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EFFECT OF HALOPRIMING ON THE INDUCTION OF NACL SALT TOLERANCE IN DIFFERENT WHEAT GENOTYPES

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Abstract

Salinity is a major environmental stress limiting plant growth and productivity of wide range of crops with impairing effects on germination and yield. The present study was conducted to assess the induction of salt tolerance in seven wheat genotypes (*Bakhtawar-92, Bhakar-2002, Fakhar-e-Sarhad, Khyber-87, Nasir-2000, Pirsabak-2005, and Uqab-2000*) at germination and seedling stage through halo-priming with NaCl. Seeds of each wheat genotype were halo-primed separately. Halo-primed seeds of each wheat genotype were subjected to 0.02 (control), 2, 4, 6 and 8 dS/m NaCl salinity under laboratory conditions. Germination % age varied significantly among various wheat genotypes; however, differences between different salt concentrations were non-significant. All the seedling growth characters (germination, plumule growth, fresh and dry weight of seedling and moisture contents) exhibited significant differences among wheat genotypes as well as under the applied salt concentration except for radicle growth which varied non-significantly under salt stress. Interaction between various wheat genotypes and salt concentration was also significant for all the seedling growth characters, while it was non-significant for germination %age. It is concluded that NaCl proved to be effective priming agents in inducing salt tolerance in the tested wheat genotypes.

Key words: Priming; Salinity tolerance; Wheat; Germination; Seedling growth.

Introduction

World population is increasing at alarming rate and expected to reach about 9.2 billion by the end of year 2050 (Anon., 2009). On the other hand food productivity is decreasing due to the various biotic and abiotic stresses. Therefore, minimizing these losses is a major concern for all the nations to cope with the increasing food requirement. Salinity is a major environmental stress limiting plant growth and productivity of wide range of crops (Athar *et al*., 2008). Salinity impairs seed germination, retards plant growth and reduces crop yield. Out of 25 million hectares of cultivated land in Pakistan, 10 million hectares are affected with salinity (Anon., 2008). Agriculture is the largest sector in Pakistan economy and account for about 25% of gross domestic product and about 75% of the population depends on agriculture (Anon., 2013). Wheat (*Triticum aestivum* L.) is one of the most important crops among the cultivated plants with respect to human nutrition. It is a moderately salt tolerant crop and fulfills 95% of the food requirements of our country (Anon., 2013). The significance of soil salinity for agricultural yield is enormous as it affects the establishment, growth and development of plants leading to huge losses in productivity (Mathur *et al*., 2007).

Various strategies are applied to overcome the deleterious effects of salinity on plants. Seed priming seems to be a promising technique to raise successful crop in arid and semiarid tropics. Various seed priming techniques have been developed; each has advantages and disadvantages and may have varying effects depending upon plant species, stage of plant development, concentration/dose of priming agent, and incubation period (Ashraf & Foolad, 2005). Among the various strategies, pre-sowing soaking of seeds in salt solutions enhance germination and seedling emergence uniformly under adverse environmental conditions. It is the most important, low cost, low risk and effective approaches for induction of salt tolerance in wheat (Khalil *et al*., 2010). Seed priming enhances speed and uniformity of germination, induces several biochemical changes in the seed which are required to start the germination process (Asgedom & Becker, 2001; Khalil *et al*., 2010), resulting in improved stand establishment that can increase the drought and salt tolerance and crop yield (Yari *et al*., 2011). From the review of literature it is clear that few workers have under taken studies regarding salinity tolerance in *Triticum aestivum* (Basra *et al*., 2005; Iqbal & Ashraf, 2005; Afzal *et al*., 2006 a, b; Iqbal *et al*., 2006; Khan *et al*., 2006; Xu *et al*., 2006; Afzal *et al*., 2007 a, b; Gurmani *et al*., 2007; Hajihashemi & Kiarostami, 2007; Iqbal & Ashraf, 2007; Wahid *et al*., 2007; Afzal *et al*., 2008; Farooq *et al*., 2008 ; Hamid *et al*., 2008; Nawab & Bakht, 2008; Sakr & El-Metwally, 2009; Abbasdokht *et al*., 2010; Murungu & Madanzi, 2010; and Yari *et al*., 2010, 2011).

The present study was therefore, planned to assess the effect of priming on the germination and growth improvement of wheat genotypes under different levels of salinity. The aim was also to determine the genotypic variability in their tolerance to salinity both at the germination and seedling stage.

Materials and Methods

Seeds of seven wheat genotypes viz. *Bakhtawar-92, Bhakar-2002, Fakhar-e-Sarhad, Khyber-87, Nasir-2000, Pirsabak-2005 and Uqab-2000* were obtained from Agricultural Research Institute (ARI) Pirsabak, Nowshera. Seed priming was done by keeping 1:5 ratios of seed and solution. Seeds of each genotype (500) were exposed to halo-priming with 4 dS/m NaCl solution for 12 hours at 25°C in the dark. Seeds were rinsed thrice and re-dried up to original weight under shade (Basra *et al*., 2005).

The halo-primed seeds of each genotype were grown in 2, 4, 6 and 8 dS/m saline solution of NaCl. Dry seeds of each wheat genotype were used in the control. Seeds were placed on twice folded Whatman # 1 filter paper as seed beds in petri dishes. Each petri dish in the saline treatments was provided with 8 ml of the respective salt concentration. Ten seeds of each wheat genotype were sown using 10 replicates. While each replicate, in the non-saline environment was provided with the same amount of distilled water. The glassware was thoroughly washed with tap water followed by rinsing with distilled water. The dried glassware was then sterilized at 170°C for 4 hours before use. The experiment was laid out in completely randomized design (CRD) with two factorial arrangements in an incubator at 25°C. The germination, plumule and radicle length were recorded after 72 hours. Five seedlings from each replicate of each treatment were randomly selected for fresh weight and then kept in oven at 65°C for 72 hours for dry weight determination. Moisture contents were measured following Hussain (1989). The collected data was subjected to two ways Analysis of Variance (ANOVA). The means were compared by Least Significant Difference (LSD) test at 5 % level of probability (Steel &Torrie, 1980).

Results

Germination % age: Analysis of variance (ANOVA) revealed that germination % age of wheat genotypes was significantly affected by halo-priming with NaCl under saline conditions. However, salinity and their interaction with genotypes were non-significant (Table 1). Genotypic means showed that *Nasir-2000* exhibited maximum germination followed by *Khyber-87*. While, minimum germination % age was observed in *Bakkar-2002* which is statistically similar to *Bakhtawar-92*. Concentrations means showed that halo-primed seeds performed better than control even at 8 dS/m salinity. Among the interaction *Nasir-2000* showed the highest germination % age at 8 dS/m salt concentration; however, *Bhakkar-2002* showed least germination % age at 6dS/m NaCl (Table 2).

Table 1. Means squares of the analysis of variance for germination (%), plumule and radicle growth (mm), seedling fresh and dry weight (mg), moisture contents (%).

Source	d.f	Germination (%)	Plumule growth (mm)	Radicle growth (mm)	Fresh weight (mg)	Dry weight (mg)	Moisture contents (%)
Genotypes (G)	6	10528.556*	335.493*	2472.470*	8790.36*	1499.830*	25746.603*
Concentration (C)	4	27.737NS	107.134*	108.855NS	3220.352*	34.215*	17107.334*
G X C	24	133.737NS	56.968*	183.508*	373.796*	32.703*	3567.157*
Error	140	172.920	10.515	73.467	161.715	15.803	1649.213
Coefficient of variation (%)		20.81	16.53	22.23	11.00	10.35	19.67

d.f. = Degree of freedom; NS= Non-significant; *= Significant

Table 2. Effect of halopriming on the germination (%) of different wheat genotypes under NaCl salt stress.

Wheat genotypes	Concentration (dS/m)					Genotypic means
	Control	2 dS/m	4 dS/m	6 dS/m	8 dS/m	
Bakhtawar-92	40.0 -	44.0 (110.00)	40.0 (100.00)	40.0 (100.00)	47.0 (117.50)	42.3 e
Bhakkar-2002	30.0 -	36.0 (120.00)	43.0 (143.33)	30.0 (100.00)	40.0 (133.33)	36.0 e
Fakhar-e-Sarhad	54.0 -	52.0 (96.29)	56.0 (103.70)	58.0 (107.00)	50.0 (92.59)	54.0 d
Khyber-87	80.0 -	74.0 (92.50)	86.0 (107.50)	80.0 (100.00)	86.0 (107.50)	81.2 b
Nasir-2000	90.0 -	94.0 (104.44)	90.0 (100.00)	92.0 (102.22)	100.0 (111.11)	93.2 a
Pirsabak-2005	74.0 -	66.0 (89.18)	64.0 (86.48)	74.0 (100.00)	62.0 (83.78)	68.0 c
Uqab-2000	66.0 -	78.0 (118.18)	66.0 (100.00)	64.0 (96.96)	64.0 (96.96)	67.6 c
Concentration Means	62.0 -	63.5 (102.41)	63.6 (102.58)	62.6 (100.96)	64.2 (103.54)	

LSD value at 0.05 alpha level for genotype means = 7.353

Means in the last column sharing the same letter do not differ significantly from each other at 5% probability level

Figures in parenthesis represent % of control

Table 3. Effect of halopriming on plumule growth (mm) of different wheat genotypes under NaCl salt stress.

Wheat genotypes	Concentration (dS/m)					Genotypic means
	Control	2 dS/m	4 dS/m	6 dS/m	8 dS/m	
Bakhtawar-92	15.9 klmno -	20.0 fghij (125.78)	13.4 nop (84.27)	15.0 lmno (94.33)	12.1 op (76.10)	15.3 e
Bhakkar-2002	14.5 mno -	19.1 ghijk (131.72)	18.2 ijklm (125.51)	23.1 bcdefg (159.31)	17.9 ijklm (123.44)	18.6 c
Fakhar-e-Sarhad	24.2 bcde -	18.1 ijklm (74.79)	19.0 hijkl (78.51)	14.4 mno (59.50)	12.7 nop (52.47)	17.7 cd
Khyber-87	26.5 ab -	25.5 abcd (96.22)	21.7 defghi (81.88)	22.2 cdefgh (83.77)	20.8 efghi (78.49)	23.3 a
Nasir-2000	28.8 a -	25.9 abc (89.93)	26.1 abc (90.62)	24.6 bcde (85.41)	19.3 ghijk (67.01)	25.0 a
Pirsabak-2005	16.5 jklmn -	14.5 mno (87.87)	10.1 p (61.21)	20.8 efghi (126.06)	19.1 ghijk (115.75)	16.2 de
Uqab-2000	25.4 abcd -	23.7 bcdef (93.30)	22.4 cdefgh (88.18)	15.6klmno (61.41)	19.6 ghijk (77.16)	21.3 b
Concentration Means	21.7 a -	21.0 a (96.77)	18.7 bc (86.17)	19.4 b (89.40)	17.4 c (80.18)	

LSD value at 0.05 alpha level for genotype means = 1.813, treatment means = 1.533 and interaction = 4.055
Means in the last column/ rows sharing the same letter do not differ significantly from each other at 5% level of probability
Figures in parenthesis represent % of control

Plumule growth: ANOVA exhibited significant variation for plumule growth among wheat genotypes and salt concentrations. Interaction between genotypes and concentrations was also significant (Table 1). Genotypic means showed that maximum plumule growth was recorded in *Nasir-2000* closely followed by *Khyber-87*. Plumule growth in Uqab-2000 was significantly lower than the aforementioned genotypes while, higher than *Bhakkar-2002* and *Fakhar-e-Sarhad*, which were significantly greater than *Pirsabak-2005*. The growth of plumule in *Bakhtawar-92* was significantly lowest among all the tested genotypes. Concentration means revealed that the observed maximum plumule growth under control condition was statistically similar with 2dS/m which decreased significantly at 4 dS/m. Average plumule length at 6 dS/m was statistically same to 4 dS/m salt concentration; however it was significantly greater than plumule growth at 8 dS/m salinity (Table 3).

Radicle growth: ANOVA revealed that radicle growth varied significantly among wheat genotypes. Interaction between genotypes and concentrations was also significant. However, differences due to salt concentrations were non-significant (Table 1). Genotypic means show that maximum radicle length was observed in *Nasir-2000* followed by significantly lower and statistically similar radicle growth in *Khyber-87*, *Pirsabak-2005*, *Uqab-2000* and *Bakhtawar-92*. Radicle growth in *Fakhar-e-Sarhad* was significantly lower than the aforementioned genotypes however; it was significantly higher than radicle growth in *Bhakkar-2002*. Concentration means revealed that radicle growth of the halo primed seedlings decreased under salt stress except at 6 dS/m level of salt, whereas it increased as compared to control. Interaction between wheat genotypes and salt concentrations showed that radicle growth was maximum in *Nasir-2000* under control condition, which was statistically similar to radicle growth at 2 dS/m and 4 dS/m salt levels in the same genotype. While, the minimum radicle growth was observed in *Pirsabak-2005* at 4 dS/m salinity (Table 4).

Fresh weight: Results indicated that fresh weight varied significantly among wheat genotypes and salt concentrations. Interaction between genotypes and concentrations was also significant (Table 1). Genotypic means revealed maximum fresh weight/ seedling in *Uqab-2000*, followed *by Nasir-2000*, *Pirsabak-2005*, *Fakhar-e-Sarhad*, *Bhakkar-2002*, *Khyber-87* and *Bakhtawar-92*. Concentration means showed that maximum fresh weight in the halo-primed seedlings was recorded in control, which was statistically at par with 2 dS/m and 4 dS/m salinity level respectively. Average fresh weight at 6dS/m level of salt was significantly lower than control and higher than 2 dS/m salinity. Interactions means revealed maximum average fresh weight in the halo-primed seedlings of *Uqab-2000* under 2 dS/m level of salt which was statistically similar with average fresh weight at control and 4 dS/m level of salt in the same genotype. The minimum average fresh weight was observed in *Bakhtawar-92* at the highest concentration of NaCl (Table 5).

Table 4. Effect of halopriming on radicle growth (mm) of different wheat genotypes under NaCl salt stress.

Wheat genotypes	Concentration (dS/m)					Genotypic means
	Control	2 dS/m	4 dS/m	6 dS/m	8 dS/m	
Bakhtawar-92	33.8 ghijkl -	41.7 defghi (123.37)	35.0 ghijk (103.55)	41.1 efghi (121.59)	35.6 ghijk (105.32)	37.4 b
Bhakkar-2002	18.4 m -	18.8 m (102.17)	25.6 klm (139.13)	42.0 defgh (228.26)	24.1 lm (130.97)	25.8 d
Fakhar-e-Sarhad	35.0 ghijk -	33.4 ghijkl (95.42)	35.4 ghijk (101.14)	28.9 jklm (82.57)	26.2 klm (78.85)	31.8 c
Khyber-87	40.6 fghi -	35.9 ghijk (88.42)	39.2 fghij (96.55)	44.1 defg (108.62)	43.6 defgh (107.38)	40.7 b
Nasir-2000	68.4 a -	60.0 ab (87.71)	58.2 abc (85.08)	51.9 bcd (75.87)	51.6 bcde (75.43)	58.0 a
Pirsabak-2005	33.1 hijkl -	35.8 ghijk (108.15)	31.2 ijkl (94.25)	47.6 cdef (143.80)	43.8 defgh (132.32)	38.3 b
Uqab-2000	40.8 fghi -	40.8 fghi (100.00)	39.4 fghij (96.56)	35.1 ghijk (86.02)	33.5 ghijkl (82.10)	37.9 b
Concentration Means	38.6 -	38.1 (98.70)	37.7 (97.66)	41.5 (107.51)	36.9 (95.59)	

LSD value at 0.05 alpha level for genotype means = 4.793, and interaction = 10.72

Means in the last column/ rows sharing the same letter do not differ significantly from each other at 5% level of probability

Figures in parenthesis represent % of control

Table 5. Effect of halopriming on fresh biomass/ seedling (mg) of different wheat genotypes under NaCl salt stress.

Wheat genotypes	Concentration (dS/m)					Genotypic means
	Control	2 dS/m	4 dS/m	6 dS/m	8 dS/m	
Bakhtawar-92	85.5 o -	92.9 mno (108.65)	83.6 o (97.77)	87.0 no (101.75)	62.3 p (72.86)	82.3 f
Bhakkar-2002	110.6 hijkl -	122.7 defghi (110.94)	120.6 efghi (109.04)	129.7 cdefg (117.26)	86.9 no (78.57)	114.1 d
Fakhar-e-Sarhad	136.0 cde -	124.3 defghi (91.39)	123.6 defghi (90.88)	103.0 jklm (75.73)	108.9 ijkl (80.07)	119.2 cd
Khyber-87	114.3 ghijk -	111.8 hijk (97.81)	102.1 klmn (89.32)	95.5 lmno (83.55)	90.4 mno (79.09)	102.8 e
Nasir-2000	138.5 bcd -	131.7 cdef (95.09)	137.2 cd (99.06)	118.9 fghij (85.84)	110.2 hijkl (79.56)	127.3 b
Pirsabak-2005	125.6 defgh -	123.1 defghi (98.00)	117.3 fghijk (93.39)	127.8 defg (101.75)	118.6 fghij (94.42)	122.5 bc
Uqab-2000	154.0 ab -	155.1 a (100.71)	145.4 abc (94.41)	123.8 defghi (80.38)	125.8 defgh (81.68)	140.8 a
Concentration Means	123.5 a -	123.1 a (99.67)	118.6 a (96.03)	112.2 b (90.85)	100.4 c (81.29)	

LSD value at 0.05 alpha level for genotype means = 7.111, treatment means = 6.010 and interaction = 15.90

Means in the last column/ rows sharing the same letter do not differ significantly from each other at 5% level of probability

Figures in parenthesis represent % of control

Table 6. Effect of halopriming on dry biomass/ seedling (mg) of different wheat genotypes under NaCl salt stress.

Wheat genotypes	Concentration (dS/m)					Genotypic means
	Control	2 dS/m	4 dS/m	6 dS/m	8 dS/m	
Bakhtawar-92	28.1 ^{lmn}	25.9 ^{no}	27.8 ^{lmn}	30.2 ^{klmn}	22.3 ^{o}	26.9 ^{f}
	-	(92.16)	(98.93)	(107.47)	(79.35)	
Bhakkar-2002	45.3 ^{abcd}	36.0 ^{ghij}	40.6 ^{defg}	41.9 ^{cdef}	34.2 ^{hijk}	39.6 ^{c}
	-	(79.47)	(89.62)	(92.49)	(75.49)	
Fakhar-e-Sarhad	39.6 ^{efg}	42.9 ^{bcde}	43.6 $^{b-e}$	40.1 ^{efg}	46.7 ^{abc}	42.6 ^{b}
	-	(108.33)	(110.10)	(101.26)	(117.92)	
Khyber-87	30.5 ^{klmn}	32.3 ^{ijkl}	31.2 ^{jklm}	30.2 ^{klmn}	26.3 ^{mno}	30.1 ^{e}
	-	(105.90)	(102.29)	(99.01)	(86.22)	
Nasir-2000	36.0 ^{ghij}	35.7 ^{ghij}	37.8 ^{fgh}	36.9 ^{ghi}	37.0 ^{fghi}	
	-	(99.16)	(105.00)	(102.50)	(102.77)	36.7 ^{d}
Pirsabak-2005	49.8 ^{a}	47.0 ^{ab}	48.7 ^{a}	45.8 ^{abc}	46.3 ^{abc}	47.5 ^{a}
	-	(94.37)	(97.79)	(91.96)	(92.97)	
Uqab-2000	45.3 ^{abcd}	45.2 ^{abcd}	45.8 ^{abc}	45.8 ^{abc}	46.2 ^{abc}	45.6 ^{a}
	-	(99.77)	(101.10)	(101.10)	(101.98)	
Concentration Means	39.2 ^{a}	37.9 ^{ab}	39.4 ^{a}	38.7 ^{ab}	37.0 ^{b}	
	-	(96.68)	(100.51)	(98.72)	(94.38)	

LSD value at 0.05 alpha level for genotype means = 2.223 and interaction = 4.971

Means in the last column/ rows sharing the same letter do not differ significantly from each other at 5% level of probability

Figures in parenthesis represent % of control

Table 7. Effect of halopriming on seedling moisture contents (%) of different wheat genotypes under salt stress.

Wheat genotypes	Concentration (dS/m)					Genotypic means
	Control	2 dS/m	4 dS/m	6 dS/m	8 dS/m	
Bakhtawar-92	214.7 $^{e-k}$	285.5 ^{a}	203.7 $^{f-m}$	188.4 $^{h-o}$	189.0 $^{h-o}$	216.3 ^{b}
	-	(132.97)	(94.78)	(87.75)	(88.02)	
Bhakkar-2002	152.4 ^{nop}	233.1 $^{b-i}$	197.1 $^{g-n}$	209.2 $^{f-l}$	152.9 ^{nop}	189.0 ^{cd}
	-	(152.95)	(129.33)	(137.27)	(100.32)	
Fakhar-e-Sarhad	245.2 $^{a-g}$	189.4 $^{h-o}$	183.2 $^{i-p}$	159.4 $^{l-p}$	133.6 ^{p}	182.2 ^{d}
	-	(77.24)	(74.71)	(65.00)	(54.48)	
Khyber-87	273.2 ^{abc}	248.8 $^{a-f}$	226.5 $^{c-j}$	218.9 $^{d-k}$	245.5 $^{a-g}$	242.6 ^{a}
	-	(91.06)	(82.90)	(80.12)	(89.86)	
Nasir-2000	280.6 ^{ab}	269.5 $^{a-d}$	263.1 $^{a-e}$	222.0 $^{d-k}$	197.7 $^{g-n}$	246.6 ^{a}
	-	(96.04)	(93.76)	(79.11)	(70.45)	
Pirsabak-2005	154.2 $^{m-p}$	162.7 $^{l-p}$	141.0 ^{op}	179.3 $^{j-p}$	157.3 $^{m-p}$	158.9 ^{e}
	-	(105.51)	(91.43)	(116.27)	(102.01)	
Uqab-2000	239.2 $^{a-h}$	243.4 $^{a-g}$	220.3 $^{d-k}$	172.6 $^{k-p}$	172.8 $^{k-p}$	209.7 ^{bc}
	-	(101.75)	(92.09)	(72.15)	(72.24)	
Concentration Means	222.8 ^{ab}	233.2 ^{a}	205.0 ^{bc}	192.9 ^{cd}	178.4 ^{d}	
	-	(104.66)	(92.01)	(86.57)	(80.70)	

LSD value at 0.05 alpha level for genotype means = 22.71, treatment means = 19.19 and interaction = 50.78

Means in the last column/ rows sharing the same letter do not differ significantly from each other at 5% level of probability

Figures in parenthesis represent % of control

Dry weight: Our results revealed significant variation among wheat genotypes for dry weight of seedling. Interaction between genotypes and salt concentrations was also significant. However, differences between salt concentrations were non-significant (Table 1). Genotypic means indicated that maximum average dry weight of seedling was observed in *Pirsabak-2005*, which was statistically similar with *Uqab-2000* followed by *Fakhar-e-Sarhad*, *Bhakkar-2002*, *Nasir-2000*, *Khyber-87* and *Bakhtawar-92*. Concentrations means revealed that average dry weight of seedling was maximum at 4 dS/m level of salt followed by control, 6 dS/m, 2 dS/m and 8 dS/m levels of salt respectively. Interaction means showed maximum average dry weight in the halo-primed seedlings of *Pirsabak-2005* under control condition which was statistically similar to average dry weight at 4 dS/m level of salt in the same genotype. The minimum average dry weight of seedling was observed in *Bakhtawar-92* at 8 dS/m concentration of salt (Table 6).

Moisture contents: ANOVA exhibited that moistures contents varied significantly among wheat genotypes and salt concentrations. Interaction between genotypes and concentrations was also significant (Table 1). Genotypic means showed that maximum moisture contents was observed in *Nasir-2000*, which were statistically similar to moisture contents in *Khyber-87* followed by *Bakhtawar-92* which were in turn statistically at par with *Uqab-2000*. Moisture contents in *Bhakkar-2002* and *Fakhar-e-Sarhad* were 189.0% and 182.2%, respectively. The minimum moisture contents were observed in *Pirsabak-2005* which was significantly lower among all the genotypes studied. Concentration means reveal that moisture contents increased at 2 dS/m salt level which were statistically similar to moisture contents in control followed by 4 dS/m and 6 dS/m concentration of salt. The least moisture contents were recorded under 8 dS/m level of salt. Interaction means showed that moisture contents were highest in *Bakhtawar-92* under 2 dS/m level of salt which were statistically similar to moisture contents in *Nasir-2000* under control condition. The moisture contents in *Fakhar-e-Sarhad* at 8 dS/m level of salt were the lowest at any concentration of salt among the wheat genotypes studied (Table 7).

Discussion

Halo-priming with NaCI induces salt tolerance by diminishing the inhibitory effects of salinity on the germination and seedling growth of wheat (Afzal *et al*., 2006; Iqbal *et al*., 2006; Afzal *et al*., 2008; Farooq *et al*., 2008). The improved germination of the halo-primed seeds under increasing salinity in the present study is in contrast with Basra *et al*. (2005) and Afzal *et al*. (2007) who concluded that NaCl priming was ineffective in improving germination and seedling vigor of wheat under saline conditions. However, the present findings are in line with those of Iqbal & Ashraf (2007), who stated that priming increased the germination percentage in wheat. It is also reported that halo-priming with NaCl has improved the germination of wheat, sugarcane and sweet sorghum (Afzal *et al*., 2008; Patade *et al*., 2009; Patanè *et al*., 2009), which is also in accordance with the results of this study. The increased germination in halo-primed seeds under salt stress could be due to the faster water absorption occurring in primed seeds as compared to the non-primed (Patanè *et al*., 2009). Germination %age was maximum in *Bakhtawar-92*, *Fakhar-e-Sarhad*, *Khyber-87* and *Nasir-2000* at higher levels of salt whereas; it was maximum at lower levels of salt in *Bhakkar-2002* and *Uqab-2000*.

Significantly reduced plumule growth of seeds subjected to halo-priming under salt stress is in contrast to Wahid *et al*. (2008), Khan *et al*. (2009) and Patade *et al*. (2009), who reported that NaCl priming improved shoot or plumule length in sunflower, *Capsicum annuum* and sugarcane, respectively. Interaction between wheat genotypes and salt levels also elucidate that plumule growth in the halo primed seedlings decreased under increasing level of salt in *Bakhtawar-92*, *Fakhar-e-Sarhad*, *Khyber-87*, *Nasir-2000*, *Uqab-2000*, especially at higher concentrations of salt. The 2 dS/m treatment in *Bakhtawar-92* and *Khyber-87* and higher doses in *Pirsabak-2005* enhanced plumule growth however, it increased in *Bhakkar-2002* at all levels of applied salt. Non-significant decrease in the radicle growth of the halo-primed seedlings under different concentration of salt in the present study is in line with the findings of Amjad *et al*. (2007), who reported that seed priming with NaCl had no significant effect on root length of seedlings. On the other hand, it is also reported that priming with NaCl improved root or radicle length in sunflower and *Capsicum annuum* (Wahid *et al*., 2008; Khan *et al*., 2009), which disagree with our results. Radicle growth in the halo primed seedlings of *Bakhtawar-92*, *Bhakkar-2002*, *Khyber-87* and *Pirsabak-2005* increased while, it decreased in *Fakhar-e-Sarhad*, *Nasir-2000* and *Uqab-2000* under salt stress. Both the maximum increase and decrease in different genotypes were observed at higher salt concentrations.

Decrease in fresh weight of halo-primed seedling under salt stress in the present investigation is contradictory to the observations of Amjad *et al*. (2007) and Khan *et al*. (2009) who reported non-significant effect on fresh weight of seedlings under NaCl priming. Average seedling fresh weight of the halo-primed seeds of wheat genotypes responded in a different way under salt stress. Reduced seedling fresh weight was noted in *Fakhar-e-Sarhad*, *Khyber-87* and *Nasir-2000*; however, in *Pirsabak-2005* it decreased up to 4 dS/m salt level and increased thereafter. Average fresh weight in *Uqab-2000* increased at 2 dS/m level of salt which decreased at the subsequent higher concentration. While, in *Bhakkar-2002* it increased up to 6 dS/m level of salt and declined at the highest level of salt. However, in *Bakhtawar-92* it increased or decreased variously under salt stress. Significant decrease in the dry weight of haloprimed seedling under different concentration of salt in the present study disagrees with the findings of Farhoudi & Sharifzadeh (2006), who reported higher dry weight of seedlings derived from haloprimed seeds of canola. Interaction revealed that dry weight of the haloprimed seedlings of different genotypes increased or decreased variously under salt stress. Dry weight of the haloprimed seedlings of *Fakhar-e-Sarhad*, *Nasir-2000* and *Uqab-*

2000 increased whereas, in *Bhakkar-2002* and *Pirsabak-2005* it decreased under salt stress. While, dry weight in *Bakhtawar-92* and *Khyber-87* increased at lower concentrations and decreased at higher concentrations of salt. Moisture contents in the haloprimed seedlings of *Fakhar-e-Sarhad*, *Khyber-87* and *Nasir-2000* showed a decreasing trend under salt stress while it increased in *Bhakkar-2002* and *Pirsabak-2005*. Low dose of salt tended to increase moisture contents in *Bakhtawar-92* and *Uqab-2000* however, higher doses decreased it in both the genotypes.

It is concluded that pre-treated wheat seeds with NaCl can be used to enhance salt resistance in terms of improved germination and seedling growth. Moreover, it is suggested that halo-primed wheat seeds with different concentrations of NaCl salt can help to find a priming medium more suitable for better germination, plant growth and mineral components under control and saline field conditions.

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