay	%	20.1	53.3	-	-
Textural class	–	Sandy loam	Clayey	-	-

Table 2. Analysis of variance of 7 traits studied in 103 wheat genotypes at SSRI and BARS during 2007-08.

Source of variation	Sum of squares (Percentage of total)						
	Plant height (cm)	**Total bio mass m^{-2} (g)**	**Spike length (cm)**	**Spikelets $spike^{-1}$**	**Grains $spike^{-1}$**	**Yield m^{-2} (g)**	**1000 seed weight (g)**
Location	22.87**	33.56**	0.17	0.31	10.62*	38.55**	0.38
Replication	0.34	0.21	2.95**	1.22*	1.79**	0.72*	0.73
Block (loc* rep)	9.66**	5.07**	5.33**	5.00	4.61*	4.60**	3.38
Genotypes	35.94**	23.70**	40.89**	33.10**	34.64**	17.88**	39.10**
Loc*genotype	14.48**	17.86**	26.62**	26.38*	25.82**	19.30**	32.54**
Error	16.71	19.60	24.04	33.99	22.52	18.95	23.87
Total sum of squares	141624.11	7974152.40	841.77	2484.76	33713.58	806159.07	1950.14
CV	14.62	53.91	12.52	15.17	22.82	51.62	13.38

*****Significant at 5% probability level; ******Significant at 1% probability level.

produced greater yield than salt susceptible due to higher dry weight of shoot and spike and better grain development.

El-Hendawy et al. (2009) evaluated wheat genotypes and reported that grain weight $plant^{-1}$, number of grains $plant^{-1}$ and number of fertile spikes $plant^{-1}$ are good screening criteria under field conditions.

The objectives of the present study were to evaluate the genetic diversity in 103 wheat landraces/cultivars for salinity tolerance under saline field conditions and to identify the parents for breeding salt tolerant cultivars.

MATERIALS AND METHODS

Seeds of 103 wheat landraces/cultivars (Table 2) including 4 check cultivars namely: SARC III, SARC IV, SARC V and SARC VII, were obtained from the gene bank of Plant Genetic Resources Program, National Agricultural Research Centre, Islamabad; Saline Agriculture Research Center (SARC), University of Agriculture, Faisalabad, and Ayyub Agricultural Research Institute, Faisalabad, Pakistan. The landraces/cultivars included 64 accessions from Pakistan, 20 from Iran, 7 from Syria, 4 from Egypt and 8 from Italy.

The seeds were sown at Soil Salinity Research Institute (SSRI), Pindi Bhattian and Biosaline Agricultural Research Station (BARS), Pakka Aana (Pakistan) during the growing seasons 2007-08. Incomplete block design was followed with 2 replications keeping row to row distance of 30 cm and row length of 4 m. The experiment consisted of 12 small blocks. EC_w (electrical conductivity of water) used for irrigation was 2.0 to 2.4 dSm^{-1} at SSRI and 3.4 to 3.7 dSm^{-1} at BARS, while RSC_w (residual sodium carbonate) was 1.0 to 1.5 at SSRI and 2.0 to 2.5 meq L^{-1} at BARS. Soil analysis of both locations is given in the Table 1. Data were recorded from 10 randomly selected plants from each replication for biomass m^{-2}, plant height, spike length, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, 1000 gain weight and grain yield m^{-2}. During 2008-2009, 47 salt tolerant accessions selected from both locations during 2007-2008 on the basis of yield m^{-2} and germination and hydroponic testing at 200 mM NaCl stress (data not given) were sown at the both earlier mentioned locations following the same procedure of 2007-2008.

The data were subjected to analysis of variance using the GLM procedure in SAS (SAS Institute, 2003). The means obtained were separated by standard error of differences of means. The correlation coefficients among all the traits were computed following Kown and Torrie (1964). All the traits showed strong positive cor-

Table 3. Salt tolerance categories of 103 wheat genotypes on the basis of average yield of 2 locations.

Salt tolerant category	Grain yield (g/m^{-2})	Number of accessions	Accessions (country of collection)
Tolerant	95 (g/m^{-2}) and above	5	10795 (Pakistan), 10851 (Pakistan) 11299 (Pakistan), 10807 (Pakistan) and 11302 (Pakistan)
Moderately tolerant	67 - 95 (g/m^{-2})	27	Sakha-92 (Egypt), 11464 (Syria), Maroon (Iran), 13193 (Pakistan), Roushan (Iran), 11465 (Syria), 11462 (Syria), 11244 (Pakistan), 11186 (Pakistan), 10798 (Pakistan), 10803 (Pakistan), 11386 (Pakistan),11384 (Pakistan), 10862 (Pakistan), 11406 (Pakistan), 11478 (USA), 10834 (Pakistan), Pavon (Pakistan), 10833 (Pakistan),10800 (Pakistan), 11526 (Pakistan), 11193 (Pakistan), 11387 (Pakistan), 11419 (Pakistan), 11272 (Pakistan), SARC-VII (Pakistan), 11248 (Pakistan)
Moderately susceptible	39 - 67(g/m^{-2})	47	12114 (Pakistan), 11195 (Pakistan), 10783 (Pakistan), Tabasi (Iran), 12119 (Pakistan), Arvand (Iran), ADL (Iran), 10853 (Pakistan), 10849 (Pakistan), SARC IV (Pakistan), 11467 (Syria), 11418 (Pakistan), Giza-163 (Egypt), Karaj-II (Iran), 11133 (Pakistan), 11414 (Pakistan), 11415 (Pakistan), 11374 (Italy), 12118 (Iran), 11171 (Pakistan), 11457 (Syria), 13184 (Pakistan), Falat (Iran), 10854 (Pakistan), Moghan-1 (Iran), 10809 (Pakistan), 12117 (Pakistan), 11240 (Pakistan), Khazar-1 (Iran), 10777 (Pakistan), 11454 (Syria), 10784 (Pakistan), Chenab (Iran), 11399 (Pakistan), 11407 (Pakistan), Kayeh (Iran), Sardari (Iran), Chods (Iran), 11458 (Syria), 4098785 (Pakistan), 11409 (Pakistan), 10824 (Pakistan), 11416 (Pakistan), 11373 (Italy), SARC III (Pakistan), 4098795 (Pakistan), 11388 (Pakistan)
Susceptible	39 (g/m^{-2}) and below	24	India (Iran), 11378 (Pakistan), 10812 (Pakistan), Karaj-1 (Iran), Darab (Iran), Omid (Iran), 10788 (Pakistan), 4098815 (Pakistan), Giza-155 (Egypt), 12113 (Pakistan), 11371 (Italy), 11371 (Italy), 10811 (Pakistan), SARC-V (Pakistan), 11372 (Italy), Rasool (Iran), Hirmand (Iran), Alborz (Iran), 11370 (Italy), 11901 (Italy), 11290 (Pakistan), 11405 (Pakistan), 11792 (Pakistan), 11369 (Italy)

relation with yield m^{-2} during 2007-2008, therefore, average yield of both locations was used to classify the genotypes into four groups. Difference between the range of average yield was divided into four equal groups (Table 3), namely, salt tolerant, moderately salt tolerant, moderately salt susceptible and salt susceptible.

RESULTS

Soil analysis of two salt affected soils revealed marked differences in EC_e (electrical conductivity), SAR (sodium absorption ratio) and soil texture (Table 1). Performance of wheat genotypes under field conditions is the combined effect of genotype, environment and genotype × environment interaction. Combined analysis of both locations during 2007-08 and 2008-09 (Tables 2 and 4) revealed that genotypes differed significantly ($P < 0.01$) for all the traits studied. During 2007-08, location effect was significant ($P < 0.05$) for plant height, total biomass, grain spike^{-1} and yield m^{-2}. During 2008-09, differences due to location were significant ($P < 0.05$) for all the seven traits studied. This may be due to differences in EC_e and SAR of the two locations (Table 1). Block (location × replication) effect was significant ($P < 0.01$), except spikelets spike^{-1} and 1000 seed weight during 2007-08, however, during 2008-09, it was significant only for plant height ($P < 0.05$). The possible reason for non significance may the small size of blocks. Location × genotype effect was significant ($P < 0.01$) during the both years for all the traits, except, spikelets spike^{-1} where it was significant at $P < 0.05$ during 2007-08.

Based on average yield of two locations, 103 wheat genotypes were classified into four groups (Table 3), namely: salt tolerant included five genotypes, all from Pakistan; moderately salt tolerant included 27 genotypes, mostly from Pakistan, Egypt, Syria and Iran; moderately salt susceptible included 47 genotypes; and salt susceptible included 24 genotypes. Most of the susceptible accessions were from Pakistan, Iran and Egypt.

During 2007-08, moisture stress coupled with high salinity rise just after sowing created high ideal saline conditions for crop evaluation. This inhibited the germination and plant growth at early stage at SSRI. Due to which most of the accessions at BARS performed better as compared to SSRI. During 2008-09, a considerable

Table 4. Analysis of variance of 7 traits studied in 47 wheat genotypes at Pindi Bhattian and Pakka Aana during 2008-09.

Trait studied	Plant height (cm)	Sum of squares (Percentage of total)					
		Tiller m^{-2}	Spike length (cm)	Spikelets spike^{-1}	Grains spike^{-1}	Yield m^{-2} (g)	1000 seed weight (g)
Location	58.25**	59.89**	11.46*	28.25**	19.23**	49.26**	21.53**
Replication	0.29	0.08	0.41	0.05	0.01	0.03	0.10
Block (loc × rep)	0.53	2.20*	2.56	1.58	0.34	2.08	1.34
Genotypes	24.36**	20.40**	45.85**	31.60**	60.89**	28.52**	51.09**
Loc × genotype	10.80**	10.10**	25.72**	19.41**	14.74**	13.23**	16.50**
Error	5.77	7.33	14.00	19.11	4.78	6.88	9.43
Total sum of squares	49321.63	2218209.40	256.70	1048.07	12989.14	3294445.11	1050.27
CV	8.53	27.28	9.14	12.29	12.08	39.23	11.74

*Significant at 5% probability level; **Significant at 1% probability level.

Table 5. Correlation coefficient between various traits and yield in wheat genotypes at Pindi Bhattian (PB) and Pakka Aana (PA) during 2007-08 and 2008-09.

Trait studied	Yield (g m^{-2}) 2007-08	Yield (g m^{-2}) 2008-09
Plant height (cm)	PB 0.82** PA 0.94**	PB 0.91** PA 0.77**
Biomass (g m^{-2}) (2007-8)	PB 0.93** PA 0.96**	- -
Fertile tillers plant^{-1} (2008-09)	- -	PB 0.94** PA 0.95**
Spike length (cm	PB 0.80** PA 0.92**	PB 0.90** PA 0.74**
Spikelets spike^{-1}	PB 0.80** PA 0.92**	PB 0.90** PA 0.74**
Grains spike^{-1}	PB 0.80** PA 0.93**	PB 0.95** PA 0.73**
1000 seed weight (g)	PB 0.81** PA 0.92**	PB 0.94** PA 0.76**

**Significant at 1% probability level.

reduction was manifested in plant height, fertile tillers plant-1, spike length, spikelets spike-1, grains spike-1, 1000 grain weight and yield m-2 (Table 6). Five accessions produced above 100 cm tall plants at SSRI but >77 cm at BARS. This showed a significant reduction in plant height at BARS as compared to SSRI (Table 6).

Total dry biomass production at SSRI was less as compared to BARS during 2007-08. Accessions 10795, 10807, 10851 and 11299 produced highest total biomass at both locations. The total biomass production ranged from 47.6 to 672.2 gm-2 at BARS. It revealed a huge reduction in biomass in salt susceptible accessions as compare to salt tolerant. During 2008-09, fertile tillers m-2 showed a considerable reduction at both locations. It ranged from 125.4 to 409.2 at SSRI and 8 to 259 at BARS. Accessions 10824, 11287, 11214, 11383 and Local white were able to maintain maximum number of fertile tillers at both locations (Table 6). Fertile tillers m-2 had a positive and highly significant correlation with grain yield m-2 during 2008-09 at both locations (Table 5).

Information on the relationship between yield and its components and among the components themselves can

Table 6. Means of 7 traits studied in 47 wheat genotypes at Pindi Bhattian and Pakka Aana during 2008-09.

Accession no.	Plant height		Fertile Tiller Plant^{-1}		Spike length		Spikelets spike^{-1}		Grains spike^{-1}		1000 grain weight		Yield m^{-2}	
	PB	PA	PB	PA	PB	PA	PB	PA	PB	PA	PB	PA	PB	PA
Pavon	83.50	58.50	237.60	91.06	9.4	8.00	17.3	12.67	41.8	30.67	40.0	35.20	397.29	90.55
10783	87.00	72.00	232.65	49.24	7.8	8.78	15.0	15.88	29.2	7.78	38.0	32.80	213.89	17.04
10793	88.00	61.00	293.70	18.48	9.4	9.52	16.8	14.67	24.3	21.93	46.0	27.75	68.39	4.20
10800	79.00	53.50	196.35	40.78	9.0	5.42	17.0	9.33	35.5	18.00	38.9	36.40	269.40	6.49
10806	92.50	49.50	325.05	112.50	8.3	7.30	16.0	12.65	23.2	33.83	35.4	27.50	381.13	92.55
10807	83.00	63.50	323.40	61.00	9.8	7.50	15.2	10.50	19.0	21.00	16.5	25.35	105.57	84.25
10812	74.50	49.50	249.15	101.50	8.2	6.83	16.0	10.83	42.7	27.83	38.0	33.60	348.15	22.45
10821	82.00	63.00	140.25	11.22	7.2	9.50	15.0	14.17	11.2	8.00	19.3	25.40	40.66	19.10
10824	99.00	77.00	211.20	102.30	7.4	6.92	14.7	11.50	24.7	21.17	39.0	38.70	211.10	56.00
10828	80.50	56.00	151.80	25.00	7.5	4.83	12.3	7.17	8.3	7.50	30.6	24.40	51.76	45.20
10831	55.50	69.00	125.40	59.00	6.8	7.25	13.8	12.17	23.0	16.55	27.7	24.60	101.15	21.72
11186	99.00	60.50	265.65	29.00	6.4	7.20	10.7	13.50	23.2	24.33	28.0	30.20	296.42	24.94
11214	104.00	67.50	285.45	56.50	7.8	7.25	14.2	14.00	30.7	23.83	32.9	27.80	156.09	18.45
11287	100.50	70.50	364.65	60.50	7.0	7.17	13.8	12.50	25.8	23.33	37.0	25.15	355.59	36.00
11299	106.00	58.50	402.60	259.38	8.5	6.83	15.8	12.50	34.0	17.83	32.1	34.95	385.09	111.24
11383	104.50	66.00	321.75	133.56	9.3	8.62	15.2	11.67	26.3	17.85	31.8	24.75	311.75	67.25
11385	95.00	63.00	199.65	42.44	7.6	7.02	13.7	12.00	28.8	25.00	42.0	26.50	182.18	23.17
11401	94.50	62.00	311.85	57.00	7.4	8.25	15.2	12.83	22.0	21.00	38.7	31.80	391.07	29.70
11409	101.50	59.00	306.90	56.00	7.3	7.75	12.8	12.33	29.5	15.00	34.9	25.25	284.46	24.90
11417	94.50	55.50	379.50	40.62	6.7	7.17	12.3	11.92	22.7	14.83	38.5	21.65	253.54	8.77
11453	79.00	26.50	235.95	24.70	8.2	5.42	15.3	7.50	34.3	17.83	43.3	23.70	264.66	5.24
11454	80.50	57.50	409.20	38.96	7.0	6.92	14.5	12.83	31.8	23.33	36.2	22.65	279.23	6.54
11460	82.50	49.50	211.20	7.62	7.4	5.25	13.0	8.67	22.0	11.33	32.6	18.50	152.28	1.37
11466	94.50	58.50	267.30	37.62	7.3	8.08	15.7	13.00	33.2	19.60	36.0	29.15	205.92	16.12
11478	94.50	53.00	293.70	45.42	6.7	6.25	12.0	9.83	24.5	16.50	37.2	20.70	265.37	9.50
11526	79.50	52.50	292.05	94.00	8.2	6.58	15.3	12.50	34.8	19.33	42.5	28.15	342.54	55.50
11545	81.00	57.50	297.00	117.22	7.3	6.33	12.8	10.83	27.2	19.67	46.2	26.75	385.39	80.02
Sakha 92	72.50	55.00	237.60	168.46	9.5	6.00	18.2	12.00	29.5	24.33	35.0	25.85	242.67	62.17
Karaj II	83.50	57.00	232.65	104.46	7.3	6.85	14.7	12.17	26.0	19.32	29.9	25.75	119.79	34.69
Chenab	80.50	66.50	184.80	49.50	8.6	8.62	14.2	14.67	34.7	26.65	42.3	24.85	217.65	29.10
Maroon	76.50	46.50	343.20	39.78	7.8	5.78	15.0	11.67	31.0	14.92	44.3	32.50	313.14	11.50
Roushan	110.00	61.00	364.65	131.00	8.9	8.32	15.8	13.17	30.8	15.67	39.3	34.75	417.68	62.29
Bayat	71.50	58.50	272.25	29.82	8.0	6.08	16.5	9.67	37.2	17.17	35.3	26.00	260.21	11.23
Omid	79.50	66.00	132.00	16.74	8.1	8.58	14.2	11.50	21.5	14.75	38.8	31.00	26.07	7.35
4098775	89.00	55.00	204.60	50.82	8.6	7.58	15.7	11.83	45.0	22.98	37.1	31.30	391.46	26.00

Table 6. Contd.

4098805	86.50	49.50	313.50	31.16	9.9	8.83	15.8	15.50	39.2	42.50	41.0	28.30	458.40	15.60
Local white	105.50	67.50	260.70	168.30	8.9	7.50	17.5	11.67	30.2	26.67	43.5	30.75	393.57	122.69
Pasban 90	68.00	46.50	255.75	58.36	9.2	7.62	14.3	12.43	33.7	34.97	35.5	27.40	281.16	33.68
SARC IV	68.50	37.00	211.20	151.72	8.8	5.75	14.7	8.67	39.3	20.00	36.2	26.50	255.42	95.00
SARC VII	69.50	59.50	254.10	154.10	8.3	7.3	15.5	15.5	29.5	22.5	37.9	32.50	240.97	90.97
Shorawaki	81.50	70.40	166.65	160.65	9.8	8.1	20.2	16.5	12.7	19.7	16.7	22.40	24.96	86.75
SE_{diff}^{x}	1.74	1.52	10.31	8.27	0.15	0.19	0.26	0.32	1.24	0.16	1.19	0.72	18.04	5.12

[x]Standard error of the difference between means; no., number.

be utilized to improve the efficiency of selection in plant breeding programs. Spike length is an important yield contributing trait which showed reduction under saline field conditions. During 2007-08, spike length ranged from 4.85 to 13.97 cm at SSRI and from 6.1 to 11.1 cm at BARS. During 2008-09, spike length ranged from 6.4 to 11.3 cm at SSRI and 4.8 to 9.5 cm at BARS (Table 6).

Grains spike^{-1} also showed reduction at high salinity level. At SSRI, grains spike^{-1} ranged from 4.8 to 48.17 during 2007-08, while at BARS, it was from 16.5 to 46. During 2008-09, grains spike^{-1} ranged from 8.3 to 45 at SSRI, while at BARS, it was from 7.5 to 42.5. Reduction in grain spike-1 also causes reduction in yield at high salt stress. This reduc-tion is due to positive association between grain spike^{-1} and yield. Most of the accessions showed reduction in 1000 seed weight at BARS during both years. The foremost target of wheat breeder is to improve grain yield. Therefore, the assessment of final grain yield and growth parameters determining grain yield is a significant aspect of breeding programs. Five accessions: 10795, 10851, 11299, 10807 and 11302 (all from Pakistan) were identified as most salt tolerant on the basis of average yield performance at two locations (Table 2). Three of them: 10807, 10851 and 11299 were included in the second phase of the experiment (2008-09). Accession 10807 produced 128.71 and 91.0 gm^{-2} yield during 2007-08 and 105.6 and 84.3 gm^{-2} during 2008-09 at SSRI and BARS, respectively. Accession 11299 produced 93.55 and 127.8 gm^{-2} yield during 2007-08, and 385.1 and 111.2 gm^{-2} during 2008-09 at SSRI and BARS, respectively.

DISCUSSION

Our results revealed that wheat genotypes responded differently to salinity stress at the two locations in terms of yield and yield components. Similar findings were reported by (Richards et al., 1987; Slavich et al., 1990). The decline in total dry biomass in the sensitive accessions was most likely due to the extra energy utilization for osmotic accumulation (Wyn Jones and Gorham, 1993). Significant positive correlation between dry biomass and yield m-2 (Table 5) indicated that total dry biomass along with yield can be good selection criteria under salinity stress.

Salts present in the soil solution reduce the ability of plant to absorb water which slow down plant growth and ultimately cause reduction in yield components. This is called osmotic or water deficit effect of salinity. Salinity stress at different phenological stages inhibits photosynthetic activities of the plant because it had a direct inhibitory effect on the Calvin cycle enzymes (Ottander and Oquist, 991). Tiller plant^{-1} is the most salinity sensitive trait in wheat (El-Hendawy et al., 2005). Therefore, to increase the yield under stress condition, it is necessary to maintain high plant density. Tiller formation included tiller number and tiller biomass. Salinity reduces tiller number by delaying and reducing tiller emergence at the vegetative stage. After tiller emergence, growth of tillers at all stages is inhibited by salinity due to its damage on the essential metabolic reaction in plants, resulting in low tiller biomass and small tiller size (Mass and Poss, 1989). EC_e >7.5 dSm^{-1} in soil water could eradicate most of the secondary tillers and greatly reduce the formation of tertiary and lateral tillers. The yield potential of wheat is greatly dependent on the number of tillers plant^{-1} that is affected in the early life cycle. Number of tillers regulates grain yield by its prime influence on the number of spikes in wheat (Simons and Hunt, 1983). Our correlation results confirmed these findings. Spikelets spike^{-1} along with number of tillers was identified as the most salt sensitive yield components in wheat. At the time of spike emergence, salinity suppresses the reproductive development, spikelet initiation and ultimately number of spikelets (Mans and Rawson, 2004). Due to their response to salinity and significant positive correlation with yield, these two traits could be used as selection criteria. These traits could be determined at early growth stages and therefore, may be used to screen large population. Reduction in grains spike^{-1} was due to reduction in spikelets spike^{-1} as revealed by positive correlation between them. The 1000 grain weight was less affected as compare to the other yield components because it was determined at maturity which is the least salt sensitive stage in wheat (Frank et al., 1997).

Grain yield had strong positive correlation with plant height, dry biomass, spike length, spikelets spike^{-1}, grain spike^{-1} and 1000 grain weight (Table 5). Due to this positive correlation, yield can be used as a selection criterion under saline field conditions. Many scientists had classified crop species on the basis of grain yield under stress conditions (Sadiq et al., 1994; Jafari-Shabestari et al., 1995; Anderson et al., 1996). Reduction in yield was due to the reduction in the yield components and high EC_e at BARS was the main cause of reduction in yield and yield components. Wheat yield decline 10% when EC_e value goes >10 dSm^{-1} (Katerji et al., 2009).

Sum of square due to genotype for tillers m^{-2}, total biomass m^{-2}, spikelets spike^{-1} and yield m^{-2} revealed that these traits were adversely affected at both locations. Our results showed that these traits could be effectively used as selection criteria for screening wheat under field conditions. Accessions 10807, 11299, 11917 and cultivars Pavon performed better during both years. Cultivar Local white produced better yield at both locations during 2008-09 but check cultivar Pasban 90 performed better at SSRI as compare to BARS. The high yield of these genotypes was actually associated with high total biomass production and yield components. Accession 11299 (Pak) was found to be most salt tolerant at germination stage and seedling stage in hydroponics under 300 and 250 mM NaCl stress, respectively. Cultivar Pasban 90 and accession 10807 were also found to be salt tolerant at seedling stage in hydroponics at 250 mM NaCl stress (data not shown). These genotypes could be used as new sources of salt tolerance.

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