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The Effect of Drought Stress on Grain Yield, Yield Components and some Quality Traits of Durum Wheat (*Triticum turgidum* ssp. *durum*) Cultivars

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Abstract

Drought, one of the environmental stresses, is the most significant factor restricting plant production in the majority of agricultural fields of the world. Wheat is generally grown on arid-agricultural fields. Drought often causes serious problems in wheat production areas. A field study was conducted on clay-silt soil, in the Research Field, Southeastern Anatolia Agricultural Research Institute, in Diyarbakır during 1999-2000 growing season in order to evaluate genotypes for yield, yield components and some quality traits. Fourteen wheat (*Triticum turgidum* ssp. *durum*) cultivars were grown under well watered and natural drought conditions. Morphological traits were measured at anthesis and yield, yield components and quality traits were evaluated at ripening time. The flowering period was negatively associated with grain yield, while grain filling period, chlorophyll content, number of grains per spike and spikelets per spike were positively associated with grain yield under drought conditions. Moreover, the number of days to maturity was negatively associated with Drought Susceptibility Index (DSI), while Spike length was positively associated to DSI in drought conditions. DSI and relative yield (RY) values for grain yield were used to describe yield stability and yield potential. There were high variations in DSI and RY values within genotypes. DSI values for grain yield ranged from 0.82 to 1.07 and the mean RY values were 0.82 for well-watered plots and 0.87 for water stressed plots. The varieties 'Gidara-II', 'Sarıçanak-98', 'Balcalı-2000', 'Altıntoprak-98', 'Aydın-93' and 'Harran-95' showed high yield potential and stability (DSI<1 and RY>mean RY).

Keywords: chlorophyll content, quality traits, water stress, wheat and yield components

Introduction

Drought is a polygenic stress and is considered as one of the most important factors limiting crop yields around the world. As climate change leads to increasingly hotter and drier summers, the importance of drought constraints on yield and yield components has increased in Turkey. Wheat (*Triticum turgidum* ssp. *durum* L.) is an important crop in Southeastern Anatolia of Turkey, where high temperatures and water stress often reduce plant growth and crop yields. Therefore, wheat yield is lowered. The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important (Rashid *at al*, 2003). The response of plants to water stress depends on several factors such as developmental stage, severity and duration of stress and cultivar genetics (Beltrano and Marta, 2008).

Also, some morphological characters such as root length, tillering, spike number per m^{-2}, grain number per spike, number of fertile tillers per plant, 1000 grain weight, peduncle length, spike weight, stem weight, awn length, grain weight per spike and affect wheat tolerance to the moisture shortage in the soil (Passioura, 1977; Levitt, 1980; Kramer, 1983; Jhonson *et al*., 1983; Moustafa *et al*., 1996; Plaut *et al*., 2004; Blum, 2005).

The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important. Finlay (1968) believed that stability over environments and yield potential are more or less independent from each other. Blum (1979) suggested that one method of breeding for increased performance under water stressed conditions might be a breed for superior yield under optimum conditions on the assumption that the best lines would also perform well under sub optimum conditions. The ideal situation would be having a highly stable genotype with high yield potential (Finlay and Wilkinson, 1963; Smith, 1982).

The most widely used criteria for selecting high yield performance are mean yield, mean productivity (average yield performance under stress and non stress conditions) and relative yield performance in drought-stressed and more favorable environments (Rashid *at al.*, 2003). Stability of grain yield for each genotype is estimated by the drought susceptibility index (DSI), derived from the yield difference between stress and non stress environments (Blum *et al.,* 1989). Fischer and Maurer (1978) and Langer *et al.* (1979) involved the use of DSI, which characterizes the yield stability between two environments. There are many reports in literatures about the use of DSI for identifying genotypes with yield stability in moisture limited environments (Fischer and Maurer, 1978; Clarke *et al.*, 1984; Bruckner and Frohberg, 1987; Ehdaie *et al.,* 1988; Bansal and Sinha, 1991). The combination of high yield stability and high relative yield under drought, has been proposed as it is a useful selection criterion for characterising genotypic performance under a varying degree of water stress (Pinter *et al.,* 1990).

The objectives of this study, therefore, were to screen wheat varieties with high yield potential, stability, yield components and quality traits under water stress conditions and to determine suitable selection criteria for selecting genotypes tolerant to drought stress conditions.

Materials and methods

The experiments (under rainfed and irrigation conditions) were conducted in the research area, the Southeastern Anatolia Agricultural Research Institute, Diyarbakır during the 1999-2000 growing season. Total precipitation was recorded as 245 mm in 1999-2000 growing season. Fourteen durum spring wheat cultivars ('Altıntoprak-98', 'Aydın-93', 'Ceylan-95', 'Dicle-74', 'Diyarbakır-81', 'D.5456', 'Ege–88', 'Fırat-93', 'Gidara-II', 'Özberk', 'Harran-95', 'Sarıçanak-98', 'Sorgül' (landrace) and 'Balcalı-2000') were used for this study. The experiment was laid out according to a randomized complete block design (RCDB), with four replications. These cultivars were planted on November 01, 1999 on a clay-silt. The seeds were sown using an experimental drill in 1.2 m x 6 m plots consisting of 6 rows with a 20 cm row space and the seeding rates for both experiments were about 450 seeds per m^{-2}. The plots 1.2 m x 5 m size were harvested by a combined harvester. The plots were fertilized with 60 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} at the planting and 60 kg N ha^{-1} in spring at stem elongation for drought conditions. However, plots were fertilized with 80 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} at planting and 60 kg N ha^{-1} in spring at stem elongation for irrigation conditions. All plots of the irrigation experiment were irrigated by using an installed pipeline system and the volume of water input for each plot was controlled by using adjustable counter. The first irrigation was performed at the time of late tillering. Based on the results of soil moisture content and due to frequent precipitations, no more irrigation was required until the flowering stage. The second irrigation was applied on 10th May after flowering while the third irrigation was applied on 2nd June in the dough stage.

Grain yield was recorded after harvesting the crop at maturity. The measures of yield stability (DSI) and yield potential (RY) were calculated by using mean grain yield. The DSI (Fischer and Maurer, 1978) was as follows:

$$DSI=(1-Yd/Yw)/D,$$

where Yd=mean yield under drought, Yw=mean yield under well-watered conditions and D=environmental stress intensity=1-(mean yield of all genotypes under drought/mean yield of all genotypes under well-watered conditions).

The relative yield under drought condition was calculated as the yield of a specific genotype under drought divided by the highest yielding genotype in the population. Also, some parameters such as 1000 grain weight, peduncle length, plant height, grains per spike, chlorophyll content, protein content of grain, SDS sedimentation were determined. Meanwhile the number of days to heading, the number of days from heading to maturity (grain filling period GFP) were recorded during the growing season for each genotype. Data obtained were subjected to an analysis of variance. The analysis over treatments was also performed by using SAS (SAS, 1999), and means were compared by using Fisher's least significant difference ($P<0.01$ and 0.05), respectively.

Results and discussion

There were significant differences between number of days to heading, GFP, number of days to maturity, plant height, number of spike per m^{-2}, chlorophyll content, peduncle length, spike length, grains per spike, spikelets per spike, 1000 grain weight, SDS sedimentation in both conditions while there were no significant difference between protein content and spikelets per spike in well watered conditions (Tab. 1).

Tab. 1. The analysis of variance of the effect of drought and well watered treatments on yield, yield components and end-use quality of fourteen durum wheat cultivars in 1999/2000 growing season in Diyarbakir

Parameters	F-Values	
	Well Watered condition	Drought condition
number of days to heading	17.85 **	3.33 **
grain filling period	3.88**	2.60 *
number of days to maturity	4.14**	5.84**
plant height	5.35**	3.82**
number of spike per m2	3.44**	3.16**
clorophyll content	3.53 **	5.37 **
peduncle length	2.18 *	3.43 **
spike length	6.99 **	11.6 **
spike weight	3.35 **	3.56 **
number of grains per spike	5.40 **	4.71 **
1000 grain weight	7.87 **	6.99 *
spikelets per spike	1.84 ns	6.705**
protein content	1.53 ns	2.59 *
SDS sedimentation	3.70 **	7.95 **
grain yield	8.25 **	2.14 *

* Significant at the 0.05 probability level; ** significant at the 0.01 probability level

Means of yield components of each wheat genotype in well watered and drought conditions are given in Tab. 2, Tab. 3 and Tab. 4.

Tab. 2 presents genotype names and means for number of days to heading, GFP, number of days to maturity, plant

Tab. 2. Means of yield components of each 14 durum wheat genotypes in well watered and drought conditions

Cultivars	Number of days to heading (days)		Grain filling period (days)		Number of days to maturity (days)		Plant height (cm)		Number of spike per m2		Chlorophyll content (SPAD)	
	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed
'A.Toprak-98'	114.0^{bcd}	112.8^{bc}	37.8^{abc}	33.8^{bcd}	151.8^{bc}	146.5^{bc}	90.0^{ef}	85.1^{cde}	492.5^{cde*}	468.8^{bcd}	49.0 ^{bc}	50.0^{ef}
'Aydın-93'	112.3^{f}	110.8^{cd}	39.0^{a}	34.3^{abc}	151.3^{bcd}	145.0^{cde}	100.0^{bcd}	103.5^{ab}	517.5^{bcd}	533.8^{ab}	51.9^{ab}	54.9^{abc}
'Ceylan-95'	113.8^{cde}	113.0^{bc}	37.8^{abc}	32.5^{cde}	151.5^{bcd}	145.5^{b-e}	106.1^{ab}	95.8^{abc}	492.5^{cde}	500.0^{abc}	47.5^{de}	52.2^{de}
'Dicle-74'	113.5^{c-f}	111.5^{bcd}	38.3^{ab}	34.8^{abc}	151.8^{bc}	146.3^{bcd}	96.1^{cde}	82.0^{de}	600.0^{a}	413.8^{de}	50.5^{a-d}	55.3^{ab}
'D.Bakır-81'	114.0^{bcd}	111.8^{bcd}	37.0^{bc}	33.8^{bcd}	151.0^{bcd}	145.5^{b-e}	100.8^{bc}	90.5^{cd}	468.8^{de}	453.8^{cd}	49.6^{bcd}	53.3^{bcd}
'D.5456'	115.3^{b}	113.8^{ab}	36.8^{bc}	31.0^{e}	152.0^{b}	144.8^{de}	98.3^{b-e}	80.3^{de}	521.3^{bcd}	435.0^{cde}	49.9^{a-d}	52.4^{d}
'Ege–88'	113.0^{def}	109.5^{d}	39.0^{a}	35.3^{abc}	152.0^{b}	144.8^{de}	91.4^{def}	84.0^{cde}	488.8^{cde}	430.0^{cde}	52.6^{ab}	52.6^{cd}
'Fırat-93'	114.0^{bcd}	111.8^{bcd}	36.3^{c}	34.5^{abc}	150.3^{d}	146.3^{bcd}	91.4^{def}	91.9^{bcd}	542.5^{abc}	463.8^{bcd}	51.6^{abc}	54.0^{a-d}
'Özberk'	114.5^{bc}	112.5^{bc}	37.0^{bc}	31.5^{de}	151.5^{bcd}	144.0^{e}	92.8^{cde}	83.4^{cde}	462.5^{de}	438.8^{cde}	50.7^{abc}	52.6^{d}
'Gidara-II'	112.5^{ef}	111.8^{bcd}	38.0^{abc}	34.3^{abc}	150.5^{cd}	146.0^{bcd}	94.2^{cde}	86.2^{cde}	508.8^{cd}	460.0^{cd}	51.8^{ab}	55.9^{a}
'Harran-95'	114.0^{bcd}	111.3^{bcd}	37.3^{abc}	33.8^{bcd}	151.3^{bcd}	145.0^{cde}	91.6^{def}	83.6^{cde}	463.8^{de}	423.8^{de}	48.8^{cde}	51.9^{de}
'S.Çanak-98'	113.0^{def}	110.5^{cd}	38.3^{ab}	36.5^{abc}	151.3^{bcd}	147.0^{b}	83.2^{f}	77.4^{ae}	426.3^{e}	381.3^{e}	52.8^{a}	53.8^{a-d}
'Sorgül'	120.5^{a}	116.3^{a}	34.0^{d}	33.0b^{-e}	154.5^{a}	149.3^{a}	111.0^{a}	107.3^{a}	582.5^{ab}	547.5^{a}	46.3^{e}	49.2^{f}
'Balcalı-200'	113.5^{cf}	113.8^{ab}	37.3^{abc}	32.3^{cde}	150.8^{bcd}	146.0^{bcd}	100.9^{abc}	92.3^{bcd}	498.8^{cd}	457.5^{cd}	52.8^{a}	53.1^{bcd}
LSD(0.05)	1.4	2.6	1.83	2.63	1.41	1.51	8.9	12.7	72.2	72.4	3.01	2.29
Mean s	114.1	112.2	37.4	33.6	151.5	145.8	96.2	88.8	504.7	457.7	50.5	52.9
% Differences	-1.7		-10.2		-3.8		-7.7		-9.3		+4.8	

Means followed by different letters within a column for each year have significant differences at the level of $P<0.05$ for LSD test

height, number of spike per m^{-2} and chlorophyll content, while Tab. 3 presents peduncle length, spike length, spike weight, spikelets per spike and Tab. 4 presents 1000 grain weight, protein content, SDS sedimentation and grain yield.

Drought stress accelerated all phenological growth stages, reduced the normal growth and development periods, dry matter production and final yield. As 'Özberk', 'D-5456' and 'Ceylan-95' were early maturing cultivars, they exhibited drought escape as a drought tolerance mechanism. Drought escape is highly heritable but it is associated with lower yields (Wortmann, 1998) as shown by these results. It is showed that 'Sarıçanak-98' maintained superior performance under drought conditions despite

Tab. 3. Means of yield components of each 14 durum wheat genotypes in well watered and drought condition

Cultivars	Peduncle length (cm)		Spike length (cm)		Spike weight (g)		Number of grains per spike (number)		Spikelets per spike (number)	
	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed
'A.Toprak-98'	19.38^{a-d*}	11.53^{cde}	6.15^{bcd}	6.03^{c}	1.73^{cde}	1.20^{b}	38.40^{def}	33.00^{b*}	16.88^{a}	16.50^{bcd}
'Aydın-93'	16.95^{bcd}	15.83^{a}	5.45^{fgh}	5.32^{e}	1.66^{cd}	1.24^{b}	39.03^{c-f}	34.30^{b}	16.78^{a}	16.50^{bcd}
'Ceylan-95'	23.05^{a}	14.73^{ab}	6.48^{ab}	6.17^{bc}	1.70^{cd}	1.22^{b}	38.38^{def}	30.63^{bc}	16.70^{a}	16.88^{abc}
'Dicle-74'	23.23^{a}	13.88^{abc}	5.97^{cde}	5.94^{c}	1.86^{bcd}	1.17^{b}	43.75^{bcd}	30.13^{bc}	16.58^{a}	15.28^{efg}
'D.Bakır-81'	21.03^{ab}	13.73^{a-d}	6.25^{bcd}	6.41^{b}	1.85^{bcd}	1.21^{b}	40.25^{b-f}	32.25^{b}	16.50^{ab}	16.53^{bcd}
'D.5456'	20.25^{abc}	11.23^{cde}	6.91^{a}	6.94^{a}	1.86^{bcd}	1.17^{b}	44.15^{bc}	33.15^{b}	16.40^{ab}	16.70^{abc}
'Ege–88'	16.73^{bcd}	11.05^{de}	6.31^{bc}	6.12^{bc}	2.13^{ab}	1.22^{b}	45.15^{b}	32.68^{b}	16.38^{ab}	15.33^{efg}
'Fırat-93'	17.85^{a-d}	11.63^{cde}	5.80^{d-g}	5.89^{cd}	1.88^{bc}	1.27^{b}	37.33^{fg}	30.28^{bc}	16.28^{abc}	16.18^{cde}
'Özberk'	15.05^{cd}	10.63^{e}	5.42^{gh}	5.52^{de}	1.90^{bc}	1.33^{ab}	37.73^{efg}	30.78^{bc}	16.10^{abc}	15.03^{fg}
'Gidara-II'	20.53^{abc}	15.45^{a}	5.96^{cde}	5.53^{de}	1.70^{cd}	1.31^{b}	42.90^{b-e}	33.75^{b}	16.03^{abc}	17.55^{a}
'Harran-95'	15.65^{bcd}	12.35^{b-e}	5.81^{c-g}	5.86^{cd}	1.89^{bc}	1.33^{ab}	40.25^{b-f}	34.13^{b}	15.95^{abc}	16.53^{bcd}
'S.Çanak-98'	14.50^{d}	12.25^{be}	5.93^{c-f}	5.79^{cd}	2.28^{a}	1.49^{a}	51.70^{a}	44.33^{a}	15.43^{bc}	17.40^{ab}
'Sorgül'	20.70^{ab}	14.90^{ab}	5.14^{h}	5.26^{e}	1.57^{d}	0.99^{b}	32.83^{g}	25.53^{c}	15.40^{bc}	14.53^{g}
'Balcalı-2000'	21.18^{ab}	13.43^{a-d}	5.62^{e-h}	5.55^{de}	1.93^{bc}	1.29^{b}	41.33^{b-f}	34.25^{b}	15.25c	15.55^{def}
LSD (0.05)	5.57	2.69	0.5	0.37	0.29	0.17	5.52	5.36	1.1	0.99
Means	19.0	13.0	5.94	5.88	1.85	1.24	40.9	32.8	16.2	16.2
% Differences	-31.5		-1.0		-32.9		-19.8		0.00	

Means followed by different letters within a column for each year have significant differences at the level of $P<0.05$ for LSD test its late maturing character. This suggests that its tolerance mechanism could be associated with increased desiccation tolerance and/or improved turgor or osmotic adjustment as elsewhere (White and Izquierdo, 1991). Hence, late maturing cultivars can be grown in marginal areas although they may suffer high yield reductions during grain filling (Kımurto *et al.*, 2003). This study indicates that not all-late maturing wheat cultivars could succumb to drought stress.

Therefore, drought stress reduced the number of days to heading, GFP, number of days to maturity, plant height, number of spike per m^2, peduncle length, spike length, number of grains per spike, 1000 grain weight of genotypes while it increased the chlorophyll content, grain protein content and SDS sedimentation. Spikelets per spike were not affected by drought stress. Kılıç *et al.* (1999) has reported that the number of days to heading, number of spike per m^2, 1000 grain weight and grain yield of durum wheat is reduced in the drought and terminal heat stress conditions. Severe water stress from the seedling stage to maturity reportedly reduced all grain yield components, particularly the number of fertile ears per unit area by 60%, grain number per head by 48%, dry matter and harvest index (Giuanta *et al.*, 1993). Paknejad *et al.* (2007) reported that the improvement of cultivar yield under drought stress has resulted from a more extended grain filling duration, a higher chlorophyll content, a more sustained turgor, or a combination of them. On the other hand, Rong-hua *et al.* (2006) reported that the values of chlorophyll content in drought tolerance genotypes of barley were significantly higher than those in drought sensitive genotypes under drought stress. Although stress typically depresses grain yield (Hsiao, 1973), it can elevate the value of other components of the economic yield, such as quality of grain protein (Guttieri *at al.*, 2000).

The effect of drought and well watered regimes on grain yield is displayed in Tab. 4. Yields (calculated as kg ha^{-1}) in well watered plots varied from 4453 to 9550 kg ha^{-1}, and under the drought condition they varied from 2208 to 3505 kg ha^{-1}. Average yield reduction due to drought condition plots were 61.4 %. 'Ege-88' and 'Fırat-93' were the best yielding in well watered conditions, mainly due to 'Ege-88' higher grain filling period and number of grains per spike, whereas 'Sorgül' was the lowest yielding because of its lower grain filling period and grains per spike (Tab. 2, Tab. 3 and Tab. 4). Grain yield was greater in well watered environment than in the drought environment, a consequence of more spikes per square meter, heavier grains, and a longer plant cycle.

DSI values for the yield (Tab. 4) ranged from 0.82 to 1.07. The cultivars 'Altıntoprak-98', 'Aydın-93', 'Gidara', 'Harran-95', 'Sarıçanak-98', 'Sorgül' and 'Balcalı-2000' were relatively drought resistant (DSI values <1), while the varieties 'Ceylan-95', 'Dicle-74', 'Diyarbakır-81', 'D-5456', 'Ege-88', 'Fırat-93' and 'Özberk' were relatively drought susceptible (DSI > 1). Genotypes with low DSI values (less than 1) can be considered to be drought resistant (Bruckner and Frohberg, 1987), because they exhibited smaller yield reductions under water stress compared with well-watered conditions than the mean of all genotypes.

Tab. 4. Means for yield and quality traits of each of 14 durum wheat genotypes and effect of moisture stress on drought susceptibility index values and relative grain yield

Cultivars	1000 grain weight (g.)		Protein content (%)		SDS (ml)		Grain yield (kg ha^{-1})				
	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed	Well watered	Drought stressed	DSI	RYW	RYS
'A.Toprak-98'	46.15^{bc}	34.05^{cde}	12.53	15.69^{a-d}	23.0^{b*}	30.3^{abc}	7395.0^{c}	3165.0^{abc}	0.95	0.78	0.90
'Aydın-93'	41.88^{de}	33.98^{de}	13.32	15.65^{a-d}	23.0^{b}	28.7^{bcd}	8075.0^{bc}	3352.5^{ab}	0.95	0.85	0.95
'Ceylan-95'	46.40^{bc}	36.70^{bc}	12.81	15.60^{bcd}	22.3^{bc}	21.0^{efg}	7720.0^{bc}	2652.5^{bcd}	1.06	0.81	0.75
'Dicle-74'	44.20^{cd}	36.98^{b}	11.71	15.37^{b-e}	24.3^{ab}	27.3^{bcd}	8227.5^{bc}	3122.5^{abc}	1.01	0.86	0.89
'D.Bakır.-81'	47.7^{8b}	36.10^{bcd}	12.34	15.69^{a-d}	16.0^{d}	17.3^{g}	8007.5^{bc}	2833.5^{a-d}	1.04	0.84	0.80
'D.5456'	42.58^{de}	31.73^{e}	12.20	15.96^{abc}	24.7^{ab}	32.0^{ab}	7625.0^{bc}	2593.5^{cd}	1.07	0.80	0.73
'Ege–88'	46.98^{bc}	36.35^{bcd}	11.51	15.07^{cde}	19.7^{bcd}	23.3^{def}	9550.0^{a}	3305.0^{ab}	1.07	1.00	0.94
'Fırat-93'	52.23^{a}	40.75^{a}	13.91	16.24^{ab}	21.0^{bcd}	20.0^{efg}	8537.5^{ab}	3128.5^{abc}	1.01	0.90	0.89
'Özberk'	48.55^{b}	40.65^{a}	12.61	16.01^{abc}	19.7^{bcd}	19.7^{fg}	7957.5^{bc}	2855.0^{a-d}	1.04	0.83	0.81
'Gidara-II'	40.00^{e}	34.48^{bcd}	13.04	14.46^{e}	21.0^{bcd}	27.7^{bcd}	8167.5^{bc}	3505.0^{a}	0.93	0.86	1.00
'Harran-95'	46.20^{bc}	35.48^{bcd}	11.75	15.52^{bcd}	20.0^{bcd}	30.0^{abc}	7632.5^{bc}	3105.0^{abc}	0.97	0.80	0.88
'S.Çanak-98'	44.23^{cd}	33.88^{de}	12.57	14.89^{de}	17.0^{cd}	20.0^{efg}	8187.5^{bc}	3298.5^{abc}	0.97	0.86	0.94
'Sorgül'	46.68^{bc}	35.18^{bcd}	12.77	15.55^{bcd}	16.0^{d}	25.3^{cde}	4452.5^{d}	2208.5^{d}	0.82	0.47	0.62
'Balcalı-2000'	48.55^{b}	36.13^{bcd}	13.45	16.58^{a}	29.0^{a}	35.0^{a}	8280.0^{bc}	3380.0^{a}	0.96	0.87	0.96
LSD(0.05)	3.19	2.67	NS	0.98	5.43	5.57	1098.1	709.8			
Means	45.9	35.9	12.6	15.6	21.2	25.5	7844.0	3035.7		0.82	0.87
% Differences	-21.7		+23.8		+20.2		-61				

Means followed by different letters within a column for each year have significant differences at the level of P<0.05 for LSD test; RYW = relative yield under well watered; RYS = relative yield under water stress condition

The mean RY values under imposed well-watered and water stress treatments were 0.82 and 0.87, respectively (Tab. 4). Cultivars 'Altıntoprak-98', 'Aydın-93', 'Dicle-74', 'Ege-88', 'Fırat-93', 'Gidara', 'Harran-95', 'Sarıçanak-98', and 'Balcalı-2000' were relatively high yielding under water stress (RY>mean RY), while 'Ceylan-95', 'Diyarbakır-81', 'D-5456', 'Ege-88', 'Fırat-93', 'Sorgül' and 'Özberk' were relatively low yielding (RY<mean RY) in this treatment. These genotypes with good yield potential differed in their yield components. Under drought conditions, 'Sarıçanak-98' had the highest spike weight, number of grains per spike and GFP. 'Gidara-II' had the highest chlorophyll content and 'Aydın-93' had the longest Peduncle length. As number of grains per spike is typically the yield component that is most sensitive to high temperatures and drought, it has been suggested as a selection criterion for drought tolerance (Shpiler and Blum, 1991). Fischer and Wood (1978) also showed spikes and grains per unit area to be genotypically correlated to yield under late season drought stress during grain filling.

The results of this study are in good agreement with the early findings of Rashid *et al.* (2003), when they reported considerable variation in DSI and RY values of certain wheat genotypes under water stress condition.

In drought conditions of experiments, a positive and significant correlation was observed between grain yield and grain filling period, chlorophyll content, number of grains per spike and spike weight. However, a negative and significant correlation was observed between grain yield and number of days to heading (Tab. 5). Likewise, the negative correlation between yield under stress and flowering date has frequently been found (Dodig *et al.*, 2010). The grain yield of any cultivar is dependent on its yield components as Sheron *et al.* (1986) observed that plant height, spike length and grain per spike were directly related to grain yield. Similarly, Shams-ud-din (1987) reported that spikes per plant, grains per spike, 1000-grain weight, harvest index, glumes weight and biological yield were directly related to the grain yield of wheat. According to another study of durum wheat yield components, Simane *et al.* (1993), using path analysis, found that the number of grains per spike and grain weight had significant positive, direct effects on grain yield under moisture stress conditions, as well as under well-watered conditions.

Correlations between grain yield DSI and yield components of drought condition were evaluated for the 14 cultivars included in this study. Grain yield DSI was negatively correlated with the number of days to maturity (r=

Tab. 5. Correlation (r) between DSI for yield and yield components under drought condition

	Number of days to heading	Grain filling period	Number of days to maturity (days	Plant height	Peduncle length	Chlorop hyll content	1000 grain weight	Protein content	SDS sedimentation	Number of spike per m-2	Grains/spike	Spike weight	Spikelets/spike	Spike length	Grain yield	DSI (grain yield)
Number of days to heading	1.00															
Grain filling period	-0.679*	1.00														
Number of days to maturity	0.521	0.271	1.00													
Plant height	0.469	-0.175	0.412	1.00												
Peduncle length	0.187	0.106	0.368	0.656*	1.00											
Chlorophyll content	-0.601*	0.373	-0.354	-0.243	0.283	1.00										
1000 grain weight	-0.092	-0.039	-0.167	0.059	-0.260	0.107	1.00									
Protein content	0.424	-0.609*	-0.153	0.249	-0.283	-0.285	0.354	1.00								
SDS sedimen.	0.269	-0.3	0.005	0.005	0.11	-0.09	-0.5	0.2	1.00							
Number of spike per m-2	0.528	-0.307	0.336	0.947	*0.603	-0.319	-0.040	0.208	0.095	1.00						
Grains/spike	-0.549*	0.480	-0.163	-0.536*	-0.163	0.353	-0.390	-0.317	0.010	-0.593*	1.00					
Spike weight	-0.623*	0.374	-0.382	-0.579*	-0.268	0.483	0.097	-0.198	-0.175	-0.650	0.838*	1.00				
Spikelets/spike	-0.365	0.257	-0.180	-0.305	0.166	0.396	-0.453	-0.398	-0.015	-0.229	0.646*	0.549*	1.00			
Spike length	-0.095	-0.206	-0.365	-0.491	-0.438	-0.063	-0.255	0.096	-0.050	-0.402	0.075	-0.078	0.303	1.00		
Grain yield	-0.721**	0.552*	-0.304	-0.351	0.002	0.645*	-0.008	-0.260	0.217	-0.389	0.584*	0.6516*	0.379	-0.236	1.00	
DSI (grain yield)	-0.466	-0.140	-0.774*	-0.531	-0.506	0.271	0.225	0.152	-0.307	-0.498	0.143	0.263	0.166	0.725*	0.070	1.00

** and * significant at the 0.01 and 0.05 levels, respectively

–0.774, P, 0.05). Spike length was also positively correlated (*r*= 0.725, P, 0.05). However, grain yield DSI was uncorrelated with the number of days to heading, grain filling period, plant height, peduncle length, chlorophyll content, 1000 grain weight, protein content, SDS sedimentation, number of spike per m^2, number of grains per spike, spike weight, spikelets per spike and grain yield. Likewise, Ehdaie (1993) in his studies on the drought stress susceptibility of 10 wheat cultivars in Khuzestan province of Iran concluded that he found no correlation between yield and stress susceptibility index. Therefore, maturity date and spike length represent useful selection alternatives for introducing drought tolerance in early generations.

Conclusions

It is concluded from the results of this study that water stress reduced wheat yield and some yield components in all cultivars. The differential response of cultivars to imposed water stress condition indicates the drought tolerance ability of wheat cultivars. On an overall, our results and the findings of others show that a strategy of selecting should take into consideration early flowering, long grain filling period, late maturity period, low DSI (DSI values<1), a high number of grains per spike, high spike weight and short spike length for increasing yields under drought conditions. Cultivars 'Gidara-II', 'Sarıçanak-98', 'Balcalı-2000', 'Altıntoprak-98', 'Aydın-93' and 'Harran-95' showed high yield potential and stability under drought stress and they maintained their yield across a range of water availabilities.

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