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Variability for Drought Stress Effects on Seedling Growth in Bread Wheat (*Triticum aestivum* L.) Genotypes**

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ABSTRACT

The study was carried out under different drought/osmotic stresses (0.00 MPa-control, 0.25 MPa, 0.50 MPa, 0.75 MPa and 1.00 MPa applications) created by using PEG 6000 with 43 genotypes under laboratory, with 5 replications according to a split-plot experiment design. The genotypes constituted the main plots, and the drought/osmotic stress applications constituted the sub-plots.

In the study, seedling weight, root number, root length, root weight, shoot length, and shoot weight characters were determined. It was determined that drought stress applications caused statistically significant decreases in root and shoot characters. Osmotic stress of, 1.00 MPa and 0.75 MPa caused statistically significant reductions in root and shoot characters. The results indicated that early and mid-early varieties were more tolerant to drought than the late varieties. Although Aglika, Anapo, Enola and Hamza varieties were outstanding for their root properties, while Maden, NKU Ergene and Bezostaja-1 cultivars showed more appropriate shoot characteristics than other cultivars. Enola, Aglika, Bezostaja-1, NKU Ergene, Anapo, Hamza and Maden bread wheat varieties showed better growth characteristics under drought stress conditions in the study.

Keywords: Bread wheat, seedling, drought, PEG, root, shoot

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Introduction

World wheat production in 2020 was 780 million tons, and in Turkey, it was 20.5 million tons (FAO, 2021). Along with the increasing population around the world, it is necessary to consider the quality and yield factors as well as the varieties that have adapted to abiotic and biotic stresses in the regions where the food demand is increasing (Güngör and Dumlupınar, 2019). Drought which is one of the most common abiotic stress factors is the most important factor limiting crop production in most agricultural areas. Wheat production is generally carried out in dry agricultural areas and drought often causes serious problems in wheat production in these areas.

The decrease in productivity under drought stress conditions is one of the most important factors threatening global food production (Fahad et al., 2017). High temperatures occurring due to global climate change increase the drying rate of agricultural soils and cause higher drought stress to occur (Fischer and Knutti, 2015). Therefore, it is important for plants to withstand long-term water deficiencies, adapt to these environments, and improve the plants' ability to recover from water deficiencies. Stress tolerance of plants and the ability of plants to maintain productivity during stress periods is a complex phenotypic trait (Ngumbi and Kloepper, 2016). Plants have numerous mechanisms to tolerate drought stress down to cellular levels, such as root structure, above-ground growth, osmotic adjustment, water use optimization, and management of reactive oxygen species (Meena et al., 2017). With regard to plant growth and development, changes in root system architecture, especially the proliferation of high-grade roots, are known to be beneficial in short-term adaptation to water deficiency (Xu et al., 2015).

Drought is one of the most important environmental stress factors limiting crop production in many countries of the world. Insufficient/irregular precipitation and high temperature during the year are the main factors causing drought. One of the most important research approaches to minimize the effects of drought is the breeding of drought-resistant varieties. However, it is difficult to develop studies on this subject unless the mechanism of drought resistance and the parameters that reflect it are well understood. In arid conditions, plants reduce all enzyme activity, slow down their growth, cause the closure of stomata, causing a decrease in CO_2 assimilation (Baranyiova et al., 2014). More than 50% of wheat growing areas are affected by periodic drought. Although drought affects wheat development in all phenological periods, its greatest negative effect occurs during pollination and grain filling periods. While mild drought after pollination reduces wheat yield by 1-30%, mild drought during flowering and grain filling period reduces grain yield up to 58-92% (Farooq et al., 2014). Grain yield is affected by the interaction of genetic and environmental factors. Soil type, sowing time, sowing method, sowing frequency, fertilization and irrigation time, spacing between rows have an important role in obtaining high yields. Water stress significantly affects yield components such as the number of grains per spike and the number of spikes per plant (Aghanejad et al., 2015).

The study was carried out to identify drought resistant genotypes, which is one of the most important problems in cereal production in our country. In the study, a total of 43 genotypes, including thirty nine bread wheat, one rye, one emmer and two einkorn wheat genotypes with different growth characteristics, were used as material. Seedling and root development characteristics of these genotypes were investigated in a drought environment created with polyethylene glycol (PEG) in the laboratory.

Materials and Methods

In the study, thirty nine bread wheat, one rye, one emmer and two einkorn varieties were used as material. The research was carried out according to split-plot design in 5 different drought conditions (0.00 MPa, 0.25 MPa, 0.50 MPa, 0.75 MPa and 1.00 MPa applications) created with PEG 6000 in laboratory conditions. For sterilization, seeds were kept in 80% alcohol for 1 minute, then put into a mixture of 2% sodium hypochlorite with 2-3 drops of tween, shaken for 20 minutes and then washed 4-5 times in autoclaved sterile water. Sterile filter paper was placed in the petri dish sterilized in autoclave under a sterile cabinet and 10 ml of PEG solution was applied to the filter paper. Fifteen sterilized seeds were placed on the filter papers to which PEG solution was added. After the seeds were placed in the petri dishes, filter paper was placed on the seeds and the lid of the petri dish was closed. Petri dishes with closed lids were wrapped with cling film. Then the petri dishes were placed in the climate chamber. After 3 weeks, the seedling weight, root number, root length, root weight, shoot length and shoot weight values were determined in the germinated seedlings under stress created by PEG in each petri dish.

Results and Discussion

In the present study, seedling weight, root number, root length, root weight, shoot length and shoot weight values were measured in plants growing in 5 different drought conditions created with PEG 6000 in forty-three genotypes. Differences between genotypes were determined by performing analysis of variance and significance testing on the values obtained. As a result of the analysis of variance, the effect of PEG application on the examined characters was found to be statistically significant.

Seedling Weight, Root Number and Root Length

As a result of the analysis of variance, the effects of genotype and PEG application on seedling weight, root number and root length were found to be statistically significant. The results of the significance test (Tukey) performed revealed the differences between the applications are given in Table 1.

As a result of the significance test (Table 1), the highest value for seedling weight was found in Enola cultivar with 0.343 g. Aglika, NKU Ergene, Bezostaja-1, Falado, Anopa, Maden, NKU Lider, Ambrosia, Hamza, Bora, Anica and Selimiye statistically at par. Similar Enola. Pannonia, Quality, Hakan, Mihelca, Refikbey and Adelaide varieties were grouped together. The lowest value for seedling weight was obtained from Siyez-1 with 0.161 g. Siyez-2, Maya, Rebelde, Emmer colour, Esperia, Golia and Başkan varieties were in the same statistical group as Siyez-1.

According to the significance test, when the number of roots was examined, the highest value was found in Aglika genotypes with 5.4 unit and Quality genotypes with 5.3 unit, followed by Esperia and NKU Lider. Aglika and Quality genotypes. The lowest value for root number was seen in the Başkan variety with 3.0 unit. Emmer colour, NKU Ergene, Misiia Odes'ka, Rumeli, Masaccio, Adelaide, Ducato, Krasunia Odes'ka, Genesi varieties were in the same statistical group with the Başkan.

According to the results of the significance test, the genotype with the longest root with a root length of 24.80 cm was NKU Ergene. Hakan, Falado and Kaan varieties followed and ranked subsequent for root length. While the genotype with the lowest value for root length was Emmer colour with 5.867 cm. Siyez-2, Siyez-1 and Aldane followed this variety.

Average values and important groups for seedling weight, root number and root length obtained in PEG dose applications are given in Table 2.

When the effects of different PEG applications on the seedling weight were examined, the seedling weight varied between 0.280 - 0.230 g. The highest seedling weight was obtained in the control application with 0.280 g, followed by 0.25 MPa PEG application (0.265 g). The lowest seedling weight value of 0.230 g was obtained in the highest PEG application. This was followed by seedling weight obtained in 0.75 MPa PEG application. The results revealed that PEG application slowed down the water uptake of the plants and caused significant reductions in plant weight. It has been determined that root properties are affected significantly under water stress and decreases in characters such as root length and root dry matter ratio (Adda et al., 2005; Öztürk and Korkut, 2018).

When the effect of different PEG doses on the root length of the genotypes was examined, it was observed that the root length varied between 16.62 and 13.59 cm. The maximum root length was seen in the 0.25 MPa dose application with 16.62 cm. The control application with 16.031 cm and the 0.50 MPa dose application with 15.895 cm were in the same statistical group with the 0.25 MPa dose application. The lowest root lengths were obtained with 13.59 cm and 14.11 cm in 0.75 and 1.0 MPa applications.

It was observed that there was a change between 0.0710 g and 0.0516 g for root weight in different doses of PEG applications. The highest value was obtained in the control application with 0.071 g. The data obtained on root weight in different PEG applications revealed that there was a decrease in root weight as the PEG dose increased, but the differences were statistically insignificant. There was a significant decrease in the characters examined after the drought stress level of 5.0 bar in wheat varieties (Dolgun and Çiftçi, 2018).

Root Weight, Shoot Weight and Shoot Length

According to the variance analysis results, the effects of genotype and PEG applications on root weight, shoot length and shoot weight were statistically significant. Tukey test results, which were performed to see the significance between applications are given in Table 3.

According to the significance test, the highest root weight was from Enola genotype with 0.0862 g. Bora, Anopa, Ambrosia and Iveta varieties were found in the same statistical group as Enola. While the lowest root weight was 0.0210 g in Emmer colour genotype, Siyez-1, Siyez-2, Ducato, Enargo and Maya were followed by this genotype. In the significance test, it was observed that the highest shoot length was from Maden variety with 20,067 cm. Bezostaja-1, NKU Ergene, Hakan, Selimiye, Sarı Mustafa, Enargo and Prima varieties were in the same statistical group with this genotype. The lowest shoot length was found in Emmer colored genotype with 11,400 cm. Ambrosia, NKU Asiya, Iveta and Siyez-2 genotypes were ranked after Emmer colored genotype. In bread wheat cultivars, osmotic stress significantly reduced root length, seedling length and root fresh weight during germination and early seedling development (Balkan and Gençtan, 2013)

In the significance test, the highest value in terms of shoot weight was in Selimiye variety with 0.1554 g, Maden, Enola, Bezostaja-1, NKU Ergene, Prima and TT601 genotypes were calculated in the same statistical group with Selimiye genotype. The lowest value for shoot weight was determined in Siyez-2 with 0.0665 g. Siyez-1, Emmer colored, Maya, Rebelde, NKU Asiya, Başkan, Almeria and Masaccio genotypes were in the same statistical group as Siyez-2. Average values of root weight, shoot length and shoot weight and importance groups in PEG dose applications were given in Table 4.

When the effects of different PEG applications on root weight were examined, it was seen that root weights varied between 0.0710-0.0516 g. The highest root weight was obtained with 0.0710 in 0.00 MPa PEG application. The lowest root weight was obtained with 0.534 g and 0.0516 g in the highest applications, 0.75 and 1.0 MPa PEG applications. Obtained results showed that root weight decreased with increasing PEG dose.

It is seen that shoot length varied between 15.632 cm and 13.760 cm in different PEG applications. The highest shoot length was obtained with 15.632 cm in 0.25 MPa PEG application and 15.392 cm in plants without PEG application. The lowest shoot length was obtained with 13.760 cm from 0.75 MPa PEG application, followed by the highest dose of 1.00 MPA PEG application with 14.240 cm. The results showed that the shoot length decreased as the PEG dose increased.

When the data on shoot weight of different PEG applications were examined, the highest values were 0.1358 g in 0.25 MPa PEG application and 0.1334 g in

0.00 MPa PEG application respectively. The lowest shoot weight was 0.1072 g and 0.1079 g in 0.75 and 1.00 MPa PEG applications were obtained. In wheat, germination rate, root length and shoot length were significantly decreased in drought stress as a result of increase in PEG 6000 concentration (Hossein Pour et al., 2013).

Conclusions

In this study, seedling weight, root number, root length, root weight, shoot length and shoot weight characters were determined in the drought stress created with different PEG doses. In this study carried out with 43 genotypes, 1.00 MPa and 0.75 MPa applications of PEG 6000 caused statistically significant reductions in root and shoot characters. The results indicated that early and mid-early varieties were more tolerant to drought than the late varieties. Although Aglika, Anapo, Enola and Hamza varieties were outstanding for their root properties, while Maden, NKU Ergene and Bezostaja-1 cultivars showed more appropriate shoot characteristics than other cultivars. Enola, Aglika, Bezostaja-1, NKU Ergene, Anapo, Hamza and Maden bread wheat varieties showed better growth characteristics under drought stress conditions in the study.

Table 1. Average values and importance groups for seedling weight, root number and root length.

Genotypes	Seedling Weight (g)	Genotypes	Root Number (Unit)	Genotypes	Root Length (cm)
Enola	0.343 a	Aglika	5.400 a	Hakan	24.800 a
Aglika	0.306 ab	Quality	5.333 a	Falado	21.533 ab
NKU Ergene	0.296 abc	Esperia	5.200 ab	Kaan	21.067 abc
Bezostaja-1	0.293 a-d	NKU Lider	5.133 abc	Mihelca	20.667 a-d
Falado	0.284 a-e	Bora	5.067 a-d	Adelaide	18.267 b-e
Anopa	0.282 a-e	Anopa	5.067 a-d	Refikbey	18.233 b-e
Maden	0.282 a-e	Rebelde	5.000 a-e	Misiia Odes.	18.100 b-f
NKU Lider	0.280 a-e	TT 601	4.867 a-f	Golia	17.833 b-g
Ambrosia	0.278 a-e	Enola	4.867 a-f	Krasunia Odes.	17.567 b-h
Hamza	0.277 a-e	Hamza	4.667 a-g	Enola	17.133 b-ı
Bora	0.277 a-e	Almeria	4.667 a-g	Pannonia	17.033 b-ı
Anica	0.276 a-f	Golia	4.667 a-g	Rumeli	17.000 b-ı
Selimiye	0.274 a-f	Anica	4.667 a-g	Maden	16.900 c-ı
Pannonia	0.271 b-f	Bezostaja-1	4.600 a-h	Rebelde	16.900 c-ı
Quality	0.268 b-f	Prima	4.600 a-h	Quality	16.800 c-ı
Hakan	0.266 b-f	Selimiye	4.467 a-ı	Sarı Mustafa	16.700 c-j
Mihelca	0.266 b-f	Siyez-1	4.467 a-ı	NKU Asiya	16.533 c-j
Refikbey	0.265 b-f	Iveta	4.400 a-j	Prima	16.333 d-k
Adelaide	0.262 b-f	LG59	4.400 a-j	Iveta	16.067 e-l
TT 601	0.258 b-f	NKU Asiya	4.267 b-j	Selimiye	15.667 e-l
LG59	0.256 b-f	Maya	4.267 b-j	Başkan	15.467 e-m
Iveta	0.253 b-f	Aldane	4.200 b-j	Hamza	15.067 e-m

Continuing table 1

Genotypes	Seedling Weight (g)	Genotypes	Root Number (Unit)	Genotypes	Root Length (cm)
Ducato	0.253 b-f	Refikbey	4.200 b-j	Bezostaja-1	14.800 e-m
Aldane	0.250 b-f	Ambrosia	4.200 b-j	Almeria	14.633 e-n
Misiia Odes.	0.246 b-f	Siyez-2	4.133 c-k	Bora	14.433 e-n
Masaccio	0.246 b-f	Enargo	4.067 d-k	Aglika	14.200 e-n
Prima	0.245 b-f	Pannonia	4.000 e-l	LG59	13.933 e-n
NKU Asiya	0.244 b-f	Falado	3.933 f-l	Genesi	13.867 e-n
Enargo	0.240 b-f	Kaan	3.800 g-l	Anica	13.700 e-n
Sarı Mustafa	0.238 b-f	Mihelca	3.800 g-l	Anopa	13.633 f-n
Almeria	0.236 b-g	Sarı Mustafa	3.800 g-l	Maya	13.467 g-n
Genesi	0.234 c-g	Maden	3.733 g-l	TT601	13.233 h-n
Kaan	0.233 c-g	Hakan	3.600 h-l	Ambrosia	12.733 ı-n
Rumeli	0.233 c-g	Genesi	3.600 h-l	Ducato	12.700 ı-n
Krasunia Odes.	0.232 c-g	Krasnia Odes.	3.600 h-l	Masaccio	12.600 ı-o
Başkan	0.227 c-h	Ducato	3.533 ı-l	Esperia	12.200 j-o
Golia	0.225 c-h	Adelaide	3.533 ı-l	Enargo	11.833 k-o
Esperia	0.223 d-h	Masaccio	3.467 ı-l	NKU Lider	11.667 l-o
Emmer c.	0.213 e-h	Rumeli	3.467 ı-l	Aldane	10.967 mno
Rebelde	0.205 fgh	Misiia Odes.	3.400 jkl	Siyez-1	10.067 nop
Maya	0.205 fgh	NKU Ergene	3.400 jkl	Siyez-2	8.033 op
Siyez-2	0.165 gh	Emmer c.	3.133 kl	Emmer c.	5.867 p
Siyez-1	0.161 h	Başkan	3.000 l		

The identical letters indicate statistical groups of identical values with a 99.0% confidence level by the Student-Newman-Keul Test (SNKT)

Table 2. Average values and importance groups of seedling weight, root number and root length.

PEG Doses (MPa)	Seedling Weight (g)	PEG Doses (MPa)	Root Number (Unit)	PEG Doses (MPa)	Root Length (cm)
0.00	0.280 a	0.75	4.473 a	0.25	16.620 a
0.25	0.265 ab	0.50	4.302 a	0.00	16.031 a
0.50	0.252 bc	1.00	4.271 ab	0.50	15.895 a
0.75	0.237 cd	0.00	4.054 bc	1.00	14.109 b
1.00	0.230 d	0.25	4.023 c	0.75	13.589 b

Table 3. Average values and importance groups of root weight, shoot length and weight in genotypes.

Genotypes	Root Weight (g)	Genotypes	Shoot Length (cm)	Genotypes	Shoot Weight (g)
Enola	0.0862 a	Maden	20.067 a	Selimiye	0.1554 a
Bora	0.0799 ab	Bezostaja-1	18.833 ab	Maden	0.1538 ab
Anopa	0.0771 abc	NKU Ergene	18.633 abc	Enola	0.1531 a-c
Ambrosia	0.0765 abc	Hakan	18.100 a-d	Bezostaja-1	0.1511 a-d
Iveta	0.0762 abc	Selimiye	17.800 a-e	NKU Ergene	0.1507 a-d
Pannonia	0.0716 a-d	Sarı Mustafa	17.333 a-f	Prima	0.1433 a-e
Aglika	0.0714 a-d	Enargo	16.667 a-g	TT601	0.1423 a-e
Hamza	0.0699 a-e	Prima	16.600 a-h	Refikbey	0.1351 a-f
Mihelca	0.0691 a-f	Falado	16.233 b-ı	Aglika	0.1345 a-f
NKU Asiya	0.0691 a-f	Kaan	16.167 b-ı	Hakan	0.1331 a-f
Falado	0.0689 a-f	Anica	15.733 b-j	Falado	0.1329 a-f
Adelaide	0.0672 a-g	Rumeli	15.733 b-j	Enargo	0.1309 a-f
Quality	0.0669 a-g	Aglika	15.667 b-j	Anopa	0.1305 a-f
LG 59	0.0668 a-h	Refikbey	15.600 b-k	Hamza	0.1292 a-f
Bezostaja-1	0.0647 a-h	Enola	15.600 b-k	Golia	0.1274 a-f
Misiia Odes.	0.0637 a-h	Hamza	15.233 c-k	Aldane	0.1271 a-f
NKU Lider	0.0634 a-h	TT601	14.867 d-l	Mihelca	0.1263 a-f
Masaccio	0.0631 a-h	Misiia Odes.	14.767 d-l	Sarı Mustafa	0.1258 a-f
Hakan	0.0628 a-h	Esperia	14.667 d-l	Bora	0.1256 a-f
Kaan	0.0614 a-h	Masaccio	14.433 e-l	NKU Lider	0.1247 a-f
Krasunia Odes.	0.0607 a-h	Golia	14.400 e-l	Quality	0.1229 a-f
NKU Ergene	0.0603 b-h	Krasunia Odes.	14.267 f-l	Anica	0.1225 a-f
Anica	0.0601 b-h	Almeria	14.167 f-l	Ambrosia	0.1218 a-f
TT 601	0.0596 b-h	Quality	14.167 f-l	Pannonia	0.1197 a-f
Refikbey	0.0579 b-h	NKU Lider	14.067 f-l	Adelaide	0.1170 a-g
Esperia	0.0575 b-h	Pannonia	13.900 f-l	LG 59	0.1170 a-g
Rumeli	0.0575 b-h	Anopa	13.767 g-l	Ducato	0.1169 a-g
Almeria	0.0571 b-h	Aldane	13.700 g-l	Misiia Odes.	0.1154 a-g
Rebelde	0.0539 c-ı	Rebelde	13.633 g-l	Kaan	0.1146 a-g
Başkan	0.0520 c-ı	Genesi	13.467 g-l	Genesi	0.1139 a-g

Continuing table 3

Genotypes	Root Weight (g)	Genotypes	Shoot Length (cm)	Genotypes	Shoot Weight (g)
Aldane	0.0487 d-j	Bora	13.433 g-l	Krasunia Odes.	0.1135 a-g
Golia	0.0475 d-j	Mihelca	13.400 g-l	Rumeli	0.1117 b-g
Genesi	0.0472 d-j	Siyez-1	13.300 g-l	Iveta	0.1097 c-h
Prima	0.0451 e-k	Adelaide	13.300 g-l	Esperia	0.1085 d-h
Selimiye	0.0447 e-k	Başkan	13.267 g-l	Masaccio	0.1060 e-h
Maden	0.0443 e-k	Maya	13.133 h-l	Almeria	0.1044 e-h
Sarı Mustafa	0.0441 f-k	LG 59	12.967 ı-l	Başkan	0.1040 e-h
Maya	0.0429 g-k	Ducato	12.933 ı-l	NKU Asiya	0.1034 e-h
Enargo	0.0421 g-k	Siyez-2	12.600 jkl	Rebelde	0.1031 e-h
Ducato	0.0411 h-k	Iveta	12.467 jkl	Maya	0.1009 e-h
Siyez-2	0.0307 ıjk	NKU Asiya	12.267 jkl	Emmer c.	0.0949 fgh
Siyez-1	0.0246 jk	Ambrosia	12.167 kl	Siyez-1	0.0749 gh
Emmer c.	0.0210 k	Emmer c.	11.400 l	Siyez-2	0.0665 h

The identical letters indicate statistical groups of identical values with a 99.0% confidence level by the Student-Newman-Keul Test (SNKT)

Table 4. Average values and significance groups of root weight, shoot length and weight.

PEG Doses (MPa)	Seedling Weight (g)	PEG Doses (MPa)	Shoot Length (cm)	PEG Doses (MPa)	Shoot Length (cm)
0.00	0.0710 a	0.25	15.632 a	0.25	0.1358 a
0.25	0.0574 b	0.00	15.392 ab	0.00	0.1334 a
0.50	0.0569 b	0.50	14.802 bc	0.50	0.1222 b
0.75	0.0534 b	1.00	14.240 cd	0.75	0.1079 c
1.00	0.0516 b	0.75	13.760 d	1.00	0.1072 c

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