Pak. J. Bot., 42(6): 4113-4121, 2010.

EFFECT OF SALINITY ON YIELD AND ION ACCUMULATION OF WHEAT GENOTYPES

MOHAMMAD SHAFI[1], JEHAN BAKHT[2*] MOHAMMAD JAVED KHAN[3], MOHAMMAD AMAN KHAN[4] AND SHAZMA ANWAR[1]

[1]Department of Agronomy, [2]Institute of Biotechnology and Genetic Engineering Khyber Pakhtunkhwa Agricultural University, Peshawar, Pakistan
[3]Agricultural Research Institute Tarnab, Peshawar, Pakistan
[4]Department of Biotechnology and Bioinformatics, Q.A.University Islamabad Pakistan
**Corresponding author E-mail: jehanbakht @yahoo.co.uk*

Abstract

The present study was conducted to investigate the response of different wheat genotypes to salinity stress. Field experiments were conducted at three different locations of Khyber Pakhtunkhwa Province, Pakistan i.e., Yar Hussain, Baboo Dehari (District Swabi) and Khitab Koroona (District Charsadda) to study the performance of 11 wheat genotypes (Local, SR-24, SR-25, SR-7, SR-22, SR-4, SR-20, SR-19, SR-2, SR-23 and SR-40) for their salinity tolerance. These locations had different salinity profile i.e., Yar Hussain, EC. 3-3.5 dSm^{-1}; Baboo Dehari, EC. 4- 4.5 dSm^{-1} and Khitab Koroona, EC. 5-5.30 dSm^{-1}). Different locations and wheat genotypes had a significant ($p<0.05$) effect on biological and grain yield, shoot Na^+ and K^+ concentration (3, 6 and 9 weeks after emergence). Maximum biological and grain yield , maximum shoot K^+, and minimum Na^+ concentration (3, 6 and 9 weeks after emergence) were recorded in genotype SR-40 followed by genotype SR-23. Our results further indicated that maximum biological and grain yield and minimum shoot K^+, Na^+ concentrations (3, 6 and 9 weeks after emergence) were recorded at Yar Hussain. Maximum, K^+ and Na^+ concentration (3, 6 and 9 weeks after emergence) and minimum biological and grain yield were observed at Khitab Koroona.

Introduction

Salinity is one of the major abiotic stresses, which affect productivity of agricultural lands. Screening large numbers of genotypes for salinity tolerance in the field is difficult due to spatial heterogenity of soil chemical and physical properties. Plant species differ in their salt tolerance. Salt stress, in addition to the known components of osmotic stress and ion toxicity, also result in an oxidative stress (Ashraf, 2004). It has been well documented that NaCl cause higher plasma membrane permeability and enhanced the production of oxygen radicals and H_2O_2 in wheat. Soil salinity is one of the major abiotic stresses which substantially hamper crop productivity. Excessive soil salinity occurs in many arid and semi arid regions of the world where it inhibits the growth and yield of crop plants (Hasegawa *et al*., 2000 and 2001). When grown in saline soils, roots have to cope with osmotic stress that resulted in lowered water potential and consequent loss of cell turgor in roots. Salinity stress is known to affect various growth processes including photosynthesis, ion regulation, water relations and yield (Ashraf, 2004; Bano & Aziz, 2003; Sheeren *et al.,* 2005; Waheed *et al.,* 2006; Gurmani *et al.,* 2007). Salt stress affects plant physiology at both whole plant and cellular levels through osmotic and ionic stress (Ranjbarfordoei *et al*., 2002; Hasegawa *et al*., 2000 and 2001). The various physiological processes which are severely affected by salinity include changes in plant growth, mineral distribution, membrane instability resulting from calcium displacement by sodium, membrane permeability and decreased efficiency of photosynthesis and Na^+ and K^+ discrimination (Hasegawa *et al.*, 2000; Gupta *et al.*, 2002; Munn, 2002; Munns & James, 2003; Kao *et al.*, 2003; Sayed, 2003; Ashraf & Shahbaz, 2003). Under salinity, net photosynthetic CO_2 uptake decreases mainly because NaCl treatment decreases stomatal conductance, and consequently less CO_2 is available for carboxylation reaction in the photosynthetic apparatus. Also, the rate of ribulose-1, 5- bisphosphate carboxylase/oxygenase activity decreases under NaCl salinity and photochemical reactions are inhibited.

In Pakistan, wheat production has frequently been deficit in recent years. Yield losses of wheat in moderately saline areas of Pakistan average 65%. If varieties of wheat capable of giving high yields on slight to moderately salt-affected soils could be developed, the productivity of such lands would be increased manifold, and it might also permit expansion of agriculture into more marginal lands. Consequently, there is a pressing need to develop an appropriate technique for the screening of wheat cultivars/lines for salt tolerance. The study of ion transport and regulation within intact plant tissues of wheat will also improve the understanding of mechanisms of salt tolerance in this species and allow the development of selection markers of direct value to the breeders. The recognition of selection criteria will be a step towards the urgent goal of developing wheat varieties with a better ability to grow and produce grain in places where wheat is grown inefficiently or not at all today. The present study was conducted to screen different genotypes of wheat for their grain yield performance and tolerance to salinity under different saline environment.

Materials and Methods

The present study was conducted at three different locations in Khyber Pakhtunkhwa (Districts Swabi and Charsada) Pakistan, to study the performance of 11 high wheat genotypes (Local, SR-24, SR-25, SR-7, SR-22, SR-4, SR-20, SR-19, SR-2, SR-23 and SR-40) for their salinity tolerance. Locations included Yar Hussain (EC. 3-3.5 dSm^{-1}; District Swabi), Baboo Dehari (EC. 4-4.5 dSm^{-1}; District Swabi) and Khitab Koroona (EC. 5-5.30 dSm^{-1}; District Charsada). The experiment was carried out in randomized complete block design with three replications. Experimental plots measured 4 m x 1.8 m with row to row spacing of 30 cm were maintained during the present study. A basal fertilizer dose of 135 kg N, 120 kg P_2O_5 and 60 kg K_2O ha^{-1} was applied. Half dose of N and full does of P and K was applied at the time of emergence while the remaining half dose of N was given to the experimental plot with 2^{nd} irrigation. Recommended agronomic practice i.e., weeding hoeing, thinning, irrigation and plant protection measures were carried out at appropriate times.

Procedures for data recording: Sodium and potassium concentration in shoot was determined by flame photometer. Four central rows in each sub plot were harvested; the ears were de-husked, dried and threshed. Grain weight was recorded and then converted into kg ha^{-1}. All plants in each subplot were harvested and then weighed to note biological yield.

Statistical analysis: All data are presented as mean values of three replicates. Data were analyzed statistically for analysis of variance (ANOVA) following the method described by Gomez & Gomez (1984). MSTATC computer software was used to carry out statistical analysis (Russel & Eisensmith, 1983). The significance of differences among means was compared by using Duncun's Multiple Range test (DMRT).

Results

Data concerning shoot Na^+ contents (mg g^{-1} dry weight) 3, 6 and 9 weeks after emergence is shown in Table 2, 3 and 4. Shoot Na^+ contents were significantly ($p<0.05$) affected by various genotypes, different locations and their interactions. Maximum shoot Na^+ contents (0.671 mg g^{-1} dry weight) were noted in genotype local and minimum (0.446 mg g^{-1} dry weight) in SR-40. Exposure of plants to salinity for 6 and 9 weeks resulted in similar increase of sodium concentration by genotype local (Tables 3 and 4). The data further suggested that maximum shoot Na^+ (0.618 mg g^{-1} dry weight) was obtained at Khitab Koroona (Table 2). Similarly, treatments at Yar Hussain showed minimum (0.553 mg g^{-1} dry weight) Na^+ contents compared with other locations. Similar pattern of increase in Na content was observed at Khitab Koroona when plants were exposed for longer period of 6 and 9 weeks (Tables 3 and 4). Interaction between genotypes and locations indicated that minimum shoot Na^+ contents (0.400 mg g^{-1} dry weight) was produced in plots sown at Yar Hussain with SR-40 while maximum (0.721 mg g^{-1} dry weight) was noted at Khitab Koroona when planted with genotype local. Similar increase in Na content was noted at Khitab Koroona when data was collected after 6 and 9 weeks after salinity exposure (Tables 3 and 4).

Table 5, 6 and 7 presents data concerning shoot K^+ contents (mg g^{-1} dry weight). Shoot Ka^+ contents were significantly ($p<0.05$) affected by various genotypes of wheat, locations and their interactions. Genotype SR-40 produced maximum shoot K^+ contents (0.905 mg g^{-1} dry weight) 3 weeks after emergence while minimum shoot K^+ contents (0.738 mg g^{-1} dry weight) were produced by genotype local. Plants kept for longer period (6 and 9 weeks after emergence) produced similar results (Tables 6 and 7). Similarly, maximum shoot K^+ (0.910 mg g^{-1} dry weight) was obtained in treatments at Khitab Koroona when compared with other locations (Table 5). Our data also suggested that exposure of plants to salinity for longer period (6 and 9 weeks after emergence) resulted in similar pattern (Tables 6 and 7). Interaction between genotypes x locations showed that minimum shoot K^+ contents (0.676 mg g^{-1} dry weight) was produced in plots sown at Yar Hussain with genotype local while maximum (0.984 mg g^{-1} dry weight) was noted at Khitab Koroona when planted with SR-40. Similar interaction was observed 6 and 9 weeks after emergence (Tables 6 and 7).

Various genotypes of wheat, different locations and their interactions had a significant ($p<0.05$) effect on biological and grain yield (Tables 8 and 9). Maximum biological and grain yield was produced by SR-40 while minimum in genotype local. Our results also indicated that biological and grain yield was more in treatments at Yar Hussain when compared with the other two locations (Baboo Dehari and Khitab Koroona; Tables 8 and 9). In case of interaction maximum biological and grain yield was noted at Yar Hussain when planted with SR-40 while minimum at Khitab Koroona by genotype local.

Table 1. Physio-chemical properties of the soil from three different experimental locations.

Characteristics	Yar Hussain	Baboo Dehari	Khitab Koroona
Electric conductivity (dSm^{-1})	3-3.5	4-4.5	5-5.30
K (mg kg^{-1})	108	122	124
N (%)	0.057	0.064	0.087
P (mg kg^{-1})	9.3	8.2	9.3
Clay (%)	23.15	25.15	24.50
Silt (%)	32.10	30.90	31.20
Sand (%)	44.78	42.45	45.15
Textural Class	Loamy	Loamy	Loamy

Table 2. Shoot Na^+ contents (mg g^{-1} dry weight), 3 weeks after emergence of wheat as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	0.601	0.691	0.721	0.671a
SR-24	0.582	0.667	0.696	0.647b
SR-25	0.570	0.655	0.684	0.636b
SR-7	0.550	0.632	0.660	0.614c
SR-22	0.530	0.609	0.636	0.591c
SR-4	0.540	0.681	0.648	0.603c
SR-20	0.520	0.598	0.624	0.580c
SR-19	0.460	0.529	0.552	0.513d
SR-2	0.490	0.563	0.588	0.537d
SR-23	0.430	0.494	0.516	0.480e
SR-40	0.400	0.460	0.480	0.446f
Mean	0.553 c	0.592 b	0.618 a	

DMRT value for interactions at $p \leq 0.05$ = 0.08

Means of the same category followed by different letters are significantly different using DMRT test ($p \leq 0.05$).

Table 3. Shoot Na^+ contents (mg g^{-1} dry weight), 6 weeks after emergence of wheat as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	0.661	0.793	0.813	0.755a
SR-24	0.650	0.780	0.799	0.752a
SR-25	0.640	0.768	0.787	0.731b
SR-7	0.6 35	0.762	0.781	0.726b
SR-22	0.628	0.753	0.772	0.717bc
SR-4	0.632	0.758	0.777	0.722bc
SR-20	0.625	0.750	0.768	0.714bc
SR-19	0.618	0.741	0.760	0.706bc
SR-2	0.620	0.744	0.762	0.708bc
SR-23	0.60	0.720	0.738	0.686c
SR-40	0.580	0.696	0.713	0.663d
Mean	0.592c	0.751b	0.770a	

DMRT value for interactions at $p \leq 0.05$ = 0.125

Table 4. Shoot Na^+ contents (mg g^{-1} dry weight), 9 weeks after emergence of wheat as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	1.057	1.268	1.300	1.208a
SR-24	1.040	1.248	1.278	1.188a
SR-25	1.024	1.229	1.259	1.171a
SR-7	1.016	1.219	1.249	1.161a
SR-22	1.005	1.204	1.235	1.148a
SR-4	1.011	1.213	1.243	1.156a
SR-20	1.00	1.200	1.228	1.143a
SR-19	0.988	1.186	1.216	1.130b
SR-2	0.992	1.190	1.219	1.134b
SR-23	0.950	1.152	1.181	1.094b
SR-40	0.928	1.114	1.141	1.061b
Mean	1.001c	1.202b	1.231a	

DMRT value for interactions at $p \leq 0.05$ = 0.192

Means of the same category followed by different letters are significantly different using DMRT test ($p \leq 0.05$).

Table 5. Shoot K^+ contents (mg g^{-1} dry weight), 3 weeks after emergence of wheat as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	0.676	0.750	0.789	0.738g
SR-24	0.745	0.771	0.810	0.755f
SR-25	0.680	0.789	0.819	0.763f
SR-7	0.754	0.836	0.906	0.832e
SR-22	0.741	0.849	0.927	0.839e
SR-4	0.728	0.841	0.932	0.834e
SR-20	0.745	0.862	0.949	0.852d
SR-19	0.802	0.945	0.960	0.902c
SR-2	0.804	0.832	0.966	0.867c
SR-23	0.823	0.971	0.966	0.900b
SR-40	0.753	0.979	0.984	0.905a
Mean	0.750c	0.857b	0.910a	

DMRT value for interactions at $p \leq 0.05$ = 0.065

Discussion

Biochemical parameters (i.e., shoot Na^+ and shoot K^+ concentration) and biological and grain yield of 11 genotypes were investigated during the present research study. Our results indicated that shoot Na^+ and K^+ concentration was significantly affected by different genotypes and salinity exposure (location). Our data also revealed that among the tested genotypes, SR-40 and SR-23 performed better in term of shoot Na^+ and shoot K^+ concentration when compared with other genotypes. Genotypes SR-40 and SR-23 had maximum K^+ and less Na^+ contents in their tissue while genotype local had minimum of these parameters. These biochemical parameters (shoot Na^+ and shoot K^+ concentration) are among the few markers used for assessing salinity tolerance of a particular plant species.

Table 6. Shoot K^+ contents (mg g^{-1} dry weight), 6 weeks after emergence of wheat as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	0.706	0.780	0.815	0.767f
SR-24	0.810	0.793	0.845	0.816e
SR-25	0.732	0.823	0.858	0.804e
SR-7	0.793	0.901	0.978	0.890d
SR-22	0.771	0.884	0.962	0.872d
SR-4	0.776	0.888	0.953	0.872d
SR-20	0.806	0.892	0.960	0.886c
SR-19	0.803	0.890	0.950	0.881c
SR-2	0.820	0.888	0.950	0.886c
SR-23	0.875	0.980	1.040	0.965b
SR-40	0.880	1.010	1.150	1.013a
Mean	0.797c	0.884b	0.942a	

DMRT value for interactions at $p \leq 0.05$ = 0.068

Means of the same category followed by different letters are significantly different using DMRT test ($p \leq 0.05$).

Table 7. Shoot K^+ contents (mg g^{-1} dry weight), 9 weeks after emergence of wheat as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	0.763	0.845	0.910	0.839g
SR-24	0.860	0.867	0.900	0.876f
SR-25	0.945	0.862	0.919	0.909e
SR-7	0.852	0.983	1.049	0.961c
SR-22	0.858	0.988	1.053	0.966c
SR-4	0.836	0.962	1.018	0.939d
SR-20	0.862	1.005	1.006	0.958c
SR-19	0.901	1.036	1.008	0.982b
SR-2	0.910	1.053	1.088	1.017b
SR-23	0.932	1.062	1.095	1.030a
SR-40	0.940	1.070	1.109	1.040a
Mean	0.878c	0.976b	1.014a	

DMRT value for interactions at $p \leq 0.05$ = 0.795

Physiological mechanisms conferring exclusion of Na^+ that operate at the cellular and whole plant level have been described with particular reference to selectivity for K^+ over Na^+ (Jeschke & Hartung, 2000; Tester & Davenport, 2003). There is a strong correlation between salt exclusion and salt tolerance in many species (Munns & James, 2003) and recently reported for rice (Lee *et al*., 2003; Zhu *et al*., 2004) and wheat (Poustini & Siosemardeh, 2004). Species that retain Na^+ in woody roots or stems, a strong correlation exists between Cl^- exclusion and salt tolerance (Storey & walker, 1999).

Munns & James (2003) reported that genotypes with the lowest Na^+ concentration produced greatest dry matter. These low Na^+ genotypes had fewer injured leaves, and a greater proportion of living to dead leaves. The effect on growth was probably due to a better carbon balance in the genotypes with less Na^+. A similar relationship between shoot dry weight and leaf Na^+ was found in a population from a cross between high and low Na^+ genotypes. There was a strong correlation between shoot dry matter produced and Na^+ concentration in leaves between families from a cross between the genotypes with the highest and lowest Na^+. Species which cannot effectively exclude salt from the transpiration stream must have ways to handle the salt arriving in leaves as the water evaporates and salt gradually build up over time. The salt concentration in older leaves is much higher than in younger leaves at a given time. In the older leaves, the salt concentration eventually becomes high enough to kill the cells, unless they can compartmentalize the salt in vacuoles, thereby protecting the cytoplasm from ion toxicity. The concept that salt must either be excluded from the tissues or compartmentalized in cell vacuoles, derives from the earlier discovery by biochemists that enzymes of halophytes are no longer tolerant of high concentrations of NaCl than those of non-halophytes (also called glycophytes or plants requiring sweet water). Osmotic adjustment has been considered a crucial process in plant adaptation to salinity, because it sustains tissue metabolic activities and enables re-growth upon removing the stress but varies among genotypes.In terms of crop yield there are not many field studies showing a consistent benefit from osmotic adjustment (Quarrie *et al*., 1999), presumably because turgor maintenance in cells is often associated with slow growth (Serraj & Sinclair, 2002).

Table 8. Biological yield (kg ha^{-1}) of wheat genotypes as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	3031.67	2793.33	2548.33	2791.11d
SR-24	3052.33	2855.67	2515.33	2807.78d
SR-25	2986.67	3111.00	2475.33	2857.67d
SR-7	3451.00	2976.00	2937.67	3121.56c
SR-22	3442.33	3198.33	2940.00	3193.56bc
SR-4	3371.00	3226.67	2916.00	3171.22bc
SR-20	3469.00	3197.00	2972.33	3212.78b
SR-19	3715.33	3517.33	3220.33	3484.33a
SR-2	3717.33	3525.00	3222.33	3488.22a
SR-23	3726.00	3508.67	3243.67	3492.78a
SR-40	3750.00	3528.00	3209.67	3495.89a
Mean	3428.42a	3221.55b	2927.36c	

DMRT value for interactions at $p \leq 0.05$ = 210

Means of the same category followed by different letters are significantly different using DMRT test ($p \leq 0.05$).

Table 9. Grain yield (kg ha^{-1}) of wheat genotypes as affected by locations of different salinity level.

Genotypes	Yar Hussian	Baboo Dehari	Khitab Koroona	Mean
Local	2035.00	1820.33	1755.00	1870.11c
SR-24	2053.33	1841.00	1760.00	1884.78c
SR-25	2108.33	1818.67	1737.00	1888.00c
SR-7	2303.33	2158.33	1988.33	2150.00b
SR-22	2306.68	2130.00	2061.67	2166.11b
SR-4	2328.33	2063.33	2065.00	2152.22b
SR-20	2261.68	2185.00	2055.00	2167.22b
SR-19	2543.33	2360.00	2233.33	2378.89a
SR-2	2543.33	2346.67	2256.67	2382.22a
SR-23	2546.68	2420.00	2236.67	2401.11a
SR-40	2536.67	2360.00	2310.00	2402.22a
Mean	2324.24a	2136.67b	2041.70c	

DMRT value for interactions at $p \leq 0.05$ = 150

Means of the same category followed by different letters are significantly different using DMRT test ($p \leq 0.05$).

Biological and grain yield of the 11 genotypes under study were also significantly affected by genotypes and locations (salinity levels). Genotypes with low Na^+ accumulation (SR-40 and SR-23) yield better than genotypes with high Na+. Similarly, locations which had minimum salt in their soil had maximum grain yield. Similar results are also reported by Hussain, (2002) and Munns & James, 2003). Our results also agree with those reported by Ashraf *et al*., (2005) and Munns *et al*., (2006). It was revealed from these results that increasing salinity levels had progressively decreased growth and development which might be due to decreased water potential of rooting medium due to high ion concentration and accumulation of Na^+ and Cl^- ion to toxic levels in leaves interfering metabolic processes viz., photosynthesis, protein synthesis etc. going on in cytoplasm (Ibrahim, 2003). High concentration of these ions in the rooting medium reduced the uptake of other essential ions as K^+, Ca^+ and NO_3 etc. Similarly, Harris *et al*., (2001) concluded that significant decrease in plant performance occurs due to salinity stress.

References

Ashraf, M. 2004. Some important physiological selection criteria for salt tolerance in plants. *Flora*, 199: 361-376.

Ashraf, M. and M. Shahbaz. 2003. Assessment of genotypic variation in salt tolerance of early CIMMAT hexploid wheat germplams using photosynthetic capacity and water relations as selection criteria. *Photosynthetica*, 41(2): 273-280.

Ashraf, M., M. Shahbaz and T. McNeilly. 2005. Phylogenetic relationship of salt tolerance in early green Revolution CIMMYT wheats. *Environ. and Exp. Bot*., 53: 173-184.

Bano, A. and N. Aziz. 2003. Salt and drought stress in wheat and the role of ABA. *Pak. J. Bot.,* 35: 871-883.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research. Wiley, New York, 680 pp.

Gupta, N.K., S.K. Meena, S. Gupta and S.K. Khandelwal. 2002. Gas exchange, membrane permeability, and ion uptake in two species of Indian Jujuba differing in salt tolerance. *Photosynth.,* 40: 535-539.

Gurmani, A.R., A. Bano and M. Saleem. 2007. Effect of ABA on growth and ion accumulation of wheat under salinity stress. *Pak. J. Bot.,* 39: 141-149.

Hasegawa, P.M., R. A. Bressan, J.K. Zhu and H.J. Bohnert. 2001. Plant cellular and molecular response to high salinity. *Annu. Rev. Plant Physiol. Plant Mol. Biol.,* 51: 463-499.

Hasegawa, P.M., R.A.J. Versan, K. Zhu and H.J. Bonhert. 2000. Plant cellular and molecular responses to high salinity. *Ann. Rev. Plant Physiol. and Plant Mol. Biol.,* 51: 463-499.

Hussain, S. 2002. *Physiology and genetics of salt tolerance in durum wheat*. A thesis submitted for the degree of Doctor of Philosophy at the Australian national University, Canberra, Australia.

Ibrahim, M. 2003. *Salt tolerance studies on cotton*. M.Sc (Hons) Thesis, Inst. Soil and Environ. Sci., Univ. of Agric. Faisalabad, Pakistan.

Jeschke, W.D. and W. Hartung. 2000. Root-shoot interaction in mineral nutrition. *Plant and Soil,* 226: 57-69.

Kao, K.Y., T.T. Tsai and C.N. Shih. 2003. Photosynthetic gas exchange and chlorophyll a florescence of three wild soybean species in response to NaCl treatments. *Photosynth.,* 41: 415-419.

Lee, K.S., W.Y. Choi, J.C. Ko, T.S. Kim and G.B. Gregoria. 2003. Salinity tolerance of japonica and indica rice (*Oryza sativa* L) at the seedling stage. *Planta,* 216: 1043-1046.

Munns, R. 2002. Comparative physiology of salt and water stress. *Plant Cell and Environ.,* 25: 239-250.

Munns, R. and R. A James. 2003. Screening methods for salinity tolerance: A cas study with tertradploid wheat. *Plant and Soil,* 253: 201-218.

Munns, R., R.A. James and A. Lauchli. 2006. Approaches to increasing the salt tolerance of wheat and other cereals. *J. Exp. Bot.,* 57: 1025-1043.

Poustini, K. and A. Siosemardeh. 2004. Ion distribution in wheat cultivars in response to salinity stress. *Field Crop Res.,* 85: 124-153.

Quarrie, S.A., J. Stojanovic and S. Pekic. 1999. Improving drought resistance in small-grained cereals: a case study, progress and prospects. *Plant Growth Regul.,* 29: 1-21.

Ranjbarfordoei, A., R. Samson, R. Lemeur and P. Van Damme. 2002. Effects of osmotic drought stress induced by combination of NaCl and polyethylene glycol on leaf water status, photosynthetic gas exchange, and water use efficiency of *Pistacia khinjuk* and *P. mutica*. *Photosynth.,* 40: 165-169.

Russel, D.F. and S P. Eisensmith. 1983. *MSTATC. Crop soil science department,* Michigan state university, USA.

Sayed, O.H. 2003. Chlrophyll florescence as a tool in cereal crop research. *Photosynth.,* 41: 321-330.

Serraj, R. and T.R Sinclair. 2002. Osmolyte accumulation: Can it realy help increase crop yield under drought conditions? *Plant Cell and Environ.,* 25: 333-341.

Sheeren A., S. Mumta, S. Raza, M.A. Khan and S. Solangi. 2005. Salinity effects on seedling growth and yield components of different inbred rice. *Pak. J. Bot.,* 37: 131-139.

Steel, R.G.D. and J.H. Torrie. 1984. Principles and procedures of statistics, 2^{nd} ed., p: 172-177. McGraw Hill Book Co. Inc. Newyork.

Storey, R. and R.R. Walker. 1999. Citrus and salinity. *Sci. Horti.,* 78: 39-81.

Taster, M. and R. Davenport. 2003. Na^+ tolerance and Na^+ transport in higher plants. *Ann. Bot.,* 91: pp. 503-507.

Waheed, A., I.H. Hafiz, G. Qadir, G. Murtaza, T. Mahmood and M. Ashraf. 2006. Effect of salinity on germination, growth, yield, ionic balance and solute composition of piegeon pea. *Pak. J. Bot.,* 38: 1103-1117.

Zhu, G.Y., J.M. Kinet and S. Lutts. 2004. Characterization of rice (*Oryza sativa* L.) F_3 populations selected for salt resistance. 2. Relationship between yield-releated parameters and physiological properties. *Aust. J. Expt. Agric.,* 44: 333-342.

(Received for publication 9 May 2009)