YYÜ TAR BİL DERG
(YYU J AGR SCI)
2014, 24(2): 127- 139

Geliş Tarihi (Received): 17.03.2014
KabulTarihi (Accepted): 01.05.2014

Araştırma Makalesi/*Research Article (Original Paper)*

Salinity Effects On Germination Stage of Bread and Durum Wheat Cultivars

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Abstract: In this study 5 salt concentrations (3.5, 7.0, 10.5, 14.0 and 17.5 dS m^{-1}) and tap water (0.3 dS m^{-1}) as control were used to determine the effects of salinity on germination stage of 5 bread wheat (Golia, Gönen, Köksal - 2000, Pehlivan and Sagittario) and 3 durum wheat cultivars (Altıntaş - 95, Gediz - 75 and Pınar - 2001) in the laboratory of the Department of Field Crops, Faculty of Agriculture, University of Uludag. The experiment was carried out as randomized plots design with two factors and three replications. Water uptake, root lenght and shoot lenght, dry weight of shoot, dry weight of root, germination percentage, the reduction percentage of emergence and salt tolerance index decreased significantly depend on increasing salt concentration. As a result of resistance to salt for investigated genotypes under in vitro conditions, among the bread wheat cultivars, Köksal - 2000 and Sagittario were resistant for the other genotypes and Gediz - 75 and Pınar - 2001 with the highest tolerance was being investigated in durum wheat genotypes. Correlation analysis indicated significant relationships between salt concentration and all investigated parameters. Further study is required to see the effect of salt stress on germination of these genotypes under field conditions.

Key words: Bread and durum wheat, germination, salinity

Ekmeklik ve Makarnalık Buğday Çeşitlerinde Tuzluluğun Çimlenme Dönemi Üzerine Etkileri

Özet: Bu çalışma, 5 ekmeklik (Golia, Gönen, Köksal - 2000, Pehlivan ve Sagittario) ve 3 makarnalık buğday çeşidinin (Altıntaş-95, Gediz-75 ve Pınar-2001) çimlenme döneminde etkilerini belirlemek üzere 5 farklı tuz konsantrasyonu (3.5, 7.0, 10.5, 14.0 and 17.5 dS m^{-1}) ve kontrol olarak musluk suyu (0.3 dS m^{-1}) kullanılarak Uludağ Üniversitesi, Ziraat Fakültesi Tarla Bitkileri Bölümü laboratuvarında yürütülmüştür. Deneme Tesadüf Parselleri Deneme Deseninde iki faktörlü ve 3 tekrarlamalı olarak düzenlenmiştir. Su alımı, kök uzunluğu ve sürgün boyu, sürgün kuru ağırlığı, kök kuru ağırlığı, çimlenme yüzdesi, çimlenme oranındaki azalma ve tuz tolerans indeksi tuz konsantrasyonunun artışına bağlı olarak önemli derecede düşmüştür. Kontrollü koşullar altında kullanılan genotiplerin tuza dayanım yönünden incelenmeleri sonucunda ekmeklik buğday çeşitlerinin arasında, Köksal–2000 ve Sagittario çeşitleri diğer genotiplerden daha dayanıklı olarak belirlenirken; makarnalık buğday çeşitleri içinde ise Gediz-75 ve Pınar-2001 çeşitleri yüksek toleranslı genotipler olarak belirlenmişlerdir. Korelasyon analizi sonucunda tuz konsantrasyonu ve incelenen tüm özellikleri arasında önemli ilişkiler belirlenmiştir. Ancak bu genotiplerde çimlenmenin üzerinde tuz stresinin etkisini görmek için tarla çalışmalarının da yürütülmesi gereklidir.

Anahtar kelimeler: Ekmeklik ve makarnalık buğday, çimlenme, tuzluluk

Introduction

Salinity is a serious problem affecting one third of the irrigation land and limiting the yield potential of modern cultivars. It has been estimated that salts affected nearly 950 million ha land in the world (Taghipour and Salehi 2008). In Turkey, the soil salinity problem is becoming an important constraint on crop production particularly in arid and semi-arid regions (Eker et al. 2006). For example; Şanlıurfa, Kaarapınar.

In generally, EC values between 0 and 0.8 dS m^{-1} are acceptable for general crop growth. Soil salinity class and general crop responses for each class: soil EC value 0-0.98 dS m^{-1} is non saline and almost negligible effects, 0.98-1.71 dS m^{-1} is very slightly saline and yields of very sensitive crops are restricted, 1.71-3.16 dS m^{-1} is slightly saline and yields of most crops are restricted, 3.16-6.07 dS m^{-1} is moderately saline and only tolerant crops yield satisfactorily, and > 6.07 dS m^{-1} is strongly saline and only very tolerant crops yield satisfactorily (Kara and Kara Uysal 2010).

Germination is an important phase in the life cycle of crop plants particularly in saline soils as it determines the degree of crop establishment. Moud and Maghsoudi (2008), Saboora and Kiarostami (2006) have reported that several plants are sensitive to high salinity during germination and the seedling stage. Cereals are sensitive to elevated salinity at the germination and early seedling phase of development (Ghoulam and Fares, 2001). Wheat (*Triticum aestivum* L.) is a moderately salt-tolerant crop. In the field, where the salinity rises to 100 mM NaCl (about 10 dS m^{-1}), rice (*Oryza sativa* L.) will die before maturity, while wheat will produce a reduced yield. Even barley (*Hordeum vulgare* L.), the most-tolerant cereal, dies after extended periods at salt concentrations higher than 250 mM NaCl (equivalent to 50% seawater). Durum wheat (*Triticum turgidum* ssp. durum) is less salt tolerant than bread wheat, as are maize (*Zea mays*) and sorghum (*Sorghum bicolor* L.Moench.) (Munns et al. 2006).

The present study was undertaken to study the response of bread and durum wheat cultivars to different levels of salinity and to determine their tolerance to salinity at germination stage.

Materials and Methods

The experiment was conducted in the laboratory of the Department of Field Crops, Faculty of Agriculture, University of Uludag. In the study five bread wheat cultivars (Golia, Gönen, Köksal-2000, Pehlivan and Sagittario), three durum wheat cultivars (Altıntaş-95, Gediz-75 and Pınar-2001) were used as experimental materials. The features of the varities is given in Table 1.

The experiment was carried out as randomized plots design with two factors and three replications. Salinity levels with electrical conductivity of the solution at 25 ^{0}C were adjusted to control and EC values 3.5, 7.0, 10.5, 14.0 and 17.5 dS m^{-1} (deciSiemens m^{-1}) using different NaCl concentrations. Tap water used as a control. Three replicates of 50 seeds were germinated on filter paper in petri dishes (9 cm diameter) with 10 ml each of the respective test solution. The seeds were allowed to germinate at 25 ^{0}C in the dark for 8 days. A seed was considered to have germinated when the emerging radicle elongated to 1 mm (Atak et al. 2006). Germinated seeds were recorded every day at the same time. The effects of salinity treatments were studied by sampling on water uptake, root lenght and shoot lenght, dry weight of shoot, dry weight of root, germination percentage, the reduction percentage of emergence (RPE) and salt tolerance index (STI).

Water uptake was recorded at 12 and 24 hours after planting. Water uptake percentage was calculated by the formula given below (Rahman et al. 2008).
Water uptake (WU%) = (W2 –W1/W1)100
W1 = Initial weight of seed
W2 = Weight of seed after absorbing water in particular time (12, 24 hours)

The reduction percentage of emergence (RPE) was calculated according to the following formula (El-Madidi et al. 2004).
RPE = (1- Nx / Nc) x 100

“Nx” is the number of emerged seedlings under salt treatments and “Nc” is the number of emerged seedlings under control

Salt tolerance index (STI) was calculated by the formula given below (Bağcı et.al. 2007).
[STI = (TDW at Sx / TDW at S1) × 100]
STI = salt tolerance index, TDW = total dry weight,
S1 = lowest NaCl (control) treatment,
Sx = x treatment.

Dry weight of root and were measured after drying samples at 70 ^{o}C for 48 h in oven (Atak et al. 2006). Data were analyzed separately for bread and durum wheat cultivars. Analysis of variance was conducted with JUMP statistics package program and differences among means were compared with LSD test.

Table 1. The features of the varities used in the study.

Bread wheat varities	**Varities features**
Golia	Short plant height, with green leaves color and semi-upright structure. Spike is medium density, stringy and white in color. Grains are small, egg-shaped and dark red in color and glassy properties.1000 grain weight is 34-36 g. Good bread quality. Blending ability and fertilizer reaction is good. In artificial and natural conditions resistant to yellow rust, leaf rust and septoria. Recommended for Southeastern Anatolia Region, Cukurova and Trakya (Anonymous 2014).
Gönen	Medium plant height with green leaves and a flat structure. Spikes are parallel-sided, white, dense structure and is stringy. The grains are round, hard and white in terms of color feature and mixed with durum wheat for its glassy feature. 1000-grain weight is 30-32 g. Blending ability and fertilizer reaction is good. In artificial and natural conditions, moderately resistant to yellow rust and tolerant to leaf rust. Recommended for Aegean Region and the area of Coastal Belt (Anonymous 2014).
Köksal-2000	Stems are medium height, leaves oblique structure. Spike is medium length, yellow in color, spelled and oblong shaped. Spikelets are medium density. Grains are amber (reddish) color and 1000-grain weight is 29-35.6 g. Bread quality is good. Resistant to yellow rust, sensitive to leaf rust, tolerant to powdery mildew. Recommended for Trakya, Sakarya-Marmara region (Anonymous 2001).
Pehlivan	Stems are medium length, green color of the leaves and flag leaf curled structure. Spikes are protruding, parallel-sided, white, and has a structure in medium density. Grain's external appearance is similar to Bezostaja but darker red and grains are more coarse. 1000 grain weight is 36-37 g. Bread quality is good. Winter type, blending ability and fertilizer reaction of this variety is good. Resistant to yellow rust and tolerant to leaf rust in artificial and natural conditions. Recommended for Trakya and Southeastern Anatolia Region (Anonymous 2014).
Sagittario	Strong stem and resistant to lodging. Grains are red in color.1000-grain weight is between 40-44 g. Resistant to cold, rust and septoria. Rcommended for the area of Coastal Belt and gate regions.
Durum wheat varities	**Varities features**
Altıntaş-95	Stems are 110-120 cm tall. Spikes are stringy and brown glumes. Grain amber-colored, glassy structure. Resistant to lodging and drought. 1000-grain and hectoliter weight are high, durum quality is good. In field conditions resistant to yellow rust, stem rust and medium resistant to leaf rust. Resistant to winters of Central Anatolia and the western gate region(Anonymous 2014).
Gediz-75	Stems length is medium, the leaves are green, hairless, long and narrow structure. Spikes are stringy, white-haired, medium-long and spike is often the upright position. Grain rigid structure, amber-colored, oval and long medium width. Weight of 1000 grains is 42-45 gr. Drought resistance is medium, medium early, stem is sturdy and resistant to lodging. Good reaction to fertilizer, better blending ability and a productive variety. Resistant to yellow and leaf rust black medium resistant against stem rust and septoria. Recommended for Mediterranean Region (Amik Plain and Gaziantep region) with Aegean Region (Anonymous 2014).
Pınar-2001	Medium length of the stems, leaves half horizontal structure. Spikes are stringy, medium length, yellow in color and oblong shaped. 1000-grain weight is between 38-44 g. Resistant to cold, drought and lodging. Tolerant to yellow, leaf rust and powdery mildew. Recommended for Trakya - Marmara and Sakarya-Marmara Region (Anonymous 2001).

Results and Discussion

Water Uptake (WU): According to results of variance analysis, water uptake in 12 hours (for salt concentration for bread wheats) and in 24 hours (for variety and salt concentration) were significant in both bread wheats and durum wheats. Interaction between genotypes and salt concentration was also significant for durum wheats (Table 2,3).

Table 2. Analysis of variance for the parameters investigated in 5 bread wheat cultivars in response to salinity stres

Source	DF	WU 12	WU 24	RL	SL	DRW
Cultivar (A)	4	70.10	291,1**	27,81**	6,77**	0,0002
Salt Conc.(B)	5	367,2**	597,9**	207,33**	16,92**	0,002**
AxB	20	83,73	48,46	1,40	0,92**	0,0001
Error	60	52,11	66,84	0,70	0,10	0,00009
Total	89					
Source	**DF**	**DSW**	**GP**	**RPE**	**STI**	
Cultivar (A)	4	0,0005**	906,84**	504,49**	1428,8**	
Salt Conc.(B)	5	0,0012**	679,96**	804,57**	5339,2**	
AxB	20	0,0002	377,43**	455,43**	515,9	
Error	60	0,0001	19,56	32,10	358,3	
Total	89					

WU 12: Water Uptake in 12 hours, WU 24: Water Uptake in 24 hours, RL: Root Lenght, SL: Shoot Lenght, DRW: Dry Root Weight, DSW: Dry Shoot Weight, GP: Germination Percentage, RPE: Reduction Percentage of Emergence, STI: Salt Tolerance Index

Table 3. Analysis of variance for the parameters investigated in 3 durum wheat cultivars in response to salinity stres

Source	DF	WU 12	WU 24	RL	SL	DRW
Cultivar (A)	2	602.32**	698,16**	4,54**	0,11	0,0018**
Salt Conc.(B)	5	285,61**	206,40**	86,73**	12,31**	0,0013**
AxB	10	100,09**	72.14**	0,967	0,17	0,0001
Error	36	19,73	18,40	0,745	0,12	0,00006
Total	53					
Source	**DF**	**DSW**	**GP**	**RPE**	**STI**	
Cultivar (A)	4	0,0018**	2795,0**	2254,1**	3392,0**	
Salt Conc.(B)	5	0,0008**	2093,8**	2506,8**	7917,3**	
AxB	20	0,00007*	293,3**	363,9**	366.4	
Error	60	0,00003	73,8	98,7	275,2	
Total	89					

WU 12: Water Uptake in 12 hours, WU24: Water Uptake in 24 hours, RL: Root Lenght, SL: Shoot Lenght, DRW: Dry Root Weight,DSW: Dry Shoot Weight, GP: Germination Percentage, RPE: Reduction Percentage of Emergence, STI: Salt Tolerance Index

The highest water uptake in 12 and 24 hours was observed from control applications in both bread and durum wheats (Table 4,5). Among the bread wheats the highest water uptake was observed in Golia, Köksal-2000 and Sagittario cultivars (Table 4). The highest water uptake was from control level with Gediz-75 cultivar (43.05%) (53.06%) among durum wheats (Table 5). When salt concentration increase to 14.0 and 17.5 dS m^{-1} the water uptake ability decrease in comparison to control.

Table 4. Mean values of the parameters of water uptake in 12 and 24 hours for bread wheat cultivars, different salinity levels and interactions

Bread wheat varities	NaCl concentrations (dS m^{-1}) water uptake in 12 hours (%)						Mean of varities
	Control	3,5	7,0	10,5	14,0	17,5	
Golia	34,88	33,84	33,70	32,17	29,30	25,68	31,59
Gönen	37,25	34,38	23,35	29,22	27,81	24,82	29,47
Köksal-2000	32,36	38,37	27,68	38,19	40,19	29,46	34,37
Pehlivan	50,50	28,63	22,57	24,79	24,26	27,24	29,67
Sagittario	45,37	32,23	25,57	25,30	27,73	30,33	31,09
Mean of NaCl Conc.	40.07 a	33,49 b	26,57 c	29,93 bc	29,86 bc	27,51 c	
Bread wheat varities	**NaCl concentrations (dS m^{-1}) water uptake in 24 hours (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Golia	57,38	44,29	49,94	49,83	42,35	31,55	45,89 a
Gönen	47,47	42,62	42,41	34,46	30,47	28,53	37,66 b
Köksal-2000	54,89	47,11	33,43	43,03	43,68	37,41	43,26 a
Pehlivan	50,07	35,33	35,55	37,44	32,49	28,86	36,62 b
Sagittario	49,08	45,59	42,21	47,16	38,79	37,97	43,47 a
Mean of NaCl Conc.	51,78 a	42,99 b	40,71 b	42,38 b	37,56 bc	32,87 c	

Table 5. Mean values of the parameters of water uptake in 12 and 24 hours for durum wheat cultivars, different salinity levels and interactions

Durum wheat varities	NaCl concentrations (dS m^{-1}) water uptake in 12 hours (%)						Mean of varities
	Control	3,5	7,0	10,5	14,0	17,5	
Altıntaş-95	32,62 bc	30,24 cd	31,86 b-d	31,73 b-d	30,12 cd	21,81 e-g	29,73 a
Gediz-75	43,05 a	37,69 ab	32,43 bc	24,88 d-f	15,36 g	15,25 g	28,11 a
Pınar-2001	25,29 c-e	20,46 e-g	16,45 g	16,77 g	17,44 g	17,60 fg	19,00 b
Mean of NaCl Conc.	33,65 a	29,46 ab	26,91 bc	24,46 cd	20,97 de	18,22 e	
Durum wheat varities	**NaCl concentrations (dS m^{-1}) water uptake in 24 hours (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Altıntaş-95	43,98 bc	40,33 b-d	42,66 bc	41,04 bc	42,71 bc	41,20 bc	41,99 a
Gediz-75	53,06 a	45,12 b	43,7 bc	33,56 d-f	22,19 f	28,16 f	38,80 b
Pınar-2001	36,89 c-e	31,50 ef	30,06 ef	27,07 f	27,37 f	26,90 f	29,97 c
Mean of NaCl Conc.	44,64 a	38,99 b	38,80 b	33,89 c	33,09 c	32,09 c	

Root Lenght (RL): Analysis of variance revealed that the effect of NaCl concentration on root lenght of various genotypes and differences between different concentrations were significant. However, interaction between genotypes and concentrations was non-significant in both bread and durum wheats (Table 2,3).

Among various genotypes the highest root lenght was observed from Sagittario cultivar with 8.85 cm followed by Köksal-2000 (8.43 cm) in bread wheats and Pınar-2001 and Gediz-75 (5.97and 5.58 cm, respectively) in durum wheats. Concentrations means showed that maximum root lenght was recorded under control levels for bread wheats and control and 3.5 dS m^{-1} levels for durum wheats. Generally root lenght decreased as NaCl concentration increased (Table 6).

Shoot Lenght (SL): The result of variance analysis showed significant variation for shoot lenght among bread wheat cultivars and different salinity concentrations. The interaction between genotypes and concentrations was also significant for bread wheat cultivars. For durum wheats only salt concentrations was found significant (Table2,3).

Mean of shoot lenght varied between 4.17 cm and 2.63 cm for varities and 4.68 cm to 1.89 cm for NaCl concentrations. The longest shoot lenght was observed in the 3.5 dS m-1 of Pehlivan and control of Köksal-2000 cultivars in bread wheat genotypes. Among durum wheats the longest shoot lenght observed in the 3.5 dS m^{-1} level by 3.97 cm followed by 7.0 dS m^{-1} level (386 cm) (Table 7).

Table 6. Mean values of the parameters of root lenght for bread and durum wheat cultivars, different salinity levels and interactions

Bread wheat varities	**NaCl concentrations (dS m^{-1}) root lenght (cm)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Golia	11,507	11,033	7,750	6,822	4,833	3,617	7,59 b
Gönen	11,877	8,539	4,883	3,660	2,833	2,253	5,67 c
Köksal-2000	14,317	11,617	8,753	7,083	5,131	3,683	8,43 a
Pehlivan	11,817	10,483	7,450	5,817	3,923	3,267	7,12 b
Sagittario	15,617	11,700	9,167	7,310	5,326	4,015	8,85 a
Mean of NaCl Conc.	13,02 a	10,67 b	7,60 c	6,18 d	4,40 e	3,36 f	
Durum wheat varities	**NaCl concentrations (dSm^{-1}) root lenght (cm)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Altıntaş-95	8,15	8,53	4,91	4,11	2,75	1,41	4,98 b
Gediz-75	8,84	9,18	6,56	4,35	3,46	1,08	5,58 a
Pınar-2001	10,02	8,68	7,38	5,26	3,24	1,26	5,97 a
Mean of NaCl Conc.	9,00 a	8,80 a	6,28 b	4,58 c	3,15 d	1,25 e	

Table 7. Mean values of the parameters of shoot length for bread and durum wheat cultivars, different salinity levels and interactions

Bread wheat varities	**NaCl concentrations (dS m^{-1}) shoot lenght (cm)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Golia	3,53 j-l	3,92 h-j	4,25 f-i	4,30 e-h	3,74 i-k	2,72 op	3,74 b
Gönen	2,91 m-p	3,27 k-m	3,01 l-p	3,16 l-o	1,94 q	1,52 q	2,63 c
Köksal-2000	5,25 b	5,11 bc	4,76 b-f	4,48 d-h	3,43 j-m	2,00 q	4,17 a
Pehlivan	4,98 b-d	6,02 a	4,70 c-f	4,32 e-h	2,61 p	1,72 q	4,06 a
Sagittario	4,13 g-i	5,10 bc	4,81 b-e	4,60 c-g	2,85 n-p	1,52 q	3,83 b
Mean of NaCl Conc.	4,1 b	4,68 a	4,30 b	4,17 b	2,91 c	1,89 d	
Durum wheat varities	**NaCl concentrations (dSm^{-1}) shoot lenght (cm)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Altıntaş-95	3,73	4,06	3,85	3,30	2,18	0,50	2,94
Gediz-75	3,44	3,99	3,54	3,41	2,50	1,11	3,00
Pınar-2001	3,35	3,88	4,20	3,51	2,50	1,14	3,09
Mean of NaCl Conc.	3,50 b	3,97 a	3,86 a	3,41 b	2,39 c	0,91 d	

Dry Root Weight (DRW): Analysis of variance exhibited significant differences among salt concentration for bread wheat and among various genotypes, different salt concentrations for durum wheats for dry root weight. The interaction between genotypes and concentration between genotypes and concentrations was non-significant in both bread and durum wheats (Table 2,3). Concentration means showed that maximum dry root weight was observed under conrol level in both bread and durum wheats by 0.052 g and 0.040 g, respectively. Genotypic means showed that dry root weights ranged from 0.039- 0.029 g for bread wheats and 0.033-0.013 g for durum wheats (Table 8).

Table 8. Mean values of the parameters of dry root weight for bread and durum wheat cultivars, different salinity levels and interactions

Bread wheat varities	NaCl concentrations (dS m^{-1}) dry root weight (g)						Mean of varities
	Control	3,5	7,0	10,5	14,0	17,5	
Golia	0,058	0,037	0,028	0,024	0,017	0,011	0,029
Gönen	0,056	0,029	0,016	0,032	0,033	0,025	0,032
Köksal-2000	0,041	0,034	0,033	0,035	0,021	0,022	0,031
Pehlivan	0,046	0,041	0,022	0,032	0,025	0,013	0,030
Sagittario	0,061	0,048	0,039	0,029	0,035	0,023	0,039
Mean of NaCl Conc.	0,052 a	0,038 b	0,027 c	0,030 c	0,026 c	0,019 d	
Durum wheat varities	NaCl concentrations (dSm^{-1}) dry root weight (g)						Mean of varities
	Control	3,5	7,0	10,5	14,0	17,5	
Altıntaş-95	0,035	0,015	0,012	0,008	0,004	0,003	0,013 c
Gediz-75	0,035	0,032	0,026	0,023	0,022	0,004	0,024 b
Pınar-2001	0,051	0,040	0,040	0,036	0,026	0,004	0,033 a
Mean of NaCl Conc.	0,040 a	0,029 b	0,026 b	0,022 bc	0,017 c	0,004 d	

Dry Shoot Weight (DSW): According to result of variance analysis, among of variuos genotypes and salt concentrations were significant in both bread and durum wheats for dry shoot weight. The interaction between genotypes and concentrations was significant for only durum wheats (Table 2,3).

Among various genotypes maximum dry shoot weight was recorded in Sagittario and Köksal-2000 by 0.044 and 0.041 g respectively for bread wheats and Pınar-2001 with 0.033g for durum wheats (Table 9). Concentration means revealed that dry shoot weight was maximum in the 3.5 dS m^{-1} salt concentration level followed by 7.0 dS m^{-1} and control level in bread wheat and maximum dry shoot weight recorded under control level followed by 3.5,7.0 and 10.5 dS m^{-1} levels of salt concentrations. The maximum dry shoot weight was recorded in genotype Pınar-2001 under control, 7.0 and 10.5 dS m^{-1} salt concentration levels (Table 9).

Table 9. Mean values of the parameters of dry shoot weight for bread and durum wheat cultivars, different salinity levels and interactions

Bread wheat varities	NaCl concentrations (dS m^{-1}) dry shoot weight (g)						Mean of varities
	Control	3,5	7,0	10,5	14,0	17,5	
Golia	0,047	0,040	0,032	0,026	0,024	0,016	0,031 c
Gönen	0,027	0,043	0,031	0,037	0,035	0,027	0,033 bc
Köksal-2000	0,050	0,036	0,055	0,044	0,033	0,029	0,041 a
Pehlivan	0,044	0,064	0,048	0,042	0,021	0,019	0,040 ab
Sagittario	0,050	0,052	0,059	0,038	0,046	0,023	0,044 a
Mean of NaCl Conc.	0,044 a	0,047 a	0,045 ab	0,037 bc	0,032 c	0,023 d	
Durum wheat varities	NaCl concentrations (dSm^{-1}) dry shoot weight (g)						Mean of varities
	Control	3,5	7,0	10,5	14,0	17,5	
Altıntaş-95	0,027 cd	0,015 e-g	0,014 f-h	0,014 f-h	0,008 g-i	0,002 i	0,013 c
Gediz-75	0,026 cd	0,025 cd	0,023 d	0,025 cd	0,019 d-f	0,004 hi	0,020 b
Pınar-2001	0,042 a	0,039 ab	0,042 a	0,042 a	0,030 bc	0,006 g-i	0,033 a
Mean of NaCl Conc.	0,032 a	0,026 a	0,026 a	0,027 a	0,019 b	0,004 c	

Germination Percentage (GP): Analysis of variance performed on germination percentage revealed significant differences among various genotypes, different salt concentration and interaction between genotypes and concentration in both bread and durum wheats (Table 2,3).

Genotypic means reveal that the highest germination (95.44 %) was recorded in Pehlivan followed by Köksal-2000 with 92.77 % for bread wheats (Table 10). Among various durum wheat maximum mean germination observed in Pınar -2001 (Table 10). Concentration means showed that maximum germination percentage was recorded under control and 3.5 dS m^{-1} salt level for bread wheats and under control level for durum wheats (Table 10).

Interaction of genotypes and concentrations showed that maximum germination percentage was recorded in the genotype Pehlivan by 100% under control for bread wheats and in the genotypes Gediz-75 and Pınar-2001 by 94.66 % under control and 14.0 dS m^{-1}salt level (Table 10). Results showed that by increasing NaCl concentration to 17.5 dS m^{-1} germination percentage decreased.

Table 10. Mean values of the parameters of germination percentage for bread and durum wheat cultivars, different salinity levels and interactions

Bread wheat varities	**NaCl concentrations (dS m^{-1}) germination percentage (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Golia	90,67 c-f	96,00 a-d	93,33 a-e	89,33 d-f	67,33 g	28,00 h	77,44 c
Gönen	94,00 a-e	92,67 b-e	92,67 b-e	90,00 d-f	85,33 f	92,00 b-e	91,11 b
Köksal-2000	96,00 a-d	95,33 a-e	94,00 a-e	92,67 b-e	88,67 ef	90,00 ef	92,77 ab
Pehlivan	100,00 a	94,67 a-e	97,33 a-c	93,33 a-e	98,00 ab	89,33 d-f	95,44 a
Sagittario	92,67 b-e	94,00 a-e	94,00 a-e	90,67 c-f	94,00 a-e	88,67 ef	92,33 b
Mean of NaCl Conc.	94,66 a	94,53 a	94,26 ab	91,20 b	86,67 c	77,60 d	
Durum wheat varities	**NaCl concentrations (dSm^{-1}) germination percentage (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Altıntaş-95	84,66 a-c	74,66 cd	52,00 ef	62,66 d-f	50,66 f	33,33 g	60,00 c
Gediz-75	94,66 a	81,33 a-c	80,00 bc	65,33 de	52,00 ef	54,66 ef	71,33 b
Pınar-2001	93,33 ab	92,00 ab	92,00 ab	84,00 a-c	94,66 a	53,33 ef	84,88 a
Mean of NaCl Conc.	91,55 a	82,66 b	74,66 bc	70,66 cd	65,77 d	47,11 e	

Reduction Percentage of Emergence (RPE): According to variance analysis results, the reduction percentage of emergence was significantly influenced by different NaCl concentrations in both bread and durum wheats. Similiarly, the interaction between genotypes and NaCl concentrations in both bread and durum wheats were significant. The results showed that the reduction percentage of emergence of bread and durum wheats increased depend on increasing of salt concentrations (Table 2,3).

The lowest reduction percentage of emergence was recorded from control application followed by 3.5 and 7.0 dS m^{-1} for bread wheats and from control application for durum wheats. The highest was observed in 17.5 dS m^{-1} salt level in both bread and durum wheat genotypes (Table 11).

The highest reduction percentage of emergence was observed from Golia and Altıntaş-95 and Gediz-75 among bread and durum wheats, respectively. The lowest reduction percentage of emergence recorded in the genotypes of Sagittario and Pınar 2001 by 0.24 and 8.90 respectively (Table 11). Among the bread wheats the highest reduction percentage of emergence was obtained from Golia x17.5 dS m^{-1} interaction (68.35 %) and Altıntaş-95 x17.5 dS m^{-1} interaction among durum wheats (Table 11).

Salt Tolerance Index (STI): Variance analysis results showed significant variation for salt tolerance index among various genotypes and different salinity concentrations in both bread and durum wheats. The interaction between genotypes and concentrations was non-significant for bread and durum wheats (Table 2,3).

The highest salt tolerance index was determined from control and 3.5 dS m^{-1} NaCl application and the lowest salt tolerance index recorded in 14.0 and 17.5 dS m^{-1} salt concentrations. Among bread and durum wheats the highest salt tolerance index obtained from Köksal-2000 and Gönen, followed by Pehlivan (78.18 %) and Pınar-2001 and Gediz-75 cultivars, respectively (Table 12).

Table 11. Mean values of the parameters of reduction percentage of emergence for bread and durum wheat cultivars, different salinity levels and interactions

Bread wheat varities	**NaCl concentrations (dS m^{-1}) reduction percentage of emergence (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Golia	0,00 d-g	-6,41 g	-3,63 fg	1,05 d-g	25,19 b	68,35 a	14,09 a
Gönen	0,00 d-g	1,44 c-g	1,22 d-g	4,17 c-f	9,15 cd	2,17 c-g	3,02 bc
Köksal-2000	0,00 d-g	0,66 d-g	2,07 c-g	3,40 c-f	7,58 c-e	6,17 c-e	3,31 bc
Pehlivan	0,00 d-g	5,33 c-f	2,66 c-g	6,66 c-e	2,00 c-g	10,66 c	4,55 b
Sagittario	0,00 d-g	-1,66 e-g	-1,66 e-g	1,98 c-g	-1,66 e-g	4,50 c-f	0,24 c
Mean of NaCl Conc.	0,00 c	-0,12 c	0,13 c	3,45 c	8,45b	18,37a	
Durum wheat varities	**NaCl concentrations (dSm^{-1}) reduction percentage of emergence (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Altıntaş-95	0,00 fg	13,80 e-g	40,31 bc	27,11 c-e	41,31 bc	60,63 a	30,53 a
Gediz-75	0,00 fg	14,13 e-g	15,45 d-f	30,85 b-d	45,22 ab	42,51 bc	24,69 a
Pınar-2001	0,00 fg	1,38 fg	1,13 fg	9,59 fg	-1,64 g	42,92 bc	8,90 b
Mean of NaCl Conc.	0,00 d	9,77 c	18,97 bc	22,52 b	28,29 b	48,69 a	

Table 12. Mean values of the parameters of salt tolerance index for bread and durum wheat cultivars, different salinity levels and interactions

Bread wheat varities	**NaCl concentrations (dS m^{-1}) salt tolerance ındex (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Golia	100,00	62,05	52,46	61,26	48,24	27,04	58,50 b
Gönen	100,00	87,59	57,55	84,30	83,08	62,85	79,22 a
Köksal-2000	100,00	77,01	95,51	87,55	59,30	56,73	79,35 a
Pehlivan	100,00	114,89	80,28	83,48	53,36	37,12	78,18 a
Sagittario	100,00	90,74	88,41	61,56	74,31	41,47	76,08 a
Mean of NaCl Conc.	100,00 a	86,46 ab	74,84 b	75,63 b	63,66 c	45,04 d	
Durum wheat varities	**NaCl concentrations (dSm^{-1}) salt tolerance ındex (%)**						**Mean of varities**
	Control	**3,5**	**7,0**	**10,5**	**14,0**	**17,5**	
Altıntaş-95	100,00	54,10	46,00	38,52	22,41	10,38	42,23 b
Gediz-75	100,00	82,05	71,88	69,36	59,43	12,52	65,87 a
Pınar-2001	100,00	83,87	88,13	84,31	60,08	11,01	71,23 a
Mean of NaCl Conc.	100,00 a	73,34 b	68,67 b	64,06 b	47,31 c	11,30 d	

Correlation Coefficients: In order to identify the relationship between salinity concentrations and other parameters the correlation coefficients were calculated. Significant negative correlation coefficients were found between salinity concentrations, water uptake in 12 and 24 hours, root lenght, shoot lenght, dry root weight, dry shoot weight, germination percentage and salt tolerance index, while positive significant correlations coefficients were found between salt concentration and reduction percantage of emergence in both bread and durum wheat varities. Water uptake in 12 hours was positively and significantly correlated with water uptake in 24 hours and root lenght in both bread and durum wheats. However, significant correlations were determined only between water uptake in 12 hours and shoot lenght for durum wheats and only between water uptake in 12 hours and dry root weight for bread wheats. Water uptake in 24 hours showed significantly positive correlation with root lenght in both bread and durum wheats and significant positive correlation with shoot lenght and negative significant correlation with reduction percantage of emergence for bread wheats. Root lenght exhibited significant correlations with all parameters in both bread and durum wheats. Shoot lenght was significantly correlated with all parameters except germination percentage and reduction percantage of emergence for bread wheats. Significant

possitive correlations were found between dry root weight and dry shoot weight, germination percentage and salt tolerance index, while negative correlations were found between dry root weight and reduction percantage of emergence in both bread and durum wheats. Similiar results were obtained from dry shoot weight. Germination percentage showed significantly negative corelation with reduction percantage of emergence and positive correlation with salt tolerance index. Negative significant correlation coefficients were determined with reduction percantage of emergence and salt tolerance index (Table 13).

The study showed the parameters in the germination period of the investigated wheat varities were significantly influenced by NaCl concentrations. Kara and Kara Uysal (2010) reported that nearly all plants are sensitive to high salinity during germination and first development stage. In our study, the reduction was greater at higher NaCl concentrations for the both bread and durum wheat varities for all of the investigated parameters compared to control.

Decreases in water uptake was observed by increasing NaCl levels. Similiarly, a number of studies have demonstrated that water uptake in wheat is significantly reduced under salt or water stress conditions (Sabora and Kiarostami 2006; Moud and Mahgsoudi 2008; Akbarimoghaddam et al. 2011). However, Atak et al. (2006) reported that water uptake of cultivars did not vary much with NaCl levels. Seed absorbed water much faster during the first 6 hours. In our study, the means of water uptake in 12 hours of bread wheat cultivars also did not vary much with incerasing NaCl levels. Root and shoot lenghts are the most important parameters for salt stress because roots are indirect contact with soil and absorb water from soil and shoot supply it to the rest of the plant. For this purpose, root and shoot lenght provides an important clue to the response of plants to salt stress (Bahrani and Hogh Joo 2012). In the study, generally root and shoot lenght decreased as NaCl concentration increased and salt stress inhibited the growth of shoot more than root in both bread and durum wheat genotypes. Similiar observations have been reported in Atak et al. (2006), Moud and Mahgsoudi (2008), Akbarimoghaddam et al. (2011), Bahrani and Hagh Joo (2012).

As NaCl concentration increased, it affected dry root and shoot weight. Reduction of dry weights relatively depended on shoot and root lenghts. The similiar results reported by Ghoulam and Fores (2001) and Akbarimoghaddam et al. (2011). Kara and Kara Uysal (2010) obtained that from dry shoot and root weight showed that shoots and roots were inhibited severely salinity levels, however roots were more inhibited than the shoots.

In the study the results showed that by increasing NaCl concentrations, germination percentage decreased. Similiar decreases in germination percentage have been reported in the study of Sharma et al. (2004), Khan et al. (2005), Akbari et al. (2007), Abdel-Ghani (2009). However, Muhammad and Hussain (2012) negate all the above mentioned reports in their study.

Increasing NaCl levels in both bread and durum wheat genotypes decreased in the reduction percentage of emergence. Similiar results determined by Kara and Kara Uysal (2010).

Increasing NaCl levels decreased to salt tolerance index of bread and durum wheats. In the study the decreases reduced at $3.5 \leq$ (dS m^{-1}) NaCl concentrations. Similiar findings observed by Bağcı et al. (2007) and Kara and Kara Uysal (2010).

Table 13. Correlation coefficients

Parameters		Salinity	WU 12	WU 24	RL	SL	DRW	DSW	GP	RPE	STI
WU 12	**Bread Wheat**	-0,392**	-								
	Durum Wheat	-0,572**	-								
WU 24	**Bread Wheat**	-0,529**	0,399**	-							
	Durum Wheat	-0,496**	0,795**	-							
RL	**Bread Wheat**	-0,909**	0,452**	0,549**	-						
	Durum Wheat	-0,940**	0,472**	0,402**	-						
SL	**Bread Wheat**	-0,664**	0,207	0,361**	0,692**	-					
	Durum Wheat	-0,789**	0,396**	0,289	0,797**	-					
DRW	**Bread Wheat**	-0,664**	0,317**	0,255	0,687**	0,353**	-				
	Durum Wheat	-0,675**	0,099	0,027	0,769**	0,583**	-				
DSW	**Bread Wheat**	-0,508**	-0,059	0,135	0,496**	0,597**	0,464**	-			
	Durum Wheat	-0,573**	-0,061	-0,143	0,659**	0,647**	0,822**	-			
GP	**Bread Wheat**	-0,413**	0,156	0,204	0,326**	0,247	0,333**	0,356**	-		
	Durum Wheat	-0,675**	0,108	0,023	0,709**	0,621**	0,784**	0,788**	-		
RPE	**Bread Wheat**	0,428**	-0,210	-0,287**	-0,350**	-0,217	-0,382**	-0,343**	-0,927**	-	
	Durum Wheat	0,697**	-0,216	-0,077	-0,725**	-0,647**	-0,757**	-0,754**	-0,978**	-	
STI	**Bread Wheat**	-0,625**	0,169	0,150	0,571**	0,492**	0,765**	0,770**	0,407**	-0,381**	-
	Durum Wheat	-0,771**	0,255	0,195	0,814**	0,751**	0,833**	0,822**	0,770***	-0,769**	-

WU 12: Water Uptake in 12 hours, WU24: Water Uptake in 24 hours, RL: Root Lenght, SL: Shoot Lenght, DRW: Dry Root Weight, DSW: Dry Shoot Weight, GP: Germination Percentage, RPE: Reduction Percentage of Emergence, STI: Salt Tolerance Index

Correlation analysis indicated significant relationships between salt concentration and all investigated parameters. A few non-significant relationships determined in the study between water uptake in 12 hours with dry root weight for durum wheat, dry shoot weight, germination percentage, reduction percentage of emergence, salt tolerance index, between water uptake in 24 hours with shoot lenght (for durum wheat), dry root weight, dry shoot weight, reduction percentage of emergence and salt tolerance index. The correlation coefficients were found significant between the other investigated parameters. Similiarly, Shahzad et al. (2012) reported positively and significantly correlations between shoot lenght and root lenght, shoot dry weight. Bahrani and Hagh Joo (2012) reported a negative correlation between germination percentage and root lenght, shoot lenght, dry root and shoot weight, which is line with the present findings. Bağcı et al. (2007) explained that the correlation coefficients were significant between salt tolerance index and dry root weight, dry shoot weight and germination percentage. The results of the current study in agreement with those results.

In the study, salt stress affected all investigated parameters. It can be concluded that to select cultivars for better salt stress tolerance at germination stage root and shoot elongation may be used as breeding criterions.The results in the study also indicated that among the measurements needed for a reliable ranking of genotypes for salt stress tolerance, an important emphasis should be given to the germination percentage and the determination of the salt tolerance index based on dry root and shoot weight.Munns et al. (2006) reported as durum wheat is less salt tolerant than bread wheat. In the study compared to bread and durum wheat varities, durum wheat varities were seen less salt tolerant, relatively. The genotypes Köksal-2000 and Sagittario were resistant for the others genotypes in bread wheat varities and Gediz-75 and Pınar -2001 with the highest tolerance was being investigated in durum wheat genotypes while Gönen and Golia in bread wheat genotypes and Altıntaş-95 with the largest susceptibility to salt stress for the investigated parameters. Further study is required to see the effect of salt stress on germination and seedling growth of these genotypes under field conditions.

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