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Characterization for drought resistance at early stages of wheat genotypes based on survival, coleoptile length, and seedling vigor

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Abstract: In order to develop genotypes having a stable higher yield, it is necessary to characterize genetic resources based on drought adaptation, determine the suitable genotypes, and use them in breeding programs. This study was carried out in greenhouses, plant growth chambers, and research farms of the Faculty of Agriculture at Atatürk University. A total of 64 certified and local bread wheat genotypes were used to test survival after drought, coleoptile length, and seedling vigor. There were significant differences with respect to the selection parameters in this study. Seedling survival ranged from 18.5% to 51.1% and coleoptile lengths were 39–74 mm. Leaf width and specific leaf area were 3.27–4.71 mm and 164.4–204.2 cm^2/g, respectively. Genotypes Lancer, Kıraç 66, Gerek 79, Mızrak, Harmankaya 99, Alparslan, Dağdaş 94, and Doğu 88 had stable high seedling survival rates and were tolerant to early drought with respect to seedling survival after drought. Local genotypes and old cultivars had higher coleoptile length compared to modern cultivars. Genotypes Ak Buğday, Tir, Lancer, Sert Buğday, and Conkesme, having long coleoptiles, could be used as genitors for the breeding of new genotypes with short plant height and longer coleoptile. Genotypes Kıraç 66 and Müfitbey, ranked best in terms of first leaf width and specific leaf area, could adapt themselves to places where early drought is observed and could be used as parents in breeding programs.

Key words: Coleoptile, drought, specific leaf area, survival

1. Introduction

Drought is a serious stress factor restricting agricultural production in many parts of the world, including Turkey. Plants can be exposed to drought from seeding to harvesting (Gunes et al., 2006). There are 2 main effects of drought on crop production: the prevention of seedling emergence and a decrease in development and yield. In the early stages of development, particularly in insufficient water conditions, it is important for plants to effectively use available soil moisture (Clarke et al., 1984; Acevedo, 1987; Richards, 1992). Drought in the early development stages causes earlier flowering and decreases in plant height, leaf area, and the number of fertile tillers (Day and Intalap, 1970; Robertson and Giunta, 1994). Even if sufficient soil moisture is supplied in the postflowering stage, drought prior to flowering lowers the grain-filling period and grain weight (Öztürk and Çağlar, 1999).

Due to irregular and insufficient rainfall, drought can be experienced during the sowing period, emergence, and seedling development periods in dry farming areas of different geographical regions of the world (Adjei and Kirkham, 1980; El Hafid et al., 1998), including Turkey. It is important to have good and early seedling establishment for high yield and stable wheat production in dry farming conditions. Insufficient available water in the early development stages significantly constrains grain yield through decreasing germination, emergence, seedling development, and establishment (Blum et al., 1980; Naylor and Gurmu, 1990; Richards and Lukacs, 2002).

For stable crop production, it is important to minimize yield loss due to stress factors. This can be done by selection or breeding plants resistant to stress factors. Several selection criteria were set to determine the best parents to use in breeding programs and to classify populations based on tolerance to drought in the early development stages (Gavuzzi et al., 1997; Dhanda et al., 2004). Coleoptile length (Rebetzke et al., 1999), seedling survival after drought (Winter et al., 1988), and seedling vigor (Rebetzke et al., 2004; Reynolds et al., 2006) measurements have been successfully used for selection of drought tolerant wheat genotypes in respected breeding programs.

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Attention has been paid to the capability of seedlings to overcome drought and to the genetic variation of this character (Monneveux and Belhassen, 1996). Winter et al. (1988) assessed 8 different elimination criteria for breeding of drought-tolerant winter wheat and emphasized that the most suitable method for elimination in large populations is seedling survival after drought. Coleoptile length affects the percentage of seedling emergence and development of seedlings. In cases of hand-sowing (where it is difficult to adjust the sowing depth), no-till, and mulch tillage, coleoptile length is an important criterion for the emergence of shoots to the surface and for stand establishment. Short coleoptiles in seed beds that are unsuitable with respect to moisture and sowing depth decrease yield by extending the duration of emergence, decreasing the number of emergent seedlings, and resulting in smaller leaf area indices and weak seedlings (Richards, 1992; Schillinger et al., 1998). In order to suppress weeds and increase yield, the best practice is to select winter varieties having longer coleoptiles in regions having low rainfall (Murphy et al., 2008a).

A well-known response of plants to drought is to decrease the leaf area by forming fewer and smaller leaves (Rawson et al., 1977). Restricting leaf area to control transpiration is not suitable for agronomical reasons because losses in leaf area decrease the potential yield by limiting the necessary assimilates for grain filling (Clarke et al., 1984). The water use efficiency of cereals in the early stages is associated with leaf area and seedling vigor (Richards and Townley-Smith, 1987; Lopez-Castaneda and Richards, 1994). The rapid development of leaves in winter wheat increases the ability to compete with weeds, water use efficiency, and grain yield (Rebetzke et al., 2004). Greater leaf area increases plant growth rate, biomass, and particularly the grain yield of late-sown wheat by utilization of sunlight in places having short vegetation (Regan et al., 1997). Seedling vigor increases water use efficiency in dry farming conditions by decreasing evaporative water loss from the soil surface, increasing transpiration efficiency (Lopez-Castaneda and Richards, 1994), and elevating the ability to compete with weeds (Coleman et al., 2001). In addition, it also increases the growth rate and grain yield through increasing light utilization (Rebetzke et al., 2004). This parameter is significant in drought-prone places like the Mediterranean where 40% of the usable water is lost directly by evaporation (Loss and Siddique, 1994).

This study was conducted to determine suitable genotypes for places where drought is experienced in the early developmental stages of wheat and that could be used as parents in breeding programs to improve drought tolerance. A total of 64 wheat genotypes were assessed with respect to seedling survival after drought, coleoptile length, and seedling vigor measurements.

2. Materials and methods

In this study, 64 bread wheat genotypes were used as plant material (Table 1). Ammonium sulfate and triple superphosphate were used as fertilizer. Commercial soil "T.T. Makro seedling soil" containing 0.98% N, 0.02% P, 0.09% K, 0.84% Ca, 0.28% Mg, 2820 ppm Fe, 41 ppm Mn, 9 ppm Zn, 36.6% organic matter, and 49% moisture, and with a pH of 6.7 was used in the greenhouse and outdoor experiments.

2.1. Climate and soil properties of the experimental fields

2.1.1. Field and outdoor experiments

The soil of the field experimental area was determined to be clay-loamy, low in organic matter content, neutral, medium in P, and rich in K. The total precipitation of Erzurum Province based on the long term average over the years was 395.2 mm and the average temperature was 5.0 °C. The total rainfall during the experimental years (2009–2010 and 2010–2011) was 533.2 and 513.3 mm, respectively.

2.1.2. Greenhouse experiments

Daily minimum and maximum temperatures were determined in the greenhouse where the seedling survival after drought experiment was carried out. During September–October 2009, the daily minimum and maximum temperatures were 6–11 °C and 18–24 °C, respectively, and the daily relative moisture was 48%–52%. During April–May 2010, the daily minimum and maximum temperatures were 5–18 °C and 20–30 °C, respectively, and the daily relative moisture was 40%–60%. During September–October 2010, the daily minimum and maximum temperatures were 7–11 °C and 19–28 °C, respectively, and the daily relative moisture was 45%–60%.

2.2. Methods

2.2.1. Seed source

In order to use seeds that were the same age and same size in all experiments, all genotypes were grown under dry conditions with standard cultivation techniques in the experimental fields of the Faculty of Agriculture of Atatürk University in the 2008–2009 cropping season. Harvested seeds were cleaned and uniformly sized seeds were selected using sieves with pores of 3.6 mm and 3.2 mm (Lafond and Fowler, 1989).

2.2.2. Seedling survival after drought

This experiment was conducted in the Faculty of Agriculture greenhouse during 3 different seasons: September–October 2009, April–May 2010, and September–October 2010. Wooden boxes, 80 × 100 × 12 cm in size, were lined with paper and filled with seedling soil as described above. The experimental design was a completely randomized design with 4 replications. Fifty seeds from each genotype were sown 3-cm deep with interrow and interplant spacing of 5 cm and 2 cm, respectively. The plants were well watered

Table 1. Bread wheat genotypes used in the study.

No.	Genotype	Origin/Institute	Growth habit
Listed in 2007 national cultivar list			
1	Aksel 2000	Central Research Institute of Field Crops, Ankara	Facultative
2	Alparslan	Eastern Anatolia Agricultural Research Institute, Erzurum	Winter
3	Altay 2000	Anatolia Agricultural Research Institute, Eskişehir	Winter
4	Atlı 2002	Central Research Institute of Field Crops, Ankara	Facultative
5	Aytın 98	Anatolia Agricultural Research Institute, Eskişehir	Winter
6	Bağcı 2002	Bahri Dağdaş International Agricultural Research Institute, Konya	Facultative
7	Bayraktar 2000	Central Research Institute of Field Crops, Ankara	Facultative
8	Bolal 2973	Anatolia Agricultural Research Institute, Eskişehir	Facultative
9	Çetinel 2000	Anatolia Agricultural Research Institute, Eskişehir	Winter
10	Dağdaş 94	Bahri Dağdaş International Agricultural Research Institute, Konya	Facultative
11	Demir 2000	Central Research Institute of Field Crops, Ankara	Facultative
12	Doğankent 1	Çukurova Agricultural Research Institute, Adana	Spring
13	Doğu 88	Eastern Anatolia Agricultural Research Institute, Erzurum	Winter
14	Gerek 79	Anatolia Agricultural Research Institute, Eskişehir	Winter
15	Gün 91	Central Research Institute of Field Crops, Ankara	Winter
16	Harmankaya 99	Anatolian Agricultural Research Institute, Eskişehir	Winter
17	İkizce 96	Central Research Institute of Field Crops, Ankara	Facultative
18	İzgi 2001	Anatolia Agricultural Research Institute, Eskişehir	Winter
19	Karahan 99	Bahri Dağdaş International Agricultural Research Institute, Konya	Winter
20	Kate A-1	Trakya Agricultural Research Institute, Edirne	Winter
21	Kıraç 66	Anatolia Agricultural Research Institute, Eskişehir	Winter
22	Kırgız 95	Anatolia Agricultural Research Institute, Eskişehir	Winter
23	Kırkpınar 79	Trakya Agricultural Research Institute, Edirne	Facultative
24	Kutluk 94	Anatolia Agricultural Research Institute, Eskişehir	Winter
25	Lancer	Eastern Anatolia Agricultural Research Institute, Erzurum (introduction cultivar, US)	Winter
26	Mızrak	Central Research Institute of Field Crops, Ankara	Facultative
27	Müfitbey	Anatolia Agricultural Research Institute, Eskişehir	Winter
28	Nenehatun	Eastern Anatolia Agricultural Research Institute, Erzurum	Winter
29	Palandöken 97	Eastern Anatolia Agricultural Research Institute, Erzurum	Winter
30	Pamukova 97	Sakarya Agricultural Research Institute, Sakarya	Spring
31	Pehlivan	Trakya Agricultural Research Institute, Edirne	Winter
32	Prostor	Trakya Agricultural Research Institute, Edirne	Winter
33	Seri 82	Çukurova Agricultural Research Institute, Adana	Winter
34	Soyer02	Anatolia Agricultural Research Institute, Eskişehir	Winter
35	Sönmez 2001	Anatolia Agricultural Research Institute, Eskişehir	Winter
36	Sultan 95	Anatolia Agricultural Research Institute, Eskişehir	Winter
37	Süzen 97	Anatolia Agricultural Research Institute, Eskişehir	Winter
38	Tosunbey	Central Research Institute of Field Crops, Ankara	Winter
39	Türkmen	Central Research Institute of Field Crops, Ankara	Facultative
40	Uzunyayla	Central Research Institute of Field Crops, Ankara	Facultative
41	Yakar 99	Central Research Institute of Field Crops, Ankara	Facultative
42	Zencirci 2002	Central Research Institute of Field Crops, Ankara	Facultative

Table 1. (Continued).

Local and old genotypes not listed in 2007 national cultivar list			
43	Ak-702	Anatolia Agricultural Research Institute, Eskişehir	Winter
44	Ak Buğday	Central Anatolia Region	Winter
45	Ankara 093/44	Central Research Institute of Field Crops, Ankara	Winter
46	Conkesme	Eastern Anatolia Region	Facultative
47	Haymana 79	Central Research Institute of Field Crops, Ankara	Winter
48	Hawk (Şahin)	Eastern Anatolia Agricultural Research Institute, Erzurum (introduction cultivar, US)	Winter
49	Kılçıksız Buğday	Central Anatolia Region	Winter
50	Kırik	Eastern Anatolia Region	Facultative
51	Kırmızı Kılçık	Eastern Anatolia Region	Facultative
52	Kırmızı Yerli	Eastern Anatolia Region	Facultative
53	Koca Buğday	Central Anatolia Region	Winter
54	Köse 220/39	Central Research Institute of Field Crops, Ankara	Facultative
55	Orso	Sakarya Agricultural Research Institute, Sakarya	Facultative
56	Özlü Buğday	Central Anatolia Region	Winter
57	Polatlı Kösesi	Central Anatolia Region	Facultative
58	Sert Buğday	Central Anatolia Region	Winter
59	Sürak 1593/51	Central Research Institute of Field Crops, Ankara	Winter
60	Tir	Eastern Anatolia Region	Winter
61	Yayla 305	Anatolia Agricultural Research Institute, Eskişehir	Winter
62	Zerin	Central Anatolia Region	Facultative
Control genotypes			
63	Bezostaja 1	Anatolia Agricultural Research Institute, Eskişehir (introduction cultivar, Russia)	Winter
64	Karasu 90	Eastern Anatolia Agricultural Research Institute, Erzurum	Winter

until the 3-leaf stage. Water was then withheld until most of the seedlings appeared to be dead. Soil moisture content was determined using a HH2 soil moisture meter, and volumetric soil moisture content was 0.0%–0.05% at these stages. The boxes were then rewatered, and survival was counted after 10 days. Seedling survival after drought was calculated as a percentage (Winter et al., 1988).

2.2.3. Coleoptile length

The experiment was conducted in growth chambers based on a completely randomized design with 4 replications and repeated twice. Fifty seeds from each genotype were sown 3-cm deep with interrow and interplant spacing of 5 cm and 2 cm, respectively, in wooden boxes as stated above. The boxes, which were watered after sowing, were kept in growth chambers at 15 °C under dark conditions for 13 days and 8 h, until the accumulation of 200 °C total temperature. Coleoptile length was recorded as the distance from the scutellum to where the first leaf had broken through the tip of the coleoptile (Rebetzke et al., 1999) in 10 randomly selected plants from each genotype.

2.2.4. Seedling vigor

2.2.4.1. Outdoor experiment

This experiment was conducted during 3 seasons, September–October 2009, April–May 2010, and September–October 2010 in wooden boxes placed outdoors. The experimental design was a completely randomized design with 4 replications. Fifty seeds from each genotype were sown 3-cm deep with interrow and interplant spacing of 5 cm and 2 cm, respectively, in wooden boxes as described above. The boxes were watered after sowing until sampling and weeds were removed by hand. After emergence, the number of plants per row was reduced to 25 (500 plants/m^2). When the average number of leaves for each plant reached 4, or a value of 14 on the Zadoks scale (Zadoks et al., 1974), 10 plants were randomly sampled. The sampling was performed by cutting plants one by one from the soil surface between 08:00 and 10:00 in the morning. The maximum width of the first leaf from each plant was measured using an electronic caliper. The first 3 leaves were then removed from the plant and the total leaf area was measured using a portable leaf area meter (LI-COR LI3000C). The leaves were dried at 70 °C in an oven for 72 h and the total dry weight was determined on a microbalance. Specific leaf area was calculated using the formula specific leaf area (cm^2/g) = total leaf area/total leaf dry weight (Rebetzke et al., 2004).

2.2.4.2. Field experiment

This experiment was conducted in the experimental fields of the Faculty of Agriculture of Atatürk University for 2 seasons, September–October 2009 and September–October 2010, according to a randomized complete block design with 4 replications. The genotypes were distributed randomly into blocks. The experimental blocks were fertilized with 60 kg/ha N and 50 kg/ha P_2O_5. Sowing was performed by hand into 1-m-long lines, 3–5 cm deep, with interrow and interplant spacing of 20 cm and 1 cm, respectively, onto a fallow area where sowing preparation had been completed. The blocks were watered after sowing until sampling, and weeds were removed by hand. When the average number of leaves reached 4–5 for each plant, or a value of 15 on the Zadoks scale (Zadoks et al., 1974), 10 plants were randomly sampled. First leaf width and specific leaf area were calculated using the formula (Rebetzke et al., 2004) as stated for outdoor experiments above.

2.3. Statistical analysis

The routines of the MSTAT-C (1991) statistical program were used throughout. When "genotype × season" interactions were not significant, data were combined over seasons, and means were presented. When "genotype × season" interactions were significant, seasons were analyzed separately. Duncan's multiple range test was used to determine the differences among the genotypes.

3. Results and discussion

3.1. Seedling survival after drought

Significant differences were observed among the genotypes based on seedling survival percentages of 18.3%–56.0%, 19.8%–57.7%, and 15.9%–44.3% for September–October 2009, April–May 2010, and September–October 2010, respectively. The effect of season on seedling survival was also significant. A considerably lower seedling survival percentage was recorded in the September–October 2010 season compared to the September–October 2009 and April–May 2010 seasons (Table 2).

Variability in the order of genotypes based on seedling survival percentage resulted in a significant "genotype × season" interaction (Table 2). Averaged over 3 seasons, the seedling survival percentage of the genotypes was 18.5%–51.1% and significant differences were observed (Table 2). The highest seedling survival rate after drought was recorded in the Lancer cultivar with 51.1%, followed by Kıraç 66 (50.9%), Gerek 79 (47.9%), Mızrak (46.5%), Harmankaya 99 (46.0%), and Alparslan (45.9%). The lowest seedling survival rate was observed in the Karasu 90 cultivar with 18.5%, followed by Bezostaja 1 (19.0%), Orso (20.5%), and Pamukova 97 (20.6%) (Table 2). Similar to the findings reported by Winter et al. (1988) and Aydın (1999), significant variations were observed among the genotypes based on seedling survival rate. Tomar and Kumar (2004) reported that the trait of seedling survival is controlled by a single dominant gene, which can be used as a selection criterion in the development of drought tolerance in the seedling stage. In spite of their relatively high variation and a "genotype × season" interaction, the Lancer, Kıraç 66, Gerek 79, Mızrak, Harmankaya 99, Alparslan, Dağdaş 94, and Doğu 88 cultivars demonstrated a high and stable survival rate in the 3 seasons. When seedling survival percentage was considered as a criterion, these genotypes were tolerant in the early development stage. Karasu 90 and Bezostaja 1 cultivars, which were suggested for irrigated farming conditions and used as controls in this study, had the lowest survival rate. The Orso, Pamukova 97, Ak Buğday, Tir, Kırik, Ak-702, and Köse 220/39 genotypes could also be defined as susceptible in the early developmental stage based on this criterion. In addition, other than Zerin, the local cultivars could not be considered as promising genetic resources for this parameter.

3.2. Coleoptile length

There were significant differences among the genotypes in terms of coleoptile length. The effect of seasons on coleoptile length was also significant. A considerably greater coleoptile length was measured in the January–March 2010 season (53 mm) compared to the January–March 2011 season (48 mm). Generally, after the final drying stage of maturation, a seed is in a condition of maximum vigor and from this point it gradually deteriorates toward ultimate viability loss. Bingham et al. (1994) concluded that the rate of radicle and coleoptile extension was more sensitive to seed aging than germination percentage. In our study, variability in genotypes based on coleoptile length resulted in significant "genotype × season" interactions (Table 2).

The coleoptile lengths of the genotypes ranged between 40 mm and 78 mm in January–March 2010 and between 36 mm and 71 mm in January–March 2011. The longest coleoptile length in January–March 2010 was recorded in Lancer (78 mm), followed by the Ak Buğday (77 mm), Tir (76 mm), and Özlü Buğday (71 mm) genotypes. The longest coleoptile length from the January–March 2011 season was recorded in Ak Buğday (71 mm), followed by the Sert Buğday (66 mm), Tir (64 mm), Conkesme (60 mm) and Lancer (59 mm) genotypes.

The average coleoptile lengths over the seasons varied between 39 mm and 74 mm, and significant differences were identified. The genotype having the longest coleoptile

Table 2. Seedling survivability after drought and coleoptile length of wheat genotypes[1].

No.	Genotype	Seedling survivability (%)				Coleoptile length (mm)		
		September–October 2009	April–May 2010	September–October 2010	Mean	January–March 2010	January–March 2011	Mean
1	Aksel 2000	41.7 b–k	40.8 e–l	37.9 a–f	40.1 d–j	46 u–z	39 s–u	42 z
2	Alparslan	46.8 a–e	47.5 a–g	43.3 ab	45.9 a–d	50 l–x	44 j–t	47 r–z
3	Altay 2000	45.2 a–f	41.8 e–k	31.5 e–k	39.5 e–j	51 j–w	41 n–u	46 t–z
4	Atlı 2002	40.7 c–k	30.8 i–t	36.2 c–h	35.9 h–l	54 g–r	45 i–t	50 k–x
5	Aytın 98	29.0 k–s	32.5 i–s	23.3 n–x	28.3 o–t	53 i–t	44 j–t	48 o–z
6	Bağcı 2002	40.2 c–k	38.3 f–o	27.7 i–q	35.4 i–m	45 w–z	42 m–u	43 z
7	Bayraktar 2000	30.6 i–s	30.9 i–t	21.0 q–y	27.5 p–u	59 e–i	46 h–t	52 j–q
8	Bolal 2973	31.5 h–s	31.0 i–t	25.6 l–v	29.4 m–s	50 l–x	38 tu	44 yz
9	Çetinel 2000	19.4 qrs	19.8 t	26.3 k–s	21.8 u–x	41 yz	36 u	39 z
10	Dağdaş 94	47.3 a–e	49.5 a–f	39.3 a–d	45.3 a–e	53 i–u	46 i–t	49 l–z
11	Demir 2000	25.2 m–s	26.2 o–t	21.1 q–y	24.2 r–x	48 n–x	44 i–t	46 s–z
12	Doğankent 1	39.7 c–k	39.1 e–n	23.6 m–w	34.1 j–o	47 s–y	46 g–t	47 r–z
13	Doğu 88	46.2 a–f	48.3 a–f	37.8 a–f	44.1 b–e	49 m–x	51 e–k	50 k–x
14	Gerek 79	50.5 abc	52.5 abc	40.9 abc	47.9 ab	54 h–s	47 g–s	50 k–x
15	Gün 91	24.5 n–s	26.0 p–t	26.0 l–t	25.5 q–v	49 l–x	41 p–u	45 xyz
16	Harmankaya 99	49.8 a–d	50.5 a–e	37.6 a–f	46.0 a–d	40 z	43 k–u	42 z
17	İkizce 96	33.2 f–q	32.5 i–s	27.1 j–r	30.9 l–q	55 f–p	47 g–r	51 j–u
18	İzgi 2001	39.0 c–l	42.1 c–j	24.2 m–w	35.1 j–n	48 p–x	40 r–u	44 yz
19	Karahan 99	42.8 b–i	42.8 c–i	27.8 i–q	37.8 g–k	48 r–y	43 l–u	45 w–z
20	Kate A-1	29.2 k–s	30.0 j–t	27.3 j–r	28.8 o–t	47 s–y	44 j–u	45 v–z
21	Kıraç 66	56.0 a	57.7 a	39.0 a–d	50.9 a	54 g–r	49 f–p	51 j–t
22	Kırgız 95	44.1 a–h	42.2 c–j	30.8 f–m	39.0 f–j	56 f–l	50 e–m	53 h–q
23	Kırkpınar 79	40.0 c–k	41.1 e–l	29.4 h–p	36.8 g–l	54 g–r	42 m–u	48 q–z
24	Kutluk 94	35.7 e–o	36.0 g–q	30.9 f–l	34.2 j–o	57 e–k	46 g–t	52 j–s
25	Lancer	54.1 ab	55.0 ab	44.3 a	51.1 a	78 a	59 bcd	69 bc
26	Mızrak	49.4 a–d	51.8 a–d	38.3 a–e	46.5 abc	45 w–z	39 stu	42 z
27	Müfitbey	44.9 a–g	45.0 b–h	35.2 c–h	41.7 c–h	53 i–t	48 g–q	50 k–w
28	Nenehatun	35.5 e–o	38.9 e–n	31.1 f–l	35.1 j–n	47 r–y	51 e–k	49 l–y
29	Palandöken 97	39.3 c–l	39.6 e–m	30.3 g–o	36.4 g–l	48 o–x	48 g–p	48 p–z
30	Pamukova 97	21.4 qrs	21.9 rst	18.5 u–y	20.6 vwx	47 s–y	44 i–t	46 u–z
31	Pehlivan	31.9 g–r	31.9 i–t	29.3 h–p	31.0 l–q	60 d–h	49 e–o	55 g–k
32	Prostor	30.4 j–s	30.8 i–t	21.6 q–y	27.6 p–u	53 i–t	49 e–t	51 k–u
33	Seri 82	30.4 i–s	27.4 n–t	25.3 m–w	27.7 p–u	45 w–z	39 tu	42 z
34	Soyer02	34.9 e–p	37.5 f–p	29.8 h–o	34.0 j–o	53 i–t	44 j–t	49 n–z
35	Sönmez 2001	41.6 b–k	46.0 b–g	37.0 b–g	41.5 c–i	50 k–w	45 i–t	48 q–z
36	Sultan 95	38.1 c–m	40.3 e–m	33.8 d–j	37.4 g–k	47 t–z	42 m–u	44 yz
37	Süzen 97	43.3 b–i	38.2 f–o	34.8 c–i	38.8 f–j	57 e–j	51 e–l	54 g–m
38	Tosunbey	40.4 c–k	40.0 e–m	33.5 d–k	37.9 g–k	55 f–o	52 c–i	54 g–n
39	Türkmen	40.0 c–k	40.5 e–m	30.4 g–n	37.0 g–l	49 m–x	47 g–s	48 q–z
40	Uzunyayla	42.1 b–j	45.9 b–g	39.7 a–d	42.6 b–g	50 l–x	47 g–s	48 o–z

Table 2. (Continued).

41	Yakar 99	20.8 qrs	29.7 k–t	22.2 p–y	24.2 r–x	45 v–z	41 o–u	43 z
42	Zencirci 2002	28.6 k–s	31.5 i–t	27.6 i–r	29.2 n–s	54 h–s	51 e–k	52 i–q
43	Ak-702	21.8 p–s	21.9 rst	21.0 q–y	21.6 u–x	54 g–r	50 e–n	52 j–r
44	Ak Buğday	24.9 n–s	22.6 rst	15.9 y	21.1 vwx	77 ab	71 a	74 a
45	Ankara 093/44	26.8 l–s	27.4 n–t	25.8 l–u	26.7 q–v	52 i–v	56 c–f	54 g–l
46	Conkesme	33.5 f–q	30.1 j–t	25.6 l–v	29.7 m–r	63 de	60 bc	61 de
47	Haymana 79	33.2 f–q	33.8 h–r	29.3 h–p	32.1 k–p	51 j–w	46 i–t	48 p–z
48	Hawk (Şahin)	37.3 d–n	41.0 e–l	33.4 d–k	37.2 g–k	51 j–w	50 e–l	50 k–v
49	Kılçıksız Buğday	30.4 i–s	30.0 j–t	22.1 p–y	27.5 p–u	61 d–g	54 c–h	57 e–i
50	Kırik	23.5 o–s	21.7 rst	19.7 s–y	21.6 u–x	54 g–q	54 c–g	54 g–l
51	Kırmızı Kılçık	24.2 n–s	26.2 p–t	23.0 o–y	24.5 r–x	57 e–j	49 e–p	53 h–p
52	Kırmızı Yerli	30.7 i–s	28.4 m–t	23.2 n–y	27.4 p–u	66 cd	54 c–h	60 ef
53	Koca Buğday	24.7 n–s	28.6 m–t	21.9 q–y	25.1 q–w	55 f–m	57 cde	56 f–j
54	Köse 220/39	23.1 o–s	23.2 rst	18.7 t–y	21.7 u–x	50 l–x	47 g–q	49 m–z
55	Orso	20.6 qrs	23.0 rst	18.0 wxy	20.5 vwx	43 xyz	48 f–p	46 u–z
56	Özlü Buğday	24.5 n–s	24.4 q–t	20.3 r–y	23.0 s–x	71 bc	46 i–t	58 efg
57	Polatlı Kösesi	25.7 m–s	24.3 q–t	21.2 q–y	23.7 r–x	55 f–o	51 e–j	53 h–p
58	Sert Buğday	29.2 k–s	26.4 o–t	21.5 q–y	25.7 q–v	65 d	66 ab	66 cd
59	Sürak 1593/51	28.6 k–s	29.3 l–t	20.9 q–y	26.3 q–v	52 i–v	50 e–n	51 k–u
60	Tir	22.5 o–s	23.5 rst	18.1 wxy	21.4 u–x	76 ab	64 ab	70 ab
61	Yayla 305	21.9 p–s	23.1 rst	23.0 o–y	22.7 t–x	52 i–v	44 j–u	48 q–z
62	Zerin	41.7 b–k	38.8 e–n	33.7 d–j	38.1 g–k	55 f–n	52 d–j	54 g–o
63	Bezostaja 1	18.3 s	20.5 st	18.3 v–y	19.0 wx	56 f–m	45 i–t	50 k–x
64	Karasu 90	19.0 rs	20.3 st	16.1 xy	18.5 x	61 def	54 c–g	58 e–h
Mean		34.1 A	34.5 A	27.9 B	32.2	53 A	48 B	51
F value (Genotype)		10.99**	13.01**	19.72**	36.44**	26.68**	13.67**	33.30**
F value (Season)		–	–	–	149.59**	–	–	360.15**
F value (G × S)		–	–	–	1.36**	–	–	4.82**
LSD (0.01) (G)		10.7	9.9	6.0	5.2	5.6	6.6	4.3
LSD (0.01) (S)		–	–	–	1.1	–	–	0.8
LSD (0.01) (G × S)		–	–	–	9.1	–	–	6.1
CV (%)		17.1	15.6	11.8	15.4	5.7	7.5	6.6

[1] Means in a column not sharing a common letter are significantly different. ** = significant at $P < 0.01$.

length was Ak Buğday (74 mm), followed by Tir (70 mm), Lancer (69 mm), Sert Buğday (66 mm), and Conkesme (61 mm). In this research, the coleoptile lengths of 5 genotypes were 61–74 mm, 34 genotypes measured 50–60 mm, and 25 genotypes were 42–49 mm.

In accordance with the findings reported by Rebetzke et al. (1999), Murphy et al. (2008a, 2008b), and Moud and Maghsoudi (2008), it was found that wheat genotypes displayed significant genetic variation with respect to coleoptile length. Coleoptile length can also vary because of research or growth conditions. In addition, when we consider the coleoptile lengths reported as 49–119 mm by Schillinger et al. (1998), 64–131 mm by Murphy et al. (2008a), and 59–159 mm by Murphy et al. (2008b), it can be stated that the coleoptile lengths of the bread wheat genotypes used in this study showed narrow variation. Moreover, the fact that the local cultivars and cultivars with old registration dates had longer coleoptiles than the modern and current cultivars took our attention. Cultivar Tir, grown widely in Van Province and known to have a long coleoptile length, was first in this study in terms of coleoptile length.

Genotypes with long coleoptile length that have good emergence and seedling establishment can provide advantages for yield (Radford, 1987). In this study the genotypes Ak Buğday, Tir, Lancer, Sert Buğday, and Conkesme, although having relatively long coleoptiles, have low yield potential and do not have yield advantages in environments where there is early drought. However, these genotypes could be used as genetic resources in breeding programs intended for development of wheat genotypes that are short in plant height and longer in coleoptile length.

3.3. Seedling vigor

3.3.1. Outdoor experiment

There were significant differences among the wheat genotypes based on the parameters of seedling vigor: leaf width and specific leaf area. The effect of season on these 2 parameters was significant. According to an average of the genotypes, first leaf width was highly significant in September–October 2009 (4.59 mm) compared to April–May 2010 (4.47 mm) and September–October 2010 (4.18 mm). On the other hand, a considerably higher specific leaf area was observed in September–October 2010 (236.6 cm^2/g) compared to September–October 2009 (181.5 cm^2/g) and April–May 2010 (196.3 cm^2/g). The different specific leaf area responses of the genotypes to climate conditions resulted in changes in the order of genotypes to seasons and the "genotype × season" interaction (Table 3).

Wheat genotypes showed stability for season based on first leaf width. First leaf width varied between 3.97 mm and 4.88 mm as averaged over the seasons. The widest first leaves were recorded in Tir (4.88 mm), İzgi 2011 (4.78 mm), Seri 82 (4.77 mm), and Altay 2000 (4.75 mm) and no significant differences were observed in these genotypes. The narrowest first leaf was observed in genotype Kırmızı Kılçık (3.97 mm). This was followed by Kırmızı Yerli (4.01 mm), Kate A-1 (4.08 mm), and Pamukova 97 and significant differences were found among these genotypes. Rebetzke et al. (2004) stated that leaf width in wheat genotypes varied from 4.3 to 5.2 mm. They also defined this parameter as an important indicator due to its high inheritance level and strong genetic relationship to specific leaf area. The specific leaf area of the genotypes showed variation between 154.3 cm^2/g and 219.0 cm^2/g during the September–October 2009 season. The highest specific leaf areas in this season were observed in Müfitbey, Doğu 88, and Uzunyayla with 219.0, 211.6, and 205.6 cm^2/g, respectively. The lowest values for specific leaf area were calculated in the Koca Buğday, Tir, and Yakar 99 genotypes. In the April–May 2010 season, specific leaf areas in the genotypes varied between 165.3 and 226.8 cm^2/g. In the same season, the highest specific leaf areas were recorded in Zerin, Doğankent 1, and Gün 91 with values of 226.8, 220.0, and 219.2 cm^2/g, respectively. The lowest specific leaf areas were seen in the Türkmen, Ankara 093/44, and Conkesme genotypes. For the September–October 2010 season, the specific leaf areas of the genotypes were between 194.6 cm^2/g and 278.2 cm^2/g. The highest specific leaf areas in this season were observed in Bayraktar 2000 (278.2 cm^2/g), Kate A-1 (265.5 cm^2/g), and Doğankent 1 (264.1 cm^2/g). The lowest values for specific leaf area were calculated in Uzunyayla, Nenehatun, and Sönmez 2001.

When values were averaged over the seasons, the specific leaf areas of the genotypes ranged between 183.8 cm^2/g and 222.2 cm^2/g. The highest specific leaf areas were observed in Gün 91 (222.2 cm^2/g), Doğankent (221.5 cm^2/g), Bayraktar 2000 (218.9 cm^2/g), and Alparslan (218.3 cm^2/g). The lowest values for specific leaf area were recorded in Ankara 093/44, Nenehatun, Yakar 99, and Aksel 2000. Similar to our results, Rawson et al. (1987), Richards and Lukacs (2002), and Rebetzke et al. (2004) stated that there is significant variation in wheat genotypes in terms of specific leaf area. The values for specific leaf area in this research, 183.8–222.2 cm^2/g, were lower than the values (276–335 cm^2/g) reported by Rebetzke et al. (2004). Specific leaf area can vary due to soil nitrogen content, sowing density, plant height, winter-spring type properties, and photoperiod properties. Specific leaf area is low in winter-type genotypes, semidwarf genotypes (Rebetzke et al., 2004) and with longer photoperiods (Roy and Murty, 1970). The lower specific leaf area values obtained from this study could be due to high light intensity when high altitude is taken into account.

3.3.2. Field experiments

There were also significant differences among the wheat genotypes based on first leaf width and specific leaf area in the field experiments. The effect of season on these 2 parameters was significant. According to the average of the genotypes, differences in first leaf width and specific leaf area were highly significant between September–October 2009 (4.02 mm, 184.7 cm^2/g) and September–October 2010 (3.68 mm, 180.4 cm^2/g). In addition, both first leaf width and specific leaf area exhibited stability with respect to season and a "genotype × season" interaction was observed based on these parameters (Table 4).

Under field conditions, the first leaf width of the genotypes ranged from 3.50 mm (Yayla 305) to 4.47 mm (Sultan 95) in September–October 2009, and 3.01 mm (Kırmızı Yerli) to 4.21 mm (Kırkpınar 79, Pehlivan) in September–October 2010. Averaged over the seasons, first leaf width varied between 3.27 and 4.71 mm. The largest first leaves were measured in İkizce 96 (4.71 mm), Kırkpınar 79 (4.29 mm), Kıraç 66 (4.23 mm), and Süzen 97 (4.20 mm). The narrowest first leaves were observed in Kırmızı Yerli, Pamukova 97, Kırik, and Köse 220/69. Similar to our findings, Rebetzke et al. (2004) found significant differences in first leaf width among wheat genotypes.

Table 3. First leaf width and specific leaf area of wheat genotypes in outdoor experiment[1].

No.	Genotype	First leaf width (mm)				Specific leaf area (cm^2/g)			
		September–October 2009	April–May 2010	September–October 2010	Mean	September–October 2009	April–May 2010	September–October 2010	Mean
1	Aksel 2000	4.37	4.15	4.23	4.25 j–t	176.0 r–w	183.1 abc	216.8 bcd	192.0 efg
2	Alparslan	4.29	4.07	3.97	4.11 r–t	200.3 cde	204.9 abc	249.8 a–d	218.3 a–d
3	Altay 2000	4.70	4.94	4.62	4.75 abc	186.9 j–n	202.7 abc	245.6 a–d	211.7 a–f
4	Atlı 2002	4.50	4.52	4.35	4.46 b–o	183.4 l–p	218.9 ab	232.2 a–d	211.5 a–f
5	Aytın 98	4.55	4.40	4.26	4.40 d–r	178.9 o–w	209.7 abc	250.3 a–d	213.0 a–f
6	Bağcı 2002	4.43	4.34	4.12	4.30 h–s	180.1 o–u	198.0 abc	238.4 a–d	205.5 a–g
7	Bayraktar 2000	4.89	4.86	4.37	4.71 a–e	175.6 s–w	203.0 abc	278.2 a	218.9 abc
8	Bolal 2973	4.62	4.53	4.33	4.50 b–l	183.8 k–p	215.9 ab	249.6 a–d	216.5 a–d
9	Çetinel 2000	4.84	4.61	4.33	4.59 a–ı	197.1 def	191.4 abc	223.9 a–d	204.1 a–g
10	Dağdaş 94	4.60	4.50	4.21	4.43 c–q	177.0 r–w	194.0 abc	246.9 a–d	206.0 a–g
11	Demir 2000	4.97	4.62	4.45	4.68 a–f	180.0 o–v	214.7 ab	243.3 a–d	212.7 a–f
12	Doğankent 1	4.21	4.39	4.10	4.23 k–t	180.4 o–u	220.0 ab	264.1 ab	221.5 ab
13	Doğu 88	4.55	4.30	3.89	4.24 j–t	211.6 b	200.4 abc	241.3 a–d	217.8 a–d
14	Gerek 79	4.32	4.18	3.83	4.11 r–t	184.2 k–o	194.4 abc	249.9 a–d	209.5 a–f
15	Gün 91	4.68	4.55	4.21	4.48 b–m	188.6 i–l	219.2 ab	258.7 abc	222.2 a
16	Harmankaya 99	4.08	4.15	4.04	4.09 r–t	200.0 cde	181.4 abc	236.9 a–d	206.1 a–g
17	İkizce 96	4.66	4.29	4.22	4.39 e–r	187.4 j–m	201.9 abc	244.8 a–d	211.4 a–f
18	İzgi 2001	4.97	4.79	4.58	4.78 ab	167.5 yz	185.1 abc	261.6 abc	204.7 a–g
19	Karahan 99	4.75	4.51	4.57	4.61 a–h	175.3 s–w	198.9 abc	254.0 abc	209.4 a–f
20	Kate A-1	4.13	4.24	3.87	4.08 r–t	179.6 o–w	206.7 abc	265.5 ab	217.3 a–d
21	Kıraç 66	4.72	4.52	4.24	4.49 b–l	187.5 j–m	198.8 abc	255.0 abc	213.7 a–f
22	Kırgız 95	4.61	4.41	4.35	4.45 b–o	173.3 w–z	192.2 abc	235.6 a–d	200.4 a–g
23	Kırkpınar 79	4.90	4.82	4.40	4.71 a–e	179.8 o–v	198.6 abc	235.6 a–d	204.7 a–g
24	Kutluk 94	4.61	4.67	4.23	4.50 b–l	166.7 yz	185.7 abc	258.8 abc	203.7 a–g
25	Lancer	4.43	4.34	4.28	4.35 g–r	181.1 n–s	191.7 abc	233.9 a–d	202.2 a–g
26	Mızrak	4.59	4.60	4.39	4.52 b–l	199.6 def	200.3 abc	231.9 a–d	210.6 a–f
27	Müfitbey	4.82	4.74	4.14	4.57 a–j	219.0 a	191.2 abc	232.1 a–d	214.1 a–e
28	Nenehatun	4.67	4.42	4.18	4.42 c–q	174.1 u–x	188.7 abc	205.7 dc	189.5 fg
29	Palandöken 97	4.72	4.44	4.00	4.39 e–r	181.5 m–s	205.5 abc	236.0 a–d	207.7 a–g
30	Pamukova 97	4.46	4.11	3.68	4.08 r–t	196.5 d–g	178.6 bc	243.5 a–d	206.2 a–g
31	Pehlivan	4.46	4.41	4.04	4.30 h–s	168.8 x	189.5 abc	236.7 a–d	198.3 a–g
32	Prostor	4.73	4.32	4.29	4.45 b–p	179.6 o–w	195.7 abc	254.5 abc	209.9 a–f
33	Seri 82	4.87	4.75	4.71	4.77 ab	196.1 efg	189.0 abc	220.9 bcd	202.0 a–g
34	Soyer02	4.77	4.88	4.41	4.68 a–f	202.2 cd	178.2 bc	212.1 bcd	197.5 b–g
35	Sönmez 2001	4.45	4.36	3.85	4.22 l–t	189.6 h–k	203.6 abc	207.8 dc	200.3 a–g
36	Sultan 95	4.80	4.77	4.34	4.64 a–g	174.2 u–x	189.9 abc	227.7 a–d	197.3 b–g
37	Süzen 97	4.86	4.69	4.62	4.72 a–d	183.6 k–p	177.0 bc	241.3 a–d	200.6 a–g
38	Tosunbey	4.77	4.42	4.20	4.46 b–n	193.7 f–i	188.3 abc	238.5 a–d	206.8 a–g
39	Türkmen	4.66	4.23	3.90	4.26 i–t	190.5 g–j	165.3 c	248.8 a–d	201.5 a–g
40	Uzunyayla	4.65	4.32	4.15	4.37 f–r	205.6 c	183.8 abc	194.6 d	194.7 c–g

Table 3. (Continued).

41	Yakar 99	4.75	4.51	4.14	4.46 b–n	161.8 yz	183.1 abc	223.8 a–d	189.5 fg
42	Zencirci 2002	4.82	4.61	4.26	4.57 a–k	183.3 l–q	206.6 abc	251.9 abc	213.9 a–e
43	Ak-702	4.44	4.19	4.04	4.22 l–t	167.8 y	191.5 abc	245.5 a–d	201.6 a–g
44	Ak Buğday	4.77	4.96	4.32	4.68 a–f	168.8 x	200.1 abc	235.6 a–d	201.5 a–g
45	Ankara 093/44	4.68	4.58	4.33	4.53 b–l	165.9 yz	167.6 c	217.9 bcd	183.8 g
46	Conkesme	4.54	4.55	4.05	4.38 e–r	195.1 e–h	176.7 bc	217.9 bcd	196.6 c–g
47	Haymana 79	4.78	4.55	4.22	4.51 b–l	194.2 e–i	198.1 abc	218.0 bcd	203.4 a–g
48	Hawk (Şahin)	4.26	4.20	4.00	4.15 m–t	174.5 t–x	179.4 bc	228.3 a–d	194.1 d–g
49	Kılçıksız Buğday	4.67	4.64	4.09	4.47 b–n	182.1 m–r	215.6 ab	212.4 bcd	203.3 a–g
50	Kırik	4.45	4.19	3.73	4.12 p–t	196.3 d–g	205.7 abc	240.5 a–d	214.1 a–e
51	Kırmızı Kılçık	4.10	4.16	3.66	3.97 s–t	179.4 o–w	181.0 abc	247.5 a–d	202.6 a–g
52	Kırmızı Yerli	4.11	4.25	3.67	4.01 s–t	161.9 yz	215.0 ab	230.6 a–d	202.5 a–g
53	Koca Buğday	4.54	4.15	3.92	4.21 l–t	154.3 z	202.3 abc	228.2 a–d	194.9 c–g
54	Köse 220/39	4.35	4.19	3.88	4.14 n–t	183.8 k–p	197.5 abc	227.1 a–d	202.8 a–g
55	Orso	4.95	4.70	4.17	4.61 a–h	180.7 n–t	216.1 ab	239.4 a–d	212.1 a–f
56	Özlü Buğday	4.69	4.66	4.22	4.52 b–l	174.3 t–x	188.5 abc	219.8 bcd	194.2 d–g
57	Polatlı Kösesi	4.72	4.31	4.27	4.43 c–q	166.0 yz	198.3 abc	233.0 a–d	199.1 a–g
58	Sert Buğday	4.80	4.72	4.06	4.53 b–l	164.8 yz	194.1 abc	249.0 a–d	202.6 a–g
59	Sürak 1593/51	4.13	4.40	4.27	4.26 i–t	176.3 r–w	198.6 abc	239.0 a–d	204.7 a–g
60	Tir	5.07	5.01	4.55	4.88 a	161.4 z	205.2 abc	215.8 bcd	194.1 d–g
61	Yayla 305	4.31	4.13	3.94	4.13 o–t	166.0 yz	182.7 abc	235.8 a–d	194.8 c–g
62	Zerin	4.58	4.31	4.06	4.32 g–s	173.6 v–y	226.8 a	220.8 bcd	207.1 a–g
63	Bezostaja 1	4.61	4.62	4.28	4.50 b–l	166.7 yz	202.4 abc	240.9 a–d	203.3 a–g
64	Karasu 90	4.38	4.30	4.17	4.28 h–t	177.7 p–w	192.5 abc	218.4 bcd	196.2 c–g
Mean		4.59 A	4.47 B	4.18 C	4.41	181.5 C	196.3 B	236.6 A	204.8
F value (Genotype)		–	–	–	8.57**	79.98**	1.71**	1.80**	2.55**
F value (Season)		–	–	–	185.17**	–	–	–	636.14**
F value (G × S)		–	–	–	1.0	–	–	–	2.38*
LSD (0.01) (G)		–	–	–	0.27	5.4	36.7	44.1	19.1
LSD (0.01) (S)		–	–	–	0.06	–	–	–	4.1
LSD (0.05) (G × S)		–	–	–	–	–	–	–	33.05
CV (%)		–	–	–	5.7	1.6	10.2	10.1	8.8

[1] Means in a column not sharing a common letter are significantly different. ** = significant at P < 0.01.

The specific leaf areas of the genotypes ranged from 162.9 (Demir 2000) to 220.6 cm^2/g (Doğu 88) in September–October 2010 and from 147.8 (Karahan 99) to 226.5 cm^2/g (İzgi 2001) in September–October 2010. Averaged over the seasons, the specific leaf areas of the genotypes were 164.4–204.2 cm^2/g. The highest specific leaf areas were from genotypes Sürak 1593/51, İzgi 2001, Mızrak, Kıraç 66, and Müfitbey with values of 204.2, 201.6, 201.3, 200.8, and 199.8 cm^2/g, respectively. The lowest specific leaf areas were recorded in genotypes Demir 2000, Karahan 99, Sert Buğday, Kırmızı Yerli, and Ankara 093/44 (Table 3). Similar to our findings, Rawson et al. (1987), Richards and Lukacs (2002), and Rebetzke et al. (2004) reported significant differences among wheat genotypes based on specific leaf area. According to the average values of the genotypes, the values for specific leaf area calculated in the field experiment (182.6 cm^2/g) were lower than the values obtained from the outdoor experiment (204.8 cm^2/g). This result was in parallel to values reported by Rebetzke et al. (2004).

Table 4. First leaf width and specific leaf area of wheat genotypes in field experiment[1].

No.	Genotype	First leaf width (mm)			Specific leaf area (cm^2/g)		
		September–October 2009	September–October 2010	Mean	September–October 2009	September–October 2010	Mean
1	Aksel 2000	4.07	3.33	3.70 bcd	194.3	162.5	178.4 a–e
2	Alparslan	3.62	3.71	3.67 bcd	192.5	177.1	184.8 a–e
3	Altay 2000	4.40	3.83	4.12 abc	201.4	164.3	182.8 a–e
4	Atlı 2002	3.98	3.71	3.84 bcd	174.1	184.1	179.1 a–e
5	Aytın 98	4.09	3.49	3.79 bcd	200.9	188.4	194.6 a–e
6	Bağcı 2002	3.87	3.62	3.75 bcd	184.9	186.5	185.7 a–e
7	Bayraktar 2000	4.20	3.60	3.90 bcd	185.6	208.8	197.2 a–d
8	Bolal 2973	4.25	3.70	3.97 a–d	183.3	175.9	179.6 a–e
9	Çetinel 2000	4.13	3.73	3.93 a–d	196.6	186.9	191.8 a–e
10	Dağdaş 94	4.29	3.94	4.12 abc	185.2	186.7	186.0 a–e
11	Demir 2000	4.07	3.64	3.86 bcd	162.9	165.9	164.4 e
12	Doğankent 1	3.88	3.49	3.69 bcd	200.9	197.3	199.1 a–d
13	Doğu 88	3.75	3.60	3.67 bcd	220.6	158.5	189.6 a–e
14	Gerek 79	3.73	3.58	3.66 bcd	189.9	158.7	174.3 a–e
15	Gün 91	4.10	4.26	4.18 abc	180.9	183.1	182.0 a–e
16	Harmankaya 99	3.67	3.44	3.55 bcd	198.7	176.6	187.7 a–e
17	İkizce 96	4.17	5.26	4.71 a	174.9	179.9	177.4 a–e
18	İzgi 2001	4.22	4.01	4.11 abc	176.6	226.5	201.6 ab
19	Karahan 99	4.20	4.10	4.15 abc	181.0	147.8	164.4 e
20	Kate A-1	3.77	3.28	3.53 bcd	184.3	195.3	189.8 a–e
21	Kıraç 66	4.31	4.15	4.23 abc	207.7	193.8	200.8 ab
22	Kırgız 95	4.22	3.36	3.79 bcd	169.1	201.2	185.2 a–e
23	Kırkpınar 79	4.38	4.21	4.29 ab	181.1	172.4	176.8 a–e
24	Kutluk 94	4.11	3.80	3.95 a–d	167.1	183.7	175.4 a–e
25	Lancer	4.15	3.58	3.87 bcd	186.1	177.7	181.9 a–e
26	Mızrak	4.07	3.71	3.89 bcd	200.2	202.4	201.3 ab
27	Müfitbey	4.42	3.96	4.19 abc	219.3	180.4	199.8 abc
28	Nenehatun	3.93	3.55	3.74 bcd	180.1	188.8	184.5 a–e
29	Palandöken 97	4.00	3.62	3.81 bcd	178.6	201.3	190.0 a–e
30	Pamukova 97	3.75	3.07	3.41 cd	192.2	179.3	185.8 a–e
31	Pehlivan	4.05	4.21	4.13 abc	163.9	176.0	170.0 cde
32	Prostor	4.13	3.79	3.96 a–d	170.8	198.0	184.4 a–e
33	Seri 82	4.22	3.91	4.06 a–d	187.7	181.1	184.4 a–e
34	Soyer02	4.15	3.73	3.94 a–d	199.8	179.7	189.8 a–e
35	Sönmez 2001	3.97	3.58	3.78 bcd	191.9	189.8	190.8 a–e
36	Sultan 95	4.47	3.48	3.97 a–d	176.0	180.2	178.1 a–e
37	Süzen 97	4.43	3.96	4.20 abc	180.9	168.6	174.8 a–e
38	Tosunbey	3.93	3.66	3.79 bcd	193.7	168.3	181.0 a–e
39	Türkmen	3.75	3.79	3.77 bcd	189.7	188.7	189.2 a–e
40	Uzunyayla	4.15	4.03	4.09 a–d	197.2	183.4	190.3 a–e

Table 4. (Continued).

41	Yakar 99	4.18	3.75	3.96 a–d	176.7	174.1	175.4 a–e
42	Zencirci 2002	4.33	3.61	3.97 a–d	179.6	185.0	182.3 a–e
43	Ak-702	3.69	3.49	3.59 bcd	172.2	179.3	175.7 a–e
44	Ak Buğday	4.46	3.53	3.99 a–d	174.8	210.4	192.6 a–e
45	Ankara 093/44	4.08	3.42	3.75 bcd	176.0	155.2	165.6 e
46	Conkesme	3.78	3.73	3.75 bcd	199.5	171.2	185.4 a–e
47	Haymana 79	4.06	3.83	3.94 a–d	195.8	182.9	189.4 a–e
48	Hawk (Şahin)	3.97	3.34	3.66 bcd	177.0	179.4	178.2 a–e
49	Kılçıksız Buğday	3.97	3.63	3.80 bcd	181.4	169.7	175.6 a–e
50	Kırik	3.67	3.23	3.45 cd	195.4	178.5	187.0 a–e
51	Kırmızı Kılçık	3.64	3.37	3.51 bcd	180.4	171.5	175.9 a–e
52	Kırmızı Yerli	3.53	3.01	3.27 d	166.1	166.9	166.5 e
53	Koca Buğday	3.59	3.44	3.52 bcd	164.3	183.3	173.8 b–e
54	Köse 220/39	3.71	3.28	3.49 bcd	183.6	167.5	175.5 a–e
55	Orso	4.06	3.75	3.90 bcd	184.7	185.9	185.3 a–e
56	Özlü Buğday	4.20	3.84	4.02 a–d	174.4	174.4	174.4 a–e
57	Polatlı Kösesi	3.76	3.55	3.66 bcd	173.6	179.4	176.5 a–e
58	Sert Buğday	3.97	3.80	3.88 bcd	168.0	164.8	166.4 e
59	Sürak 1593/51	3.93	3.52	3.73 bcd	203.4	205.0	204.2 a
60	Tir	4.28	3.92	4.10 a–d	180.5	158.0	169.2 de
61	Yayla 305	3.50	3.65	3.58 bcd	174.7	163.7	169.2 de
62	Zerin	3.83	3.30	3.56 bcd	182.7	170.3	176.5 a–e
63	Bezostaja 1	3.98	3.63	3.80 bcd	175.7	169.0	172.3 b–e
64	Karasu 90	4.02	3.65	3.83 bcd	178.3	194.9	186.6 a–e
Mean		4.02 A	3.68 B	3.85	184.7 A	180.4 B	182.6
F value (Genotype)		–	–	1.94**	–	–	1.38*
F value (Season)		–	–	56.10**	–	–	4.27*
F value (G × S)		–	–	0.71	–	–	1.30
LSD (0.01) (G)		–	–	0.66	–	–	23.16
LSD (0.01) (S)		–	–	0.12	–	–	4.1
CV (%)		–	–	13.2	–	–	12.9

[1] Means in a column not sharing a common letter are significantly different. ** = significant at P < 0.01.

Seedling vigor, defined as the rapid development of specific leaf area in the early development stage (Richards and Lukacs, 2002), increases water use efficiency of wheat in dry farming conditions by lowering water loss from the soil surface via evaporation (Lopez-Castaneda and Richards, 1994), increasing transpiration efficiency (Fischer, 1979), and increasing the competitive capability of plants to weeds (Coleman et al., 2001). In addition, it increases wheat development rate and grain yield by increasing light use efficiency (Rebetzke et al., 2004). In light of our results, it could be said that the field experiments gave more reliable results in evaluation of the genotypes with respect to seedling vigor by reflecting both the performance of the genotypes in natural growing conditions and the seasonal stability of the genotypes based on first leaf width and specific leaf area parameters. Genotypes İkizce 96, Kırkpınar 79, Kıraç 66, Süzen 97, and Müfitbey ranked first based on first leaf width, and genotypes Sürak 1593/51, İzgi 2001, Mızrak, Kıraç 66, and Müfitbey ranked first based on specific leaf area. These genotypes may have a greater adaptive ability in a drought environment in the early developmental stage. Genotypes

Kıraç 66 and Müfitbey, which were notable in terms of both parameters, could be used as parents in breeding programs related to drought resistance.

The substantially different selection criteria analyzed in this study revealed significant genetic differences that would enable us to select drought-tolerant genotypes. However, a genotype defined as tolerant based on one criterion could be susceptible with respect to another criterion. It could be that the selection parameters used in this study are controlled by different genetic and physiological factors, making it difficult to assess and recommend suitable genotypes for places where early drought is experienced.

Based on seedling survival, genotypes Lancer, Kıraç 66, Gerek 79, Mızrak, Harmankaya 99, Alparslan, Dağdaş 94, and Doğu 88 had stable and high seedling survival rates and were tolerant to drought in the early developmental stage. The genotypes generally showed narrow variation in coleoptile length, and the local genotypes and old cultivars had a greater coleoptile length compared to the modern cultivars. Genotypes Ak Buğday, Tir, Lancer, Sert Buğday, and Conkesme, having long coleoptiles, could be used as genitors for breeding of new genotypes having short plant height and a longer coleoptile. Genotypes Kıraç 66 and Müfitbey, ranked best in terms of first leaf width and specific leaf area, could adapt themselves to places where early development drought is observed and could be used as parents in breeding programs.

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