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Full Length Research Paper

Effect of salinity and seed priming on growth and biochemical parameters of different barely genotypes

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An experiment was conducted to investigate the interactive effect of salinity and seed priming on barely genotypes at the Institute of Biotechnology and Genetic Engineering (IBGE), Khyber Pakhtun Khwa Agricultural University Peshawar Pakistan. The experiment was carried out in completely randomized design (CRD) with three replications consisting of twelve barely genotypes (Haider-93, Soorab-96, Arabic Asward, NRB-37, Frontier-87, Jau-83, Balochistan-Local, NRB-31, KPK-Local, Sanober-96, Awarn-2002 and AZ-2006) at two seed conditions (seed priming with 30 mM NaCl or no seed priming) under four salinity levels (0, 50, 100 and 150 mM). The results revealed that seed priming and salinity had significantly ($p \leq 0.05$) affected all the parameters under study. However, the effect of seed priming was non significant ($p > 0.05$) on shoot chlorophyll a content (mg g^{-1} fresh weight) and root sugar content (mg g^{-1}dry weight). Salinity stress had adversely affected growth and biochemical parameters of barley genotypes, however, seed priming with NaCl had diminished the negative impact of salt stress. Maximum shoot dry weight plant^{-1} (1.81 g), root dry weight plant^{-1} (0.42 g), shoot K^+ content (1.41 mg g^{-1} dry weight), root sugar content (7.55 mg g^{-1}dry weight) were recorded in Balochistan-Local. Similarly, Haider-93 produced highest root K^+ content (0.67 mg g^{-1} dry weight), shoot sugar content (16.36 mg g^{-1}dry weight), shoot chlorophyll a content (3.44 mg g^{-1} fresh weight) and shoot chlorophyll b content (1.78 mg g^{-1} fresh weight). Maximum shoot Na^+ content (1.20 mg g^{-1}) and root Na^+ content (1.47 mg g^{-1}) was recorded in Frontier-87. Seed priming had significantly ($P < 0.05$) enhanced all the aforementioned parameters. The positive effect of seed priming was more profound in Balochistan-Local followed by Haider-93 as compared to other genotypes.

Key words: Barely, salinity, seed priming, Na^+, K^+, chlorophyll a and b.

INTRODUCTION

Soil salinity is one of the major environmental stresses limiting crop production in many countries of the world (Munns, 2005; Rengasamy, 2006; Ashraf et al., 2008; Katerji et al., 2009). Excess salts severely damage plant growth and the land beyond economic repair (Flower, 2004; Munns et al., 2006). Out of 271 million ha of irrigated lands about 40 million ha is affected by salinity worldwide (Chaudhary and Ehrenreich, 2000). Gradually, vast agricultural area is becoming uncultivable due to salinity than the new or reclaimed lands are brought under agriculture (Vose, 1983; Barret-Lennard, 2000). Salinity is a problem particularly in low lying areas where evaporation concentrate the salts received from more elevated locations in surface water and rainfall is insufficient to cause leaching of these salts beyond the root-zone, resulting in their accumulation in soil profile. One possible strategy to cope with salinity is the use of salt tolerant crop varieties with improved cultural practices to enhance production from saline areas (Mass and Hoffman, 1977; Ashraf and Leary, 1996). Salt tolerance of barley is the highest (Mass and Hoffman, 1977; Mano and Takeda, 1998; Forster et al., 2000). Barley is an important crop used as feed for animals, malt and human food. It has better ability to grow and produce in marginal areas characterized by drought, low temperature and salinity (Van Oosterom et al., 1993;

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Maas and Hoffman, 1997; Baum et al., 2004) as compared with other cereals. Higher salt concentrations in upper layers of the soil reduces seed emergence and is a major constraint for higher crop production (Harris et al., 1999; Bakht et al., 2010). One of the most important progresses in this connection is the halopriming that is a pre-sowing soaking of seeds in salt solutions which improves germination and seedling emergence under adverse environmental conditions (Cantliffe, 1997). It has been reported that salt tolerance in wheat has increased by treatment of seeds with NaCl solutions before sowing (Ashraf et al., 1999).

Halopriming alters plant physiological and biochemical responses to salt stress (Cayuela et al., 1996; Bakht et al., 2011). To encourage the use of salt tolerant crops, the present study was designed to examine the effect of seed priming and salinity stress on growth and salt tolerance of difference barely genotypes.

MATERIALS AND METHODS

An experiment was conducted to study the interactive effect of salinity and seed priming on barely genotypes at the greenhouse of the Institute of Biotechnology and Genetic Engineering (IBGE), Khyber Pakhtunkhwa Agricultural University, Peshawar during winter 2007 to 2008. The experiment was carried out in completely randomized design (CRD) with three replications, twelve barely genotypes (Haider-93, Soorab-96, Arabic Asward, NRB-37, Frontier-87, Jau-83, Balochistan-Local, NRB-31, KPK-Local, Sanober-96, Awarn-2002 and AZ-2006) at two seed conditions (seed priming with 30 mM NaCl and no seed priming) under four salinity levels (0, 50, 100 and 150 mM). In case of priming, seeds of barley genotypes were first primed with saline water (30 mM) for 12 h at 25°C. Sand was washed 3 times with water and sterilized before using in pots. Twenty primed or unprimed seeds as per treatment were grown in each pot containing sand salinized with the desired salinity (NaCl) levels. After complete emergence, ten plants per pot were maintained through thinning. Hoagland solution (Hoagland and Arnon, 1950) salinized with the required NaCl levels was applied to the pots periodically. The position of the replication in the greenhouse was changed periodically so that all the experimental units may be exposed uniformly to micro variation of the green house. Plants were harvested 50 days after sowing. Data were recorded on shoot dry weight (g plant^{-1}), root dry weight (g plant^{-1}), shoot chlorophyll a content (mg g^{-1}fresh weight), shoot chlorophyll b content (mg g^{-1}fresh weight), shoot sugar content (mg g^{-1}dry weight), root sugar content (mg g^{-1}dry weight), shoot Na^+ content (mg g^{-1} dry weight), root Na^+ (mg g^{-1} dry weight), shoot K^+ content (mg g^{-1}dry weight) and root K^+ content (mg g^{-1}dry weight). The shoots and root of three randomly selected plants in each treatment were dried in an oven at 80°C for 48 h and at complete drying weighed and averaged to record shoot dry weight. The dried and grinded shoot and root samples in each treatment were used for estimation of Na^+ and K^+ content according to the methods of US Salinity Staff (1954). First digestion was carried out according to the procedure of Benton et al. (1991).

For digestion, 10 ml of concentrated HNO_3 (Nitric acid) was added to 0.5 g sample in a volumetric flask and was kept overnight. 4 ml of concentrated $HClO_4$ (Perchloric acid) was added to the solution and heated at 350°C until the solution became colorless and produced colorless white fumes. On cooling, filtration was done and volume was adjusted to 100 ml by adding distilled water. The flame photometer (Jenway PFP-7) was calibrated against standard solutions, Na^+ and K^+ content was determined in the samples. The sugar content was determined according to the method of Fales (1951). Shoot and root samples in each treatment were taken separately. Dried tissue powder (50 mg) from each sample was taken and heated in water bath at 100°C for 15 min after adding HCl. The solution was cooled in ice bath and transferred to a 100 ml measuring flask after filtration and make up the volume by adding distilled water. The anthrone solution was prepared by dissolving 0.4 g of anthrone in 200 ml of sulphuric acid. The acid solution was then slowly added to flask containing 60 ml of distilled water and 15 ml of 95% ethyl alcohol. The solution was cooled and mixed during the addition. About 4.5 ml of anthrone reagent was added to 0.5 ml of the prepared solution in a clean dried test tube, heated at 97°C for 10 min cooled in ice bath and read in UV spectrophotometer at 625 nm. Chlorophyll a and b was estimated according to the methods of Lichtenthaler (1987). Briefly, 5 to 10 fresh leaves were collected from each treatment and then were cut into small pieces (0.5 cm) with a pair of scissors. A sample of 0.30 g was transferred to cleaned dried glass colored tubes immediately after weighing. 80% acetone was added to the sample and then transferred the samples to refrigerator for extraction overnight. The samples were protected from light by using colored bottle or tubes wrapping them in aluminum foil or black polythene sheet. The lid must be properly placed on tubes and sealed by para film to avoid acetone loss.

The extract of each sample was centrifuged at 14000 × g for 5 min. The absorbance of the supernatant was measured at 646 and 663 nm by using spectrophotometer.

RESULTS

Shoot dry weight (g plant^{-1})

Statistical analysis of the data revealed significant ($P<0.05$) effect of various salinity levels, seed priming and genotypes on shoot dry weight (Table 1). All possible interactions except seed priming x salinity x genotypes were also significant ($P<0.05$). Maximum shoot dry weight was produced by Balochistan-Local (1.81 g plant^{-1}). Haider-93 and KPK-Local ranked 2nd and 3rd with shoot dry weight of 1.77 and 1.74 g plant^{-1} respectively. Minimum shoot dry weight was recorded in Frontier-87 (1.35 g plant^{-1}). Primed seeds proved superior and enhanced shoot dry weight by 9.68% in primed seed (1.66 g plant^{-1}) than un-primed seed (1.51 g plant^{-1}). Shoot dry weight was reduced by 20.32, 32.98 and 49.01% at salinity level of 50, 100 and 150 mM respectively when compared with the control.

Root dry weight (g plant^{-1})

Table 1 shows significant ($P<0.05$) effect of various salinity levels, genotypes and seed priming on root dry weight. All possible interactions except seed priming x salinity x genotypes were also significant ($P<0.05$). Highest root dry weight was recorded in Balochistan-Local (0.42 g plant^{-1}). Haider-93 and KPK-Local ranked 2nd and 3rd with root dry weight of 0.39 and 0.38 (g plant^{-1}) respectively. Lowest root dry weight was produced by Frontier-87 (0.23 g plant^{-1}). The treatment of

Table 1. Plant weight and photosynthetic pigments of barely genotypes as affected by salinity and seed priming.

Genotypes	Shoot dry weight (g plant^{-1})	Root dry weight (g plant^{-1})	Shoot chlorophyll a content (mg g^{-1} fresh weight)	Shoot chlorophyll b content (mg g^{-1} fresh weight)
Haider-93	1.77^{b}	0.39^{b}	3.44^{a}	1.78^{a}
Soorab-96	1.69^{c}	0.36^{d}	3.06^{d}	1.57^{b}
Arabic Asward	1.65^{d}	0.34^{e}	2.91^{e}	1.55^{b}
NRB-37	1.61^{e}	0.32^{f}	2.85^{e}	1.48^{bc}
Frontier-87	1.35^{k}	0.23^{l}	2.20^{j}	1.03^{e}
Jau-83	1.39^{j}	0.25^{k}	2.23^{ij}	1.05^{e}
Balochistan-Local	1.81^{a}	0.42^{a}	3.33^{b}	1.74^{a}
NRB-31	1.56^{f}	0.31^{g}	2.70^{f}	1.43^{c}
KPK-Local	1.74^{b}	0.38^{c}	3.23^{c}	1.69^{a}
Sanober-96	1.42^{i}	0.26^{j}	2.30^{i}	1.07^{e}
Awarn-2002	1.47^{h}	0.27^{h}	2.61^{g}	1.32^{d}
AZ-2006	1.53^{g}	0.29^{i}	2.49^{h}	1.23^{d}
Salinity (mM)				
0	2.13^{a}	0.46^{a}	3.51^{a}	1.88^{a}
50	1.69^{b}	0.34^{b}	2.98^{b}	1.49^{b}
100	1.43^{c}	0.28^{c}	2.58^{c}	1.30^{c}
150	1.08^{d}	0.20^{d}	2.04^{d}	0.98^{d}
Seed priming				
Un-primed	1.51^{b}	0.30^{b}	2.76	1.35^{b}
Primed	1.66^{a}	0.33^{a}	2.80	1.47^{a}
$LSD_{(0.05)}$ for G	0.027	0.008	0.086	0.035
$LSD_{(0.05)}$ for S	0.016	0.004	0.050	0.020
$LSD_{(0.05)}$ for P	0.011	0.003	0.035	0.014
Interactions				
G x P	S	s	ns	s
P x S	S	s	ns	s
G x S	S	s	s	s
P x S x G	Ns	ns	ns	ns

s and ns represent significant and non significant at P<0.05 level respectively. G = genotypes, P = seed priming, S = salinity. Means of same category followed by same letters are not significantly different at P≤0.05 using LSD test.

seed priming enhanced root dry weight by 8.88% in primed seed (0.33 g plant^{-1}) than un-primed seed (0.30 g plant^{-1}). Application of each additional increment of salinity had gradually reduced root dry weight. Salinity levels of 50, 100 and 150 mM had significantly decreased root dry weight by 26.65, 37.66 and 57.23% respectively when compared with the control.

Chlorophyll a content (mg g^{-1}fresh weight)

Different salinity levels and genotype x salinity interaction had significantly (P<0.05) affected chlorophyll a content of different barely genotypes (Table 1). The main effect of seed priming and all remaining possible interactions were non-significant (P>0.05). Maximum chlorophyll a

concentration was measured in genotype Haider-93 (3.44 mg g^{-1}) followed by Balochistan-Local and KPK-Local with chlorophyll a content of 3.33 mg g^{-1} fresh weight and 3.23 mg g^{-1} fresh weight respectively. Minimum chlorophyll a content was observed in genotype Frontier-87 (2.20 mg g^{-1}). Non-significantly higher chlorophyll a content was maintained in primed seed when compared with un-primed seed (2.80 *vs*. 2.76 mg g^{-1}). Application of salinity levels had gradually reduced chlorophyll a content. Chlorophyll a content was reduced by 41.78% with the application of 150 mM NaCl (2.04 *vs*. 3.51 mg g^{-1}) and 26.42% at 100 mM ((2.58 *vs*. 3.51 mg g^{-1}) as compared with the control.

Chlorophyll b content (mg g^{-1} fresh weight)

It is evident from mean values that application of increasing salinity stress and seed priming had significantly (P<0.05) affected chlorophyll b content of barley genotypes (Table 1). Interaction of genotypes x seed priming, genotypes x salinity and seed priming x salinity was significant (P<0.05). Highest chlorophyll b concentration was maintained by genotype Haider-93 (1.78 mg g^{-1}) which was statistically at par with Balochistan-Local (1.74 mg g^{-1}) and KPK-Local (1.69 mg g^{-1}). Lowest chlorophyll b concentration was recorded in genotype Frontier-87 (1.03 mg g^{-1}) which was statistically equal to Jau-83 (1.05 mg g^{-1}) and Sanober-96 (1.07 mg g^{-1}). The data further revealed 8.79% high chlorophyll b content from the treatment of primed seed when compared with un-primed seed (1.47 *vs*. 1.35 mg g^{-1} fresh weight). Chlorophyll b content was decreased by 48.21% at 150 mM salinity as compared with the control (1.88 *vs*. 0.98 mg g^{-1}) and 31.22% at 100 mM (1.88 *vs*. 1.30 mg g^{-1}).

Shoot sugar content (mg g^{-1}dry weight)

Analysis of the data explicated that different salinity levels and seed priming had significantly (P<0.05) affected endogenous shoot sugar content of barely genotypes (Table 2). All possible interactions were non significant except seed priming x genotypes x salinity. Mean values of the data showed maximum shoot sugar concentration in genotype Haider-93 (16.36 mg g^{-1}). Balochistan-Local and KPK-Local ranked 2nd and 3rd with shoot sugar concentration of 15.97 and 15.44 mg g^{-1} dry weight respectively. Minimum shoot sugar concentration was recorded in genotype Frontier-87 (11.57 mg g^{-1}) and Jau-83 (11.64 mg g^{-1}). Shoot sugar content was 12.10% more accumulated in primed seed when compared with un-primed seed (14.59 *vs*. 13.02 mg g^{-1}). Application of increasing salinity levels had persistently enhanced shoot sugar concentration. Shoot sugar content was 127.95% increased in plants treated with 150 mM NaCl (19.52 *vs*. 8.56 mg g^{-1}) followed by 74.19% at 100 mM salt stress (14.92 *vs*. 8.56 mg g^{-1}) when compared with control.

Root sugar content (mg g^{-1}dry weight)

Table 2 reveals significant (P<0.05) effect of various salinity levels, genotypes and genotype x salinity interaction on endogenous root sugar content. The main effect of seed priming and all remaining possible interactions were non-significant (P>0.05). Balochistan-Local produced highest (7.55 mg g^{-1}) root sugar content which was statistically at par with Haider-93 (7.41 mg g^{-1}) while minimum was maintained from genotype Frontier-87 (5.50 mg g^{-1}) which was statistically at par with Jau-83 (5.63 mg g^{-1}). Seed priming non-significantly increased (6.51 mg g^{-1}) root sugar content when compared with un-primed seed (6.44 mg g^{-1}). In case of salinity, sugar content enhanced with increasing salt stress. Root sugar content was 64.97% higher in plants treated with 150 mM NaCl when compared with control (8.00 *vs*. 4.85 mg g^{-1}) followed by 38.13% at 100 mM salt stress (6.70 *vs*. 4.85 mg g^{-1}).

Shoot Na^+ content (mg g^{-1}dry weight)

Significant (p<0.05) differences in shoot Na^+ content was observed due to salinity levels, genotypes and seed priming on shoot Na^+ content (Table 2). Interaction of genotypes x seed priming, genotypes x salinity and seed priming x salinity were also significant (P<0.05). However, interaction of seed priming x salinity x genotypes was non significant (P>0.05). Highest shoot Na^+ content was recorded in Frontier-87 (1.20 mg g^{-1}) and was statistically at par with Jau-83 (1.19 mg g^{-1} dry weight). This was followed by Sanoobar-96 and Awarn-2202 with shoot Na^+ content of 1.17 and 1.14 mg g^{-1} dry weight respectively. Lowest shoot Na^+ content was observed in Balochistan-local (0.97 mg g^{-1}). The treatment of seed priming reduced shoot Na^+ content by 14.23% (1.01 mg g^{-1}) than un-primed seed (1.17 mg g^{-1}). Significant (P<0.05) increase in shoot Na^+ was noted with the application of each additional increment of salinity. Shoot Na^+ content enhanced by 503.68, 614.91 and 795.85% with the application of 50, 100 and 150 mM salinity levels respectively when compared with the control.

Root Na^+ content (mg g^{-1} dry weight)

Significant (P<0.05) effect of salinity, seed priming and genotypes was noted on root Na^+ (mg g^{-1} dry weight). All possible interactions except salinity x seed priming x seed priming were significant (P<0.05). Highest root Na^+ contents (1.47 mg g^{-1}) were recorded from Frontier-87

Table 2. Biochemical parameters of barely genotypes as affected by salinity and seed priming.

Genotype	Shoot sugar content (mg g^{-1} dry weight)	Root sugar content (mg g^{-1} dry weight)	Shoot Na^+ content (mg g^{-1} dry weight)	Root Na^+ content (mg g^{-1} dry weight)	Shoot K^+ content (mg g^{-1} dry weight)	Root K^+ content (mg g^{-1} dry weight)
Haider-93	16.36^{a}	7.41^{a}	0.99^{i}	1.12^{i}	1.37^{b}	0.67^{a}
Soorab-96	14.79^{d}	6.83^{c}	1.04^{g}	1.28^{g}	1.30^{c}	0.60^{d}
Arabic Asward	14.39^{e}	6.65^{d}	1.06^{g}	1.30^{f}	1.26^{d}	0.58^{e}
NRB-37	13.93^{f}	6.47^{e}	1.08^{f}	1.28^{g}	1.22^{e}	0.55^{f}
Frontier-87	11.57^{k}	5.50^{i}	1.20^{a}	1.47^{a}	1.02^{j}	0.43^{l}
Jau-83	11.64^{k}	5.63^{i}	1.19^{ab}	1.43^{b}	1.05^{i}	0.44^{k}
Balochistan-Local	15.97^{b}	7.55^{a}	0.97^{j}	1.09^{j}	1.41^{a}	0.65^{b}
NRB-31	13.50^{g}	6.37^{ef}	1.10^{e}	1.40^{d}	1.19^{f}	0.54^{g}
KPK-Local	15.44^{c}	7.15^{b}	1.01^{h}	1.16^{h}	1.35^{b}	0.64^{c}
Sanober-96	12.14^{j}	5.83^{h}	1.17^{b}	1.39^{e}	1.08^{h}	0.47^{j}
Awarn-2002	13.08^{h}	6.06^{g}	1.14^{c}	1.38^{e}	1.16^{g}	0.50^{i}
AZ-2006	12.84^{i}	6.20^{fg}	1.12^{d}	1.41^{c}	1.14^{g}	0.52^{h}
Salinity (mM)						
0	8.56^{d}	4.85^{d}	0.19^{d}	0.31^{d}	1.62^{a}	0.67^{a}
50	12.21^{c}	6.34^{c}	1.14^{c}	1.26^{c}	1.30^{b}	0.57^{b}
100	14.92^{b}	6.70^{b}	1.35^{b}	1.57^{b}	1.10^{c}	0.51^{c}
150	19.52^{a}	8.00^{a}	1.69^{a}	2.10^{a}	0.83^{d}	0.44^{d}
Seed priming						
Un-primed	13.02^{b}	6.44	1.17^{a}	1.39^{a}	1.16^{b}	0.53^{b}
Primed	14.59^{a}	6.51	1.01^{b}	1.23^{b}	1.26^{a}	0.57^{a}
$LSD_{(0.05)}$ for G	0.099	0.172	0.019	0.010	0.026	0.010
$LSD_{(0.05)}$ for S	0.057	0.099	0.011	0.006	0.015	0.006
$LSD_{(0.05)}$ for P	0.040	0.070	0.008	0.004	0.011	0.004
Interactions						
G x P	s	ns	s	s	S	s
P x S	s	ns	s	s	S	s
G x S	s	s	s	s	S	s
P x S x G	ns	ns	ns	ns	Ns	ns

s and ns represent significant and non significant at 95% probability level respectively. G = genotypes, P = seed priming, S = salinity. Means of same category followed by same letters are not significantly different at P≤0.05 using LSD test.

followed by Jau-83 and AZ-2006 with root Na^+ content of 1.43 and 1.41 mg g^{-1} dry weight respectively. Lowest root Na^+ content was recorded in Balochistan-Local (1.09 mg g^{-1}). Primed seed had reduced root Na^+ content by 11.52% (1.23 mg g^{-1}) than un-primed seeds (1.39 mg g^{-1} dry weight). Statistical analysis of the data also revealed steady raise in root Na^+ content with the application of each additional increment of salinity. Maximum root Na^+ content (2.10 mg g^{-1} dry weight) was recorded from 150 mM NaCl when compared with other treatments (Table 2).

Shoot K^+ content (mg g^{-1}dry weight)

Mean values of the data described significant ($P<0.05$) effect of salinity levels and seed priming on shoot K^+ content of barely genotypes (Table 2). Interaction of genotypes x seed priming, genotypes x salinity and seed priming x salinity was significant ($P<0.05$). Highest shoot K^+ content was produced from Balochistan-local (1.41 mg g^{-1}) followed by Haider-93 with shoot K^+ content of 1.37 mg g^{-1}. Lowest shoot K^+ content (1.02 mg g^{-1}) was observed in Frontier-87. Shoot K^+ content was 8.57% more in the treatment of primed seeds (1.26 mg g^{-1}) than un-primed seeds (1.16 mg g^{-1}). Shoot K^+ content was decreased by 20.07, 31.97 and 49.05% with the application of salinity levels of 50, 100 and 150 mM respectively when compared with the control.

Root K^+ content (mg g^{-1} dry weight)

Analysis of the data indicated that root K^+ content of barely genotypes was significantly ($P<0.05$) affected by different salinity levels and seed priming (Table 2). All possible interactions except seed priming x salinity x genotypes were significant ($P\leq0.05$). Maximum root K^+ content of 0.67 mg g^{-1} dry weight was recorded from the treatment of Haider-93 followed by Balochistan-Local and KPK-Local with root K^+ content of 0.65 and 0.64 mg g^{-1} respectively as compared with minimum root K^+ content from Frontier-87 (0.43 mg g^{-1}). Root K^+ content was enhanced by 6.15% in primed seed (0.57 mg g^{-1}) than un-primed seeds (0.53 mg g^{-1}). Mean values of the data indicated gradual reduction in root K^+ content with application of enhancing salinity levels. Root K^+ content (mg g^{-1}) increased by 15.04, 23.96 and 34.67% with the application of salinity level of 50, 100 and 150 mM respectively when compared with the control.

DISCUSSION

Seed priming and salinity levels had significantly affected shoot dry weight (g $plant^{-1}$) of barely genotypes. Balochistan-Local performed better by maintaining maximum shoot dry weight while Frontier-87 produced least quantity of dry weight. Shoot weight decreased with the rise of stress level compared with the control plants in barely (El-Tayeb, 2005; Niazi et al., 1992), sugar beet plants (Ghoulam et al., 2001) and wheat (Shafi et al., 2010). At high salt levels, physical damage to roots and toxic effect of sodium decreased the ability of roots to absorb water and nutrient and thus created marked reduction in photosynthesis, enzymatic process and protein synthesis (Tester and Davenport, 2003), this all results in stunted growth, less leaf area development and reduced shoot fresh and dry weight (Shafi et al., 2009). It is evident from results, that primed seeds in comparison with dry seeds resulted in more crop growth rate. The use of salt as an osmoticum can lead to greater plant weight (Cantliffe, 1997; Brocklehurst et al., 1987; Harris et al., 2001; Basra et al., 2003). Barely genotypes, seed priming and salinity produced marked effect on root dry weight. This effect was highest in Frontier-87 and least in Balochistan-Local and Haider-93. Under salinity stresses, ion toxicity, water deficiency and lower production and availability of photosynthates to roots causes marked decrease in root volume, diameter and density in wheat (Shafi et al., 2010). Salts in the rooting media create water deficiency by generating low external water potential. It also reduces xylem transport of water and solutes (Marschner, 1981). Cell wall modifies the metabolic activities of the cell due to salt accumulation and limits the cell wall elasticity and becomes rigid as a consequence, the turgor pressure efficiency in cell enlargement decreases. These processes may also reduce growth and dry matter of roots and shoot. Our results are in agreement with those reported by Rottella and Martinez (1997), Ashraf et al. (2005) and Munns et al. (2006). Ashraf et al. (1999) also reported that higher EC values were observed in seeds treated with NaCl than in the non-primed seeds. Photosynthetic pigments (chlorophylls a and b) of all barely genotypes were significantly affected by salinity stress and seed priming. Magnitude of loss in photosynthetic pigments was highest in sensitive genotypes (Frontier-87 and Jau-83) than tolerant genotypes (Haider-93 and Balochistan-Local). The photosynthetic pigments (chlorophylls a and b) as a chief component of the photosynthetic system governing the dry matter participation, decreased significantly in NaCl treated barely plants in comparison to controls (El-Tayeb, 2005).

Growth performance of plants growing under saline conditions depends on their ability to minimize the accumulation of toxic Na^+ and to have lower Na^+: K^+ in their leaves (Schatchman and Munns, 1992: Rashid et al., 1999; Saqib et al., 1999). This will lead to higher photosynthetic rate and stomatal conductance and hence relatively higher growth resulted. Reduction in chlorophyll level might be due to enhancement of chlorophyllase activity or due to reduction in 'de novo' chlorophyll synthesis (Sudhakar et al., 1991). Seeds preconditioning

has lessen damage to photosynthetic pigments more in tolerant than sensitive species (Hamid et al., 2008). Perusal of the results revealed that salinity had a significant effect on shoot and root sugar concentration (mg g^{-1} dry weight) of barely genotypes. Sugar accumulation was more in tolerant genotype of Balochistan-Local and Haider-93 as compared with sensitive genotypes of Frontier-87 and Jau-83. Sugar accumulation under salinity stress is a common phenomenon (Cheeseman, 1988; Khan et al., 1995; Munns and James, 2003) and is responsible for osmotic adjustment under salinity stress in grasses (Vacher et al., 1994; Prado et al., 2000; Akhtar et al., 2004). During stress, sugar protects the plant cells. The hydroxyl group of sugars may substitute for water to maintain hydrophilic interactions in membranes and proteins. Thus, sugar prevents protein denaturation by interacting with protein and membranes through hydrogen bonding (Sanchez et al., 1995). Our results confirm that seed priming had significant effect on shoot sugar content and to lesser extent root sugar content. High salt tolerance of plants from primed seeds is due to maintenance of higher osmotic adjustment. Plants from primed seeds have more sugars and organic acids in leaves and more Na^+ and Cl^- in roots than plants from non-primed seeds (Cayuela et al., 1996). Our findings reveal significant effect of salinity levels and seed priming on shoot and root Na^+ content (mg g^{-1} dry weight) of different barely genotypes. Highest Na^+ was accumulated in the shoots and roots of sensitive genotypes (Frontier-87 and Jau-83) while tolerant genotypes (Balochistan-local) maintained the lowest Na^+ content in their shoot and root. The Na^+ content in shoots increased markedly in all genotypes of barley with increase in salinity stress (Willadino et al., 1994; Shadi et al., 1999; Xia at al., 2000) and roots (El-Tayeb, 2005).

The ability of roots to exclude Na^+ from uptake via either restricting Na^+ influx or enhanced Na^+ extrusion from the cytosol (Tyerman and Skerrett, 1999; Blumwald, 2000; Tester and Davenport, 2003) is considered a key feature of salt tolerance. Under saline condition, Na^+ and Cl^- concentration increased in the leaves of salt tolerant species and is probably linked with the salinity tolerance mechanism (Bajji et al., 1998; Chen et al., 1998; Heuer and Nadler, 1998; Weimberg and Shannon, 1988; Yasin and Zahid, 2000; Bakht et al., 2011). Sodium chloride can exert its toxic effect on plants by interfering with the uptake of other nutrient ions, especially K^+ leading to nutrient ion deficiency. Under saline condition in barely cultivars, the ability to restrict entry of the potentially toxic Na^+ into the shoot is greater in the salt-tolerant than in salt-susceptible cultivar. The ability to restrict entry of the potentially toxic Na^+ into the shoot, often termed as ion exclusion is known to be the most useful trait for salt tolerance in barley and wheat (Colmer et al., 2005). Sodium ion in the xylem can be removed by the exclusion system operating in the upper part of the root, stem, petiole or leaf sheath (Munns, 2002; Tester and Davenport, 2003). Metabolic toxicity of Na^+ is largely caused by competition with K^+ for binding sites of protein components essential for cellular processes where Na^+ cannot substitute the role of K^+. Our results depict that with priming, Na^+ concentration was reduced significantly. Similar results were observed by (Afzal et al., 2006, 2008; Iqbal and Ashraf, 2007) who reported that salinity tolerance is linked with reduced Na^+ and enhanced K^+ up take and retention that in turn increased growth and yield. The capacity of plants to counteract salinity stresses depends on the status of their K^+ nutrition (Maathuis and Amtmann, 1999). Tolerant genotypes (Balochistan-local and Haider-93) retained maximum K^+ content in shoots and roots as compared with sensitive genotype (Frontier-87). Potassium plays an important role in regulating osmotic pressure, activating enzymes, balancing membrane potential and tropisms (Cherel, 2004). Because of similarities in the physical and chemical structures of Na^+ and K^+, elevated Na^+ in the cytosol causes destruction of K^+ dependent metabolic processes. Also, many K^+ transport systems have some affinity for Na^+ transport (Blumwald, 2000; Véry and Sentenac, 2002; Shabala, 2003). Plant cells under salinity must adjust their osmotic potential to prevent water loss. This is achieved either by uptake of inorganic ions or by synthesis of organic osmolytes (Serrano et al., 1999; Shabala and Lew, 2002). Under mild saline conditions, barley roots took up inorganic cations (specifically, K^+) instead of following the energy-expensive synthesis of compatible solutes (Cerda et al., 1995; Huang and Redmann, 1995). Cell's ability to retain K^+ is at least as important for plant salt tolerance as its ability to exclude or compartmentalize toxic Na^+ (Shabala, 2000; Shabala et al., 2003).

Similar to our results, Iqbal et al. (2006) stated that K^+ content of primed cultivars increased significantly as compared to dried seeds under saline conditions.

REFERENCES

Afzal I, Basra SMA, Farooq M, Nawaz A (2006) Alleviation of salinity stress in spring wheat by hormonal priming with salicylic acid and ascorbic acid. Int. J. Agri. Biol., 8: 23-28.

Afzal I, Rauf S, Basra SMA, Murtaza G (2008) Halopriming improves vigor, metabolism of reserves and ionic contents in wheat seedlings under salt stress. Plant Soil Environ., 54: 382-388.

Akhtar J, Mahmood K, Malik KA, Mardana A, Ahmad M, Iqbal MM (2004). Effects of hydrogel amendment on water storage of sandy loam and loam soils and seedling growth of barley, wheat and chickpea. Plant Soil Environ., 50: 463-469.

Ashraf M, Leary JW (1996). Responses of some newly developed salt-tolerant genotypes of spring wheat to salt stress 1. Yield components and ion distribution. J. Agro. Crop Sci., 176: 91-101.

Ashraf M, Akhtar N, Tahira F, Nasim F (1999). Effect of NaCl pretreatment for improving seed quality cereals. Seed Sci., Tech. 20: 435-440.

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

Ashraf M, Athar HR, Harris PJC, Kwon TR (2008). Some prospective strategies for improving crop salt tolerance. Adv. Agron., 97: 45-110.

Bajji M, Kinet JM, Lutts S (1998) Salt stress effects on roots and leaves of Atriplex halimus (L.) and their corresponding callus cultures. Plant Sci., 137: 131-42.
Bakht J, Shafi M, Shah R (2010). Effect of various priming sources on yield and yield components of maize cultivars. Pak J. Bot., 42: 4123-4131.
Bakht J, Shafi M, Jamal Y (2011). Response of maize (Zea mays L.) to seed priming with NaCl and salinity stresses. Spanish J. Agric. Res., 9: 252-261.
Basra SMA, Ehsanullah E, Warraich A, Cheema MA, Afzal I (2003). Effect of storage on growth and yield of primed canola seed Int. J. Agric. Bio., 117-120.
Baum M, Grando S, Ceccarelli S (2004). Localization of quantitative trait loci for dry land characters in barley by linkage mapping. Challenges and Strategies for Dryland Agriculture. CSSA Special Pub., 32: 191–202.
Benton JJ, Wolf B, Mills HA (1991). Plant analysis hand book. A practical sampling, preparation, analysis and interpretation guide. Micro-Macro Pub. Ins., USA.
Blumwald E (2000). Sodium transport and salt tolerance in plants. Curr. Opin. Cell Bio., 12: 431– 434.
Brocklehurst PA, Dearman J, Drew RLK (1987). Recent developments in osmotic treatment of vegetable seeds. Acta Hort., 215: 193-200.
Cantliffe DG (1997). Industrial processing of vegetable seeds. J. Korean Soc. Hort. Sci., 38: 441-445.
Cayuela E, Perez Alfocea F, Caro M, Bolaryn MC (1996). Priming of seeds with NaCl induces physiological changes in tomato plants grown under salt stress. Physiol. Plantar., 96: 231-236.
Cerda A, Pardines J, Botella MA, Martinez V (1995). Effect of potassium on growth, water relations and the inorganic and organic solute contents for two maize cultivars grown under saline conditions. J. of Plant Nut., 18: 839–851.
Chaudhary WR, Ehrenreich JH (2000). Agroforestry: A tool to develop problem soils. In. international seminar on “prospects for saline agric. April 10-12, Islamabad Pakistan, page 14.
Cheeseman JM (1988). Mechanism of salt tolerance in plants. Plant Physiol., 87: 547– 550.
Chen DM, Keiper FJ, Defilippiss LF (1998) Physiological changes accompanying the induction of salt tolerance in Eucalyptus microcorys shoots in tissue culture. J. of Plant Physiol., 152: 555-63.
Cherel L (2004). Regulation of K^+ channel activities in plants: from physiological to molecular aspects. J. Exp. Bot., 55: 337-51.
Colmer TD, Munns R, Flowers TJ (2005) Improving salt tolerance of wheat and barley: future prospects. Aust. J. Exp. Agric., 45: 1425-1443.
El-Tayeb MA (2005). Response of barley grains to the interactive effect of salinity and salicylic acid. Plant Growth Reg. 45: 215-224.
Fales FW (1951). The assimilation and degradation of carbohydrates of yeast cells. J. Bio. Chem., 193: 113-118.
Flowers TJ (2004). Improving crop salt tolerance. J. Exp. Bot., 55: 1-13.
Forster BP, Ellis RP, Thomas WTB, Bahri DMH Ben-Salem M (2000). The development and application of molecular markers for abiotic stress tolerance in barley. J. Exp. Bot., 51: 19–27.
Ghoulam CF, Ahmed F, Khalid F (2001). Effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. Environ. Exp. Bot., 47: 139-150.
Hamid M, Ashraf MY, Rehman KU, Arshad M (2008). Influence of salicylic acid seed priming on growth and some biochemical attributes in wheat grown under saline conditions. Pak. J. Bot., 40: 361-367.
Harris D, Joshi A, Khan AP, Gothkar P, Sodhi SP (1999). On-farm seed priming in semi-arid agriculture development and evaluation in maize, rice and chickpea in India using participatory methods. Exp. Agric., 35: 15-29.
Harris D, Pathan AK, Gothkar P, Joshi A, Chivasa W, Nyamudeza P (2001). On farm seed priming: using participatory methods to revive and refine a key technology. Agric. Syst., 69: 151-164.
Heuer B, Nadler A (1998) Physiological response of potato plants to soil salinity and water deficit. Plant Sci., 137: 43-51.
Hoagland DR, Arnon DI (1950). The water culture method for growing plants without soil. Calif. Agric. Exp. St. Cir., 347. 32.
Huang J, Redmann RE (1995). Salt tolerance of Hordeum and Brassica species during germination and early seedling growth. Can. J. Plant Sci., 75: 815–819.
Iqbal M, Ashraf M, Jamil A, Rehman SU (2006). Does Seed priming induce changes in the levels of some endogenous plant hormones in hexaploid wheat plants under salt stress? J. Integ. Plant Bio., 48: 181−189.
Iqbal M, Ashraf M (2007) Seed preconditioning modulates growth, ionic relations and photosynthetic capacity in adult plants of hexaploid wheat under salt stress. J. Plant Nutr., 30: 381-396.
Katerji N, Mastrorilli M, Van Horn JW, Lahmer FZ, Hamdy A, Oweis T (2009). Durum wheat and barley productivity in saline-drought environments. Eur. J. Agron., 31: 1–9
Khan MG, Silberbush M, Lips SH (1995). Physiological studies on salinity and nitrogen interaction in Alfalfa. J. Plant Nutr., 17: 93-99.
Lichtenthaler HK (1987). Chlorophyll and carotenoids pigments of photosynthetic biomembranes. Meth. Enzymol., 148: 350-382.
Maas EV, Hoffman GJ (1997). Crop salt tolerance, current assessment. J. Irrig. Drain. Div. ASCE. 103: 115-134.
Maathuis FJM, Amtmann A (1999). K^+ nutrition and Na^+ toxicity: the basis of cellular K^+/Na^+ ratios. Ann. of Bot., 84: 123-133.
Mano Y, Tekeda K (1998). Genetic resources of salt tolerance in wild *Hordeum* species. Euphy., 103: 137-141.
Marschner H, Kylin A, Kuiper PJC (1981). Differences in salt tolerance of three sugar beet genotypes. Physiol. Plantar., 51: 234-238.
Munns R (2002) Comparative physiology of salt and water stress. Plant Cell Environ., 25: 239- 250.
Munns R (2005). Genes and salt tolerance: bringing them together. New Phytol., 167: 645-663.
Munns R, James RA (2003). Screening methods for salinity tolerance: a case study with tetraploid wheat. Plant and Soil. 253: 201-218.
Munns R, James RA, Lauchli A (2006). Approaches to increasing salt tolerance of wheat and other cereals. J. Exp. Bot., 5: 1025-1043.
Niazi MLK, Mahmood K, Mujtaba SM, Malik KA (1992). Salinity tolerance in different cultivars of barley. Biol. Plantar., 34: 465-469.
Prado FE, Boero C, Gallardo M, Gonzalez JA (2000). Effect of NaCl on germination, growth and soluble sugar. Bot. Bull. Acad. Sin., 41: 27-34.
Rashid A, Qureshi RH, Hollington PA, Wyne Jones RG (1999). Comparative responses of wheat (Triticum aestivum L.) cultivars to salinity at the seedling stage. J. Agron. Crop Sci., 182: 199-207.
Rengasamy P (2006). World salinization with emphasis on Australia. J. Exp. Bot., 57: 1017–1023.
Rottella BA, Martinez V (1997) Effect of salinity on the growth and nitrogen uptake by wheat seedling. J. Plant Nutr., 20: 793-804.
Sanchez M, Revilla G, Zarra I (1995). Changes in peroxidase activity associated with cell walls during pine hypocotyls growth. Ann. Bot., 75: 415-419.
Saqib M, Qureshi RH, Akhtar J, Nawaz S, Aslam M (1999). Effect of salinity and hypoxia on growth and ionic composition of different genotypes of wheat. Pak. J. Soil Sci., 17: 1-8.
Schachtman DP, Munns R (1992). Sodium accumulation in leaves of Triticum species that differ in salt tolerance. Aust. J. Plant Physiol., 19: 331-340.
Serrano R, Mulet JM, Rios G, De Marquez JA, Larrinoa I, Leube MP, Mendizabal I, Ahuir AP, Profit M, Ros R, Montesinos C (1999). A glimpse of the mechanisms of ion homeostasis during salt stress. J. Expt. Bot., 50: 1023–1036.
Shabala SN (2000). Ionic and osmotic components of salt stress specifically modulate net ion fluxes from bean leaf mesophyll. Plant Cell, Environ., 23: 825-837.
Shabala SN, Lew RR (2002). Turgor regulation in osmotically stressed Arabidopsis epidermal root cells: direct support for the role of inorganic ion uptake as revealed by concurrent flux and cell turgor measurements. Plant Physiol., 129: 290-299.
Shabala SN, Shabala L, Van Volkenburgh E (2003). Effect of calcium on root development and root ion fluxes in salinized barley seedlings. Funct. Plant Biol., 30: 507–514.
Shadi AI, Rashed MA, Sarwat MI, El Din MAT, Abo Doma AF (1999) Salt tolerance evaluation of some maize inbreeds (Zea mays L.) as detected by biochemical and genetic indices. Ann. Agric. Sci., Cairo. 44: 459-477.

Shafi M, Bakht J, Raziuddin, Zhang G (2009). Effect of cadmium and salinity stresses on growth and antioxidant enzymes activity of wheat genotypes. Bull. Environ. contam.Toxicol., 82: 772-776.
Shafi M, Bakht J, Khan MJ, and Khan MA (2010). Effect of salinity and ion accumulation of wheat genotypes. Pak J. Bot., 42: 4113-4121.
Sudhakar C, Reddy PS, Veeranjaneyulu K (1991). Changes in respiration, its allied enzymes, pigment composition, chlorophyllase and Hill reaction activity of horse gram seedling under salt stress. Ind. J. Plant Physiol., 34: 171-177.
Tester M, Davenport R (2003). Na^+ tolerance and Na^+ transport in higher plants. Ann. Bot., 91: 503-527.
US Salinity Staff (1954). Diagnosis and improvement of saline and alkaline soils. USDA Hand Book 60. US Depart. Agric., Washington DC.
Vacher JJ, Dizes J, Spindola G, Del Castillo C (1994). VIII Congreso International de Sistemas Agropecuarios Andinos. Valdivia-Chile. 22: 20.
Van Oosterom EJ, Ceccarelli S, Peacock JM (1993). Yield response of barley to rainfall and temperature in Mediterranean environments. J. Agric. Sci. (Cambridge), 121: 307-313.
Véry AA, Sentenac H (2002). Cation channels in the Arabidopsis plasma membrane. Trends in Plant Sci., 7: 168-175.
Vose PB (1983). Rational of selection for specific nutrition characters in crop improvement with Phaseolus vulgaris L. Plant and Soil, 72: 351-364.
Weimberg R, Shannon MC (1988) Vigor and salt tolerance in three lines of tall grass. Physiol. Plantar., 73: 232-237.
Willadino L, Camara TR, Tabosa JN, Andrade AG, Gdino RV, Souza AJD, De Souza AJ (1994) Evaluation of maize cultivars in the saline soil of semi-arid region of Pernambuco. Pesquisa Agrope. Brasil., 29: 1059-1065.
Xia Y, Lin S, Zhang F, Hu H, Tao H, Xia Y, Lin S, Zhang FS, Hu, Tao HB (2000) Effect of NaCl stress on growth and mineral nutrient content of maize varieties. Acta Pratac. Sin., 9: 24-31.
Yasin M, Zahid MA (2000) Genotypic behavior of lentil cultivars toward salinity. In: International seminar on “Prospects for Saline Agric., April 10-12, 2000, Islamabad (Pakistan), page 72.