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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Agronomic Performance of Seeds of Some Bread Wheat *(Triticum aestivum L.)* Cultivars Exposed to Drought Stress

Kuraklık Stresinde Kalmış Bazı Ekmelik Buğday *(Triticum aestivum L.)* Çeşitlerinin Tohumluklarının Agronomik Performansları

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Abstract

This study was carried out to determine agronomic performance of seeds of some bread wheat cultivars exposed to artificial drought stress. Seeds obtained from eight bread wheat cultivars with different response to drought (Konya 2002, Alpu 2001, Sultan 95 and Eser as drought sensitive cultivars; Karahan 99, Tosunbey, Kate A1 as drought resistant cultivars and Golia as moderate drought resistant cultivar) after their treatment, in previous years, by artificial drought stress through using chemical desiccant (4% potassium cholorate-KClO3) at the post-anthesis stage were used as experimental material. The field experiment was arranged in a split-plot design with 3 replicates during 2009-2010 and 2010-2011 wheat growing seasons. Cultivars were adjusted as main plots and seeds were allotted as subplots. In the experiment, seeds obtained from desiccant applied plants (SDAP) and control (non-desiccant) plants (SCP) were compared for plant height (PH), spike length (SL), number of grain per spike (NGPS), grain weight per spike (GWPS), grain yield (GY) and thousand kernel weight (TKW). It was determined that the drought resistant cultivars had generally higher values for PH, GWPS, GY and TKW than the other cultivars. However, the highest NGPS was obtained from the drought sensitive cultivars. The study has shown that desiccant application has detractive impact on seed size in all cultivars. Therefore, the SCP showed significantly higher performance for all examined traits than the SDAP. Consequently, data showed that artificial drought stress by chemical desiccant application at the post-athesis stage affected negatively seed quality in bread wheat.

Keywords: Potassium chlorate, drought, seed quality, grain yield, yield components.

Öz

Bu çalışma, yapay kuraklık stresinin etkisinde kalmış bazı ekmeklik buğday çeşitlerinin tohumluklarının agronomik performanslarını belirlemek amacıyla yürütülmüştür. Bir önceki yıl çiçeklenme sonrası dönemde kimyasal desikant (%4 potasyum klorat-KClO3) kullanılarak oluşturulan yapay kuraklık stresinin etkisinde bırakılmış kurağa yanıtları farklı sekiz ekmeklik buğday çeşidinden (Konya 2002, Alpu 2001, Sultan 95 ve Eser kurağa hassas çeşitler; Karahan 99, Tosunbey, Kate A1 kurağa dayanıklı çeşitler ve Golia kurağa orta dayanıklı çeşit) elde edilen tohumluklar deneme materyali olarak kullanılmıştır. Tarla denemesi 2009-2010 ve 2010-2011 buğday yetiştirme dönemlerinde bölünmüş parseller deneme desenine göre 3 tekrarlamalı olarak kurulmuştur. Çeşitler ana parsellere, tohumluklar ise alt parsellere yerleştirilmiştir. Denemede, desikant uygulanmış bitkilerden elde edilmiş tohumluklar (DUBT) ile kontrol bitkilerden elde edilmiş tohumluklar (KBT) bitki boyu (BB), başak uzunluğu (BU), başakta tane sayısı (BATS), başakta tane ağırlığı (BATA), tane verimi (TV) ve bin tane ağırlığı (BTA) bakımından karşılaştırılmıştır. Genellikle, BB, BATA, TV ve BTA bakımından kurağa dayanıklı çeşitler hassas çeşitlerden daha yüksek değerlere sahip olmuştur. Bununla birlikte, en yüksek BATS kurağa hassas çeşitlerden elde edilmiştir. Çalışmada, desikant uygulamasının bütün çeşitlerde tane boyutu üzerine olumsuz etki yaptığı görülmüştür. Bu nedenle, incelenen tüm özellikler bakımından KBT, DUBT'dan daha iyi performansı göstermiştir. Sonuç olarak, elde edilen veriler ekmeklik buğdayda çiçeklenme sonrası dönemde kimyasal desikant uygulanarak oluşturulan yapay kuraklık stresinin tohumluk kalitesini olumsuz etkilediğini göstermiştir.

Anahtar Kelimeler: Potasyum klorat, kuraklık, tohumluk kalitesi, tane verimi, verim unsurları.

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Wheat (*Triticum* aestivum L.) is a strategic plant and a stable food for more than 35% of the world's population (Khakwani et al., 2011), and it is also one of the most important cereal crops in Turkey. According to FAO's latest forecast, wheat production of the world and Turkey are 749.4 Mt and 20.6 Mt, respectively (Anonymous, 2016). While wheat is the second crop after maize (1.06 Bt) as production amount in the world, it is the first crop in Turkey. Wheat grows as a rain-fed crop in semi-arid and arid regions of Turkey, where large fluctuations occur in the amount and frequency of precipitation from year by year.

In recent years, abiotic stress factors result from global climate change has greatly affected by wheat production in many arid and semi-arid regions of the world. Drought is one of the most common abiotic/environmental stresses that affect growth and development of plants. It is assumed that by the year 2025, around 1.8 billion people will face absolute water shortage and 65% of the world's population will live under water-stressed environments (Nezhadahmadi et al., 2013). The response of plants to water stress depends on several factors such as developmental stage, severity and duration of stress and cultivar genetics (Beltrano and Ronco, 2008). Although all phenological stages of wheat are affected by drought stress, especially the reproductive and grain-filling stages are the most sensitive (Pradhan et al., 2012). Drought during reproductive and grain-filling stages is known as terminal drought (Reynolds et al., 2005). Under terminal drought, the grain-filling rate decreases due to reduced photosynthesis, accelerated leaf senescence, and sink limitations (Farooq et al., 2014). Therefore, terminal drought early grain development curtails potential grain size by reducing the rate and duration of grain filling (Saini and Westgate, 2000). Cseuz (2009) indicated that drought stress during post-anthesis and grain-filling stages may cause grain yield reduction due to seed shriveling as high as 20-50%.

One of the methods that were approved as effective for the selection of cereal varieties resistant to drought is the chemical desiccant application (Dogan et al., 2012). For this purpose, chemical desiccants such as potassium iodide (Sawhney and Singh, 2002), magnesium chlorate (Blum et al., 1983), sodium chlorate (Haley and Quik, 1993) and potassium chlorate (Budaklı et al., 2007) are used. Artificial drought stress induced by applying chemical desiccant at the post-anthesis stage caused the reduction in seed size and weight (Blum et al., 1983; Haley and Quik, 1993; Chandra et al., 2005; Cseuz, 2009; Mohammadi et al., 2009).

Seed size is an important physical indicator of seed quality that affects vegetative growth and it is frequently related to yield, market grade factors and harvest efficiency (Rukavina et al., 2002). Seed size as a characteristic of seed quality, also plays a major role on germination and establishment of vigorous seedlings that is essential to achieving high yield in wheat (Nik et al., 2011). Generally, large seed has better field performance than small seed (Ambika et al., 2014). Farahani et al. (2011) explained that the effect of seed size was significant on germination percentage, seedling dry weight and seedling vigour in bread wheat. The highest germination percentage, seedling dry weight, seedling vigour, and seedling length were achieved came up to large seeds. Kara and Akman (2007) indicated that 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, but tillering and root/dry weight ratio of above-soil surface organs were not affected from seed size. Akinci et al. (2008) reported that effect of seed size on plant height, spike length, spikelet number, grains number per spike and grain weight per spike was not significant in durum wheat. They also indicated that increasing seed size increased seedling emergence, thousand kernel weight and grain yield. Taner et al. (2011) stated that thousand kernel weight, test weight and grain yield was higher in larger seeds than small seeds, and plant height was not affected by seed size. Zareian et al. (2012) emphasized that increasing seed size increased seedling emergence percentage, number of spikes per m^2 and grain yield in three bread wheat cultivars. Kahraman and Avcı (2016) stated that thousand kernel weight, test weight and grain yield were higher in large seeds than small seeds in bread wheat. They also found no interaction between seed size and number of spike per m^2 and number of grain per spike. Haider et al. (2016) studied on influence of seed priming and seed size on wheat performance under different tillage systems. Researchers found that large seeds had better performance than small seeds in terms of plant height, spike length, number of productive tillers per m^2, spikelets per spike, grains per spike, thousand kernel weight, biological yield, straw yield and grain yield.

In our previous study, it was examined the characteristics of germination and seedling growth of seeds obtained from plants exposed to artificial drought stress using potassium chlorate in bread wheat cultivars. We found that non-desiccant/large 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/small seeds (Balkan, 2012). Thus, the aim of this study was to determine grain yield and yield components of seeds of some bread wheat cultivars exposed to artificial drought stress under field conditions, and also to examine effect of artificial drought stress on seed quality in bread wheat.

Materials and Methods

Experimental site and growing conditions:

This study was carried out in the experiment area of Field Crops Department of Agricultural Faculty of Tekirdağ Namik Kemal University, Tekirdağ, Turkey between 2009-2010 and 2010-2011 wheat growing seasons. Tekirdağ district locates at latitude 40° 36'-40° 31' and longitude 26° 43'-28° 08'and asl is 10 m.

According to soil analysis results, experimental area's soil was clay-loam, slightly acidic (pH 6.7), limeless, and poor (1.05%) in the organic matter. In addition, K_2O content of the soil was adequate, but P_2O_5 and nitrogen content was very low.

The climate data during the 2009-2010 and 2010-2011 wheat growing seasons and long-term average were given in Table 1. In the first year of the study, the total precipitation, the average temperature and relative humidity were 525.0 mm, 12.1 °C and 84.0%, respectively. The total precipitation and relative humidity of this year was higher than long-term (Table 1). In the second year of the study, the total precipitation, the average temperature and relative humidity were 459.0 mm, 11.3 °C and 78.0%, respectively. The climatic data of the second year were similar to the long-term (Table 1).

Experimental materials and design:

Eight bread wheat cultivars with different responses to drought (Konya 2002, Alpu 2001, Sultan 95 and Eser as drought sensitive cultivars; Karahan 99, Tosunbey, Kate A1 as drought resistant cultivars and Golia as moderate drought resistant cultivar) were used as experimental material in this study. These cultivars were grown in separate plots of 5 m^2 in the experimental area of Field Crops Department of Agricultural Faculty of Tekirdağ Namık Kemal University during 2007-2008 and 2008-2009 growing seasons. Fourteen days after the heading of cultivars (Zadoks 69. stage-post-anthesis), artificial drought stress 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 the field experiments in 2009-2010 and 2010-2011 consisted of these seeds. A thousand kernel weights (TKW) of seeds obtained from desiccant applied plants (SDAP) and control (non-desiccant) plants (SCP) in 2009 and 2010 are given at Table 2. As can be seen from Table 2, seeds of control plants (non-desiccant) were larger than seeds of desiccant applied plants in all cultivars.

Table 1. Some climatic parameters during the wheat growing season in 2009-2010 and 2010-2011.

Months	Precipitation (mm)			Average Temperature (°C)			Relative Humidity (%)		
	2009-10	2010-11	Long-term	2009-10	2010-11	Long-term	2009-10	2010-11	Long-term
November	32.2	30.6	81.3	11.9	15.3	11.4	97.6	82.6	81
December	132.8	107.8	86.2	9.2	8.8	7.2	97.4	78.5	82
January	74.6	45.8	69.9	4.8	5.3	4.4	94.2	84.7	82
February	150.2	40.2	54.7	7.9	5.1	5.3	85.5	77.1	80
March	46.6	22.2	55.6	8.5	7.3	6.8	79.2	77.0	79
April	27.6	75.2	42.9	13.2	10.5	11.5	73.7	76.5	76
May	14.4	41.8	37.6	18.7	16.5	16.6	71.9	77.4	75
June	46.6	95.4	37.8	22.7	21.9	28.9	72.9	70.4	71
Total	*525.0*	*459.0*	*466.0*	-	-	-	-	-	-
Average	-	-	-	*12.1*	*11.3*	*11.5*	*84.0*	*78.0*	*78.2*

Source: Tekirdağ Meteorological Station.

The field experiment was carried out in a split-plot design with cultivars as main plots and seeds as subplots, with 3 replicates in 2009-2010 and 2010-2011 years. Experimental plots consisted of six rows, 5 m long and spaced 20 cm apart. The experiments were sowed on 07 November 2009 and 11 November 2010 with a seedling rate of 500 seeds m^{-2}. At sowing, 5 kg da^{-1} pure nitrogen (N) and 5 kg da^{-1} pure phosphor (P_2O_5) were applied as 20.20.0 composed fertilizer. Also, 8 kg da^{-1} pure N as urea fertilizer (46% N) and 3 kg da^{-1} pure N as ammonium nitrate fertilizer (26% N) were applied at tillering and stem elongation stages, respectively. Weeds in the plots were controlled with chemical control methods between tillering and stem elongation stages in spring. The plots were harvested with a HEGE-160 combine harvester on the July 2010 and 2011 during the maturity (Zadoks 93. stage).

In the experiment, grain yield (GY-kg da^{-1}), plant height (PH-cm), spike length (SL-cm), number of grains per spike (NGPS-no), grain weight per spike (GWPS-g), harvest index (HI-%), thousand kernel weight (TKW-g) were determined.

Table 2. Mean thousand kernel weights of seeds of each cultivar

Cultivars	TKW (g)			
	2009		2010	
	SCP	SDAP	SCP	SDAP
Kate A1	36.82	20.18	34.70	23.92
Golia	30.56	17.01	29.67	21.97
Konya 2002	38.62	24.18	36.57	24.97
Karahan 99	33.54	21.17	32.96	22.47
Alpu 2001	37.31	23.00	33.07	23.53
Sultan 95	24.59	19.17	24.00	17.23
Tosunbey	35.93	22.38	35.27	27.93
Eser	24.62	19.30	23.10	17.41

Statistical analysis:

All the data obtained from the experiments were subjected to variance analysis (ANOVA) using JMP 5.0.1 statistical software, and mean values were compared using Fisher's Least Significant Difference (LSD) test (Steel & Torrie 1960).

Results and Discussion

ANOVA results indicate significant effect of both cultivars and seeds on PH, SL, NGPS, GWP, GY and TKW in both years (Table 3-6).

Plant height (PH-cm):

PH was significantly affected by cultivar, seed and cultivar x seed interaction in both years (Table 3 and 5). In 2010, PH varied between 57.4 and 110.7 cm for cultivars. The highest PH was measured in Karahan 99 cultivar followed by Konya 2002 cultivar (101.0 cm), and the lowest Golia cultivar (Table 3). PH of SCP (94.9 cm) was significantly more than SDAP (90.1 cm) (Table 3). In cultivar x seed interaction, PH varied from 54.0 to 114.5 cm. SCP of Karahan 99 cultivar had the longest PH followed by SDAP of same cultivar (106.9 cm) (Table 3). The shortest PH was determined in SDAP of Golia cultivar followed by SCP of same cultivar (60.8 cm). Similar results to the first year were obtained in the second year of the experiment (Table 5). Karahan 99 cultivar had the highest mean value of PH (120.4 cm) followed by Konya 2002 cultivar with 114.0 cm. The shortest PH occurred in Golia cultivar (65.0 cm) followed by Eser cultivar with 90.8 cm. There was a significant difference between SCP and SDAP, and their mean values for PH were determined as 104.3 cm and 96.8 cm, respectively (Table 5). Mean PH values were varied between 62.0 cm and 125.2 cm in cultivar x seed interaction (Table 5). The longest PH was measured in SCP of Karahan 99 cultivar followed by SCP of Konya 2002 cultivar with 120.2 cm. SDAP of Golia cultivar had the shortest PH followed by SCP of Golia cultivar with 68.0 cm.

Our results showed that mean values of PH in 2011 were higher than 2010 year. This may result from the higher amount of precipitation in the second year at the stem elongation stage of plants (in April) (Table 1). A significant variation for PH was determined among cultivars. This may be associated with different genetic structure of the cultivars. Golia cultivar already has a genetically short plant height. Results of this study showed that SDAP had significantly lower mean values of PH than SCP. Mean PH values of SDAP was 5.06% and 7.19% lower in the experiment years, in comparison with SCP. This situation can be ascribed to their seed size. This result is also in agreement with the observations of Shahwani et al. (2014) and Haider et al. (2016), who found that large seeds had longer PH than small seeds. However, Taner et al. (2011) stated that PH was not affected by seed size.

Spike length (SL-cm):

The effects of cultivar and seed on SL were statistically significant in both experimental years. Cultivar x seed interaction was not significant in the first year, but significant in the second year (Table 3 and 5). In the first year, mean values of cultivars for SL varied between 8.6 and 11.3 cm (Table 3). Eser cultivar had the highest SL followed by Sultan 95 cultivar with 10.7 cm. The lowest SL was obtained from Golia cultivar with the shortest PH. Mean values of SL in SCP and SDAP were 10.6 cm and 9.7 cm, respectively (Table 3). In 2011, Karahan 99 cultivar had the highest SL with 11.1 cm, followed by Kate A1 (9.8 cm) and Sultan 95 (9.7 cm) cultivars. Golia cultivar had the lowest SL. In cultivar x seed interaction, mean values of SL varied between 6.9 and 11.8 cm. The highest SL value was obtained from SCP of Karahan 99 cultivar followed by SDAP of same cultivar (10.5 cm). SDAP of Golia cultivar had the lowest SL followed by SCP of same cultivar (7.2 cm) (Table 5).

In this study, mean values of SL in 2010 year were lower than 2011. This may be associated with PH values of years. As stated by Genç (1977), increasing PH value caused decreasing of SL. The effects of cultivars on SL were statistically significant. As similar to plant height values, Golia cultivar had the shortest SL in both years. When SDAP (small size) compared with SCP (large size), it had the 8.49% to 10.20% shorter SL than SCP. Our results were similar to the finding of Sarker and Malaker (2009), Shahwani et al. (2014) and Haider et al. (2016). However, Akinci et al. (2008) reported that effect of seed size on SL was not significant.

Number of grains per spike (NGPS-no):

NGPS was significantly affected by cultivar, seed and their interaction in both experimental years (Table 3 and 5). Among cultivars, NGPS varied between 37.0 and 62.2 in 2010, 36.6 and 50.1 in 2011. In the first year, Alpu 2001 (62.2) and Eser (62.1) cultivars had the highest NGPS, these followed by Sultan 95 cultivar (56.8). The lowest NGPS were obtained from Karahan 99 cultivar followed by Kate A1 cultivar (39.8) (Table 3). Similarly, in the second year, the highest mean values of NGPS were determined in Sultan 95 (50.1), Eser (45.5) and Alpu 2001 (44.4), respectively. Kate A1 (36.6), Karahan 99 (36.7) and Golia (37.6) had the lowest mean values of NGPS (Table 5). Results shown that SDAP had the lower mean value of NGPS than SCP in both years. While mean values of NGPS in SDAP were 46.9 and 44.5, SCP had 46.9 and 38.7 mean value of NGPS (Table 3 and 5). In cultivar x seed interaction, in 2010, SCP of Eser (65.8) and Alpu 2001 (64.5) had the highest NGPS value, SDAP of Karahan 99 (35.3) was the lowest (Table 3). In 2011, the highest mean value of NGPS was recorded for SCP of Sultan 95 (52.4). The lowest NGPS was determined in SDAP of Golia (33.1), Karahan 99 (33.5) and Konya 2002 (35.2) (Table 5).

According to results of the present study, mean values of NGPS in 2010 were higher than 2011. This may be due to the spikes were longer in 2010 and precipitation was higher. Differences among 8 cultivars were significant for NGPS. This result indicated that cultivars used in this study are genetically different for this trait. As an expected result, drought sensitive cultivars, which were improved for irrigated conditions, had the higher NGPS values than the other cultivars. There was also a significant difference between SDAP and SCP for NGPS in both years. Mean values of SCP for NGPS were 12.82% to 13.03% higher than SDAP. This result indicated that large seeds in bread wheat produced more NGPS. This result is also agreement with the results of Shahwani et al. (2014) and Haider et al. (2016), who reported that large seeds had higher NSPS than small seeds. In contrary, Sarker and Malaker (2009) and Zareian et al. (2012) found that NGPS was significantly decreased by increasing of seed size. Besides, Akinci et al. (2008) and Kahraman and Avcı (2016) stated that NGPS in wheat was not significantly affected by seed size.

Grain weight per spike (GWPS-g):

Effects of cultivar, seed and cultivar x seed interaction on GWPS were statistically significant in both years (Table 3 and 5). In the first year, mean value of GWPS in cultivars ranged from 1.52 to 2.26 g. The highest GWPS was determined in Alpu 2001 cultivar closely followed by Tosunbey (2.23 g). GWPS was the lowest in Golia cultivar (Table 3). It was determined that GWPS value of SCP (2.09 g) was higher than SDAP (1.60 g). Mean values of GWPS varied between 1.25 and 2.62 g in cultivar x seed interaction (Table 3). SCP of Alpu 2001 had the highest GWPS, and the lowest in SDAP of Sultan 95. In the second year, mean values of GWPS ranged from 1.11 to 1.50 g among 8 cultivars (Table 5). The highest GWPS obtained in the Tosunbey cultivar followed by Konya 2002 (1.45 g) and Kate A1 (1.42 g) in the same statistical group. GWPS was the lowest in Sultan 95 cultivar. There was a significant difference between SCP and SDAP for GWPS, and their GWPS was determined as 1.45 and 1.13 g, respectively (Table 5). In cultivar x seed interaction, the highest GWPS was recorded for SCP of Tosunbey cultivar (1.72 g) followed by SCP of Kate A1 (1.67 g). SDAP of Sultan 95 cultivar (1.00 g) had the lowest GWPS followed by SDAP of Eser (1.02 g), Alpu 2001 (1.04 g) and Golia (1.07 g) in the same statistical group (Table 5).

The results of this study shown that mean values of GWPS in the first were higher than the second year. The more NGPS was obtained with the effect of high precipitation in the first year. This caused increasing of GWPS. There were significant differences among 8 cultivars in terms of GWPS. Generally, Sultan 95, Eser and Golia cultivars had the lower mean values of GWPS than other cultivars in both years. This may be due to that these cultivars have genetically small seeds. This research also indicated that SDAP with small size had the 23.44% to

22.06% lower GWPS than SCP with large seed. Our results were similar to the findings of Rukavina et al. (2002) in barley, who found that GWPS of large seeds was higher than small seeds. However, Akinci et al. (2008) reported that effect of seed size on GWPS was not significant.

Grain yield (GY-kg da^{-1}):

GY was significantly affected by cultivar, seed and their interaction in 2010 (Table 4). GY ranged from 424.3 to 631.3 kg da^{-1} among examined cultivars. The highest GY was determined in Kate A1 cultivar followed by Golia (607.6 kg da^{-1}). Sultan 95 cultivar had the lowest GY followed by Eser (426.6 kg da^{-1}) in the same statistical group (Table 4). GY of SCP (569.1 kg da^{-1}) with large seeds was significantly higher than SDAP (497.2 kg da^{-1}) with small seeds. In cultivar x seed interaction, the highest GY was recorded for SCP of Kate A1 (656.0 kg da^{-1}) closely followed by SCP of Golia (640.5 kg da^{-1}) and Tosunbey (638.6 kg da^{-1}). SDAP of Sultan 95 (376.3 kg da^{-1}) had the lowest GY followed by SDAP of Alpu 2001 (390.2 kg da^{-1}) and Eser (395.9 kg da^{-1}) (Table 4). In 2011, the effects of cultivar and seed on GY were statistically significant. However, cultivar x seed interaction was not significant for GY (Table 6). Mean values of cultivars for GY ranged from 330.5 to 629.5 kg da^{-1} (Table 6). Golia cultivar had the highest GY followed by Tosunbey (510.6 kg da^{-1}) and Kate A1 (508.1 kg da^{-1}). The lowest GY was determined in Karahan 99 cultivar followed by Eser (359.7 kg da^{-1}) and Alpu 2001 (361.7 kg da^{-1}). GY of SCP (476.3 kg da^{-1}) was significantly higher than SDAP (398.2 kg da^{-1}) with small seed (Table 6).

In the present study, as an expected result, mean values of GY in 2010 were higher than 2011. The high precipitation in the first year may have caused this. In both years, Sultan 95, Eser and Alpu 2001 cultivars had the lowest mean values for GY. This result shown that these cultivars were more affected by chemical desiccation than the other cultivars. This research also indicated that SDAP with small size had 12.63% to 16.40% lower GY than SCP with large seed. Similar findings were recorded by Akinci et al. (2008), Sarker and Malaker (2009), Taner et al. (2011), Zareian et al. (2012), Shahwani et al. (2014), Haider et al. (2016), Kahraman and Avcı (2016), who reported that large seeds had higher GY than small seeds in wheat.

Thousand kernel weight (TKW-g):

The cultivar and seed had significant effect on TKW, but effect of their interaction was not significant in 2010 (Table 4). Among cultivars, Konya 2002 had the highest TKW (38.1 g) in 2010 followed by Tosunbey (37.7 g) in the same statistical group. The lowest TKW value occurred in Eser (30.2 g) followed by Sultan 95 (31.0 g) in the same statistical group (Table 4). Mean value of SCP (36.8 g) for TKW was higher than SDAP (32.6 g). In 2011, TKW was significantly affected by cultivar, seed and their interaction (Table 6). Tosunbey cultivar (31.5 g) had the highest TKW followed by Konya 2002 (30.9 g), Kate A1 (30.6 g) and Alpu 2001 (30.4 g). The lowest TKW value was obtained from Eser cultivar (24.8 g) followed by Sultan 95 with 25.1 g in the same statistical group. In cultivar x seed interaction, mean values of TKW varied between 22.6 and 32.9 g (Table 6). The highest TKW value was determined in SCP of Kate A1 cultivar followed by SCP of Tosunbey and Alpu 2001 cultivars with 32.6 g in the same statistical group. SDAP of Eser cultivar had the lowest TKW followed by SDAP of Sultan 95 cultivar with 24.3 g (Table 6).

Our results showed that mean values of TKW in 2010 year were more than 2011. This may be associated with precipitation amount of year. The precipitation amount in 2010 was higher than 2011. Differences among 8 cultivars for TKW were statistically significant. This result indicated that cultivars had genetically different seed size. SDAP had 11.41% to 10.20% lower TKW than SCP. This result may be associated with the reduction in seed size due to chemical desiccant application. Sarker and Malaker (2009), Taner et al. (2011), Şahin et al. (2013), Aydoğan et al. (2014), Shahwani et al. (2014), Haider et al. (2016) and Kahraman and Avcı (2016) found similar results in that large seeds have higher TKW in comparison with small seeds.

Table 3. Mean values and significance groups for plant height (PH), spike length (SL), number of grains per spike (NGPS) and grain weight per spike (GWP) in 2010.

Cultivars	PH (cm)			SL (cm)			NGPS (no)			GWPS (g)		
	Seeds		Mean	Seeds		Mean	Seeds		Mean	Seeds		Mean
	SCP	SDAP		SCP	SDAP		SCP	SDAP		SCP	SDAP	
Kate A1	100.9 d	98.0 ef	99.5 c	10.2	9.3	9.7 d	42.1 g	37.5 h	39.8 f	1.85 de	1.65 f	1.75 c
Golia	60.8 l	54.0 m	57.4 g	8.9	8.4	8.6 e	53.9 d	42.1 g	48.0 d	1.65 f	1.39 g	1.52 d
Konya 2002	103.7 c	98.4 e	101.0 b	10.5	9.5	10.0 bcd	50.7 e	41.7 g	46.2 e	2.12 bc	1.76 e	1.94 b
Karahan 99	114.5 a	106.9 b	110.7 a	10.9	9.7	10.3 bcd	38.8 h	35.3 ı	37.0 g	1.86 de	1.42 g	1.64 cd

(Continuation of the Table 3)

Alpu 2001	89.5 j	84.5 k	87.0 f	10.9	10.1	10.5 bc	64.5 a	59.9 b	62.2 a	2.62 a	1.90 d	2.26 a
Sultan 95	96.6 fg	93.2 hı	94.9 de	11.2	10.3	10.7 ab	59.8 bc	53.7 d	56.8 b	2.02 c	1.25 h	1.64 cd
Tosunbey	97.7 ef	93.8 h	95.7 d	10.3	9.2	9.8 cd	54.6 d	46.6 f	50.6 c	2.41 b	2.05 c	2.23 a
Eser	95.9 g	92.0 ı	94.0 e	11.7	10.9	11.3 a	65.8 a	58.4 c	62.1 a	2.17 b	1.34 gh	1.76 c
Mean	94.9 a	90.1 b	92.5	10.6 a	9.7 b	10.1	53.8 a	46.9 b	50.3	2.09 a	1.60 b	1.84
LSD $_{(P\leq0.05)}$	C^{**}: 1.351, S^{**}: 0.563, CxS^{**}: 1.592			C^{**}: 0.736, S^{**}: 0.260, CxS^{ns}: -			C^{**}: 1.415, S^{**}: 0.512, CxS^{**}: 1.448			C^{**}: 0.144, S^{**}: 0.040, CxS^{**}: 0.109		

**: Significant at 1%, ^{ns}: Non-significant

Table 4. Mean values and significance groups for grain yield (GY) and thousand kernel weight (TKW) in 2010.

Cultivars	GY (kg da^{-1})			TKW (g)		
	Seeds			Seeds		
	SCP	SDAP	Mean	SCP	SDAP	Mean
Kate A1	656.0 a	606.6 c	631.3 a	35.6	33.7	34.7 bc
Golia	640.5 b	574.6 e	607.6 b	33.5	31.2	32.4 cd
Konya 2002	583.4de	498.5 g	540.9 d	40.0	36.2	38.1 a
Karahan 99	617.6 c	547.9 f	582.8 c	39.3	35.4	37.4 ab
Alpu 2001	487.6 f	390.2 j	438.9 e	38.8	33.7	36.3 ab
Sultan 95	472.3 h	376.3 k	424.3 f	33.9	28.1	31.0 d
Tosunbey	638.6 b	587.3 d	613.0 b	39.8	35.5	37.7 a
Eser	457.3 ı	395.9 j	426.6 f	33.2	27.2	30.2 d
Mean	569.1 a	497.2 b	533.1	36.8 a	32.6 b	34.7
LSD $_{(P\leq0.05)}$	C^{**}: 8.634, S^{**}: 4.243, CxS^{**}: 11.999			C^{**}: 2.808, S^{**}: 0.792, CxS^{ns}: -		

** and *: Significant at 1% and 5%, ^{ns}: Non-significant

Table 5. Mean values and significance groups for plant height (PH), spike length (SL), number of grains per spike (NGPS) and grain weight per spike (GWP) in 2011.

Cultivars	PH (cm)			SL (cm)			NGPS (no)			GWPS (g)		
	Seeds		Mean	Seeds		Mean	Seeds		Mean	Seeds		Mean
	SCP	SDAP		SCP	SDAP		SCP	SDAP		SCP	SDAP	
Kate A1	115.6 c	109.9 d	112.7 c	10.3 b	9.3 de	9.8 b	37.7 gh	35.4 hı	36.6 e	1.67 ab	1.17 f	1.42 a
Golia	68.0 l	62.0 m	65.0 h	7.2 h	6.9 h	7.0 d	42.0 ef	33.1 ı	37.6 de	1.28 e	1.07 g	1.18 cd
Konya 2002	120.2 b	107.7 e	114.0 b	9.4 d	8.4 g	8.9 c	43.5 de	35.2 ı	39.3 d	1.61 b	1.29 e	1.45 a
Karahan 99	125.2 a	115.7 c	120.4 a	11.8 a	10.5 b	11.1 a	39.9 fg	33.5 ı	36.7 e	1.37 d	1.20 f	1.29 b
Alpu 2001	95.7 h	91.7 j	93.7 f	9.9 c	8.9 f	9.4 bc	48.3 b	40.5 f	44.4 bc	1.50 c	1.04 g	1.27 bc
Sultan 95	105.6 f	99.7 g	102.6 e	10.3 b	9.1 ef	9.7 b	52.4 a	47.8 b	50.1 a	1.22 ef	1.00 g	1.11 d
Tosunbey	110.5 d	100.1 g	105.3 d	9.4 d	8.8 f	9.1 bc	45.1 cd	40.5 f	42.8 c	1.72 a	1.28 e	1.50 a
Eser	93.5 ı	88.1 k	90.8 g	9.8 c	8.8 f	9.4 bc	47.3 bc	43.7 de	45.5 b	1.23 ef	1.02 g	1.13 d
Mean	104.3 a	96.8 b	100.6	9.8 a	8.8 b	9.3	44.5 a	38.7 b	41.6	1.45 a	1.13 b	1.29
LSD $_{(P\leq0.05)}$	C^{**}: 1.039, S^{**}: 0.423, CxS^{**}: 1.195			C^{**}: 0.715, S^{**}: 0.107, CxS^{**}: 0.304			C^{**}: 2.560, S^{**}: 0.871, CxS^{**}: 2.464			C^{**}: 0.094, S^{**}: 0.024, CxS^{**}: 0.077		

**: Significant at 1%, ^{ns}: Non-significant

Table 6. Mean values and significance groups for grain yield (GY) and thousand kernel weight (TKW) in 2011.

Cultivars	GY (kg da^{-1})			TKW (g)		
	Seeds		Mean	Seeds		Mean
	SCP	SDAP		SCP	SDAP	
Kate A1	555.9	460.3	508.1 b	32.9 a	28.4 d	30.6 a
Golia	699.7	559.4	629.5 a	30.0 c	26.7 ef	28.3 b

(Continuation of the Table 6)

Konya 2002	451.9	385.0	418.4 c	31.8 ab	30.1 c	30.9 a
Karahan 99	353.1	307.8	330.5 e	30.0 c	27.8 de	28.9 b
Alpu 2001	400.6	322.8	361.7 de	32.6 a	28.1 de	30.4 a
Sultan 95	400.9	357.8	379.4 d	26.0 f	24.3 g	25.1 c
Tosunbey	560.6	460.6	510.6 b	32.6 a	30.4 bc	31.5 a
Eser	387.8	331.6	359.7 de	27.0 def	22.6 h	24.8 c
Mean	476.3 a	398.2 b	437.2	30.4 a	27.3 b	28.9
LSD $_{(P\leq0.05)}$	C**:32.364, S**: 15.534 CxS^{ns}: -			C**: 1.226, S**: 0.530, CxS*: 1.499		

** and *: Significant at 1% and 5%, ^{ns}: Non-significant

Conclusion

As a result, it was determined that artificial drought stress by chemical desiccant application affected negatively seed quality due to its detractive effect on seed size in bread wheat. Generally, this effect in drought sensitive cultivars was more than resistance cultivars. Consequently, it can be said that it is necessary to use large seeds, which obtained from grown plants in areas without drought stress, to reach high grain yield in bread wheat.

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