Effect of artificial drought stress on seed quality of bread wheat

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Abstract

The aim of the present study was to determine effects of artificial drought stress on the characteristics of germination and seedling growth in bread wheat cultivars. The material of experiment consisted of seeds obtained from eight bread wheat cultivars with different response to drought (Alpu 2001, Sultan 95, Konya 2002, Eser as sensitive cultivars; Karahan 99, Tosunbey, Kate A1 as resistant cultivars and Golia as moderate-resistant cultivar) after their treatment, in the previous year, by artificial drought stress through using chemical desiccant (4% potassium chlorate-$KClO_3$). The laboratory experiment was conducted in randomized split plot design with 4 replicates. Results indicated that cultivars had almost a significant effect on all measured characteristics. The highest water uptake and root number were observed in the moderate-resistant cultivar. The resistant cultivars had relatively higher values than the other cultivars for germination percentage, coleoptile length, seedling length, shoot fresh weight, shoot dry weight and root dry weight. However, the highest mean germination time, root length and root fresh weight were observed in drought sensitive cultivars. The non-desiccant seeds showed higher performances for root number, coleoptiles length, seedling length, seedling fresh weight, seedling dry weight, root fresh weight and root dry weight than desiccated seeds. In contrast, desiccated seeds had better values of water uptake and germination percentage than non-desiccant seeds. As a result, it was concluded that artificial drought stress by desiccant application affected negatively seed quality due to its detractive impact on seed size in bread wheat.

Keywords: chemical desiccant; germination; seedling growth; *Triticum aestivum* L., water uptake

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Introduction

Wheat is an important food crop for more than one third of the world population and is also a staple food of Turkey. The wheat crop is mainly cultivated under arid and semi-arid conditions in Turkey. In recent years, drought stress, which is related to global climate change, has become threatening in seed production areas of wheat. In wheat growing, the most frequent type of drought stress is the post-anthesis stress which includes the grain filling stages. At this stage, drought stress may cause grain yield depression due to seed shriveling as high as 20-50% (Cseuz, 2009). In addition, artificial drought induced by applying chemical desiccant at the post-anthesis caused the reduction in kernel size and weight (Cseuz et al., 2002; Chanda et al., 2005; Cseuz, 2009 and Mohammadi et al., 2009).

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At the same time, drought induced earlier mobilization of non-structural carbohydrates (largely, fructans) from stem and leaf sheaths, which provided a greater proportion of kernel dry weight (endosperm) at maturity (Gupta et al., 2011). These carbohydrates in the form of glucose, fructose, sucrose and starch are used to germinate as an energy source (Leonova et al., 2010). Rapid seedling establishment is an important requirement for successful crop production in dryland farming systems. The heterotrophic seedling growth can be defined as a product of two components: (1) the weight of mobilized seed reserve, and (2) the conversion efficiency of utilized seed reserve to seedling tissue (Soltani et al., 2006). Thus, seed size, as a characteristic of seed quality, plays a major role in germination and establishment of vigorous seedlings that is essential to achieving high yield in wheat (Nik et al., 2011a). Bouaziz and Hick (1990) emphasized that seed size and weight are important criteria for determining seedling vigor and stand establishment in wheat. Helm and Spilde (1990) explained that small kernels of wheat may germinate very well, but the seedlings will be smaller and weaker. Guberac et al. (1999) studied on the influence of seed size in winter wheat, spring barley and spring oat on shoot and root length. Researchers found that large seeds (owing to larger endosperm and bigger quantity of nutrients) had the longest shoot, whereas small seeds resulted in the shortest shoot. Similarly, the largest seeds had the highest values of root length; also the smallest one had the shortest root, with all tested cereals. Chaudhry and Hussain (2001) reported that the small seeds of wheat had the maximum number of seedling and germinated seeds. Cai et al. (2004) stated that seed dry weight was genetically correlated with mean germination time, seed reserve depletion ratio and germination index. In addition, path coefficient analysis showed that conversion efficiency of seed reserve and seed reserve utilization ratio had strong direct effect on seedling weight. Phillips and Edwards (2006) explained that if grain-fill stops at the soft-dough stage, it will shrink considerably as it dries down. This will produce a significantly smaller endosperm with potentially reduced germination capacity and less seedling vigor. They also emphasized that the germination percentage of seeds of wheat plants exposed to drought was lower than seeds of normal (intact) wheat plants. Kara and Akman (2007) also explained that the emergence rate, seedling length, dry weight of above-soil surface organs and root dry weight were higher in large seeds than small and medium seeds in bread wheat. Mut and Akay (2010) stated that decreasing seed size increased mean germination time and decreased the final germination percentage, root length and shoot length in five naked oat genotypes. However, Mian and Nafziger (1994) found no effect of seed size on germination of wheat seeds.

The objective of this research was to determine characteristics of germination and seedling growth of seeds of bread wheat plants exposed to artificial drought stress using chemical desiccant.

Material and Methods

This study was carried out at controlled conditions in seed laboratory of the Field Crops Department of Agricultural Faculty of Namık Kemal University, Tekirdağ, Turkey during 2008-2009 growing season. In this study, eight bread wheat cultivars with different responses to drought (Alpu 2001, Sultan 95, Konya 2002, Eser as sensitive cultivars; Karahan 99, Tosunbey, Kate A1 as resistant cultivars and Golia as moderate resistant cultivar) were used as experimental material. These cultivars were grown in the experimental area of the Field Crops Department of Agricultural Faculty of Namık Kemal University during 2007-2008 growing season. The experiment was performed in randomized block design with 3 replicates. Each genotype was sown in a plot of 6 rows and 0.17 m spacing and 5 m length. The seedling rate was 500 seeds per square meter of plot. Fourteen days after the heading of cultivars (Zadoks 69. stage), artificial drought was induced by spraying chemical desiccant (4% potassium chlorate-$KClO_3$) on 1 m^2 part of each plot (Budaklı and Çelik, 2005). Thus, the complete drying of the plants was achieved after 48 hours of desiccant application. Desiccant applied parts and non-desiccant (control) parts of each plot were harvested separately when the plants reached maturity. The material of

Table 1
Mean thousand kernel weights of seeds of each cultivar

Cultivars	TKW (g)	
	SDAP	SCP
Kate A1	20.18	36.82
Golia	17.01	30.56
Alpu 2001	23.00	37.31
Sultan 95	19.17	24.59
Eser	19.30	24.62
Tosunbey	22.38	35.93
Karahan 99	21.17	33.54
Konya 2002	24.18	38.62

laboratory experiment consisted of these seeds. A thousand kernel weights (TKW) of seeds obtained from desiccant applied plants (SDAP) and control (non-desiccant) plants (SCP) are given at (Table 1).As can be seen from Table 1, seeds of control plants (non-desiccant) were larger than seeds of desiccant applied plants in all cultivars.

The laboratory experiment was conducted in randomized split plot design with cultivars as main plots and seeds as subplots, with 4 replicates. Before cultivation, the initial weights of seeds were measured for the determination of water uptake percent. Then, twenty seeds were sown in 9 cm diameter Petri dishes on filter papers (Whatman No 1 filter paper) beds, irrigated with 10 ml distilled water and incubated at 20 ± 1^0 C in 16 h light and 8 h dark conditions during 8 days in a climatic cabinet (ISTA, 1996). The water uptake of seeds was recorded for 3rd, 6th, 12th, 24th, 36th and 48th hours. The water uptake (WU) was calculated according to the formula presented in Rahman et al. (2008):

$$WU, \% = W_2\text{-}W_1/W_1 \times 100$$

Where, W_1= Initial weight of seed and W_2= weight of seed after absorbing water in a particular time.

A seed was considered to be germinated when radicle came out 2 mm long (ISTA, 1996). The germinated seeds were counted daily, and the mean germination time (MGT) was computed each day for every application of each cultivar by the following formula (Ellis and Roberts, 1980):

$$MGT = \sum(fx) / \sum f$$

Where, f is the number of germinated seed in the day of counting and x is the number of counting days.

The seeds were counted on the 8th day, and this was considered as germination percentage (GP, %) (ISTA, 1996). Five plants were also randomly selected from each Petri dish on the 8th day, and the root number (RN, no), root length (RL, cm), coleoptile length (CL, cm), seedling length (SL, cm), shoot fresh weight (SFW, mg), shoot dry weight (SDW, mg), root fresh weight (RFW, mg) and root dry weight (RDW, mg) were determined. Dry weights of seedling parts were measured after drying samples at 70° C in an oven until a constant weight was achieved (Kaydan and Yagmur, 2008). Variance analysis was performed in randomized split plot design using MSTAT-C computer packet program. LSD test ($P\leq0.05$) was used for the determination of differences among means (Steel and Torrie, 1980).

Results

Germination characteristics

Water uptake: Differences among the cultivars were statistically significant for water uptake (WU) at the 3rd, 6th and 12th hours, but these were not significant at the 24th, 36th and 48th hours (Table 2). The highest WU was recorded in Golia for the 3rd, 6th and 12th hours (27.89, 32.14 and 44.41%, respectively). Sultan 95 (17.30%) and Konya 2002 (17.80%) for 3rd h, Karahan 99 (27.64%), Konya 2002 (27.63%), Tosunbey (27.95%) and Alpu 2001 (28.08%) for 6th h, and Alpu 2001 (35.12%) for 12th h had the lowest WU (Table 3). It is an interesting result that these cultivars except Karahan 99 and Tosunbey were drought sensitive. There were statistically significant differences between seeds for WU (Table 2). WU of SDAP was more than SCP for all record times (Table 3). The effect of cultivar x seed interaction on WU was statistically significant for all record times (Table 2). The highest WU for 3rd, 6th, 12th and 24th hours was observed from SDAP of Golia as 36.52, 40.17, 56.25 and 66.74%, respectively. SDAP of Kate A1 (75.83%) for 36th h and SDAP of Sultan 95 (94.43%) for 48th h had the highest WU. The

Table 2
F value from analysis of variance for measured characteristics.

SV	df	WU at 3rd h	WU at 6th h	WU at 12th h	WU at 24th	WU at 36th h	WU at 48th h	GP	MGT
C	7	67.21**	2.69*	2.80*	1.21^{ns}	1.12^{ns}	1.41^{ns}	2.98*	3.76**
S	1	476.69**	318.32**	231.25**	266.46**	205.55**	338.67**	13.17**	0.42^{ns}
C x S	7	26.62**	4.86**	3.98**	4.05**	3.62**	4.37**	2.83*	5.45**

SV	df	RN	RL	CL	SL	SFW	SDW	RFW	RDW
C	7	14.73**	3.17*	18.86**	3.44*	3.67**	2.71*	9.02**	9.29**
S	1	118.29**	2.23^{ns}	8.96**	25.49**	117.81**	253.37**	46.97**	150.13**
C x S	7	4.38**	0.82^{ns}	2.69*	3.89**	2.00^{ns}	2.68*	0.46^{ns}	0.55^{ns}

SV: Source of variation, df: degree of freedom, C: Cultivar, S: Seed, C x S: Cultivar x seed interaction, ** and *: Significant at 1% and 5% , ^{ns}: Non-significant

Table 3.
Mean values and significance groups for water uptake at the 3rd, 6th, 12th, 24th, 36th and 48th hours.

Cultivars	WU at the 3rd h (%)			WU at the 6th h (%)			WU at the 12th h (%)		
	Seed		Mean	Seed		Mean	Seed		Mean
	SCP	SDAP		SCP	SDAP		SCP	SDAP	
Kate A1	15.11 gh	33.63 b	24.37 b	19.85 de	40.04 a	29.95 ab	30.72 f	51.36 ab	41.04 ab
Golia	19.26 e	36.52 a	27.89 a	24.12 cd	40.17 a	32.14 a	32.58 f	56.25 a	44.41 a
Alpu 2001	12.43 hı	26.86 c	19.65 de	19.42 e	36.74 ab	28.08 b	28.53 f	41.70 de	35.12 c
Sultan 95	18.29 ef	16.31 fg	17.30 f	21.61 de	36.92 ab	29.26 ab	30.90 f	48.65 bc	39.78 abc
Eser	19.45 e	23.63 d	21.54 c	28.13 c	32.90 b	30.52 ab	39.52 e	45.17 cde	42.35 ab
Tosunbey	15.77 fg	22.87 d	19.32 e	23.12 de	32.78 b	27.95 b	32.30 f	44.69 cde	38.50 bc
Karahan 99	14.94 gh	26.58 c	20.76 cd	21.53 de	33.76 b	27.64 b	31.95 f	43.89 cde	37.92 bc
Konya 2002	11.95 ı	23.65 d	17.80 f	19.74 de	35.73 ab	27.73 b	28.83 f	45.99 bcd	37.41 bc
Mean	15.90 b	26.26 a	21.08	22.19 b	36.13 a	29.16	31.92 b	47.21 a	39.56
LSD$_{(P≤0.05)}$	C: 1.260 S: 0.979			C: 2.882 S: 1.613			C: 5.178 S: 2.076		
	CxS: 2.769			CxS: 4.561			CxS: 5.872		

Cultivars	WU at the 24th h (%)			WU at the 36th h (%)			WU at the 48th h (%)		
	Seed		Mean	Seed		Mean	Seed		Mean
	SCP	SDAP		SCP	SDAP		SCP	SDAP	
Kate A1	38.90 d	65.60 a	52.25	44.37 e	75.83 a	60.10	51.08 ı	91.46 ab	71.27
Golia	39.54 d	66.74 a	53.14	43.53 e	70.67 abc	57.10	59.04 hı	91.68 ab	75.37
Alpu 2001	37.56 d	54.38 bc	45.97	43.58 e	65.58 bc	54.58	51.37 ı	81.34 cd	66.36
Sultan 95	40.21 d	60.50 ab	50.36	52.87 d	73.81 ab	63.34	68.51 fg	94.43 a	81.47
Eser	50.93 c	58.52 b	54.73	62.41 c	68.09 abc	65.25	72.59 ef	84.91 bc	78.75
Tosunbey	42.03 d	57.12 bc	49.57	50.00 de	69.42 abc	59.71	59.04 hı	86.88 abc	72.96
Karahan 99	42.07 d	57.17 bc	49.62	52.83 d	69.22 abc	61.03	60.15 gh	80.04 cde	70.10
Konya 2002	37.97 d	57.28 bc	47.63	45.94 de	65.22 c	55.58	53.07 hı	75.61 def	64.34
Mean	41.15 b	59.66 a	50.41	49.44 b	69.73 a	59.59	59.36 b	85.80 a	72.58
LSD$_{(P≤0.05)}$	C: - S: 2.341			C: - S: 2.921			C: - S: 2.965		
	CxS: 6.620			CxS: 8.261			CxS: 8.386		

C: Cultivar, S: Seed, C x S: Cultivar x seed interaction

lowest WU was recorded in SCP of Konya 2002 (11.95%) for 3rd h, SCP of Alpu 2001 (19.42, 28.53 and 37.56%) for 6th, 12th and 24th hours, SCP of Golia (43.53%) for 36th h, SCP of Kate A1 (51.08%) for 48th h (Table 3).

Germination percentage: The effect of cultivar, seed and their interaction on germination percentage (GP) was statistically significant (Table 2). Mean of GP varied between 88.34 and 96.66% for cultivars. The maximum GP was observed in Alpu 2001 followed by Karahan

99, Tosunbey, and the lowest in Golia (Table 4). Results showed that GP of SDAP (95.72%) was higher than SCP (92.71%). In cultivar x seed interaction, mean of GP varied between 86.68 and 100.0%. SDAP of Tosunbey and Alpu 2001 cultivars had the highest GP. The lowest GP was determined in SDAP of Golia (Table 4).

Mean germination time: Mean germination time (MGT) was significantly affected by cultivar and cultivar x seed interaction. However, differences between SDAP and SCP were not significant (Table 2). Among 8 cultivars, Konya 2002 had the longest MGT (2.40 days). However, Eser cultivar with small sized seed was germinated at the shortest time (2.11 days). In our study, MGT of SDAP and SCP were 2.24 and 2.26 days, respectively (Table 4). MGT varied between 2.02 and 2.58 days for cultivar x seed interaction. SCP of Konya 2002 took the longest time to germinate. The shortest MGT was determined in SDAP of Karahan 99 (Table 4).

Seedling characteristics

Root number: There were highly significant differences among the means of cultivar for root number (RN) (Table 2). RN ranged from 3.14 to 5.44 among the analyzed cultivars. The highest RN was determined in Golia, and the lowest in Kate A1 (Table 4). RN was significantly affected by seed (Table 2). RN of SCP (4.66 no.) was more than SDAP (3.82 no.) (Table 4). The effect of cultivar x seed interaction on RN was highly significant (Table 2). SCP of Golia had the highest RN (5.80 no.). The lowest RN (3.00 no.) was obtained in SDAP of Kate A1 (Table 4).

Root length: Effect of cultivars was significant for root length (RL) (Table 2). The longest RL obtained in the Sultan 95 cultivar (11.77 cm) followed by Eser (10.92 cm), Tosunbey (10.54 cm) and Konya 2002 (10.34 cm) in the same statistical group (Table 4). RL was the lowest in Alpu 2001 cultivar (8.15 cm). RL was not significantly influenced by the seeds and cultivar x seed interaction (Table 2). Nevertheless, RL of SCP (10.18 cm) was relatively longer than SDAP (9.83 cm).

Coleoptile length: The coleoptile length (CL) was significantly affected by cultivar, seed, and their interaction (Table 2). Among 8 cultivars, Karahan 99 produced the longest CL (3.70 cm). Konya 2002 (3.65 cm), Kate A1 (3.60 cm) and Tosunbey (3.43 cm) were in the same statistical group with this cultivar. CL was the shortest in Golia (2.45 cm) with small seed size (Table 4). SCP (3.29 cm) had the longer CL than SDAP (3.19 cm) (Table 4). Mean values of CL varied between 2.30 and 3.79 cm in cultivar x seed interaction. SCP of Karahan 99 had the longest CL, and the shortest in SDAP of Golia (Table 4).

Seedling length: The effect of cultivar, seed and their interactions was statistically significant for seedling length (SL) (Table 2). Means of cultivars indicated that SL was highest in Karahan 99 (12.23 cm) followed by Kate A1 (11.80 cm). Tosunbey demonstrated lowest

Table 4
Mean values and significance groups for GP, MGT, RN, RL and CL.

Cultivars	GP (%) Seed			MGT (days) Seed			RN (no.) Seed		
	SCP	SDAP	Mean	SCP	SDAP	Mean	SCP	SDAP	Mean
Kate A1	96.10 a-d	95.58 a-d	95.84 a	2.28 b-e	2.15 e-h	2.21 bcd	3.28 hı	3.00 ı	3.14 e
Golia	90.00 efg	86.68 g	88.34 b	2.25 b-f	2.33 bc	2.29 abc	5.80 a	5.08 b	5.44 a
Alpu 2001	93.33 c-f	100.0 a	96.66 a	2.35 b	2.31 bcd	2.33 ab	4.98 b	4.48 cde	4.73 b
Sultan 95	89.48 fg	96.10 a-d	92.79 ab	2.17 d-h	2.34 bc	2.26 bc	4.40 de	4.03 ef	4.22 bc
Eser	91.68 def	92.23 c-f	91.95 ab	2.10 gh	2.11 fgh	2.11 d	4.73 bcd	3.57 gh	4.15 cd
Tosunbey	92.23 c-f	100.0 a	96.11 a	2.06 gh	2.23 b-g	2.15 cd	4.90 bc	3.73 fg	4.32 bc
Karahan 99	94.43 b-e	98.33 ab	96.38 a	2.24 b-g	2.02 h	2.22 bcd	4.17 ef	3.23 hı	3.70 d
Konya 2002	94.43 b-e	96.83 abc	95.63 a	2.58 a	2.24 b-g	2.41 a	5.03 b	3.43 ghı	4.23 bc
Mean	92.71 b	95.72 a	94.22	2.26	2.24	2.25	4.66 a	3.82 b	4.24
LSD$_{(P\leq0.05)}$	C: 4.976 S: 1.712 CxS: 4.841			C: 0.148 S: - CxS: 0.145			C: 0.514 S: 0.160 CxS: 0.452		

C: Cultivar, S: Seed, C x S: Cultivar x seed interaction

Table 4 (continued)
Mean values and significance groups for GP, MGT, RN, RL and CL.

Cultivars	RL (cm)			CL (cm)		
	Seed		Mean	Seed		Mean
	SCP	SDAP		SCP	SDAP	
Kate A1	9.79	8.97	9.38 bc	3.69abc	3.52 cde	3.60 a
Golia	9.57	9.12	9.35 bc	2.59 h	2.30 ı	2.45 c
Alpu 2001	8.50	7.80	8.15 c	2.99 fg	2.86 g	2.93b
Sultan 95	11.98	11.55	11.77 a	3.01 fg	3.11 f	3.06 b
Eser	11.44	10.40	10.92 ab	3.12 f	3.08 f	3.10 b
Tosunbey	10.20	10.87	10.54 ab	3.50 de	3.36 e	3.43 a
Karahan 99	9.41	9.82	9.62 bc	3.79 a	3.60 bcd	3.70 a
Konya 2002	10.54	10.14	10.34 ab	3.59bd	3.71 ab	3.65 a
Mean	10.18	9.83	10.00	3.29 a	3.19 b	3.24
LSD$_{(P\leq0.05)}$	C: 1.833 S: - CxS: -			C: 0.292 S: 0.064 CxS: 0.179		

C: Cultivar, S: Seed, C x S: Cultivar x seed interaction

values (10.35 cm) for SL, followed by Sultan 95 (10.40 cm). SL of SCP (11.33 cm) was longer than SDAP (10.75 cm) (Table 5). In cultivar x seed interaction, SL varied from 9.77 cm to 12.34 cm. SCP of Karahan 99 had the longest SL followed by SCP of Kate A1 (12.12 cm), SDAP of Karahan 99 (12.12 cm) and SCP of Golia (11.83 cm). The shortest SL was determined in SDAP of Golia followed by SDAP of Tosunbey (9.99 cm) (Table 5).

Shoot fresh weight: The cultivar and seed had significant impact on shoot fresh weight (SFW), but effect of their interaction was not significant (Table 2). The highest SFW occurred in Karahan 99 (67.11 mg) having the highest seedling length, followed by Konya 2002 (58.30 mg) and Tosunbey (57.75 mg). Kate A1 had the lowest SFW (49.41 mg) followed by Eser cultivar (53.90 mg) (Table 5). Although, Kate A1 had the high values for seedling length, SFW was the lowest for this cultivar. This result showed that content of water and dry matter in seedlings of this cultivar was lower than the other cultivars having the same seedling length. Our findings showed a significant difference between SCP and SDAP for SFW, and their SFW was determined as 62.21 and 50.56 mg, respectively (Table 5).

Shoot dry weight: The effect of cultivar, seed and their interactions was statistically significant for shoot dry weight (SDW) (Table 2).

Table 5
Mean values and significance groups for SL, SFW, SDW, RFW and RDW.

Cultivars	SL (cm)			SFW (mg)			SDW (mg)		
	Seed		Mean	Seed		Mean	Seed		Mean
	SCP	SDAP		SCP	SDAP		SCP	SDAP	
Kate A1	12.12 ab	11.48 bc	11.80 ab	55.60	43.23	49.41 c	6.70 cd	5.08 ef	5.89 c
Golia	11.83 ab	9.77 g	10.80 bc	64.00	43.93	53.96 bc	7.28 abc	4.83 f	6.05 bc
Alpu 2001	11.10 cd	10.74 de	10.92 bc	61.73	49.88	55.80 bc	7.38 ab	5.30 ef	6.34 bc
Sultan 95	10.52 def	10.28 efg	10.40 c	58.53	51.18	54.85 bc	6.80 bcd	5.40 ef	6.10 bc
Eser	10.95 cde	10.63 def	10.79 bc	60.20	47.60	53.90 bc	6.53 d	5.08 ef	5.80 c
Tosunbey	10.71 de	9.99 fg	10.35 c	64.68	50.83	57.75 b	7.80 a	5.70 e	6.75 ab
Karahan 99	12.34 a	12.12 ab	12.23 a	70.90	63.33	67.11 a	7.68 a	6.83 bcd	7.25 a
Konya 2002	11.07 cd	11.01 cd	11.04 bc	62.08	54.53	58.30 b	7.38 ab	5.48 e	6.43 abc
Mean	11.33 a	10.75 b	11.04	62.21 a	50.56 b	56.39	7.19 a	5.46 b	6.33
LSD$_{(P\leq0.05)}$	C: 1.031 S: 0.236 CxS: 0.667			C: 7.806 S: 2.216 CxS: -			C: 0.858 S: 0.224 CxS: 0.634		

C: Cultivar, S: Seed, C x S: Cultivar x seed interaction

Table 5 (continued)
Mean values and significance groups for SL, SFW, SDW, RFW and RDW.

Cultivars	RFW (mg)			RDW (mg)		
	Seed		Mean	Seed		Mean
	SCP	SDAP		SCP	SDAP	
Kate A1	38.10	27.07	32.58 e	4.93	3.33	4.13 d
Golia	43.03	28.17	35.60 de	5.13	3.10	4.11 d
Alpu 2001	50.10	37.47	43.78 cd	6.18	3.80	4.99 bc
Sultan 95	65.27	57.48	61.38 a	6.13	4.80	5.46 b
Eser	58.80	53.33	56.07 ab	6.20	4.23	5.21 bc
Tosunbey	57.07	44.87	50.97 bc	7.40	5.53	6.46 a
Karahan 99	48.20	35.47	41.83 cde	5.73	3.70	4.71 cd
Konya 2002	52.48	42.80	47.64 bc	5.98	4.28	5.13 bc
Mean	51.63 a	40.83 b	46.23	5.96 a	4.09 b	5.03
$LSD_{(P≤0.05)}$	C: 9.546 S: 3.252 CxS: -			C: 0.728 S: 0.314 CxS: -		

C: Cultivar, S: Seed, C x S: Cultivar x seed interaction

Mean values of cultivars ranged from 5.80 to 7.25 mg (Table 5). Karahan 99 cultivar had the highest SDW followed by Tosunbey (6.75 mg) and Konya 2002 (6.43 mg). These cultivars also had high SFW. The lowest SDW was obtained from Eser followed by Kate A1 (5.89 mg). These cultivars also had low SFW. As an expected result, SDW of SCP (7.19 mg) was significantly higher than SDAP (5.46 mg) having small seed and the low SFW (Table 5). In cultivar x seed interaction, the highest SDW was recorded for SCP of Tosunbey (7.80 mg) closely followed by SCP of Karahan 99 (7.68 mg). SDAP of Golia (4.83 mg) had the lowest SDW followed by SDAP of Kate A1 and Eser (5.08 mg) (Table 5).

Root fresh weight: Root fresh weight (RFW) was significantly affected by cultivar and seed. However, no significant interaction was noticed between cultivar and seed (Table 2). Means comparisons showed that Sultan 95 cultivar produced the highest of RFW with 61.38 mg followed by Eser (56.07 mg) (Table 5). These two cultivars had also a long RL (Table 4). The lowest RFW (32.58 mg) was obtained in the Kate A1 cultivar. This cultivar had also a short RL (Table 4). RFW of SCP (51.63 mg) was highly greater than SDAP (40.83 mg) (Table 5). This situation may be a result of the high RN in SCP (Table 4).

Root dry weight: The effects of cultivar and seed on root dry weight (RDW) were statistically significant. However, the interaction of cultivar x seed was not significant for RDW (Table 2). Among 8 cultivars, Tosunbey had the highest RDW (6.46 mg) followed by Sultan 95 (5.46 mg) having the high RFW (Table 5). However, Golia (4.11 mg) and Kate A1 (4.13 mg) had the lowest RDW. These two cultivars had also low RFW. In terms of seed means, obtained results for RFW were also observed for RDW. RDW of SCP (5.96 mg) with large sized seeds was significantly higher than SDAP (4.09 mg) with small sized seeds(Table 5).

Discussion

Drought stress is an environmental factor affecting final seed size of wheat. In our study, it was shown that artificial drought stress induced by chemical desiccant caused the reduction in seed size and weight of all cultivars. Thus, seeds of desiccant applied plants (SDAP) were smaller than seeds of control plants (SCP) (Table1).

Results showed that significant differences among WU of cultivars were observed within first 12 hours. This may be associated with a large amount of water being taken up by seeds of wheat at the beginning of germination. Similar results were obtained by Clarke (1980) in wheat. WU of SDAP was higher than SCP for all record times and all cultivars. This may result from the fact that the desiccant applied plants have small seeds with little endosperm. This result may also indicate that

SDAP have more intense hydrophilic substance than SCP. Helm and Spilde (1990) presented similar results.

In this study, SDAP had an advantage in the process of germination due to its high WU. Thus, GP of SDAP was higher than SCP. Similar results were obtained by Chaudhry and Hussain (2001). In contrast, Phillips and Edwards (2006), Kakhki et al. (2008), Asgharipour and Rafiei (2011) in wheat and Mut and Akay (2010) in oat emphasized that large seeds had the highest GP. However, it has been reported by Mian and Nafziger (1994) in wheat and Gharoobi (2011) in barley that seed size had no effect on germination.

Our results showed the difference between SDAP and SCP was not significant for MGT, but SDAP geminated relatively faster than SCP. Our results were similar to the findings of Lafond and Baker (1986), who found that small wheat seeds germinated faster than large seeds. Our results were also inconsistent with those of Mut and Akay (2010) in oat and Asgharipour and Rafiei (2011) in wheat, who reported that MGT of a large seed was shorter than a small seed.

In the present study, RN of SCP was more than SDAP. This result indicated that the large seeds of wheat produced more root. The effect of seed on RL was not significant, but SCP had relatively longer roots than SDAP. SCP has longer roots because it has large seed and endosperm that result in the longer roots. This result is also in agreement with the observation of Guberac et al. (1999), Kakhki et al. (2008) in wheat, Kaydan and Yagmur (2008) in triticale and Mut and Akay (2010) in oat, who found that large seeds had longer RL than small seeds.

This research indicated that SCP with large size produced longer coleoptiles than SDAP with small size. This may result from the large seeds also having larger endosperm and a bigger quantity of nutrients than small seeds for growth (Guberac et al. 1999). Similar findings with our results were reported by Bouaziz and Hick (1990), and Nik et al. (2011a).

SL of SCP was higher than SDAP. This result may be associated with the reduction in seed size due to desiccant application. Thus, SDAP had shorter SL. Guberac et al. (1999), Aparicio et al. (2002), Kara and Akman (2007), Kakhki et al. (2008), Kaydan and Yagmur (2008), Mut and Akay (2010) and Farahani et al. (2011) presented similar results in that large seeds have longer SL in comparison with small seed.

Our findings also showed a significant difference between SCP and SDAP for SFW. Desiccant application caused the reduction in seed size of all cultivars. Therefore, a seedling produced by SDAP was smaller than SCP. Thus, SFW of SDAP was lower than that of SCP. Similar findings were obtained by Asgharipour and Rafiei (2011) in wheat and Gharoobi (2011) in barley, who found that large seeds had higher SFW than small seeds.

As an expected result, SDW of SCP was significantly higher than SDAP having small seed and the low shoot fresh weight. The findings of Mian and Nafziger (1994), Aparicio et al. (2002), Kara and Akman (2007), Kaydan and Yagmur (2008), Kakhki et al. (2008), Asgharipour and Rafiei (2011), Gharoobi (2011), Nik et al. (2011a), Nik et al. (2011b) confirming our results, reported that large seeds had higher shoot dry weight than small seeds.

Our results showed that, RFW of SCP with high RN was higher than SDAP. So, it can be said that a large seed of wheat has higher RFW as compared with a small seed. Our results were similar to the findings of Asgharipour and Rafiei (2011), who found that RFW of large seeds was higher than small seeds.

SCP had also higher RDW, in comparison with SDAP. Differences between SCP and SDAP can be ascribed to their seed size. Similar findings are reported by Mian and Nafziger (1994), Kara and Akman (2007), Kaydan and Yagmur (2008), Nik et al. (2011a), and Gharoobi (2011), who found that RDW was significantly increased by increasing seed size.

Consequently, it can be said that artificial drought stress by desiccant application affected negatively seed quality due to its detractive impact on seed size in wheat. However, this negative effect on seed quality was higher in drought sensitive cultivars than other cultivars. It is further suggested that the same study must be conducted as a field experiment to compare performances of SDAP and SCP under the natural conditions for more reliable findings.

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