INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2007/09–5–693–700
http://www.fspublishers.org

Evaluation of Salt Tolerance Based on Morphological and Yield Traits in Wheat Cultivars and Mutants

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ABSTRACT

To evaluate yield and salinity tolerance of twenty-five wheat cultivars and mutants, an experiment in partially balanced lattice design (5 × 5) was conducted with two replications and under two conditions at two field locations. Significant differences were observed in plant height, flag leaf node until spike distance, grain length, 1000 grain weight, harvest index and hectoliter weight under normal condition. Likewise under salinity, significant differences were observed for flag leaf area, number of fertile tiller, plant height, spike length, flag leaf node unit spike distance, number of grain per plant, 1000 grain weight and hectoliter weight. Salinity decreased many of traits in mutants as well as cultivars. T-66-58-6 (mutant of Tabassi) showed yield stability across normal and saline conditions. Path, stepwise regression and multiple regression analysis indicated that biomass and harvest index had positive direct effect on yield for yield components under either condition.

Key Words: Salinity; Wheat; Mutant; Selection method; Statistical analysis

INTRODUCTION

About 25% of the world and 15% of the Iran's total land are saline (Kamkar *et al*., 2004). Soil salinity above 4.5 dS m^{-1} decreases the percent of plants established per unit area. At 8.8 dS m^{-1}, yield of emerged wheat decreased to 50% (Francois *et al*., 1986). Soil salinity affects plant growth in three ways: (a) osmotic stress decreasing water availability, (b) ionic stress and (c) changes in the cellular ionic balance. Salinity affects in the formation and viability of reproductive organs. In cereal, it reduces the numbers of florets per ear and alters the time of flowering and maturity (Munns & Rawson, 1999). It is known that wheat genotypes respond differentially to salinity (Singh & Rana, 1984), which necessitates the identification of high yielding stable varieties under saline conditions. The agronomic and physiological traits may be important, not only to be used as quick and easy screening criteria if they are closely associated to grain yield (Noble & Rogers, 1992; Munns & James, 2003) but also improves the salt tolerance. Nonetheless, this needs a better understanding of salt tolerance mechanisms of wheat genotypes.

Some researchers have pointed out that selection of high wheat yield cultivars could be the best strategy to obtain satisfactory yields in saline condition, due to the spatial heterogeneity of salt distribution in the soil, which would allow expression of the yield potential in some plants growing in areas with lower salinity (Richards *et al*., 1981). The aims of the present study were: (1) comparison of twenty-five wheat cultivars and mutants, regarding their morphological traits and yield component, to obtain maximum grain yield in saline and normal conditions and (2) determination of morphological and yield components effects on grain yield of 1 m row in two conditions, using path and regression analysis.

MATERIALS AND METHODS

The experiments was conducted in farm with saline soil and water in region Aktharabad also the same experiments was conducted in normal condition in experimented farm in Science and Technology Research Institute (NSTRI) Agriculture, Medicine and Industry Research School, Karaj and Akhtarabad farm of Mahdasht, Karaj-Iran during the crop season 2005 – 06.

Plant materials. The experiments included 9 wheat cultivars and 16 wheat mutants. The pedigree and characteristics of these cultivars and mutants was as follows: Bezostaia has medium height, tolerance to lodging, small awns and has high vigor in cold condition- Inia is earliness and has tolerance to lodging, medium height and has high backing quality - Tajan garm was largely sown in north of Iran - Tajan was largely sown in north of Iran and show highyield potential- Azadi show medium height, high awns, Pishtaz was sown in drought environments - Omid has awns, complete lodging, high height and has performed well in north of Iran - Tabassi has complete lodging, high height - (O-64 -4/Omid) is dwarf and earliness - (O-64-1-1/Omid) is dwarf and earliness - (T-66-58-7/Tabassi) has small spike and awns - (T-67-60/Tabassi) show a small spike and lower lodging - (T-65-9-1/Tabassi) is dwarf - (T-65-58-8/Tabassi) show a small spike and lower lodging - (T-65-5-1/Tabassi) show a compact spike and without awns - (T-65-9-1P/Tabassi) is dwarf and tolerance to lodging - (T-65-7-1/Tabassi) is dwarf, tolerance to lodging and without awns - (T-65-4/Tabassi) has medium height, without awns - (T-65-58-10/Tabassi) has lodging and awns - (T-65-58-9/Tabassi) has small spike and awns - (T-65-6/Tabassi) show high height and without lodging - (T-66-58-6/Tabassi) has lodging - (T-66-58-60/Tabassi) has high height, awns and great spike - (T-66-58-12/Tabassi) has high height and high awns and (T-65-9-II/Tabassi) has high height without awns and medium lodging.

Field evaluation. In normal condition the electrical conductivity (EC) of soil used was 0.67 dS m^{-1} with pH 8.05 and the EC of the water was 0.33 dS m^{-1} with pH 8.2 and SAR 13. Physico-chemical characteristics of the soil were: 30.6% clay, 36.4% silt and 33% sand. In salinity condition, the EC of water used was 10 dS m^{-1} with pH 7.7 and SAR 13.78. The soil was composed of 8% clay, 22% silt and 70% sand. Seeding rate was 120 g seeds in plot [3 x 0.25 m (length x w)]. The distance between blocks was 1 m and between replication 3 m. Fertilizer application was at the rate of 50 kg NH_4NO_3 ha^{-1} and 150 kg $(NH_4)_2HPO_3$ ha^{-1} at planting and 100 kg NH_4NO_3 ha^{-1} at stem elongation stage.

Sampling and measurement. The data for flag leaf area (FLA), number of fertile tiller (NT), plant height (PH), fertile spikelet per spike (FSS), spike length (SL), number of node (NN), flag leaf node until spike distance (FLNSD), stem diameter (SD), grain number per spike (GNS), grain weight per spike (GWS), grain number per spike (GNP), grain weight per plant (GWP), grain length (GL), 1000 grain weight (1000 GW), Biomass (B), 1 m row yield (1RY), harvest index (HI) and hectoliter weight (HW) were recorded for each experimental unit. At maturity, one of three central rows was harvested to record grain yield in 1 m of each cultivar and mutant. The data for flag leaf area was measured by leaf area meter (Model AM100). Harvest index was obtained by converting of total dry matter in economic yield (grain yield). Hectoliter weight was equivalent of 200 mL seeds.

Statistical analysis. Analysis of variance was done and observation, were compared by using of Duncan multiple Rang test (Duncan, 1955). Coefficient of correlation, parameters of linear regression and stepwise regression were calculated using mean values of characters from two conditions. Direct and indirect effects of component characters (morphological & yield) on yield of l m row were worked out using path coefficient analysis. Stepwise and multiple regression analysis was used to find of important characters contributing to yield in 1 m row. Statistical analysis obtained using of statistical analysis system (SAS institute Release, 6. 12) and MSTATC program.

For evaluating of salinity tolerance stress susceptibility index was calculated as follows:

SSI = [1-(Ydi/Ypi)/SI] = YD/YP
SSI = Stress Susceptibility Index
SI = Stress Intensity
YD = Yield average under stress
YP = Yield average under normal condition
Ydi = Yield of each genotype under stress
Ypi = Yield of each genotype under normal condition.

RESULTS

Flag leaf area. All the cultivars and mutants showed significant differences for flag leaf area ($P < 0.01$) under both the conditions (Table I). In normal condition, the maximum flag leaf area was observed in Bezostaia, T-65-7-1, T-66-58-60 and Azadi, whereas in salinity stress condition the maximum flag leaf area was observed in T-66-58-8, T-66-58-9, T-66-58-12, Omid and Bezostaia (Table II).

Number of fertile tillers. Number fertile tiller differed significantly ($P < 0.05$) in all of cultivars and mutants under two conditions (Table I). In normal condition maximum number of fertile tiller was produced by T-67-60, T-65-4 and T-65-6, whereas in salinity condition Omid and T-66-58-12 could produce maximum of fertile tiller. The number of tillers, obviously, influenced the reaction to salt stress. Plants with a high number of tillers, in the control treatment, tended to show more sensitive reaction under salt stress condition. In normal condition, T-67-60, T-65-4 and T-65-6 were produced maximum fertile tiller, but under salinity stress condition, these mutants produced lower fertile tiller.

Table I. Analysis of variance for morphological and yield treats under normal and salinity condition

	MST		$\bar{X}$ ± SD		MSE		CV%		LSD	
	Normal	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**
FLA	165131.06 ns	130637.17**	1973±118.61	1348.88±105.5	121579.52	31198	17.67	13.09	739.17	374.43
NFT	1.99 ^{ns}	1.39 *	5.2±0.41	3.69±0.34	2.46	0.51	30.15	19.31	3.24	1.51
PH	604.3 **	78.42 **	113.8±7.18	68.83±2.58	40.54	15.19	5.6	5.66	13.49	8.26
FSS	10.01 ^{ns}	2.86 ^{ns}	15.82±0.92	14.93±0.49	7.73	1.39	17.57	7.9	5.73	2.5
SL	1.18 ^{ns}	1.31 **	8.89±0.32	8.83±0.33	0.94	0.18	10.9	4.77	2.055	0.89
NN	0/1 ^{ns}	0.16 ^{ns}	4.52±.09	4.08±0.12	0.09	0.09	6.52	7.56	0.62	0.095
FLNSD	61.87 *	12.62 ^{ns}	40.78±2.3	23.56±1.04	12.69	4.34	8.73	8.85	7.55	2.51
SD	0.56 ^{ns}	0.05 ^{ns}	3.06±0.22	2.11±0.06	0.45	0.024	22.01	7.41	1.39	0.33
GNS	91.71 ^{ns}	61.37 ^{ns}	33.96±2.79	35.77±2.29	60.25	35.14	22.85	16.57	16.45	12.56
GWS	0.15 ^{ns}	0.09 ^{ns}	1.76±0.11	1.28±0.09	0.15	0.1	21.86	25.2	0.81	0.68
GNP	2104.33 ^{ns}	1720.27 *	143.56±13.39	98.09±12.07	3301.81	584.63	40.02	24.65	118.59	51.26
GWP	5.71 ^{ns}	1.67 ^{ns}	7.37±0.7	3. 3±0.383	8.51	1.03	39.54	30.78	6.02	2.16
GL	0.52 **	0.28 *	7.11±0.21	6.76±0.15	0.09	0.14	4.25	5.5	0.62	0.37
1000GW	79.25 **	44.47 **	51.24±2.6	34.01±1.95	6.83	10.75	5.1	9.64	5.39	6.95
B	0.06 ^{ns}	0.01 ^{ns}	1.13±0.07	0.42±0.03	0.04	0.001	18.11	17.72	0.43	0.16
1MY	0.01 ^{ns}	0.001 ^{ns}	0.35±0.03	0.13±0.01	0.005	.0.001	20.71	22.32	0.15	0.061
HI	20.61 *	32.76 ^{ns}	31.58±1.32	31.09±1.67	9.302	21.41	9.66	14.88	6.46	9.55
HW	7.73 *	27.93 **	72.75±0.81	67.37±1.54	3.39	4.52	2.53	3.17	3.799	4.408

FLA : Flag Leaf Area, NFT : Number of Fertile Tiller, PH: Plant Height, FSS: Fertile Spikelet per Spike, SL : Spike Length, NN : Number of Node, FLNSD: Flag Leaf Node Until Spike Distance, SD: Stem Diameter, GNS: Grain Number per Main Spike, GWS : Grain Weight per Main Spike, GNP :Grain Number per Plant, GWP: Grain Weight per Plant, GL : Grain Length, 1000GW: 1000 Grain Weight :, B: Biomass, 1MY : Yield of I m Row, HI : Harvest Index, HW : Hectoliter Weight. LSD*:* Least Significant Difference in 0.05%, CV: Coefficient of Variation, MSE: Mean Square of Error, MST: Mean Square of Treat, SD: Standard Deviation, **, * and ns: significant at 0.01, 0.05 and non significant

Plant height and flag leaf node until spike distance. A significant (P < 0.05) difference was noted among cultivars and mutants under two conditions for the Plant height and significant (P < 0.05) difference was noted among cultivars and mutants under normal conditions (Table I). In normal condition, maximum plant height was recorded in Omid, which signed taller than other cultivars and mutants and for flag leaf node until spike distance, maximum distance was observed in Tabassi and T-65-6. On the other hand, in saline condition Tabassi, Omid and T-66-58-6 were recorded taller than other cultivars and mutants.

Spike length and number of spikelets per spike. The cultivars and mutants showed significant (P < 0.01) differences for spike length in saline condition but in normal condition there were no significant differences among cultivars and mutants. For number of spikelets per spike there were not significant differences among cultivars and mutants in two conditions. In normal condition maximum spike length was observed in Omid, O-64-1-1, O-64-4, T-66-58-12, Azadi and T-65-9-1I, whilst under saline condition, Omid had tallest spike length (than other cultivars & mutants).

Number of grain per spike and grain per spike weight. There were no significant differences among cultivars and mutants. Under normal condition, Azadi, O-64-4, O-64-1-1 and Pishtaz produced the maximum number of grains per spike weight a long with 66-58-12, while under saline condition Azadi, T-66-58-60, T-66-58-12, O-64-1-1, T-65-9-1P, and Omid had the maximum of grain per spike than others but for grain per spike weight, T-67-60, T-65-5-1, T-66-58-60, T-66-58-12 and T-6658-9 produced greatest of grain per spike weight.

Number of grain per plant and grain per plant weight. Number of grain per plant in normal condition did not show significant differences but in saline condition significant difference (P < 0.05) was noted among cultivars and mutants. All the cultivars and mutants showed no significant differences for grain per plant weight in two conditions (Table I). In normal condition O-64-4-1, T-65-6, T-66-58-9 and T-65-4 produced the maximum number of grain per plant and had greatest grain per plant weight but in saline stress condition Omid, T-65-9-1P, O-64-9-1 and T-66-58-12

Table II. Mean value of wheat cultivars and mutants and statistical significance for morphological and yield traits in two conditions

	FLA		NFT		PH		FSS		SL		NN		FLNSD		SD	
	Normal	saline	Normal	saline	Normal	saline	Normal	saline	Normal	saline	Normal	saline	Normal	saline	Normal	saline
Bezostaia	2102	1588	4.1	3.814	123.7	63.62	15.8	15.28	8.316	7.777	4.104	4.2	34.62	24.1	3.46	2.175
	AB	BCD	A	BCDEFG	BC	EFGHI	B	ABCD	ABC	GH	C	ABCD	B	ABCDEFGH	A	ABCDE
T-66-58-7	1900	1299	6.5	3.717	130.4	74.08	14.9	15.55	8.531	8.349	4.808	4.2	32	25.02	3.2	2.103
	AB	BCDEF	A	BCDEFG	AB	ABCD	B	ABCD	ABC	EFG	ABC	ABCD	B	ABCDEF	AB	ABCDE
T-67-60	1796	1439	6.9	2.962	130.1	71.84	15	16.23	8.617	8.467	4.996	4.2	30.96	25.57	3.1	2.275
	B	BCDE	A	CDEFG	AB	ABCDEF	B	A	ABC	DEFG	A	ABCD	B	ABCDE	ABC	ABCD
T-65-9-1	1957	1101	4.7	3.65	101.1	62.33	13.5	14.96	7.927	8.763	4.64	4.2	23.6	19.05	2.36	1.928
	AB	EFG	A	BCDEFG	EFG	FGHI	B	ABCD	BC	CDEFG	ABC	ABCD	B	H	DEF	DE
Omid	1678	1675	3.4	5.324	141.9	77.93	15.9	14.87	10.66	11.27	4.6	4	26.78	24.16	2.68	2.015
	B	B	A	AB	A	AB	B	ABCD	A	A	ABC	ABCD	B	ABCDEFGH	CDE	BCDE
Inia	1865	1355	5.6	3.735	87.91	58.15	13.3	12.79	8.982	8.909	4.14	3.8	30.76	21.82	3.08	2.085
	AB	BCDEF	A	BCDEFG	GH	I	B	DE	ABC	CDEF	BC	BCD	B	DEFGH	ABC	ABCDE
7T-66-58-8	2010	2071	4.9	3.738	123.3	72.51	16.3	16.07	8.917	8.491	4.844	4.1	34.82	25.23	3.48	2.28
	AB	A	A	BCDEFG	BC	ABCDE	B	AB	ABC	DEFG	AB	ABCD	B	ABCDEF	A	ABCD
T-65-5-1	1780	1497	5.6	2.784	130.4	76.37	15.8	15.44	8.642	8.809	4.532	4.4	30	27.71	3	2.179
	B	BCDE	A	EFG	AB	ABC	B	ABCD	ABC	CDEFG	ABC	AB	B	AB	ABCD	ABCDE
Tajan Garm	1758	777	4.2	3.071	83.49	64.87	14.5	13.28	8.543	9.325	4.376	3.9	27.8	22.93	2.78	2.111
	B	G	A	CDEFG	H	DEFGHI	B	BCDE	ABC	BCDE	ABC	ABCD	B	BCDEFGH	CDE	ABCDE
T-65-9-1p	1582	1237	5.4	4.446	88	60.66	16.2	15.69	8.899	8.706	4.536	4.1	26.64	20.94	2.66	2.015
	B	CDEF	A	ABCDE	GH	GHI	B	ABCD	ABC	CDEFG	ABC	ABCD	B	EFGH	CDE	BCDE
Tabassi	1644	1303	5.2	4.709	130.9	79.69	16	15.48	8.977	8.738	4.388	4.5	26.98	28.58	2.69	1.989
	B	BCDEF	A	ABC	AB	A	B	ABCD	ABC	CDEFG	ABC	AB	B	A	CDE	CDE
T-65-7-1	2323	1459	4.3	2.412	115.9	69.75	13.1	13.15	7.793	8.24	4.592	4.4	27.76	23.95	2.78	1.844
	AB	BCDE	A	FG	BCD	BCDEFG	B	CDE	BC	FGH	ABC	AB	B	ABCDEFGH	CDE	E
T-65-4	1845	1173	6.7	3.157	111.5	71.46	17.2	14.93	9.328	7.968	4.58	4.3	26.54	23.59	2.65	1.981
	B	DEFG	A	CDEFG	CDE	ABCDEF	B	ABCD	ABC	FGH	ABC	ABC	B	ABCDEFGH	CDE	CDE
T-65_58_10	2019	1383	5.6	3.145	119.1	74.26	16	14.96	8.758	8.215	4.724	4.1	52.06	24.35	3.21	2.278
	AB	BCDEF	A	CDEFG	BCD	ABCD	B	ABCD	ABC	FGH	ABC	ABCD	A	ABCDEFG	AB	ABCD
O-64-1-1	1761	1248	6	4.619	94.27	62.8	17.7	15.27	9.964	10.07	4.584	3.6	28.94	23.37	2.89	2.045
	B	BCDEF	A	ABCD	FGH	FGHI	B	ABCD	AB	B	ABC	CD	B	BCDEFGH	CDE	ABCDE
T-66-58-9	1911	1593	6.1	3.585	121	70.89	16.3	15.53	9.129	8.817	4.3	4.4	32.24	22.07	3.22	2.085
	AB	BCD	A	BCDEFG	BCD	ABCDEF	B	ABCD	ABC	CDEF	ABC	AB	B	CDEFGH	AB	ABCDE
Pishtaz	1539	971.9	4.5	2.188	95.02	60.35	16.2	11.5	9.144	7.269	4.504	4	31.32	21.07	3.13	2.074
	B	FG	A	G	FGH	GHI	B	E	ABC	H	ABC	ABCD	B	EFGH	ABC	ABCDE
T-65-6	1805	1376	6.6	2.884	127.3	70.91	15.9	14.78	8.39	8.347	4.492	4	29.36	25.4	2.94	2.372
	B	BCDEF	A	DEFG	AB	ABCDEF	B	ABCD	ABC	EFG	ABC	ABCD	B	ABCDEF	BCD	AB
T-66-58-6	2309	1306	5.4	3.521	129.8	76.6	13.8	16.01	8.73	8.874	4.436	4.1	32.82	26.81	3.28	2.426
	AB	BCDEF	A	CDEFG	AB	ABC	B	ABC	ABC	CDEF	ABC	ABCD	B	ABCD	AB	A
T-66-58-60	1865	1368	4.6	3.996	118.5	74.4	12.6	16.02	7.366	8.834	4.396	4	28.94	21.74	2.89	2.147
	AB	BCDEF	A	ABCDEF	BCD	ABCD	B	ABC	C	CDEF	ABC	ABCD	B	DEFGH	BCD	ABCDE
T-66-58-12	2331	1636	5	5.559	122.3	67.8	16.6	16.93	9.803	9.953	4.74	3.9	34.48	21.63	3.45	2.314
	AB	BC	A	A	BC	CDEFGH	B	A	AB	B	ABC	ABCD	B	EFGH	A	ABC
Azadi	2704	1245	3.2	3.062	106.8	67.51	16.6	14.9	9.938	9.555	4.244	3.6	29.06	27.02	2.91	1.931
	A	BCDEF	A	CDEFG	DEF	CDEFGHI	B	ABCD	AB	BC	BC	CD	B	ABC	CDE	DE
T-65-9-11	2243	1347	6.1	4.408	130.9	69.51	24.5	14.87	7.933	8.813	4.732	4.6	27.04	19.58	2.7	2.063
	AB	BCDEF	A	ABCDE	AB	BCDEFG	A	ABCD	BC	CDEF	ABC	A	B	GH	CDE	ABCDE
O-64-4	2272	1188	4.3	3.795	91.31	62.66	16.4	14.21	10	8.74	4.176	3.9	29.82	20.33	2.98	1.919
	AB	DEFG	A	BCDEFG	GH	FGHI	B	ABCDE	AB	CDEFG	BC	ABCD	B	FGH	CDE	DE
Tajan	2330	1086	5.1	3.97	90.39	59.85	15.5	14.52	9.06	9.44	4.536	3.5	28.8	22.93	2.88	2.11
	AB	EFG	A	ABCDEF	GH	HI	B	ABCD	ABC	BCD	ABC	D	B	BCDEFGH	CDE	ABCDE

Cont'd …

Table II. Continued from previous page

	GNS Normal	GNS saline	GWS Normal	GWS saline	GNP Normal	GNP saline	GWP Normal	GWP saline	GL Normal	GL saline	100GW Normal	100GW saline	B Normal	B saline	1m Y Normal	1m Y saline	HI Normal	HI saline	HW Normal	HW saline
Bezostaia	30.93 ABCDE	31.63 ABCDE	1.508 ABC	1.152 A	99.8 A	94.84 ABCD	4.84 A	2.92 ABC	6.459 FG	6.033 E	48.54 EFGHI	31.04 BCDEF	1.136 AB	0.4058 ABCDE	0.3692 ABC	0.1264 AB	32.2 ABCDEFG	32.08 ABCD	74.95 ABC	66.95 DEFGHI
T-66-58-7	29.73 BCDE	29.53 CDE	1.653 ABC	1.085 A	150.6 A	87.59 BCDE	8.446 A	2.959 ABC	7.803 A	7.058 ABCD	55.98 ABCD	34.6 ABCDE	1.272 AB	0.4762 ABCD	0.3628 ABC	0.152 AB	27.72 EFG	31.81 ABCD	71.95 ABCDE	64.2 GHIJ
T-67-60	28.65 CDE	35.18 ABCDE	1.67 ABC	1.426 A	156.6 A	90.41 BCDE	8.783 A	3.518 ABC	7.24 ABCDE	6.458 BCDE	54.73 BCDE	37 AB	1.167 AB	0.3309 DE	0.3534 ABC	0.09841 B	30.06 CDEFG	30.5 ABCD	70.5 CDE	65.3 FGHI
T-65-9-1	26.98 CDE	35.47 ABCDE	1.19 C	1.084 A	120.2 A	113.6 ABC	5.244 A	3.207 ABC	6.712 DEFG	6.499 BCDE	43.59 IJK	28.73 CDEFG	1.316 A	0.4557 ABCD	0.3925 ABC	0.1522 AB	29.25 DEFG	34.24 ABC	72.4 ABCDE	68.25 BCDEFG
Omid	34.7 ABCDE	40.27 ABCD	1.793 ABC	1.221 A	94.8 A	132.5 ABC	4.543 A	3.95 ABC	7.013 BCDEF	6.534 BCDE	47.27 GHIJ	26.41 FG	1.244 AB	0.4145 ABCDE	0.3684 ABC	0.0888 B	29.2 DEFG	22.08 D	70.9 CDE	59.45 J
Inia	32.96 ABCDE	35.07 ABCDE	1.745 ABC	1.337 A	151.1 A	88.51 BCDE	7.915 A	2.91 ABC	7.257 ABCDE	7.023 ABCD	52.2 CDEFG	32.47 BCDEF	1.336 A	0.3904 BCDE	0.4343 AB	0.159 AB	31.22 ABCDEFG	41.27 A	72.55 ABCDE	70.5 ABCDE
7T-66-58-8	33.46 ABCDE	33.27 ABCDE	1.967 ABC	1.258 A	125.7 A	108.1 ABC	7.43 A	4.102 AB	7.733 AB	6.994 ABCD	58.32 ABC	36.02 ABC	1.188 AB	0.4883 ABCD	0.3475 ABC	0.1539 AB	29.65 CDEFG	31.27 ABCD	69.8 E	64.35 GHIJ
T-65-5-1	30.98 ABCDE	37.02 ABCDE	1.778 ABC	1.475 A	151.4 A	87.38 BCDE	8.411 A	3.41 ABC	7.301 ABCDE	7.092 ABCD	50.89 DEFGH	37.79 AB	0.9172 AB	0.3731 BCDE	0.229 C	0.1094 B	25.23 G	29.09 BCD	72.3 ABCDE	64.15 GHIJ
Tajan Garm	30.4 ABCDE	36.01 ABCDE	1.449 ABC	1.374 A	126.7 A	84.04 CDE	5.742 A	2.991 ABC	6.203 G	6.21 DE	44.51 IJK	37.05 AB	0.9311 AB	0.3279 DE	0.3302 ABC	0.09381 B	35.29 ABCD	28.1 BCD	75.85 A	73.25 AB
T-65-9-1p	34.93 ABCDE	41.41 ABCD	1.485 ABC	1.193 A	163 A	144.3 AB	6.759 A	4.164 AB	6.622 EFG	6.621 ABCDE	42.27 JK	27.72 DEFG	1.325 A	0.3291 DE	0.4393 AB	0.1086 B	32.88 ABCDEF	31.89 ABCD	70.85 CDE	62.7 HIJ
Tabassi	34.7 ABCDE	35.98 ABCDE	1.965 ABC	1.391 A	129.4 A	120.4 ABC	6.974 A	4.448 AB	7.391 ABCD	6.786 ABCDE	53.99 BCDEF	36.48 ABC	1.15 AB	0.4651 ABCD	0.3406 ABC	0.1446 AB	29.7 CDEFG	31.32 ABCD	72.75 ABCDE	67.95 CDEFG
T-65-7-1	25.1 DE	22.88 E	1.459 ABC	0.9751 A	92.7 A	32.93 E	5.449 A	1.489 C	7.477 ABC	7.183 ABC	57.61 ABC	42.15 A	1.366 A	0.5255 AB	0.4006 ABC	0.1481 AB	29.41 DEFG	27.68 BCD	72.4 ABCDE	67.8 CDEFGH
T-65-4	34.02 ABCDE	30.63 BCDE	1.717 ABC	1.034 A	174.1 A	73.25 CDE	8.692 A	2.455 BC	7.454 ABC	7.036 ABCD	49.55 EFGHI	33.35 BCDEF	0.9856 AB	0.3452 CDE	0.3166 ABC	0.1217 AB	32.32 ABCDEFG	35.08 ABC	71.25 BCDE	64.6 GHI
T-65-58-10	31.35 ABCDE	33.92 ABCDE	1.848 ABC	1.322 A	152.5 A	77.01 CDE	8.945 A	2.83 ABC	7.629 AB	7.274 AB	57.95 ABC	37.06 AB	1.295 A	0.51 ABC	0.4298 AB	0.1595 AB	33.34 ABCDEF	31.5 ABCD	70.5 CDE	67.65 CDEFGHI
O-64-1-1	48.37 AB	43.22 ABC	1.983 ABC	1.374 A	220.1 A	151.9 A	8.924 A	4.309 AB	6.287 G	6.37 BCDE	39.48 K	28.62 CDEFG	1.263 AB	0.3863 BCDE	0.4679 A	0.1209 AB	37.12 ABC	29.64 BCD	73.3 ABCDE	72.65 ABC
T-66-58-9	35.09 ABCDE	39.95 ABCD	2.144 AB	1.555 A	174.6 A	104.3 ABC	10.68 A	3.627 ABC	7.787 A	6.8 ABCDE	61.78 A	34.94 ABCD	1.256 AB	0.53 AB	0.3735 ABC	0.1533 AB	29.89 CDEFG	29.6 BCD	72.5 ABCDE	66.35 EFGHI
Pishtaz	43.89 ABCD	27.55 DE	2.182 A	0.9918 A	155.7 A	40.19 DE	7.498 A	1.463 C	6.89 CDEFG	6.268 DE	47.98 FGHIJ	36.61 ABC	0.8679 AB	0.3979 BCDE	0.2815 BC	0.1083 B	32.66 ABCDEFG	26.88 BCD	76.3 A	71.85 ABCD
T-65-6	35.01 ABCDE	34.3 ABCDE	1.854 ABC	1.342 A	194.8 A	74.13 CDE	10.44 A	2.814 ABC	7.09 ABCDEF	6.605 ABCDE	53.54 BCDEF	37.67 AB	0.8973 AB	0.4076 ABCDE	0.2282 C	0.1235 AB	27.09 FG	30.62 ABCD	74.9 ABC	67.2 DEFGHI
T-66-58-6	31.64 ABCDE	36.79 ABCDE	1.834 ABC	1.464 A	124.6 A	86.97 BCDE	7.36 A	3.355 ABC	7.744 AB	7.087 ABCD	59.17 AB	38.37 AB	0.7762 B	0.5724 A	0.2432 C	0.188 A	31.47 ABCDEFG	33 ABCD	70.1 DE	68.35 BCDEFG
T-66-58-60	22.26 E	44.89 AB	1.238 BC	1.617 A	79.8 A	120.2 ABC	4.474 A	4.571 AB	7.626 AB	7.455 A	54.43 BCDE	37.98 AB	1.17 AB	0.3337 DE	0.3694 ABC	0.1277 AB	31.55 ABCDEFG	37.67 AB	73.6 ABCDE	68.35 BCDEFG
T-66-58-12	34.29 ABCDE	43.84 ABC	2.067 ABC	1.672 A	141.5 A	150.7 A	8.523 A	5.285 A	7.136 ABCDEF	7.045 ABCD	61.27 A	35.33 ABCD	1.241 AB	0.4846 ABCD	0.3807 ABC	0.1243 AB	31.36 ABCDEFG	26.58 BCD	72.4 ABCDE	63.5 GHIJ
Azadi	49.29 A	45.74 A	2.148 AB	1.268 A	146.9 A	95.02 ABCD	6.616 A	2.51 BC	7.177 ABCDEF	6.622 ABCDE	44.28 IJK	26.73 EFG	1.017 AB	0.46 ABCD	0.3835 ABC	0.1436 AB	38.23 A	30.76 ABCD	74.6 ABCD	70.35 ABCDEF
T-65-9-11	27.11 CDE	30.49 BCDE	1.472 ABC	1.06 A	129.7 A	108.6 ABC	6.68 A	3.808 ABC	7.091 ABCDEF	7.118 ABCD	51.24 DEFGH	34.73 ABCD	1.092 AB	0.4272 ABCDE	0.3229 ABC	0.1001 B	30.22 BCDEFG	25.25 CD	70.85 CDE	62.6 IJ
O-64-4	45.84 ABC	35.48 ABCDE	2.04 ABC	0.8924 A	162.9 A	98.3 ABCD	7.126 A	2.311 BC	6.182 G	6.33 CDE	44.45 IJK	23.06 G	0.9857 AB	0.3645 BCDE	0.3352 ABC	0.1212 AB	34.71 ABCDE	32.96 ABCD	75.8 A	72.1 ABCD
Tajan	37.46 ABCDE	33.78 ABCDE	1.736 ABC	1.303 A	169.9 A	87.18 BCDE	7.883 A	3.178 ABC	6.508 FG	6.586 ABCDE	45.92 HIJ	38.29 AB	0.9596 AB	0.2633 E	0.3563 ABC	0.09929 B	37.61 AB	36.38 ABC	75.45 AB	73.95 A

FLA: Flag Leaf Area, NFT: Number of Fertile Tiller, PH: Plant Height, FSS: Fertile Spikelet per Spike, SL: Spike Length, NN: Number of Node, FLNSD: Flag Leaf Node Until Spike Distance, SD: Stem Diameter, GNS: Grain Number per Main Spike, GWS: Grain Weight per Main Spike, GNP: Grain Number per Plant, GWP: Grain Weight per Plant, GL: Grain Length, 1000GW: 1000 Grain Weight:, B: Biomass, 1 MY: Yield of I m Row, HI: Harvest Index, HW: Hectoliter Weight

Means sharing common letters do not differ using Duncan multiple rang test at 5% p

had the maximum of grain per spike.

1000 grain weight. A significant difference ($P < 0.01$) in 1000 grain weight of all cultivar and mutants was noted under two conditions (Table I). Under normal condition maximum 1000 grain weight was observed in T-66-58-9, T-66-58-12, T-66-58-12, T-66-58-8, T-65-7-1 and T-65-58-10 and in saline condition, T-65-7-1, T-66-58-6, Tajan and T-66-58-12 produced maximum 1000 grain weight.

Biomass. All the cultivars and mutants indicated no significant differences for biomass in two conditions (Table I). Under normal condition maximum average of biomass was produced by T-65-7-1, Inia and T-65-58-10. However, under saline condition T-66-58-6, T-66-58-9, T-66-58-9 and T-66-58-10 were produced the highest biomass.

Harvest index. A significant Difference ($P < 0.05$) in harvest index among of cultivars and mutants was noted under normal conditions but under saline condition there was not (Table I). Under normal condition maximum harvest index was obtained by Azadi, Tajan, O-64-1-1, O-64-4 and Tajan Garm but under salinity was obtained by Inia, T-65-4, T-66-58-60 and Tajan Garm indicated greater harvest index.

Yield of l m row. No significant differences were found among different cultivars and mutants in normal and saline conditions (Table I). However, the maximum average of grain yield of l m row produced by 0-64-1-1, T-65-9-1P, Inia and T-65-58-10 normally, whereas under salinity T-66-58-9, T-66-58-6, T-66-58-10, Inia and T-65-9-I yielded better.

DISCUSSION

Saline condition reduced many of studied traits. Data showed that some parameters like flag leaf area and length, number of fertile tiller, plant height, flag leaf node until spike distance, number of spikelets per spike, grain per spike weight, number of grain per plant and grain per plant

Table III. Phenotypic correlation coefficient of morphological and yield traits in wheat cultivars and mutants under normal and salinity conditions

	Condition	FLA	NFT	PH	FSS	SL	NN	FLNSD	SD	GNS	GWS	GNP	GWP	GL	1000GW	B	1MY	HI	HW
FLA	Normal	1																	
	salinity	1																	
NFT	Normal	-0.31	1																
	salinity	0.3	1																
PH	Normal	0.03	0.2	1															
	salinity	0.44*	0.07	1															
FSS	Normal	0.12	0.23	0.17	1														
	salinity	0.52**	0.51**	0.49*	1														
SL	Normal	0.31	-0.23	-0.12	0.19	1													
	salinity	0.13	0.67**	0.1	0.27	1													
NN	Normal	-0.13	0.44*	0.37	0.0	-0.12	1												
	salinity	0.26	-0.12	0.52**	0.16	-0.43*	1												
FLNSD	Normal	0.1	0.1	0.83**	0.07	-0.01	0.04	1											
	salinity	0.27	-0.19	0.64**	0.29	0.02	0.09	1											
SD	Normal	0.14	0.1	0.18	-0.02	0.02	0.15	0.31	1										
	salinity	0.34	0	0.3	0.43*	0.08	-0.05	0.31	1										
GNS	Normal	0.18	-0.21	-0.41*	0.25	0.78**	-0.31	-0.14	-0.02	1									
	salinity	0.1	0.52**	0.05	0.51**	0.65**	-0.44*	0.04	0.12	1									
GWS	Normal	0.11	0	004	0.22	0.72**	-0.12	0.33	0.3	076**	1								
	salinity	0.27	0.28	0.32	0.54**	0.37	-0.15	0.31	0.59**	0.66**	1								
GNP	Normal	0.11	0.59**	-0.33	0.29	0.39	0.06	-0.19	0.06	0.61**	0.51**	1							
	salinity	0.26	0.88**	0.03	0.64**	0.65**	-0.17	-0.16	0.04	0.76**	0.42*	1							
GWP	Normal	-0.09	0.74**	0.06	0.2	0.21	0.22	0.19	0.33	0.29	0.58**	0.83**	1						
	salinity	-0.42*	0.8**	0.28	0.75**	0.54**	0.11	0.02	0.32	0.67**	0.68**	0.89**	1						
GL	Normal	0.06	0.33	0.63**	-0.14	-0.25	0.31	0.58**	0.32	-0.41*	0.11	-0.21	0.27	1					
	salinity	0.34	0.03	0.52**	0.29	-0.06	0.33	0.13	0.19	0.02	0.28	-0.05	0.21	1					
1000GW	Normal	0.16	0.31	0.62**	-0.13	-0.27	0.27	0.64**	0.48*	-0.47*	0.17	-0.23	0.34	0.82**	1				
	salinity	0.06	-0.4*	0.35	-0.03	-0.37	0.31	0.21	0.46*	0.41*	0.34	-0.5**	-0.06	0.47*	1				
B	Normal	-0.11	0.02	0.02	-0.12	-0.06	0.26	-0.02	0.11	-0.27	-0.26	-0.17	-0.13	0.15	0.13	1			
	salinity	0.43*	-0.01	0.43 *	0.18	-0.07	0.36	0.24	0.16	-0.11	0.07	-0.09	-0.11	0.38	0.17	1			
1MY	Normal	0.04	-0.15	-0.37	-0.08	0.15	0.02	-0.33	0.14	0.09	-0.14	0.01	-0.17	-0.16	-0.2	0.84**	1		
	salinity	0.23	-0.14	0.21	0.14	-0.26	0.12	0.23	0.16	0.06	.01	-0.14	-0.09	0.44*	0.15	0.76**	1		
HI	Normal	0.35	-0.35	-0.67**	0.09	0.38	-0.32	-053**	0.06	0.6**	0.2	0.25	-0.11	-0.53	-0.53**	-0.14	0.41*	1	
	salinity	-0.19	-0.13	-0.29	0	-0.29	-0.27	-0.07	0.02	0.05	0.08	-0.07	-0.07	0.2	0.01	-0.26	0.41*	1	
HW	Normal	0.07	-0.39	-.52**	-0.13	0.07	-0.59**	-0.3	-0.21	0.43*	0.14	0.15	-0.1	-0.61	-0.47*	-0.41*	-0.15	0.43	1
	salinity	-0.62**	-0.35	-0.54**	-0.52**	-0.12	-0.58**	-0.1	-0.16	-0.02	-0.05	-0.3	-0.39	-0.36*	0.04	-0.24	-0.09	0.04	1

FLA: Flag Leaf Area, NFT: Number of Fertile Tiller, PH: Plant Height, FSS: Fertile Spikelet per Spike, SL: Spike Length, NN: Number of Node, FLNSD: Flag Leaf Node Until Spike Distance, SD: Stem Diameter, GNS: Grain Number per Main Spike, GWS: Grain Weight per Main Spike, GNP: Grain Number per Plant, GWP: Grain Weight per Plant, GL: Grain Length, 1000GW: 1000 Grain Weight: B: Biomass, 1 MY: Yield of I m Row, HI: Harvest Index, HW: Hectoliter Weight. **,*and ns: significant at 0.01, 0.05 and non significant

weight, 1000 grain weight, biomass, yield of l m row and hectoliter weight were reduced by salinity and wide phenotypic differences observed for these components (Table I & II). This indicated that evaluation for salt tolerance among cultivars and mutants can be based on genetic diversity in these components (Kirst, 1989). Akram *et al*. (2002) also concluded that salinity reduced spike length, number of spikelet per spike, number of grain per spikelet, 100 grain weight and grain yield per plant. This indicated that evaluation for salt tolerance among cultivars and mutants can be based on genetic diversity in these components. El-Hendawy *et al*. (2004) reported that tiller number was affected more by salinity than leaf number and leaf area per plant. Salinity decreased dry weight per plant and spikelet number on the main stem decreased much more with salinity than spike length, grain number and 1000-grain weight. Kamkar *et al*. (2004) reported that the salinity-induced source limitation reduces yield primarily by a severe reduction in grain number and then by reduction in grain weight. Shannon (1997) reported that many physiologically processes are affected by salinity but notably these are reduced cell growth, decreased leaf area, biomass and yield. Kamkar *et al*. (2004) reported that the rate of photosynthesis was significantly reduced by increased level of salinity, which is consistent with results of Francois *et al*. (1994) and Kamkar *et al*. (2004).

At the vegetative growth stage, the three agronomic parameters (i.e., tiller number, leaf number & leaf area per plant) were used to evaluate genotypes for salt tolerance. Salt sensitive genotypes showed a greater reduction in tiller number than tolerant ones. This indicated that tiller number and their behavior under salinity can be used as simple and non-destructive character to evaluate wheat genotypes in breeding programs. Nicolas *et al*. (1994) found that salt stress during tiller emergence can inhibit their formation and can cause their abortion at later stages.

Despite decrease in the number of spikelet per spike and spike length in saline condition, the number of grain per spike increased, which indicated that salt stress reduced the number of tillers and the number of spikelet per spike. Loss in grain yield was partially offset by the increased number and weight, which occurred in response to source limitation. Such effect may be due to many factors such as total photosynthates production, leaf number and area and duration of photosynthesis. This was the most important for final grain yield reduction in salt stressed plants. Maas *et al*. (1996) reported that salt stress reduced number of tillers and spikelet per spike and the loss in grain yield was partially

Table IV. Path analysis based on phenotypic correlation coefficient for morphological and yield traits under normal and salinity conditions

1-Morphological traits

	Condition	FLA	NFT	PH	FSS	SL	NN	FLNSD	SD	Corr
FLA	Normal	(0.0178)	0.0422	-0.0103	-0.0058	0.0038	-0.0278	-0.0057	0.0292	0.044
	Salinity	(.2278)	0.0154	0.1259	0.0436	-0.0689	-0.086	0.0129	-0.0379	0.232
NFT	Normal	-0.0054	(-0.1383)	-0.0768	-0.0102	-0.0237	0.0918	-0.006	0.0216	-0.147
	Salinity	0.0674	(0.0522)	0.0206	0.0422	-0.0354	0.0385	-0.009	0	-0.141
PH	Normal	0.0005	-0.027	(-/3858)	-0.0075	-0.0123	0.079	-0.0489	0.0376	-.365
	Salinity	0.1	0.0037	(0.2869)	0.0411	-0.0526	-0.0171	0.0312	-0.0335	0.206
FSS	Normal	0.0021	-0.0314	-0.0595	(-0.045)	0.0202	0.043	-0.0043	-0.0049	-0.084
	Salinity	0.1191	0.0264	0.1414	(0.0834)	-0.139	-0.0527	0.0135	-0.0482	0.144
SL	Normal	0.001	0.0315	0.0455	-0.009	(0.1042)	-0.0244	0	0.004	0.154
	Salinity	0.0298	0.0351	0.0287	0.022	(-0.5264)	0.1417	0.001	-0.009	-0.259
NN	Normal	-0.0023	-0.06	-0.1443	-0.0092	-0.012	(0.211)	-0.0021	0.03	0.01
	Salinity	0.0595	-0.006	0.1486	0.0133	0.2263	(-0.3296)	0.0043	0.0056	0.122
FLNSD	Normal	0.0017	-0.0141	-0. 321	-0.0033	0	0.0076	(-0.0588)	0.063	-0.325
	Salinity	0.06	-0.0097	0.1848	0.0232	-0.011	-0.0293	(0.0485)	-0.0347	0.232
SD	Normal	0.0025	-0.0145	-0.071	0.0011	0.0023	0.031	-0.018	(0.2055)	0.139
	Salinity	0.0765	-0.0002	0.0852	0.0357	-0.0432	0.0015	0.015	(-0.1127)	0.159

2-Yield Component

		GNS	GWS	GNP	GWP	GL	1000GW	B	HI	HW	Corr
GNS	Normal	(-0.128)	0.066	0.044	0.021	0.018	-0.017	-0.244	0.326	-0.004	0.084
	Salinity	(0.15)	-0.077	0.098	-0.092	-0.01	0.065	-0.11	0.034	0	-0.06
GWS	Normal	-0.097	(0.087)	0.036	-0.025	0.004	-0.019	-0.235	0.109	-0.001	-0.142
	Salinity	0.099	(-0.117)	0.054	-0.093	-0.014	0.053	0.065	0.054	0	0.101
GNP	Normal	-0.078	0.044	(0.072)	-0.036	-0.008	0.026	-0.152	0.138	-0.002	0.004
	Salinity	0.114	-0.049	(0.128)	-0.122	0.002	-0.078	-0.089	-0.048	-0.003	-0.144
GWP	Normal	-0.037	0.05	0.059	(-0.044)	0.01	-0.037	-0.115	-0.097	0.057	-0.171
	Salinity	0.099	-0.079	0.114	(-0.138)	-0.01	-0.01	-0.015	-0.046	-0.004	-0.089
GL	Normal	0.053	0.01	-0.016	-0.012	(0.036)	-0.092	0.14	-0.286	0.005	-0.161
	Salinity	0.003	-0.033	-0.006	-0.029	(-0.048)	0.074	0.364	0.131	-0.004	0.444
1000GW	Normal	0.061	0.015	-0.017	-0.015	0.03	(-0.111)	0.116	-0.286	0.004	-0.203
	Salinity	0.062	-0.037	-0.064	0.009	-0.037	(0.156)	0.165	0.007	0	0.148
B	Normal	0.034	-0.022	-0.012	0.006	0.007	-0.014	(0.934)	-0.077	0.004	0.837
	Salinity	-0.017	-0.008	-0.012	0.0021	-0.018	0.027	(0.965)	-0.172	-0.003	0.763
HI	Normal	-0.077	0.017	0.018	0.005	-0.019	-0.006	-0.129	(0.544)	-0.004	0.414
	Salinity	0.008	-0.009	-0.009	0.009	-0.016	0.002	-0.25	(0.666)	0.001	0.411
HW	Normal	-0.055	0.012	0.011	0.005	-0.022	0.049	-0.373	0.234	(-0.001)	-0.148
	Salinity	-0.003	0.006	-0.039	0.054	0.018	0.006	-0.232	0.028	(0.011)	0.093

FLA: Flag Leaf Area, NFT: Number of Fertile Tiller, PH: Plant Height, FSS: Fertile Spikelet per Spike, SL: Spike Length, NN: Number of Node, FLNSD: Flag Leaf Node Until Spike Distance, SD: Stem Diameter, GNS: Grain Number per Main Spike, GWS: Grain Weight per Main Spike, GNP: Grain Number per Plant, GWP: Grain Weight per Plant, GL: Grain Length, 1000GW: 1000 Grain Weight: B: Biomass, HI: Harvest Index, HW: Hectoliter Weight. Data on parenthesis are related to indirect effect. For morphological traits Residual effect on normal condition = 0.476, Residual effect on rain fed condition=0.632. For yield components Residual effect on normal condition=0.99,Residual effect on rain fed condition= 0.94 Corr: Correlation Coefficient

offset by the increasing number and weight of kernels on remaining culms. Tanveer-ul-Haq *et al*. (2003) reported that under salinity average shoot length and fresh shoot weight decreased, whereas the number of tillers per plant increased. Francois *et al*. (1994) found smaller and less consistent increase in HI with salt stress for wheat cultivars. Kelman and Qualset (1991) reported that salinity increased the HI.

Various yield components showed different responses to salinity. A 1000 grain weight was least sensitive to salinity, whereas spikelet number was the most sensitive yield component, which is in agreement with observation on rice (Zeng & Shannon, 2000). Grain number is determined during the period of spike emergence to anthesis and grain weight is determined between anthesis and maturity; the least sensitive stage in wheat (Kirby, 1988; Mass and Grieve, 1990; Frank *et al*., 1997). Because spikelets initiate at the vegetative stage, the negative effect of salinity on spikelet number indicated that this parameter together with number of tillers per plant was more sensitive at vegetative stage. This suggested that evaluation for salt tolerance among genotypes can be based on the genetic diversity in tiller and spikelet numbers. When the developmental pattern of genotypes is so different between growth stages, assessment of the actual salt tolerance of the genotypes may be determined by comparisons of their biomass production over a long growth period, which serves as another criterion to evaluate the salt tolerance (Leland *et al.*, 1994; Munns *et al*., 2000). This indicated that the reduction in dry weight was closely related to tiller and leaf number and its area (Hu *et al*., 1997). The reduction in total biomass in the sensitive genotypes was probably due to extra energy utilized for osmolytes accumulation, for osmotic adjustment (Wyn Jones & Gorham, 1993). Salt tolerance at different growth stages was observed in Tabbasi, T65-7-1, T-65-5-1, T-66-58-6 & T-66-58-60. The characteristics of these genotypes are more tillers, higher leaf number and greater leaf area

Table V. Stepwise and multiple regression of morphologic and component traits (independent variables) on the yield (dependent variables) under normal and Salinity condition

	1-morphological Traits									
	Stepwise Regression						**Multiple Regression**			
	Normal			**Salinity**			**Normal**		**Salinity**	
	step	**R**	**Cr**	**step**	**R**	**Cr**	**Cr**	**Prob>F**	**Cr**	**Prob>F**
FLA	——	——	——	——	——	——	0	0.94	0	0.43
NFT	——	——	——	——	——	——	-0.0085	0.62	0.0015	0.9
PH	1	0.133	-0.0013	——	——	——	-0.0014	0.49	0.0012	0.55
FSS	——	——	——	——	——	——	-0.0012	0.86	0.0017	0.81
SL	——	——	——	——	——	——	0.0084	0.67	-0.016	0.22
NN	——	——	——	——	——	——	0.085	0.52	-0.03	0.43
FLNSD	——	——	——	——	——	——	-0.0002	0.91	.0005	0.89
SD	——	——	——	——	——	——	0.024	0.41	.-0.019	0.7
	2- Yield component									
GNS	——	——	——	——	——	——	-0.001	0.49	0.0007	0.24
GWS	——	——	——	——	——	——	0.019	0.57	-0.014	0.37
GNP	——	——	——	——	——	——	0.0001	0.77	0.0001	0.64
GWP	——	——	——	——	——	——	-0.0016	0.86	-0.0038	0.6
GL	——	——	——	——	——	——	0.004	0.48	-0.0033	0.43
1000GW	3	0.9914	-0.0004	——	——	——	-0.0011	0.31	-0.0008	0.31
B	1	0.7	0.3307	1	0.583	0.3099	0.3297	0.0001	0.3177	0.0001
HI	2	0.9898	0.0099	2	0.9797	0.0039	0.0104	0.0001	0.0041	0.0001
HW	——	——	——	3	0.9828	0.00041	-0.0003	0.81	0	0.84

FLA : Flag Leaf Area, NFT : Number of Fertile Tiller, PH: Plant Height, FSS: Fertile Spikelet per Spike, SL : Spike Length, NN : Number of Node, FLNSD: Flag Leaf Node Until Spike Distance, SD: Stem Diameter, GNS: Grain Number per Main Spike, GWS : Grain Weight per Main Spike, GNP :Grain Number per Plant, GWP: Grain Weight per Plant, GL : Grain Length, 1000GW: 1000 Grain Weight :, B: Biomass, HI : Harvest Index, HW : Hectoliter Weight. R _ cumulative values of R^2 (Coefficient of Determination) particular steps (independent variables involved), Cr _ coefficient of regression, in stepwise regression only those coefficient of regression are given where P>0.05

compared with other genotypes, less effect of salinity on final grain yield and the yield components of the main spike.

Salinity tolerance for cultivar and mutants was derived. Salinity sensitivity was 0.3643. In other words average yield of cultivars and mutants was reduced by 3.57%. It was evident from the data that T-66-58-6 was more flexible under salinity (Table I). Correlation of salinity intensity (SSI) with differences between salinity and non-stress for morphological and yield components revealed that SSI had positive correlation with biomass, yield of l m row and harvest index and negative one with grain length. This indicated that when biomass, yield of l m row and harvest index under salinity decrease as compared to non-stress condition, also salinity intensity increased.

Flag leaf area had positive correlation with plant height, number of fertile spikelet per spike and biomass (Table III) but a negative one with biomass and hectoliter weight under salinity. There was no correlation between biomass with flag leaf area and height under control but under salinity positive correlation were observed. Under normal condition HI had positive correlation with number of grain per spike and negative one with plant height, flag leaf node until spike distance and grain length but not under salinity stress. Yield of l m row under normal condition had no correlation with grain length but a positive one under in salinity. Under normal condition 1000 grain weight had positive correlation with plant height, flag leaf node until spike distance and stem diameter but in salinity stress condition no correlations existed.

Path analysis. Although correlation coefficient was important to determine, traits that directly affect grain yield could not determine indirect effects of these traits on grain yield. These situations are more common in cereals, because of yield traits that occurred at a different growing stage and affect each other and are explicitly studied using path coefficient analysis. The yield components have either a direct or an indirect effect on grain yield (Dofing & Knight, 1992). Therefore, it was essential to determine the effects of yield components. In this study path coefficient analysis for morphological traits under normal condition revealed that stem diameter and number of node had positive direct effect and plant height had negative effect on yield of l m row (Table IV). Under salinity stress spike length and number of node had negative effect and flag leaf area and plant height had positive effect on yield of l m row. However, under salinity stress due to indirect effect via other morphological traits, the total correlations were very low. Under normal condition flag leaf area had a positive indirect effect. Under normal condition number of node and flag leaf node until spike distance had negative indirect effect through plant height on yield of l m row, while under salinity stress number of node, number of spikelete per spike and flag leaf node until spike distance had positive indirect effect through plant height on yield of l m row. Traits path analysis for yield components revealed that under both conditions biomass and harvest index had positive direct effect on yield of l m row. Under normal condition number of grain per spike weight and hectoliter weight had negative indirect effect through biomass and number of grain per plant and hectoliter weight had positive direct effect and grain length and 1000 grain weight had negative indirect effect through harvest index on yield of 1 m row. In salt stressed plants, harvest index and hectoliter weight had negative and grain length had positive effect on biomass on yield of 1 m row.

Regression analysis. Result of stepwise regression analysis (Table V) indicated that in normal condition for morphological traits, yield of 1 m row was predominantly determined by the plant height (coefficient of determination $R^2 = 0.13$) and for yield traits yield of 1 m row was predominantly determined by the biomass, harvest index and 1000 grain weight (coefficient of determination $R^2 = 0.7$ & 0.99), whereas in salinity stress condition yield of 1 m row was determined by biomass, harvest index and hectoliter weight (coefficient of determination $R^2 = 0.58$, 0.98 & 0.98, respectively). Result of multiple regression indicated that in normal condition for morphological traits indicated that yield of 1 m row was not determined by any traits but yield traits was determined by biomass and harvest index. Under salinity stress condition for morphological traits indicated that yield of 1 m row was not determined by any traits but in yield components yield of 1 m row was determined with biomass, harvest index and hectoliter weight.

CONCLUSIONS

Values of investigated characters for cultivars and mutants in salinity condition were found lower than normal condition. T-66-58-6 showed greater yield stability across normal and salinity conditions. The correlation observed among yield of 1 m row and other traits indicated that in normal and salinity condition biomass and harvest index had positive and significant correlation with yield of 1 m row. Path analysis under normal condition indicated that morphological traits such as number of node had positive direct effect and plant height had negative direct effect on yield of 1 m row and also in salinity condition spike length and number of node had negative direct effect and plant height had positive direct effect on yield of 1 m row. In both conditions yield components such as biomass and harvest index had positive direct effect on yield of 1 m row. Data suggested that some plants traits like yield and harvest index may be used as selection criteria in wheat.

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(Received 28 November 2006; Accepted 23 February 2007)