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EFFECT OF DROUGHT STRESS ON YIELD AND QUALITY TRAITS OF COMMON WHEAT DURING GRAIN FILLING STAGE

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ABSTRACT

Wheat (*T. aestivum*) has a crucial role for human diet especially in developing countries. Changes in precipitation intensity, amounts and patterns restrict wheat growth and productivity under rainfed conditions. Thus, assessment of drought effects during growth stages of wheat on grain yield and quality traits has substantial importance. Grain filling stage, coincides with early spring when the rainfall pattern highly variable, was considered in this study to evaluate effects of drought conditions on yield and quality of 16 wheat genotypes and determine superior varieties. Drought treatment inhibited plant height (5.5 %), 1000 grain weight (9.2 %) and grain yield (17.7 %) while harvest index increased (8.5 %). However, there was no significant effect of drought conditions on grains number spike^{-1} and spike numbers m^{-2}. Protein content increased (31.6 %) in all genotypes, while the Zeleny sedimentation significantly decreased (8.2 %) with drought treatments during both growing seasons. Cultivars Pandas and Meta had higher grain yield under drought stress in both years whereas Line-28 and Pandas had better quality properties.

Keywords: bread wheat, drought, grain filling, quality, *Triticum aestivum,* yield

INTRODUCTION

Wheat is the major crop, which is grown over 200 million ha land and provides approximately one-fifth of total calorie need in human nutrition worldwide (Braun et al., 2010). Hence, yield reduction in wheat production due to adverse environmental conditions, may cause serious nutritional and economic consequences. Drought caused by fluctuations in precipitation regime related to global warming and climate change, is one of the major environmental factors which constraints yield potential in crop production. Therefore, drought conditions induced by climate change is expected to be the most important risk factor which affects wheat production (Acevedo et al., 1999) since it is mostly cultivated in arid or semi-arid regions and grain yield highly depends on the annual precipitation amount and regime (Cai et al., 2012; Luo et al., 2018). Thus, developing new drought tolerant wheat cultivars is one of the main objectives for current wheat breeding programs worldwide (Gálvez et al., 2018).

Drought decreases plant water status, inhibits photosynthesis, induces oxidative water stress, restricts growth and finally lead to yield reduction in wheat (Wang et al., 2018). However, drought affects wheat growth in different ways depending on its timing, duration and intensity (Tatar et al., 2016). Rainless periods and water scarcity might be experienced during all growth stages of wheat but the effects of drought are more remarkable during post-anthesis and grain filling stages (Istipliler et al., 2017). Mehraban et al. (2019) evaluated yield performances of 10 bread wheat cultivars under drought stress at three different growth stages including tillering, booting and post-anthesis. They have suggested that drought in pre-anthesis stages was critical for grain number per unit area, while drought in post-anthesis stage adversely affected the grain weight. In another research, significant yield losses were also recorded during post-anthesis under drought conditions in seven bread wheat genotypes (Ilker et al., 2011). Besides timing of drought period, severity of the stress conditions is also important. Thapa et al. (2019) reported that evapotranspiration, biomass production and eventually grain yield decreased consistently from higher to lower water treatments (100%, 75%, 65% and 50% of evapotranspiration). According to the meta-analysis of Zhang et al. (2018), grain yield reduction of wheat changes 21 % to 32 % in mild and severe drought conditions respectively. In addition to grain yield, variation in quality traits such as protein content, Zeleny sedimentation and falling number under drought conditions are also reported (Bella et al., 2011). Increasing protein content of wheat grains under limited water conditions has been previously reported by several studies (Gooding et al., 2003; Shahzad et al., 2018; Barutcular et al., 2016). However, drought effect on Zeleny sedimentation value, for instance, is still not clear. Barić et al. (2006) found higher Zeleny sedimentation value under drought conditions, while

Barutcular et al. (2016) reported non-significant change. According to findings of Gooding et al. (2003), falling number has marked effects on bread-making quality under drought conditions. On the other hand, Kettlewell et al. (1999) earlier reported that drought during pre-anthesis stages had no significant effect on falling number but dry periods during grain-filling stage caused an increase.

There are two promising fundamental solutions to sustain plant yield under water scarcity; (i) increasing the water use efficiency via agronomic practices (ii) development of new drought-resistant varieties (Fischer, 1999). Agronomic practices such as new nitrogen managements (Abid et al., 2016; Gevrek and Atasoy, 2012), no-tillage conditions (Iijima et al., 2007), potassium foliage application (Lv et al., 2017), drought-priming in vegetative stage (Wang et al., 2018; Liu et al., 2017) have been discussed based on their effects on water use efficiency and adaptation of wheat to dry environments. Besides, breeding new varieties and assessing present wheat elite cultivars for drought conditions considering specific growth stages are also highly substantial. Significant amount of breeding studies to increase the adaptation of wheat to dry conditions have been performed in recent years (Monneveux et al., 2002). However, yield potential of these developed varieties generally are not promising when adequate rainfall is received during growth season.

From this point of view, the aims of this study were, i) to investigate the effects of drought application in bread wheat at grain filling stage, ii) to compare the performances of elite wheat cultivars under drought in terms of their yield and quality characteristics, and iii) to identify the superior wheat cultivars that can be used for drought suffered environments.

MATERIALS AND METHODS

A field experiment was conducted in Izmir Province of Turkey (38°27’6’’N,27°13’32’’E) during 2013-14 and 2014-15 growing seasons. Totally 16 bread wheat varieties were used in the experiment (Vorabey = VOR, Basribey = BAS, Kate I = KAT, Meta= MET, Sagittario = SAG, Menemen = MEN, Golia = GOL, Ziyabey = ZIY, GÖNEN = GON, Cumhuriyet = CUM, Pandas = PAN, LINE-18, LINE-26, LINE-28, Nurkent = NUR and Dinç = DIN). Soil in experimental field was clay loam and slightly alkaline. Long-term average rainfall amount for the experimental site was 702 kg m^{-2} and the site (38°27.236 N, 27°13.576 E) was located in the coastal part of Turkey, similar to Mediterranean Climate. Air temperature (°C) and relative humidity (%) were recorded by a gauge (Tinytag Plus 2®) every 15 minutes and rain amounts (mm) were measured by pluviometer during 2 growing period of wheat in 2014 and 2015 (Figure 1).

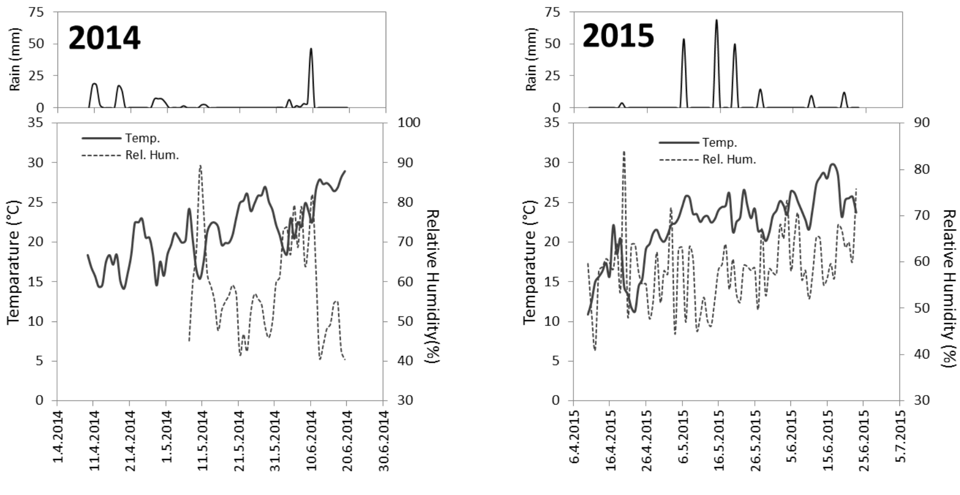

Figure 1. Rainfall (mm), temperature (°C) and relative humidity (%) records after onset of drought treatment during grain filling stage (2014 and 2015).

The experiment was set up according to the split-plot design with three replications. Plot size and sowing distance between rows were 1.2 × 4 m and 20 cm, respectively. Initially, 80 kg/ha of basal nitrogen as ammonium sulphate and 60 kg ha^{-1} phosphorus as triple superphosphate then 80 kg per ha as ammonium nitrate at the beginning of stem elongation stage were applied.

A rainout shelter was used after anthesis stage of wheat in April (7th of Apr. 2014 and 10th Apr. of 2015) to remove rain water until harvesting to apply terminal drought conditions (drought treatment). The rain out shelter was 3 m high, covered by 0.25 mm PCV on the top and 95 % transparent to photosynthetic active radiation (PAR). Plants were grown under rain-fed conditions in control treatments.

Border lines in each plot were removed from plot at harvesting time (19th of June 2014 and 23rd of June 2015). Plant height (cm), number of spike (number m^{-2}) and grains $spike^{-1}$ were determined in randomly selected 10 plants. Remaining plants were harvested by plot-harvesting machine then seeds were sampled for 1000 grain and hectoliter weight. Grain yield (kg ha^{-1}) was recorded and then harvest index (%) were calculated at the end.

The Kjeldahl method was used to determine N content of the grains and protein content was calculated as 5.7 × percent N in dry matter. Sedimentation value and falling number were determined according to the (International Association for Cereal Science and Technology) ICC standard 116/1 and 107/1 , respectively (ICC, 1991; ICC, 1994).

Data were subjected to analysis of variance for each parameter. All data were analyzed by using standard ANOVA techniques of Statistica software. The mean values of each parameter were compared according to LSD test described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Results of statistical analysis for the effects of experimental factors [Year (Y), Genotype (G) and Treatment (T)] on yield and quality parameters of wheat with *P* values were given in Table 1. Similarly with the results from Toker et al., (2009), significant differences were observed among different genotypes under drought stress. Plant height significantly differed (Table 2) and drought treatment during grain filling stage caused a slight decrease in plant height (5.5 %). Y × G and Y × T interactions for plant height were also significant ($P \leq 0.005$). Average of plants were 7.5 cm (10.6 %) shorter under drought conditions in the second year (2015) of the experiment while same plant height was found in the first year (Table 2). Shorter plant height of wheat varieties under drought conditions has been reported by Ozturk (1999). However, Shirazi et al. (2010) demonstrated that drought affected plant height during earlier growth (seedling and tillering) but not in later growth stages. Slight changes in plant height as an effect of drought stress during grain filling stage in the second year of the present study could be attributed as a result of significantly higher rain amount in May 2015 received by control plots comparison to the first year of the experiment (2014).

Table 1. ANOVA for some yield and quality traits of wheat

Experimental Factors	**Plant height (cm)**	**No spike (m^2)**	**No grain per spike**	**1000 Grain weight (g)**	**Grain Yield (kg ha^{-1})**	**Harvest Index (%)**	**Protein content (%)**	**Sedim.**	**Falling Number**
Year (Y)	0.312	0.000**	0.000**	0.000**	0.523	0.346	0.000**	0.000**	0.000**
Genotype (G)	0.000**	0.003**	0.000**	0.000**	0.000**	0.000**	0.234	0.000**	0.000**
Treatment (T)	0.000**	0.937	0.387	0.000**	0.000**	0.002**	0.000**	0.000**	0.578
Y × G	0.004**	0.026*	0.000**	0.046*	0.000**	0.000**	0.051	0.003**	0.067
Y × T	0.000**	0.351	0.371	0.666	0.023*	0.720	0.000**	0.703	0.422
G × T	0.919	0.999	0.998	0.833	0.282	0.272	0.933	0.392	0.095
Y × G × T	0.700	0.999	0.987	1.000	0.990	0.061	0.840	0.782	0.874

* and **are significant at P=0.05 and P=0.01, respectively.

Number of spike wasn't significantly affected by drought treatment during grain filling stage (Table 1). However, higher spike number was recorded in the 2nd year of the experiment (453 spike m^{-2}) than that of the 1st year (390 spike per squere meter) (Table 3). Year × genotype interaction for number of spike was statistically significant and the highest spike number recorded in cv.GOL in 2015 (525 spike per squere meter) whereas cv.KAT in 2014 (297 spike per squere meter). Talebi (2011) stated that number of spike per unit area was negatively correlated with drought conditions. However, Eskandari and Kazemi (2010) found no significant change in spike number under drought conditions during post-anthesis stage of wheat. Our findings also indicated that drought conditions did not significantly affect spike number since spikes were already formed earlier than effect of drought (Thorne 1974).

Number of grain per spike as a one of the main component of yield is also determined during earlier stages of wheat growth (Waddington eta al., 1983). Therefore, drought treatment during grain filling stage didn't significantly affect number of grain per spike (Table 1). Besides, the spikes had higher grain number in the first year of the experiment (27.2) than that of the second year (21.5) (Table 4). Although, our data are in agreement with several findings as given above, there are a few reports state that grain number was effected by later drought treatments (Fischer 2008). Higher number of grain per spike in the first year of our experiment could be attributed better rainfall distribution and higher rainfall during earlier stages of growth. Changes in number of grain per spike were different between two successive experimental seasons. The highest number of grain per spike was recorded for cv. BAS (35.3) while the lowest for cv. KAT (11.9) both in 2014.

Table 2. Plant height (cm) of bread wheat varieties under control and drought conditions during 2013-14 and 2014-15 growing seasons (*P*>0.05, LSD=8.38).

Varieties	2014			2015			Gen.
	Control	Drought	Mean	Control	Drought	Avg.	Mean
Vorobey	77.9	74.9	**76.4**	84.4	77.1	**80.7**	**78.6**
Basribey	70.8	65.4	**68.1**	74.3	71.0	**72.6**	**70.4**
Kate I	75.8	75.1	**75.5**	82.0	79.2	**80.6**	**78.0**
Meta	67.1	66.9	**67.0**	77.9	72.0	**75.0**	**71.0**
Sagittario	57.5	59.2	**58.4**	63.0	55.5	**59.2**	**58.8**
Menemen	60.2	59.3	**59.7**	72.9	66.2	**69.6**	**64.7**
Golia	50.7	53.0	**51.9**	56.9	48.4	**52.6**	**52.2**
Ziyabey	69.1	70.9	**70.0**	79.4	64.1	**71.7**	**70.9**
Gönen	60.5	57.6	**59.1**	68.9	59.5	**64.2**	**61.6**
Cumhuriyet	72.8	75.3	**74.0**	74.8	65.7	**70.3**	**72.2**
Pandas	56.4	60.2	**58.3**	71.4	56.2	**63.8**	**61.1**
LINE-18	62.0	61.6	**61.8**	59.3	59.3	**59.3**	**60.5**
LINE-26	67.5	66.9	**67.2**	63.8	64.8	**64.3**	**65.8**
LINE-28	61.3	63.9	**62.6**	56.8	49.7	**53.2**	**57.9**
Nurkent	88.1	86.8	**87.5**	85.8	65.8	**75.8**	**81.6**
Dinç	60.5	62.3	**61.4**	63.4	59.6	**61.5**	**61.5**
Mean	**66.2**	**66.2**	**66.2**	**70.9**	**63.4**	**67.2**	**66.7**

Table 3. Number of spike (number per square) of bread wheat varieties under control and drought conditions during 2013-14 and 2014-15 growing seasons (P>0.05, LSD=90.5).

Varieties	2014			2015			Gen.
	Control	Drought	Mean	Control	Drought	Mean	Mean
Vorobey	317.5	350.0	**333.8**	445.0	435.0	**440.0**	**386.9**
Basribey	435.0	403.3	**419.2**	523.3	468.3	**495.8**	**457.5**
Kate I	283.3	310.0	**296.7**	511.7	470.0	**490.8**	**393.8**
Meta	390.0	408.3	**399.2**	507.5	478.3	**492.9**	**446.0**
Sagittario	452.5	425.0	**438.8**	415.0	421.7	**418.3**	**428.5**
Menemen	377.5	417.5	**397.5**	443.3	476.7	**460.0**	**428.8**
Golia	406.7	436.7	**421.7**	540.0	510.0	**525.0**	**473.3**
Ziyabey	427.5	433.3	**430.4**	438.3	426.7	**432.5**	**431.5**
Gönen	345.0	381.7	**363.3**	405.0	368.3	**386.7**	**375.0**
Cumhuriyet	406.7	428.3	**417.5**	446.7	433.3	**440.0**	**428.8**
Pandas	442.5	475.0	**458.8**	410.0	452.5	**431.3**	**445.0**
LINE-18	318.3	326.7	**322.5**	465.0	447.5	**456.3**	**389.4**
LINE-26	411.7	426.7	**419.2**	485.0	481.7	**483.3**	**451.3**
LINE-28	347.5	356.7	**352.1**	470.0	441.7	**455.8**	**404.0**
Nurkent	455.0	407.5	**431.3**	451.7	485.0	**468.3**	**449.8**
Dinç	352.5	327.5	**340.0**	372.5	361.7	**367.1**	**353.5**
Mean	**385.6**	**394.6**	**390.1**	**458.1**	**447.4**	**452.8**	**421.4**

Thousand grain weight (TGW) significantly decreased (9.2%) under drought treatments (Table 5). The average of 1000 grain weight was 36.3 g in control, whereas 33.0 g in drought treatments. Gebbing and Schnyder (1999) stated that grain formation in spike was affected by earlier dry matter accumulation but mostly translocation of these accumulates to the grain during post-anthesis stage. Drought inhibited translocation of dry matter to the grains under drought conditions during post-anthesis stage of wheat have been previously reported (Johari-Pireivatlou et al., 2010; Eskandari and Kasemi, 2010; Tatar et al., 2016). In the present study, TGW was also significantly affected by growing seasons and differed depends on the genotypes (Table 1). The highest TGW was found for cv. CUM (41.6 g) in the first year of experiment (2014) while the lowest for cv. KAT (23.6 g) in the second year.

Final grain weight as a yield component is determined by rate and duration of grain filling (Farahbakhsh and Khasse Sirjani, 2019). Effect of drought on growth and productivity of wheat was found to be depended on the phenological stage of the plant (Garcia del Moral et al., 2003; Shpiler and Blum, 1991; Giunta et al., 1993). Spike and spikelet number were decreased in stem elongation stage by drought (Tatar et al., 2016; Shipler and Blum, 1991) whereas dry matter translocation was inhibited during grain filling stage (Garcia del Moral et al., 2003). The average grain yield, significantly decreased (17.7%)

during grain filling stage under drought conditions (Table 6). The highest average grain yield reduction was recorded in LINE-28 (46.1%), while the cv. SAG was not significantly affected in both experimental seasons. Year × genotype interaction was also significant (Table 1). Similarly, Ayranci et al. (2014) stated that grain yield values of the wheat genotypes varied among different years under drought stress conditions. The highest grain yield was 4.559 kg ha^{-1} in cv.MET and the lowest was 1.192 kg ha^{-1} in cv. KAT both in the first year of the experiment (2014).

Table 4. Number of rain per spike of bread wheat varieties under control and drought conditions during 2013-14 and 2014-15 growing seasons (P>0.05, LSD=6.34).

Varieties	**2014**			**2015**			**Gen.**
	Control	**Drought**	**Mean**	**Control**	**Drought**	**Mean**	**Mean**
Vorobey	25.5	26.4	**25.9**	23.0	23.1	**23.1**	**24.5**
Basribey	34.5	36.1	**35.3**	23.2	21.7	**22.5**	**28.9**
Kate I	10.6	13.3	**11.9**	20.6	20.9	**20.7**	**16.3**
Meta	24.5	28.7	**26.6**	20.8	25.2	**23.0**	**24.8**
Sagittario	26.7	26.4	**26.6**	20.3	20.6	**20.5**	**23.5**
Menemen	33.6	36.0	**34.8**	25.8	23.3	**24.5**	**29.7**
Golia	23.7	24.5	**24.1**	22.4	24.6	**23.5**	**23.8**
Ziyabey	28.9	30.1	**29.5**	28.0	27.0	**27.5**	**28.5**
Gönen	23.7	22.8	**23.2**	20.7	19.1	**19.9**	**21.6**
Cumhuriyet	25.4	29.5	**27.5**	18.6	16.5	**17.5**	**22.5**
Pandas	32.5	35.8	**34.2**	24.6	24.1	**24.3**	**29.3**
LINE-18	21.1	22.0	**21.6**	18.4	20.7	**19.5**	**20.6**
LINE-26	30.6	30.4	**30.5**	14.7	19.0	**16.8**	**23.7**
LINE-28	25.9	26.5	**26.2**	21.8	16.6	**19.2**	**22.7**
Nurkent	25.3	28.0	**26.6**	23.8	20.4	**22.1**	**24.4**
Dinç	31.0	29.3	**30.1**	17.1	20.6	**18.8**	**24.5**
Mean	**26.5**	**27.9**	**27.2**	**21.5**	**21.5**	**21.5**	**24.3**

Table 5. 1000-grain weight (g) of bread wheat varieties under control and drought conditions during 2013-14 and 2014-15 growing seasons (P>0.05, LSD=4.52).

Varieties	**2014**			**2015**			**Gen.**
	Control	**Drought**	**Mean**	**Control**	**Drought**	**Mean**	**Mean**
Vorobey	38.1	37.2	**37.6**	40.1	40.2	**40.1**	**38.9**
Basribey	31.1	26.2	**28.6**	36.9	30.3	**33.6**	**31.1**
Kate I	25.0	22.2	**23.6**	39.0	34.4	**36.7**	**30.1**
Meta	35.5	34.0	**34.7**	40.3	36.9	**38.6**	**36.7**
Sagittario	32.5	29.7	**31.1**	36.5	33.3	**34.9**	**33.0**
Menemen	32.0	28.2	**30.1**	35.4	31.9	**33.6**	**31.9**
Golia	32.2	28.6	**30.4**	37.5	32.2	**34.9**	**32.6**
Ziyabey	35.8	30.9	**33.3**	40.9	36.2	**38.6**	**35.9**
Gönen	32.1	25.4	**28.8**	36.6	30.2	**33.4**	**31.1**
Cumhuriyet	39.8	38.4	**39.1**	42.3	40.9	**41.6**	**40.4**
Pandas	34.4	34.2	**34.3**	37.0	35.6	**36.3**	**35.3**
LINE-18	37.3	34.1	**35.7**	38.5	34.7	**36.6**	**36.2**
LINE-26	31.7	27.7	**29.7**	37.5	33.7	**35.6**	**32.6**
LINE-28	39.5	33.2	**36.3**	40.9	35.7	**38.3**	**37.3**
Nurkent	33.7	30.8	**32.2**	39.6	37.5	**38.5**	**35.4**
Dinç	34.4	35.5	**34.9**	37.2	35.3	**36.3**	**35.6**
Mean	**34.1**	**31.0**	**32.5**	**38.5**	**34.9**	**36.7**	**34.6**

Harvest index (HI) significantly increased from 29% to 32%in 2014 and from 30% to 0.32% in 2015 under drought treatments comparison to control treatments (Figure 2). Contrary to our results, a significant decrease in HI induced by post-anthesis drought has been reported by Sangtarash (2010). On the other hand, Yong'an et al. (2010) found an increase in HI due to shorter vegetation period under drought conditions. The highest HI was recorded in LINE-28 (40 %) in 2015, while the lowest for cv. KAT (12 %) in 2014.. Protein content is highly dependent on genotype as well as management (*i.e.*, fertilization, irrigation) or environment (*i.e.*, years) (Torrion and Stougaard, 2017).

Protein content of grains was also increased due to drought conditions (Table 1). Ozturk and Aydın (2004) reported that water stress conditions between milky ripe and maturity stages has increased grain protein content by 8.3%. The relative increases were 38.6% in the first year, whereas 24.5% in the second year of the experiment. The average protein content was 12% and there were not significant differences in wheat genotypes. Although the changes in sedimentation values of the genotypes differed under drought treatments, significant reduction was found in both years 2014 (7.0%) and 2015 (9.4%) due to limited water during grain filling (Figure 2). In parallel with our results, Barić et al. (2006) suggested that different genotypes had variable responses to drought stress on grain filling stage. However, the same researchers found higher sedimentation values in drought stress induced plants than control plants. Additionally, Ozturk and Aydin (2004) stated that water stress at any stages of growth significantly increased the sedimentation volume. Cultivar PAN had the highest sedimentation (47.8) in 2014 and cv. MET had the lowest (27.3) in 2015 in the present study.

Table 6. Grain yield (kg per ha) of bread wheat varieties under control and drought conditions during 2013-14 and 2014-15 growing seasons (P>0.05, LSD=741).

Varieties	**2014**			**2015**			**Gen.**
	Control	**Drought**	**Mean**	**Control**	**Drought**	**Mean**	**Mean**
Vorobey	3115	2893	3004	3295	3127	3211	3107
Basribey	4441	3555	3998	3576	2786	3181	3589
Kate I	1320	1065	1192	3346	3329	3338	2265
Meta	4828	4290	4559	4531	3213	3872	4215
Sagittario	2618	2697	2657	2515	2463	2489	2573
Menemen	3350	2921	3136	3258	2225	2742	2939
Golia	3446	3166	3306	4442	3722	4082	3694
Ziyabey	3128	2770	2949	3741	3232	3486	3218
Gönen	3180	2531	2856	3113	1719	2416	2636
Cumhuriyet	3461	3445	3453	3172	2071	2621	3037
Pandas	4254	4100	4177	4281	3378	3830	4003
LINE-18	3132	3122	3127	3708	2735	3222	3174
LINE-26	3125	2987	3056	3232	2483	2858	2957
LINE-28	3425	2099	2762	3392	1581	2487	2624
Nurkent	4005	3098	3551	4136	3177	3657	3604
Dinç	4281	3666	3974	3740	2971	3356	3665
Mean	**3444**	**3025**	**3235**	**3592**	**2763**	**3178**	**3206**

Falling number (FN) is the test which measures the activity of α-amylase enzyme which breaks down the starch molecules into the sugar (Brijs et al., 2009). The increase in activity of α-amylase enzyme is generally caused by pre-harvest sprouting of the grains in the field due to prolonged exposure of wet conditions (Liu et al., 2008; Torrion and Stougaard, 2017). In this research, FN values were only significantly different among experimental seasons and wheat genotypes (Figure 2). Average FN was higher (507) in the first year than that (360) of second year of the experiment. The highest FN values were recorded in cv. NUR (542), cv. PAN (535) and LINE-26 (524) while the lowest in cv. MEN (342). Our results were compatible with those of Torrion and Stougaard (2017) reported that FN trait varied by wheat cultivars, however researchers have also observed a decrease in FN with the irrigation.

As conclusion, drought treatment inhibited some agronomic traits such as plant height (5.5 %), 1000 grain weight (9.2%) and grain yield (17.7%), but harvest index increased (8.5%) under stress conditions. However, there was not significant effect of drought conditions on number of grain per spike and number of spike per square meter. Protein content increased (31.6%) in all genotypes, while the Zeleny sedimentation significantly decreased (8.2 %) under drought treatments during both growing seasons. Drought conditions had not significant effect on falling number. Cultivars Pandas and Meta had higher grain yield under drought stress in both years, whereas Line-28 and Pandas had better quality properties.

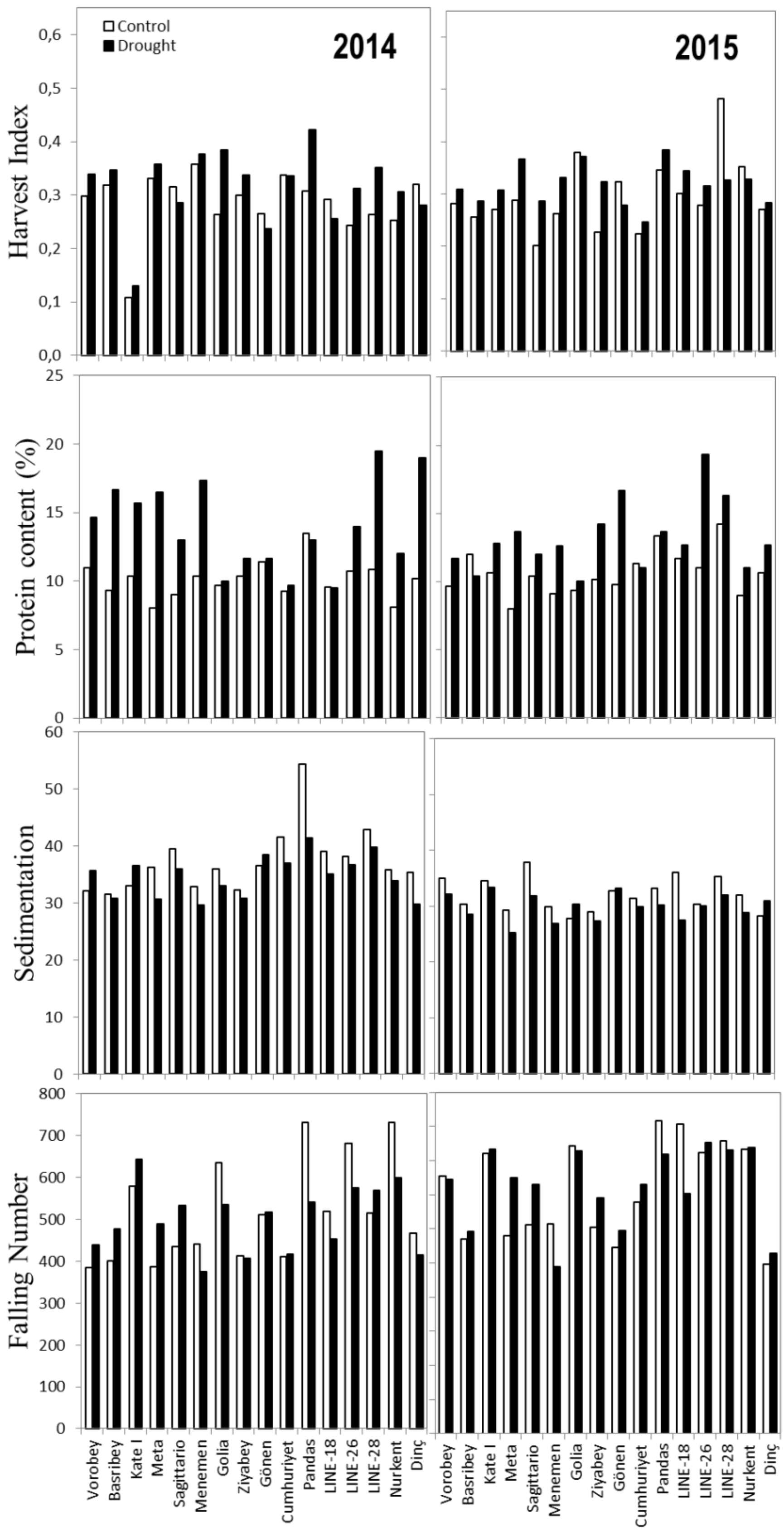

Figure 2. Harvest index (*P*>0.05, LSD=0.07), protein content (*P*>0.05, LSD=6.42), sedimentation (*P*>0.05, LSD=5.78) and falling number (*P*>0.05, LSD=112) values of bread wheat varieties under control and drought conditions during 2013-14 (2014) and 2014-15 (2015) growing seasons.

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