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Germination Stage Water Scarcity in Bread and Einkorn Wheat

Didem ASLAN[1], Bülent ORDU[2], Mehmet Erhan GÖRE[3], Beyhan AKIN[4],
*Nusret ZENCİRCİ[1]

[1]Abant İzzet Baysal Univ., Art and Sciences Faculty, Biology Dep., Bolu,Turkey
[2]Abant İzzet Baysal Univ., Economical and Commercial Fac., Business Dep., Bolu, Turkey
[3]Abant İzzet Baysal Univ., Agriculture and Natural Sciences Faculty, Department of Plant Protection, Bolu, Turkey
[4]International Maize and Wheat Improvement Centre (CIMMYT), PO Box: 39, Ankara, Turkey

*Corresponding author e-mail *(Sorumlu yazar e-posta):* nzencirci@yahoo.com

Abstract

Germination (GR, %) and power (GP, %) rates, coleoptile (CL, cm), shoot lenght (SL, cm), and root (RL, cm) length, shoot/root length ratio (SRLR), root fresh weight (RFW, mg) and dry (RDW, mg) weight, and root fresh/dry root ratio (RFDWR) of 12 bread and 10 einkorn wheat genotypes were investigated under 7 drought stress levels. SL and SRLR in the study were the most sensitive traits and followed by CL and RL. The mean performance of all traits was worsened starting at various stress levels. The highest percent reduction was in SL (100.00%), SRLR (100.00%), and RL (99.07%), and the lowest one was in GP (55.9%). The common applied drought tolerance indices grouped the entries as tolerant, moderate, and susceptible. Einkorn populations from higher rainfall Blacksea region responded worse under drought stress than bread wheat cultivars, which were improved for drier or relatively drier Central Anatolia, Sub-Marmara, and Thrace regions.

Keywords: Bread wheat, drought, einkorn, germination stages

Ekmeklik ve Siyez Buğdayında Çimlenme Dönemi Su Eksikliği

Öz

On iki ekmeklik ve on siyez buğdayının yedi kurak düzeyindeki çimlenme hızı (GR, %) ve çimlenme gücü (GP, %), koleoptil uzunluğu (CL, cm), çim uzunluğu (SL, cm) ve kök boyu (RL, cm) çim/kök uzunluğu oranı (SRLR), kök yaş ağırlığı (RFW, mg) ve kök kuru ağırlığı (RDW, mg) ve kök yaş/kuru ağırlık oranı (RFDWR) incelenmiştir. Kurağa karşı en duyarlı olan karakterler RL ve SRLR olmuş, bunları CL ve RL izlemiştir. Tüm karakterlerin gelişmesi değişik stress düzeylerinde gerilemiştir. Gelişmesi en kötü olan karakterler SL (%100.00), SRLR (%100.00) ve CL (%99.07%) olup en iyi gelişen karakter ise GR (%55.9)'dır. Yaygın olarak kullanılan kurak tolerans indeksi buğday genotiplerini tolerant, orta ve duyarlı olarak gruplamıştır. Yüksek yağışlı Karadeniz bölgesinin siyez populasyonları kurak ve kurakça olan Orta Anadolu, Alt-Marmara ve Trakya bölgeleri için geliştirilmiş olan ekmeklik buğday çeşitlerine göre kurak stresi altında daha zayıf gelişmişlerdir.

Anahtar Kelimeler: Çimlenme dönemleri, ekmeklik buğday (*Triticum aestivum* L.), kurak, siyez (*Triticum monococcum* ssp. *monococcum*)

Introduction

Bread wheat (*Triticum aestivum* L.) delivers calorie and protein to 50% of person in one-third of the world. Widely adapted drought tolerant wheat genotypes yield higher (Braun et al., 2001; Rajaram, 2001; Cattivelli et al., 2008) under drought stress. Because of drought like stress factors (Turner, 1986), crops have, on the other hand, accumulated various defense characteristics. Those better defense mechanisms including security features, necessitate wider–newer genetic variation, which may exist in landraces or wild relatives (Zencirci et al., 1994; Zencirci and Kün, 1996; Zencirci, 1998; Tan, 1998; Koç et al., 2000) and rapid-efficient testing-screening methods (Winter et al., 1988; Morgan, 1989). Einkorn (*Triticum monococcum spp. monococcum*), the wheat ancestor, which has resistance to

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cold, drought, and salinity stress (Karagöz and Zencirci, 2005; Zencirci and Karagöz, 2005; Aslan et al., 2016a; Aslan et al*.,* 2016b; Arzani and Ashraf, 2017) is considered possibly a good genetic resource against these stresses. Selecting a well-designed single or multi drought-resistant trait(s) from these resources and to incorporate into high yielding wheat genotypes seems feasible today (Braun et al., 1998; Merah, 2001).

The tolerance to water shortage (Ludlow and Muchow, 1990; Liley and Ludlow, 1996) with yield should, therefore, go together for a sustainable higher yield. Achieving a yield increase under drought stress, otherwise, would be an unsuccessful adventure (Blum, 2005). Therefore, many drought screening tests (Winter et al., 1988; Reynolds et al., 1998), promising laboratory and evaluation techniques, indices, and computational methods for drought (Zencirci et al., 1990; El-Hendawy et al., 2005; Mahmoodzadeh et al., 2013; Ali and El-Sadek, 2016) have been developed. Some are root density and depth (Gregory, 1989), root–shoot splitting (Dewar, 1993; Thornley, 1998), four-leaf early growth period vigor (Turner and Nicolas, 1987; Hafid et al. 1998), leaf H_2O content (Kumar and Singh, 1998), cell osmotic tissue constancy (Premchandra et al., 1990), germination under osmotic stress conditions (Emmerich and Hardegree, 1991), drought total (Zencirci et al., 1990) and drought tolerance indices (El-Hendawy et al., 2005; Mahmoodzadeh et al., 2013), stress susceptibility and tolerance indexes, mean and geometric mean productivities (Ali and El-Sadek, 2016; Dhanda et al., 1995), newer–wider genetic resources such as einkorn and emmer wheats (Zencirci and Karagöz, 2005; Karagöz et al., 2010), and the application of powerful molecular tools (Munns, 2005).

Polyethylene glycol (PEG), a non-ionic water polymer (Rauf et al., 2007), application is, nowadays, one popular way to induce drought stress. PEG does not infiltrate into plant material swiftly (Kawasaki et al., 1983), but Na^+ plus Cl^- does. The Na^+ and Cl^- ions store in the vacuole of the tolerant or in the cytoplasm of delicate plants (Genc et al., 2007). A low-Na^+ locus on the 2A chromosome long arm carries several markers linked to a gene at a QTL designated Nax1 (Na^+ exclusion), (Lindsay et al. 2004), which is a region on the long arm of the chromosome 2A contains a QTL for Na+ exclusion and K^+/Na^+ discrimination (Munns, 2006).

We, here, aimed to determine the response of germination rate (GR, cm), germination power (GP, cm), coleoptile length (CL, cm), shoot length (SL, cm), root length (RL, cm), shoot/root length ratio (SRLR), root fresh weight (RFW, mg), root dry weight (RDW, mg), root fresh weight/root ratio (RFDWR) under PEG 600 induced drought stress during 2014-2015.

Materials and Methods

Seed material was 12 bread wheat cultivars (Gerek-79, İkizce-96, Kıraç-66, Kenanbey, Flamura-85, Momtchil, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000, and Gün-91) grown in various regions of Turkey and 10 different einkorn populations (Population-1, Population-2, Population-4, Population-5, Population-6, Population-9, Population-10, Population-11, Population-14, and Population-15), (Table 1). Bread wheat cultivars were selected based on their geographic origins, for where they were improved: drier Central Anatolia, and relatively drier sub-Marmara and Thrace in order to represent a possible drought tolerance diversity in bread wheat entries. Einkorn populations also exemplified the whole western Blacksea region, where einkorn was largely planted in Turkey. All entries were evaluated for germination rate (GR %), germination power (GP %), coleoptile length (CL, cm), shoot length (SL, cm), root length (RL, cm), shoot/root length ratio (SRLR), root fresh weight (RFW, mg), root dry weight (RDW, mg), and root fresh/dry weight ratio (RFDWR) under PEG 600 induced drought stress. Bread wheat cultivars were obtained from research institutes in Turkey and einkorn wheat populations by Quality Feed Company, Bolu, Turkey.

Drought stress tests were applied at the Biology Department, Abant İzzet Baysal University, Bolu, Turkey during 2014-2015. Surface sterilization of 3x30 seeds (of each wheat entry per treatment) was in 96%

Table 1. Bread cultivar and einkorn wheat study materials
Çizelge 1. Çalışmada kullanılan ekmeklik buğday çeşitleri ve siyez buğdayları

Numbers	Cultivars and populations	Institutes improved or places originated[1]
1	Gerek-79	ARI
2	İkizce-96	CRIFC
3	Kıraç-66	ARI
4	Kenanbey	CRIFC
5	Flamura-85	TARI
6	Momtchil	TARI
7	Bayraktar-2000	CRIFC
8	Tosunbey	CRIFC
9	Pandas	CARI
10	Pehlivan	TARI
11	Demir-2000	CRIFC
12	Gün-91	CRIFC
13	Population-1	Bolu, Seben, Haccağız Village
14	Population-2	Bolu, Seben, Boğaz Region
15	Population-4	Bolu, Seben, Kavaklı Yazı Village
16	Population-5	Bolu, Seben, Kavaklı Yazı Village
17	Population-6	Bolu, Seben, Kavaklı Yazı Village
18	Population-9	Kastamonu, İhsangazi, Çatalyazı Village
19	Population-10	Kastamonu, İhsangazi, Uzunoğlu District
20	Population-11	Kastamonu, İhsangazi, Çay District
21	Population-14	Kastamonu, İhsangazi, Center
22	Population-15	Kastamonu, İhsangazi, Center

[1]CRIFC: Central Research Institute for Agricultural Research, Ankara; [2]ARI: Anatolian Research Institute, Eskişehir; [3]TARI: Thrace Agricultural Research Institute, Edirne; [4]CARI: Çukurova Agricultural Research Institute, Adana

[1]CRIFC (TBMAE): Tarla Bitkileri Merkez Araştırma Enstitüsü, Ankara; [2]ARI (ATAE): Anadolu Tarımsal Araştırma Enstitüsü, Eskişehir; [3]TARI (TTAE); Trakya Tarımsal Araştırma Enstitüsü, Edirne; [4]CARI (ÇTAE): Çukurova Tarımsal Araştırma Enstitüsü, Adana

ethanol for 30 seconds and in 10% sodium hypochlorite for 15 min. They were later rinsed twice in distilled water (Baloch et al. 2012). Then, 10 (X3) seeds were germinated on 5 ml pre-prepared solution added wet filter paper: one control and six 100 ml doses of PEG 600 (0: control, 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M, and 27.45 ml: 0.51M). 5 ml of PEG into treatments and distilled water were added every two days in order to avoid drying in the petri dishes. Concentration of each entry was pH 5.9±1. Germination of seeds was 8 days at 23±1 °C in a black growing room. After 4 days GR (%) and afterward 8 days GP (%), CL (cm), SL (cm), RL (cm),), SRLR, FRW (mg), DRW (mg), RFDWR were recorded.

A 3 replicate randomized Ccomplete Block Design was chosen as the trial. After analysis of variance (ANOVA) was run, Fisher's protected F and least significant difference (LSD) tests were applied the separation of for means. Spearman correlations amid entries in drought and non–drought settings (Snedecor and Cochran, 1980; Gomez and Gomez, 1984; Petersen, 1985), Pearson linear correlations (Kalaycı, 2006), drought tolerance (Zencirci et al.,1990; El-Hendawy et al., 2005; Mahmoodzadeh et al., 2013), (Table 5), stress susceptibility and tolerance indexes, mean and geometric mean productivities (Ali and El-Sadek, 2016) were calculated by Microsoft Excel software. In addition, SPSS statistical package (Zobel et al., 1988) outputted principal component analysis (PCA) as well as dendograms.

Results and Discussion

Analysis of variance revealed that blocks differed for SL, RL, RFDWR (P<0.05), GR, GP, CL, SRLR, RFW, RDW (P<0.01); drought levels for all characters (P<0.01) and cultivars/populations for GR, GP, CL, RL, RDW, and RFDWR (P<0.01), and for SRLR and RFW (P<0.01). Cultivars/populations did not differ for SL. Except for GR, RL, and RDW (P<0.01), no cultivar/population by drought level interactions occurred (Table 2).

The mean of all characters was higher under control than drought. Some characters also developed better at some other lower PEG 600 levels up to 0.25-0.34 M. Starting 0.43-0.51 M PEG 600, all studied characters totally worsened. The highest reduction percentage was in SL (100%), SRLR (100%), RFW (99.07%), RFW (98.87%), CL (98.69%), and RDW (97.60%); and the lowest in GP (55.90%; Table 3). Population-4 (92.90%), Population-6 (92.90%) Population-5 (90.00%), Population-1 (88.60%), Population-2 (88.10%), Population-9 (86.70%), Population - 15 (84.80%), Gün 91 (83.30%), and Population-11 (82.40%) had higher GR values while Kıraç-66 (62.90%) had the lowest (Table 4). In contrast, Population-6 (95.70%), Population-5 (94.80%), Population-4 (94.30%), Population-1 (93.30%), Population-9 (92.40%), Population-2 (91.90%), Gün-91 (89.00%), Population-15 (88.60%),

Population-10 (88.10%), Population-14 (88.10%), Kenanbey (86.70%), and Population-11 (85.70%) had highest GP while Pehlivan (71.90%) had the lowest. Similarly, Bayraktar-2000 (2.73), Kenanbey (2.68), Gün-91 (2.63), Gerek-79 (2.57), Demir-2000 (2.53), Momtchil (2.46), İkizce-96 (2.39), Population-1 (2.37), Population-5 (2.24), and Pehlivan (2.23) had the longest CL while Population-10 (1.66) had the lowest.

Cultivars and populations did not differ for SL (cm). Bayraktar-2000 (5.97), Gerek-79 (5.79), Kenanbey (5.65), Pandas (5.64), Momtchil (5.55), Tosunbey (5.50), Gün 91 (5.33), Flamura-85 (5.26), İkizce-96 (5.26) and Demir-2000 (4.63) had the longest RL while the Population-10 (3.20) had the shortest. Population-5 (1.76) had the highest SRLR while Flamura-85 (0.64) had the lowest.

Kenanbey (58.46), Bayraktar-2000 (55.87), Momtchil (55.02), Gün-91 (51.55), Tosunbey (51.46), Flamura-85 (50.00), İkizce-96 (48.97), Gerek-79 (47.12), and Pandas (46.14) had the heaviest RFW (mg) while Population-10 (27.22) had the lightest. Kenanbey (7.73), Bayraktar-2000 (7.60), İkizce-96 (6.99), Gün-91 (6.61), Momtchil (6.36), and Flamura-85 (6.25) had the heaviest RDW (mg) while the Population -10 (0.64) had the lightest. Momtchil (7.60), Tosunbey (7.52), Gerek-79 (7.41), Populasyon-9 (7.18), Gün-91 (7.02), Kıraç-66 (6.98), and Flamura-85 (6.97) had the highest RFDWR while Population-10 (6.10), Population-4 (6.09), Population-5 (6.05), İkizce 96 (6.05), Population-1 (6.05), Population-6 (5.95), and Population-11 (5.85) had the lowest value.

Drought is among the common harms everywhere in the sphere and undesirably distresses germ development and sprout advance (Davidson and Chevalier, 1987; Kiem and Kronstad, 1981; Owen, 1972; Passioura,

Table 2. F values in ANOVA for the GR, GP, CL, SL, RL, SRLR, RFW, RDW, and RFDWR under 0 (Control), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M, and 27.45 ml: 0.51M drought stresses.

Çizelge 2. GR, GP, CL, SL, RL, SRLR, RFW, RDW ve RFDWR'nın 0 (Kontrol), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M ve 27.45 ml: 0.51M kurak stresleri altındaki F değerleri

Sources of variation	DF	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Blocks	2	10.67**	3.78**	0.07**	8.64 *	3.34 *	0.27**	9.02**	2.97^{ns}	0.67 *
Treatments	153	27.92**	17.87**	1.13**	56.25**	44.18**	5.88**	56.16**	39.53**	13.31**
Cultivar	21	6.18**	3.90^{ns}	0.07**	1.98 *	5.91**	0.62^{ns}	7.68^{ns}	7.11**	1.26**
Levels	6	189.83**	113.06**	8.83**	456.42*	339.71**	37.81**	434.21**	295.62**	100.25**
Cultivar *Levels	126	1.23**	1.20^{ns}	0.03^{ns}	0.71^{ns}	0.72**	0.48^{ns}	0.78^{ns}	0.74**	0.40^{ns}
Error	306									

*Significant at 0.01, **0.05 significant at 0.05 probability level, ^{ns}no significant;

**P<0.01 düzeyinde önemli, **P<0.05 düzeyinde önemli, ^{ns}önemli değil*

†GR: Germination, GP: Germination power rates, CL: Coleoptile, SL: Shoot, RL: Shoot root lengths, SRLR: Shoot/root length ratio, RFW: Root fresh, RDW: Root fresh dry weights, RFDWR: Root fresh/dry root ratio

†GR: Çimlenme hızı, GP: Çimlenme gücü, CL: Koleoptil uzunluğu, SL: Çim uzunluğu, RL Çim kök boyu, SRLR: Çim/kök uzunluğu oranı, RFW: Kök yaş ağırlığı, RDW: Kök kuru ağırlığı, RFDWR: Kök yaş/kuru ağırlık oranı

Table 3. Differences among for GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under (0 (Control), 0.09M, 0.17M, 0.25M, 0.34M, 0.43M and 0.51M)

Çizelge 3. 0 (Kontrol), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M ve 27.45 ml: 0.51M kurak stresleri altında GR, GP, CL, SL, RL, SRLR, RFW, RDW ve RFDWR arasındaki farklılıklar

Levels	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Control	98.50 a	100.00 a	4.08 a	14.08 a	8.64 ab	1.89 ab	87.26 a	7.60 a-c	11.46 a
0,09 M	98.00 ab	100.00 ab	4.57 ab	12.29 b	9.01 a	3.96 a	86.41 ab	9.90 ab	8.71 ab
0,17M	94.40 a-c	97.60 a-c	4.11 a-c	7.37 bc	7.48 a-c	0.97 b	68.04 a-c	9.96 a	6.83 a-c
0,25M	90.90 a-d	95.20 a-d	1.95 a-c	0.74 d	4.49 a-c	0.12 b	36.87 a-c	6.73 a-c	5.49 b-d
0,34M	83.90 a-e	87.30 a-e	0.33 d	0.00 de	1.85 c	0.00 b	13.78 c	2.94 a-c	4.93 b-e
0,43M	63.20 a-f	75.50 a-f	0.16 d	0.00 de	0.38 c	0.00 b	3.53 c	0.90 c	4.45 b-
0,51M	26.70 f	44.10 fg	0.06 d	0.00 de	0.08 c	0.00 b	0.99 c	0.24 c	4.11 b-e
%Decrease	72.89	55.90	98.69	100.00	99.07	100.00	98.87	97.60	64.13

*Significant at the 0.01, **0.05 significant at 0.05 probability level, ns no significant;
**P<0.01 düzeyinde önemli, **P<0.05 düzeyinde önemli,* ns önemli değil

†*GR: Germination, GP: Germination power rates, CL: Coleoptile, SL: Shoot, RL: Shoot root lengths, SRLR: Shoot/root length ratio, RFW: Root fresh, RDW: Root fresh dry weights, RFDWR: Root fresh/dry root ratio*

†*GR: Çimlenme hızı, GP: Çimlenme gücü, CL: Koleoptil uzunluğu, SL: Çim uzunluğu, RL Çim kök boyu, SRLR: Çim/kök uzunluğu oranı, RFW: Kök yaş ağırlığı, RDW: Kök kuru ağırlığı, RFDWR: Kök yaş/kuru ağırlık oranı*

1988). Reduced sprouting and declined sprout development consequence in poor establishing and sporadically crop fiasco. Poor starting in turn causes: (1) declined crop competitiveness with weeds; (2) lower sheltering of the soil and subsequently higher soil water loss through evaporation and hence, lower water readiness for crop; (3) lesser light seizure and yield possibility; (4) inferior development in early age when vapor density deficit is squat. Here, in this study, we may name the best genotypes by their characters of germination against drought were the following: Kıraç-66 for GR; Population-10 for GP; Bayraktar-2000 for CL; Demir-2000 for RL; Population-5 for SRLR; Kenanbey for RFW and RDW; Momtchil for RFDWR. SL did not significantly for genotypes.

Pearson linear correlation coefficients (r; Kalaycı 2006) among GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR were significant at different levels (Table 6a). Those highly linear significant relationships, of which their r ranged between 0.900-1.000, existed among GR-GP, CL-RFW, CL-RL, RL-RDW, RL-RFW, and RFW-RDW. Those linear significant relationships, of which their r ranged between 0.700-0.890, occurred only between CL-RDW. Those lower linear relationships with r= 0.260-0.490 existed among GR-RFDWR, GR-SRLR, and GP-RFDWR, GP-SRLR, GP-SL, and RL-RFDWR. There was no character pairs without any linear relationships. Spearman correlation coefficients between GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR either with or without drought stresses were calculated (Table 6b), as well. Under drought stress, GR-GP, CL-RDW, CL-RFW, CL-SRLR, CL-RL, SL-RFDWR, SL-RFW, SL-RL, RL-RDW, RL-RFW were positively GP-SRLR negatively correlated (P < 0.01). Without drought stress, few characters were correlated: SL-RFDWR, RL-RDW, and RL-RFW (P>0.01) GR-CL, RFW-RFDWR, and RFW-RDW (P<0.05) were positively; RL-SRLR, SRLR-RFW were negatively correlated (P<0.05).

A ≥0.3 PC coefficient is significant (Hair et al.1987). RL (0.378), RDW (0.494), and RFW (0.354) formed PC 1; SL (0.305) and SRLR (0.822), RFDWR (0.359) PC2; GP (0.622) and GR (0.593) PC3. Collective variance in first three PC is 92.254%. PC1 segment was 73.491%, PC2 12.666%, and PC3 6.097% in whole variant (Table 7). A general avarege dendogram for 22 entries ended up in two core groups with two sub groups (Figure 1a). All einkorn populations with Kıraç-66 were in the first main set. Pehlivan,Population-13, Population-17, Population-16, Population-18, Kıraç-66 and Population-10 were in the

Table 4. Differences amid 12 bread and 10 einkorn wheats under the effect of PEG 600: : 0 (Control), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M, and 27.45 ml: 0.51M

Çizelge 4. On iki ekmeklik ve 10 siyez buğdayının PEG 600 (0 (Kontrol), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M ve 27.45 ml: 0.51M) kurak stresi altındaki farklılıkları

Cultivars and populations	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Gerek-79	70.38 f-q	80.50 g-q	2.57 a-d	5.74 a-c	5.79 ab	0.68 k-s	47.12 a-h	5.79 c-h	7.41 a-c
İkizce-96	76.70 d-m	83.30 d-m	2.39 a-g	5.56 a-d	5.26 a-i	0.69 k-r	48.97 a-g	6.99 a-c	6.05 h-s
Kıraç-66	62.90 o-v	76.20 l-t	2.01 f-n	3.58 a-u	3.77 j-q	0.68 k-r	40.24 d-k	5.57 c-k	6.98 a-f
Kenanbey	78.60 c-j	86.70 a-k	2.68 ab	5.76 ab	5.65 a-c	0.73 k-p	58.46 a	7.73 a	6.52 d-k
Flamura-85	72.90 g-s	82.90 e-o	1.80 i-s	4.08 a-s	5.26 a-h	0.64 l-t	50.00 a-f	6.25 a-f	6.97 a-g
Momtchil	75.20 e-o	82.90 e-p	2.46 a-f	4.94 a-m	5.55 a-e	0.76 i-n	55.02 a-c	6.36 a-e	7.60 a
Bayraktar-2000	78.10 c-l	83.30 d-n	2.73 a	5.47 a-f	5.97 a	0.76 i-n	55.87 ab	7.60 ab	6.36 d-n
Tosunbey	73.80 f-p	80.00 g-r	1.81 i-r	3.60 a-u	5.50 a-f	0.69 k-r	51.46 a-e	5.87 b-g	7.52 ab
Pandas	73.30 g-r	79.00 g-s	1.86 h-q	5.30 a-h	5.64 a-d	0.83 i-m	46.14 a-i	5.76 c-j	6.42 d-l
Pehlivan	66.20 j-u	71.90 q-v	2.23 a-j	4.74 a-o	4.34 c-k	0.91 e-l	37.44 f-p	4.58 f-q	6.61 c-l
Demir-2000	70.00 j-t	75.70 l-u	2.53 a-e	6.34 a	4.63 a-j	1.04 c-j	44.32 b-j	5.76 c-l	6.52 d-j
Gün-91	83.30 a-h	89.00 a-g	2.63 a-c	4.79 a-n	5.33 a-g	0.95 d-k	51.55 a-d	6.61 a-d	7.02 a-e
Population-1	88.60 a-d	93.30 a-d	2.37 a-l	5.46 a-f	3.82 h-p	1.09 b-i	38.65 d-m	5.21 d-l	6.05 h-t
Population-2	88.10 a-e	91.90 a-f	2.04 e-m	5.15 a-j	3.69 j-r	1.14 b-f	32.62 i-t	4.19 g-t	6.65 c-h
Population-4	92.90 a	94.30 a-c	2.09 d-k	5.12 a-k	3.96 f-n	1.12 b-h	34.13 h-r	4.66 e-p	6.09 h-q
Population-5	90.00 a-c	94.80 ab	2.24 a-l	5.25 a-i	3.91 h-o	1.76 a	37.68 f-o	5.13 d-m	6.05 h-r
Population-6	92.90 a	95.70 a	2.15 c-k	5.02 a-l	4.19 e-m	1.14 b-g	38.61 d-e	4.88 d-n	5.95 h-u
Population-9	86.70 a-f	92.40 a-e	2.07 d-l	5.39 a-g	4.24 e-l	1.23 b-d	39.62 d-l	4.86 e-o	7.18 a-d
Population-10	76.20 d-n	88.10 a-i	1.66 k-u	3.95 a-t	3.20 k-u	1.17 b-e	27.22 k-v	3.76 l-v	6.10 h-p
Population-11	82.40 a-i	85.70 a-l	1.72 k-t	4.18 a-r	3.46 j-t	1.24 b	29.44 j-u	4.07 h-u	5.85 h-v
Population-14	78.10 c-k	88.10 a-j	1.89 g-p	4.41 a-q	3.67 j-s	1.24 bc	34.68 h-q	4.41 g-r	6.23 e-o
Population-15	84.80 a-g	88.60 a-h	1.99 f-o	4.55 a-p	3.54 j-t	1.35 b	33.80 h-s	0.64 y	6.40 d-m
Decrease % Cultivars	24.48	19,21	30.97	37.84	36.85	32.63	35.95	39.73	19.34
Decrease % Populations	15.93	9.65	29.95	1,28	24.52	31.81	31,29	87,71	18,52
Decrease % Overall	32.29	24.87	39.19	43.53	46,39	63.63	53.44	51.36	23.02

*Significant at the 0.01, **0.05 significant at the 0.05 probability level, ^{ns}insignificant;

**P<0.01 düzeyinde önemli, **P<0.05 düzeyinde önemli, ^{ns}önemsiz.*

†GR: Germination, GP: Germination power rates, CL: Coleoptile, SL: Shoot, RL: Shoot root lengths, SRLR: Shoot/root length ratio, RFW: Root fresh, RDW: Root fresh dry weights, RFDWR: Root fresh/dry root ratio

†GR: Çimlenme hızı, GP: Çimlenme gücü, CL: Koleoptil uzunluğu, SL: Çim uzunluğu, RL Çim kök boyu, SRLR: Çim/kök uzunluğu oranı, RFW: Kök yaş ağırlığı, RDW: Kök kuru ağırlığı, RFDWR: Kök yaş/kuru ağırlık oranı

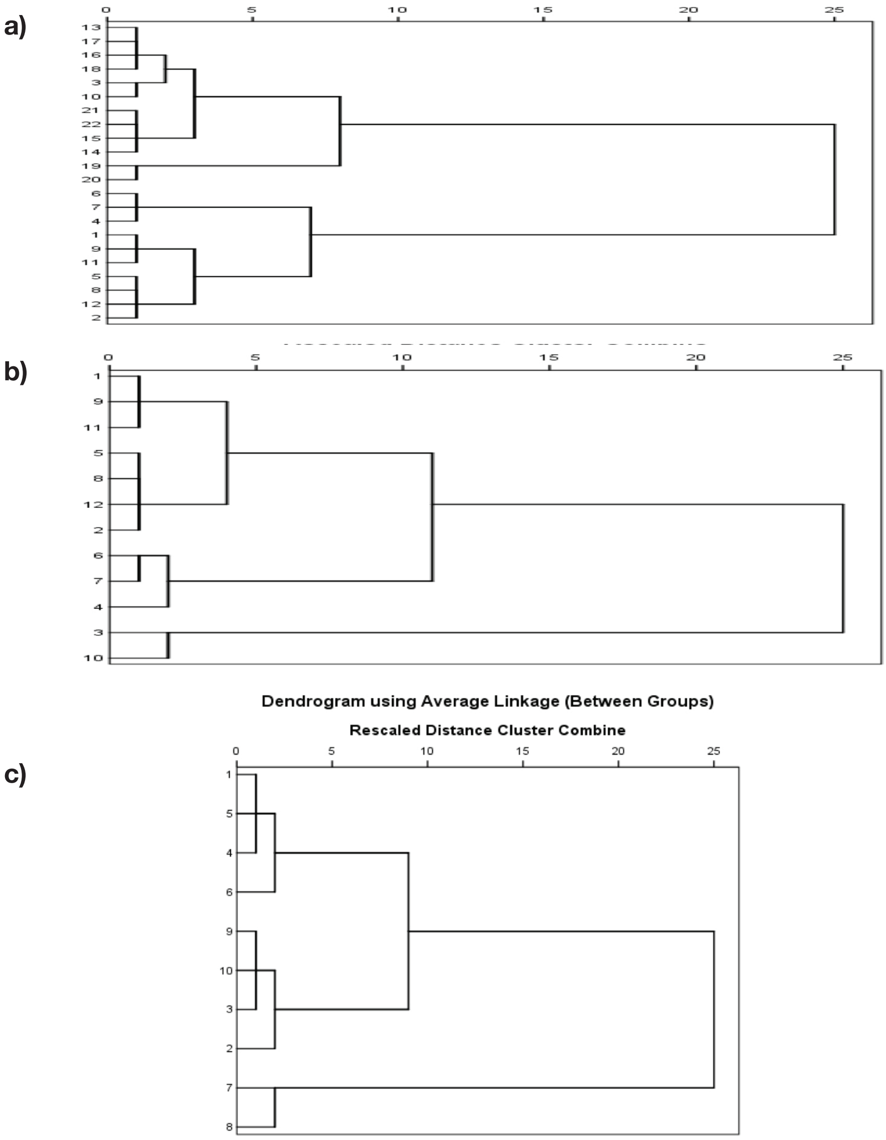

Figure 1. Dendogram for a) both 12 bread and 10 einkorn wheats, b) 12 bread wheats, and c) 10 einkorn wheats

Şekil 1. a) On iki ekmeklik ve 10 siyez buğdayının, b) 12 ekmeklik buğdayın ve c) 10 siyez buğdayının öbek ağacları

primary subgroup of first central group Population-21, Population-22, Population-15 and Population-14 were in the second subgroup of main group 1. Population-19 and Population-20 were the third subgroup of main group 1. The second main group had only bread wheat cultivars: Gerek-79, İkizce-96, Kenanbey, Flamura-85, Momtchil, Bayraktar-2000, Tosunbey and Demir-2000 (Figure 1a). Bread wheat cultivars formed two main dendograms (Figure 1b). Gerek-79, Pandas and Demir 2000 settled in the first sub - group of the main dendogram 1. Population-15 and Population-14 were in the second subgroup of main group Flamura, Tosunbey, Gün-91 and İkizce-96 were in the second, and Momtchil, Bayraktar-2000 and İkizce-96 in the third subgroup of main dendogram 1 (Figure 1b). Einkorn populations (Figure 3c) fitted into three sub groups. Population-21, Population-1, Population-5, Population-4 and Population-9 were in the first sub-sub- group; Population-14, Population-15 and Population-4 were in the second sub-sub-group and Population-10 and Population-11 were the third sub group.

Table 5. Grouping wheat entries into tolerant, moderate, and susceptible by overall wheat drought evaluation indices based on different germination characters

Çizelge 5. Buğdayların değişik çimlenme karakterlerinden elde edilen indislerle tolerant, orta tolerant ve duyarlı olarak gruplanmaları

Entries†	Drought tolerance indices	Stress susceptibility index	Stress tolerance index	Mean productivity	Geometric mean productivity
TOLERANT					
Kenanbey	6.67	0.87	0.93	21.05	9.66
Bayraktar	7.33	0.00	1.00	18.18	9.67
Gün-91	7.44	0.87	0.93	18.51	9.66
Momtchill	9.00	1.30	0.90	20.30	9.49
Population-9	9.00	0.87	0.93	16.12	9.66
İkizce-96	9.00	1.39	0.89	18.63	8.82
MODERATE					
Gerek-79	9.22	1.30	090	17.84	9.49
Population-5	9.78	0.43	0.97	15.98	9.83
Demir-2000	9.89	1.34	090	17.59	915
Population-1	10.33	0.87	0.93	17.49	9.66
Population-6	10.67	0.00	1.00	17.96	10.00
Population-4	11.33	0.00	1.00	15.55	10.00
Population-2	12.22	0.87	093	14.69	9.66
Pandas	12.44	1.30	090	18.53	9.49
Tosunbey	12.78	2.17	0.83	19.14	9.13
Population-15	13.78	0.00	1.00	15.33	10.00
SUSCEPTIPLE					
Pehlivan	14.00	1.79	0.86	16.36	8.98
Flamura-85	14.00	0.93	0.93	18.24	8.99
Population-14	14.22	0.45	0.97	16.17	9.50
Kıraç 66	16.22	1.86	0.86	1611	8.64
Population-11	16.56	-0.08	0.90	14.82	9.49

†Genotypes were ordered based on drought tolerance indices.

†Genotipler, kuraklık tolerans endekslerine göre sıralanmıştır.

In previous studies, there had been some similar and dissimilar results to what we found here. Different germination percentages for wheat genotypes were also observed by Sapra et al. (1991), Kumar and Singh (1998), and Dhanda et al. (2004) under low water conditions. In a study by Öztürk et al. (2016), the average germination (94.9%) significantly decreased (67.7%) below minus 5 bar osmotic potential. Delayed germination and decreased percentage in wheat (Lafond and Fowler, 1989; Dhanda et al.2004; Razzaq et al. 2013) were noted. RL, RFW, and RDW decreased (Dhanda et al., 2004; Rauf et al., 2007; Ahmadizadeh et al., 2011; Baloch et al., 2012) with increased drought stress. RLs in Rauf et al. (2007) study decreased 45.55 to 64.91% under –0.6 and –0.8 MPa treatments, respectively. Baloch et al. (2012) and Dhanda et al. (2004) similarly observed a 53.8-74.4% decreased RLs in wheat genotypes as well.

The drought tolerance indices, which was based on the ranks of cultivars/populations together with other (El - Hendawy et al. 2005; Mahmoodzadeh et al. 2013; Ali and El – Sadek, 2016) indices were calculated to group wheat entries. Drought tolerance indices, as informed by Zencirci et al. (1990) and Oyiga et al. (2016) grouped the entries as tolerant, moderate, and susceptible (Table 5). As seen

Table 6. a. Pearson correlation coefficients amongst GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR in drought stress

Çizelge 6. a. Kurak stresi altında GR, GP, CL, SL, RL, SRLR, RFW, RDW ve RFDWR arasındaki Pearson korelasyon katsayıları

Characters	GR†	GP	CL	SL	RL	SRLR	RFW	RDW
RFDWR	0.419	0374	0.708	0.812	0.747	0.621	0.783	0.915
RDW	0.674	0.650	0.893	0.722	0.924	0.513	0.915	-
RFW	0.636	0.605	0.923	0.889	0.976	0.633	-	
SRLR	0.413	0.381	0.687	0.758	0.610	-		
RL	0.655	0.621	0.915	0.857				
SL	0.525	0.488	0.877	-				
CL	0.627	0.593	-					
GP	0.926	-						

†GR: Germination, GP: Germination power rates, CL: Coleoptile, SL: Shoot, RL: Shoot root lengths, SRLR: Shoot/root length ratio, RFW: Root fresh, RDW: Root fresh dry weights, RFDWR: Root fresh/dry root ratio

†GR: Çimlenme hızı, GP: Çimlenme gücü, CL: Koleoptil uzunluğu, SL: Çim uzunluğu, RL Çim kök boyu, SRLR: Çim/kök uzunluğu oranı, RFW: Kök yaş ağırlığı, RDW: Kök kuru ağırlığı, RFDWR: Kök yaş/kuru ağırlık oranı

Table 6. b. Spearman correlation coefficients among GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under drought and control (no-drought)

Çizelge 6. b. Kurak stresi control koşullarında GR, GP, CL, SL, RL, SRLR, RFW, RDW ve RFDWR arasındaki Pearson korelasyon katsayıları

Characters	GR†	GP	CL	SL	RL	SRLR	RFW	RDW
UNDER DROUGHT								
RFDWR	-0.26††	-0.12	0.20	0.86	0.50	0.22	0.46	0.18
RDW	-0.13	-0.10	0.83	-0.01	0.67	0.47	0.46	
RFW	-0.14	0.08	0.62	0.63	0.86	0.38	-	
SRLR	-0.45	-0.67	0.73	0.35	0.56	-		
RL	-0.17	-0.30	0.61	0.83	-			
SL	-0.18	-0.46	0.84	-				
CL	-0.12	-0.29	-					
GP	0.70	-						
Characters	GR†	GP	CL	SL	RL	SRLR	RFW	RDW
CONTROL								
RFDWR	0.36††	-0.28	0.16	0.86	0.32	-0.33	0.44	0.02
RDW	-0.37	0.23	-0.09	-0.08	0.79	-0.36	0.44	-
RFW	-0.15	0.13	-0.01	-0.24	0.86	-0.47	-	
SRLR	0.22	0.01	0.41	-0.25	-0.45	-		
RL	-0.09	0.14	-0.11	0.27	-			
SL	0.34	-0.05	0.57	-				
CL	0.46	0.03	-					
GP	0.16	-						

††Significance at 0.01 is 0.549 and at 0.05 is 4.33

††0.01 de önemlilik 0.549 ve 0.05 de 4.33'tür.

†GR: Germination, GP: Germination power rates, CL: Coleoptile, SL: Shoot, RL: Shoot root lengths, SRLR: Shoot/root length ratio, RFW: Root fresh, RDW: Root fresh dry weights, RFDWR: Root fresh/dry root ratio

†GR: Çimlenme hızı, GP: Çimlenme gücü, CL: Koleoptil uzunluğu, SL: Çim uzunluğu, RL Çim kök boyu, SRLR: Çim/kök uzunluğu oranı, RFW: Kök yaş ağırlığı, RDW: Kök kuru ağırlığı, RFDWR: Kök yaş/kuru ağırlık oranı

Table 7. Three basic germination character PC coefficients with variations and explained variances in each of them.

Çizelge 7.Çimlenme karakterlerinin üç ana AB katsayılarıyla her bir karakterdeki varyasyonlar ve açıkladıkları varyasyon değerleri

Characters	Principal components			Sums of squared	
	1	2	3	% of variance	Cumulative %
SL	0.038	0.305	-0.105	73.491	73.491
SRLR	-0.513	0.822	0.092	12.666	86.157
CL	0.257	-0.019	-0.062	6.097	92.254
GP	-0.248	-0.015	0.622		
GR	-0.235	0.003	0.593		
RL	0.378	-0,160	-0,083		
RDW	0.494	-0.385	-0.027		
RFW	0.354	-0.107	-0.103		
RFDWR	-0.012	0.359	-0.166		

†GR: Germination, GP: Germination power rates, CL: Coleoptile, SL: Shoot, RL: Shoot root lengths, SRLR: Shoot/root length ratio, RFW: Root fresh, RDW: Root fresh dry weights, RFDWR: Root fresh/dry root ratio

†GR: Çimlenme hızı, GP: Çimlenme gücü, CL: Koleoptil uzunluğu, SL: Çim uzunluğu, RL Çim kök boyu, SRLR: Çim/kök uzunluğu oranı, RFW: Kök yaş ağırlığı, RDW: Kök kuru ağırlığı, RFDWR: Kök yaş/kuru ağırlık oranı

from the Table 5, Kenanbey, Bayraktar-2000, Gün-91, Momtchill, Population-9 and İkizce-96 were tolerant; Pehlivan, Flamura - 85, Population-14, Kıraç-66, Population-11 and Population-10 were susceptible. Stress susceptibility and tolerance index, mean and geometric mean productivity were compared according to Ali and El – Sadak (2016) were not related with the drought tolerance indices.

Shoot lengths, which were highly susceptible to stress (Baloch et al. 2012) significantly differed (57.5–68.4%) under stress (Naylor and Gurmu, 1990; Dhanda et al., 2004; Rauf et al., 2007). SL, which was also the plant characteristic under stress (Jajarmi 2009) had positively and significantly correlated with GR, RL, and (Rauf et al., 2007). CL in older seed and coleoptile emergence in general were restricted under low water potential (Naylor and Gurmu, 1990). Wheat genotypes, as expected, responded differently against drought stress and their developments decreased 70.02 - 85.34% at –0.6 to–0.8 MPa compared to no normal (Ahmadizadeh et al., 2011). A longer coleoptile, which was expected to play a significant role in seedling establishment (Baloch et al., 2012) was observed. Shoot length and seed vigor index decreased (Öztürk et al., 2016; Naylor and Gurmu, 1990; Dhanda et al., 2004), which indicated greater susceptibility of shoot than root length.

Not many correlation coefficients have been calculated in the previous studies, comparison, therefore, was hardly possible. Dhanda et al. (2004) found that genotypic correlations were calculated higher than the phenotypic ones in the alike course, which indicated the characteristic links in numerous types. Root-to-shoot length ratio (Siddique et al.,1990; Sharma and Lafever, 1992) presented lower associations with further characters under usual conditions, but under osmotic pressure it was undesirably linked with shoot length ($r = 0.42$, $P<0.01$) and membrane thermal constancy ($r = 0.42$, $P<0.05$), which indicated that the subversive part of the plants carried a vital role under drought stress circumstances. Similarly, in our study, characters were much more and highly correlated under stress than they were under no-stress conditions.

Conclusions

Drought is one of the severe ecological stress issues across all wheat growing regions. It disturbs wheat differently at various growth stages, of which the worst at the germination and early stages. Genetic differences and heritability of the characters under pressure is somewhat a straight outcome of great environmental alterations (variance) within the stress environment (Blum 1989 and partly a result of the conquest of genetic inconsistency under such circumstances (Ludlow and Muchow, 1990). Entire appeals were worsened by increased stress levels. Determining new genetic resources against drought stress, developing new laboratory and/or field screening techniques for drought testing, and utilization of modern physiological and molecular ways to better understand drought mechanisms would bring more drought resistant gene pools and improved cultivars with sustainably higher yields into use.

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