Turkish Journal of
Field Crops
2013, 18(2), 144-150

THE EFFECT OF WATER STRESS ON SPIKELET POSITION WEIGHT VARIATION IN WHEAT

Mustafa YILDIRIM

Kelkit Aydin Dogan Vocational High School, Gumushane University, Gumushane, TURKEY.
Corresponding author: myildirimkm@gmail.com

Received: 09.07.2013

ABSTRACT

This study was conducted in Eskisehir during the 2004-05 and 2005-06 growing seasons, and aimed to evaluate the response of six bread wheat varieties to rainfed and irrigated conditions in terms of grain yield, heading date, plant height and position weight variation (PWV). Of the six varieties tested, three (Sultan, Yildiz, Bezostaja) are drought-sensitive cultivars and three (Gerek, Altay, Sonmez) are drought-tolerant cultivars. Spikes from each variety were divided into five spikelet groups in order to study the effect of spikelet position upon grain weight (S1, S2, S3, S4 and S5, with S1 the spikelet closest to the base). This study focused on position weight variation (PWV) in order to better understand how 1000-kernel weight is affected by spikelet position under both rainfed and irrigated conditions and thus gains a better understanding of wheat resistance to drought. Linear increases in grain yield, heading date and plant height were observed in response to irrigated conditions, whereas a linear increase in PWV was observed in response to rainfed conditions for both seasons. Grain yield was negatively associated with heading date (r=-0.746). PWV was positively associated with grain yield and negatively associated with heading date (p<0.01; r=0.804 and r=-0.860, respectively). The observed differences in grain weight between spikelet positions have important implications for drought tolerance in wheat and can be used as a new parameter for predicting drought tolerance.

Key Words; spikelet position weight, water stress, wheat

INTRODUCTION

An increase in yield per unit area is required to feed an ever-expanding world population which was estimated at 7 billion as of 2011 (Rosenberg, 2012). According to the FAO (2009), annual cereal production will need to rise to about 3 billion tons from 2.1 billion. However, in recent years, drought has sprung up unpredictably in a world experiencing climate change (Brown, 2008). In order to support climate-related decisions such as which varieties to plant and when, how much water is needed for irrigation, when and where disease outbreaks are likely to occur, or whether to reduce livestock numbers in case of drought, monthly, seasonal and decadal climate predictions are needed (Bernardi, 2011).

The greater adaptation of bread wheat relative to other cultivated species has made it one of the most important global food crops (Rajaram, 2005) cultivated across different environments. In the process of screening wheat genotypes for breeding, grain yield is considered the most important parameter (Yildirim, 2005; Forgone, 2009). Rain is the most important factor affecting grain yield (Altay, 2006), the improvement of which is the primary goal of most wheat-breeding programs. Under drought conditions, however, actual yield is dependent upon genotype phenology as well as yield potential (Acevedo, 1991). Unfortunately, plant response to moisture stress has a negative effect on grain yield (Schmidt, 2003), which decreases significantly as a result of drought stress (Madani et al., 2010). In temperate climates, grain yields are limited by drought conditions occurring in early summer, which coincides with the grain-filling period of wheat (Forgone, 2009). Given the polygenic character of drought tolerance, a single drought-tolerance parameter may not be very meaningful on its own (Sadiq, 1994; Tirado and Cotter, 2010); rather, breeders must work with a number of parameters to achieve drought tolerance (Cekic, 2007), and considerable variations can be found among varieties developed for rainfed conditions versus those designed for irrigated conditions (Cekic, 2007). Drought conditions often involve not only water, but also heat stress, which reduces the duration of grain filling (Blum, 1998) and negatively affects the translocation of dry matter after flowering (Garcia del Moral et al., 2003; Ilker et al., 2011). This process occurs at different levels: tillers, spikelets and even grains within spikelets (Ozturk and Aydin, 2004).Breeders believe that tall varieties tolerate drought stress better than shorter varieties (Blum et al., 1999; Atay, 2006). Flowering is another parameter used for measuring drought tolerance, with late flowering resulting in reductions in grain yield under drought conditions (Rajaram et al., 1995; Blum et al., 1999).

Grain yield is determined by the number of spikes per plant, number of grains per spike and grain weight. Grain weight, which is one of the most important traits in terms of yield and has been an important criterion in the selection of higher-yielding plants (Roderet al., 2008), is affected by differences in kernel weight, which varies according to spike position (Bremner, 1972). Grain filling rates and durations for individual kernels are affected by environmental factors such as drought stress (Li et al., 2001). Wheat flowering as well as grain filling begin at mid-spike and continue upwards and downwards (Peterson, 1965), and it is possible to distinguish between varieties developed for rainfed and irrigated conditions according to the order of spikelet grain filling within the spike. This study is based on the assumption that the effect of water stress on kernel weight varies according to spikelet position; thus, the aim of the study was to examine the effects of drought on plant height, grain yield, heading date and position weight variation (PWV) of six bread wheat varieties over two growing seasons.

MATERIALS AND METHODS

This study was carried out at Anatolian Agricultural Research Institute in Eskisehir, Turkey during the 2004-2005 and 2005-2006 growing seasons. The experiment station is located at 39° 45' N latitude, 30° 33' E longitude at an altitude of 801 m above sea level (Anon., 2012a). The trial area was divided into two areas, one for each year of the experiment, and each of these was sub-divided into two separate growing areas, one for irrigated and one for rainfed conditions. Wheat varieties included Sultan, Yildiz and Bezostaja, which are bread wheat cultivars registered in Turkey for cultivation under irrigated conditions, and Gerek, Altay and Sonmez, which were registered in Turkey for cultivation under rainfed conditions (Anon., 2003). The experimental design and agronomic treatments from planting to harvest for both growing seasons are presented in Table 1 (Cekic, 2007). Experimental plots consisted of 5-m long with six rows 20-cm apart on each row.

Table 1. Experimental design and agronomic treatments from planting to harvest.

Material and Methods		2004-2005 Crop Season		2005-2006 Crop Season	
		Irrigated	**Rainfed**	**Irrigated**	**Rainfed**
Cultivars		6	6	6	6
Replications		3	3	3	3
Sowing density		550 seeds m^{-2}	550 seeds m^{-2}	550 seeds m^{-2}	550 seeds m^{-2}
Sowing date		14 Oct., 2004	14 Oct., 2004	12 Oct., 2005	12 Oct., 2005
Irrigation	**1st**	14 Oct., 2004	14 Oct., 2004	12 Oct., 2005	12 Oct., 2005
	2nd	8 Apr., 2005	-	3 Apr., 2006	-
	3rd	4 May 2005	-	8 May 2006	-
	4th	7 June 2005	-	5 June 2006	-
Fertilization	**Sowing date**	P_2O_5 ;70 kg ha^{-1} DAP; 27 kg ha^{-1}	P_2O_5;70 kg ha^{-1} DAP; 27 kg ha^{-1}	P_2O_5 ;70 kg ha^{-1} DAP; 27 kg ha^{-1}	P_2O_5;70 kg ha^{-1} DAP; 27 kg ha^{-1}
	Zadoks 24 †	AN; 40 kg ha^{-1}	AN; 70 kg ha^{-1}	AN; 40 kg ha^{-1}	AN; 70 kg ha^{-1}
	Zadoks 50 †	AN; 30 kg ha^{-1}	-	AN; 30 kg ha^{-1}	-
Weed control		Herbicide	Herbicide	Herbicide	Herbicide

†Zadoks, 1974.

The soil in the experimental area was characterized as loamy with mild alkalinity, no salinity problem, medium amounts of organic matter and calcium, poor in terms of available phosphorus and rich in terms of available potassium (Anon., 2004).

Monthly rainfall data over two growing seasons and long-term are shown in Figure 1 (Anon., 2006). As the figure shows, rainfall was below average in both the 2004-05 and 2005-06 growing seasons (287.1 and 280.3 mm, respectively). Early summer drought limits grain yield and yield components. Precipitation amount in April, May and June are very important in terms of total rainfall. Therefore, precipitation in these months was low enough in terms of drought in these years.

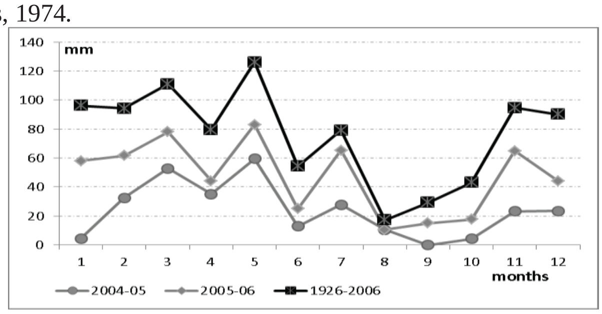

Figure 1 Average monthly rainfall (mm) in Eskisehir during the 2004-05 and 2006-06 experimental years and over the long-term.

Growing parameters measured in this study included grain yield, heading date, plant height and 1000-kernel weight by spikelet position. Heading date was calculated from May 1 to heading stage. Plant height was measured in centimeters during the pre-harvest period. Plot yields were measured in kilograms after harvesting and were converted to hectare yields. For each irrigated and rainfed plots, 40 main stem of plants with the same heading date were marked and cut pre-harvest. In order to study the effect of spikelet position upon grain weight, fertile spikelets from each spikes were distributed equally among 5 spikelet regions (S1, S2, S3, S4 and S5, starting at the spike base and proceeding upwards (Figure 2), with remaining spikelets distributed from the center spikelet (S3) outwards. (For example, in grain spikes with 22 spikelets, 4 spikelets each were included in S1, S2, S4 and S5 and 6 spikelets were included in S3, whereas in grain spikes with 23 spikelets, 4 spikelets each were included in S1 and S5 and 5 spikelets each were included in S2, S3 and S4.) Sterile spikelets were not counted. Spikelets from 40 spikes were divided according to spikelet position, and spikelets from the same position were combined for measurement in the same cup, with seeds separated from spikelets by hand to prevent grain loss. Grain was weighed on a precision scale with an accuracy of 200g/0.001g, and 1.000-kernel weight was calculated by spikelet position.

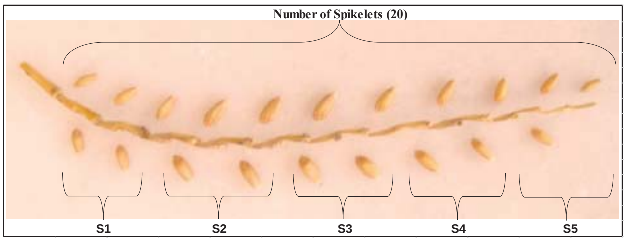

Figure 2 A grain spike divided into 5 regions of fertile spikelets.

Severity of Water Stress and Drought Sensitivity Index were calculated as follows (Fischer and Maurer, 1978:

$$\text{Severity of Water Stress} \quad \frac{(\text{Yield of Irrigated Condition*} - \text{Yield of Rainfed Condition*})}{\text{Mean Yields of Irrigated}}$$

* The mean of yields of all varieties for each condition.

$$\text{Drought Sensitivity Index} \quad \frac{[(\text{Yield of Irrigated}\dagger - \text{Yield of Rainfed}\dagger) / \text{Yield of Irrigated}\dagger]}{\text{Severity of Water Stress}}$$

† The grain yield of variety.

PWV was calculated using the following formulas;

$$PWV\ddagger = P_{S3} - \frac{(P_{S1}+P_{S5})}{2}$$

PWV : Position weight variation (g),
P_{S1} :1.000-kernel weight of bottom spikelets (g),
P_{S3} :1.000-kernel weight of middle spikelets (g),
P_{S5} :1.000-kernel weight of top spikelets (g),
‡ In these calculations, S1, S3 and S5 were used. S2 and S4 were not included in the calculation.

DTKW: Differences in 1.000-kernel weight of spikelet positions between irrigated and rainfed conditions (g),

$$DTKW_{(sn)} = (P_{sn} \text{ of Irrigated§} - P_{sn} \text{ of Rainfed§})$$

sn: Calculated 1.000-kernel weight of spikelet position (g),
§ Calculated using the overall mean of all plots for both years

Mean values of grain yield, plant height, heading date and PWV for each variety and each year were calculated according to the following formula:

$$D_{(n)} = (Irrigated_{(n)}\P - Rainfed_{(n)}\P)$$

¶ *the mean of all plots of a variety in a treatment*

$D_{(n)}$: Data for the parameter being calculated,

Degree of freedom (SD) was calculated using the following formula:

$$SD = (2 \text{ years} \times 6 \text{ varieties}) - 1 = 11$$

All data analysis was performed using the MSTAT statistical package for analysis of variance (ANOVA) (Anon., 1986). Correlation values were calculated and graphs drawn using MS-Excel 2010 (Anon., 2012b).

RESULTS AND DISCUSION

This study found a wide range of heading dates, grain yields and PWVs for irrigated and rainfed plants. Genotype and treatment (irrigated vs. rainfed) had the greatest effect on the parameters tested ($p<0.01$). Treatment had the highest effect ($p<0.01$) on grain yield and PWV in both 2004-05 and 2005-06. Whereas heading date, grain yield and plant height all increased with irrigation, PWV decreased with irrigation. A mean increase of 51.2% in grain yields and a mean decrease of 42.9% in PWV values of drought-sensitive cultivars were observed for the two growing seasons studied (Table 2). Earliest mean heading dates were obtained for Sonmez, Gerek and Altay varieties (17, 17 and 20 days, respectively) under rainfed conditions. When the effects of irrigation treatment on grain yields are examined, Altay was found to have the highest grain yields under rainfed conditions (3.410 $kgha^{-1}$), whereas Sultan performed best under irrigated condition (6.546 $kg\ ha^{-1}$).

Table 2 Mean heading dates, grain yields, plant heights and PWV values for combined experimental years by treatment (irrigated vs. Rainfed conditions) and variety.

Treatment	Varieties	Heading (day)	Grain Yield (ha^{-1})	Height (cm)	PWV (g)
Rainfed*	Gerek	17 ^{E}	2.791 ^{B}	73.7 ^{A}	17.2 ^{BC}
	Sonmez	17 ^{E}	3.321 ^{A}	71.0 ^{AB}	20.6 ^{A}
	Altay	20 ^{D}	3.410 ^{A}	66.3 ^{C}	18.3 ^{AB}
	Sultan	29 ^{A}	2.184 ^{C}	60.5 ^{D}	7.7 ^{D}
	Yildiz	28 ^{B}	2.017 ^{D}	69.0 ^{BC}	9.6 ^{D}
	Bezostaja	24 ^{C}	2.034 ^{D}	71.3 ^{AB}	14.7 ^{C}
LSD (P < 0.05)		0.5	106	3.2	2.8
Irrigated#	Gerek	23 ^{F}	5.142 ^{D}	109.8 ^{A}	9.3 ^{D}
	Sonmez	23 ^{E}	5.388 ^{C}	109.2 ^{A}	13.6 ^{B}
	Altay	25 ^{D}	5.161 ^{D}	110.6 ^{A}	11.1 ^{C}
	Sultan	30 ^{A}	6.546 ^{A}	101.0 ^{C}	12.2 ^{C}
	Yildiz	29 ^{B}	5.752 ^{B}	99.1 ^{C}	9.1 ^{D}
	Bezostaja	26 ^{C}	4.467 ^{E}	105.4 ^{B}	16.3 ^{A}
LSD (P < 0.05)		0.6	207	2.5	1.2

#Mean heading dates, grain yields, plant heights and PWV values for combined experimental years.

The PWV values of Sonmez, Altay and Gerek (20.6%, 18.3% and 17.2%, respectively) were higher than the PWV values of Bezostaja, Yildiz and Sultan (14.7%, 9.6% and 7.7%, respectively) under rainfed conditions (Figure 3). The PWV value of Gerek was decreased by 7.9 percentage points to 9.3% under irrigated conditions in comparison to rainfed conditions, indicating that under drought conditions, central spikelets of Gerek spikes receive more nutrients, with top and bottom spikelets receiving fewer nutrients. A similar phenomenon was observed in Sonmez and Altay, two-other drought-tolerant cultivars tested, whereas irrigation did not have a significant effect on the PWV values of any of the drought-sensitive cultivars tested.

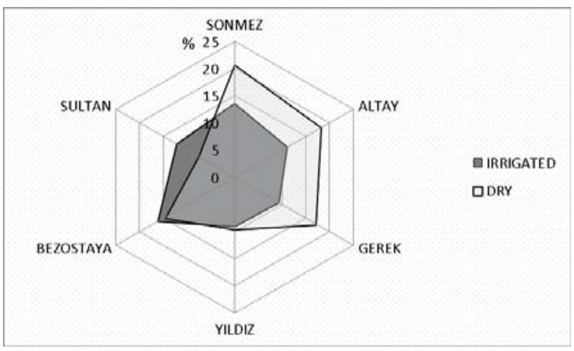

Figure 3 Position weight variations (PWV) of six wheat varieties under irrigated and Rainfed conditions.

The water stress severities of irrigated and rainfed treatments were 49% and 54% (2004-2005 and 2005-2006 growing seasons, respectively). Drought sensitivity index values of the varieties tested are given in Table 3. The values showed that grain yields of Bezostaja, Yildiz and Sultan (1.06, 1.26 and 1.29, respectively) were higher than those of Altay, Sonmez and Gerek (0.66, 0.75 and 0.89, respectively). (It should be noted that in the formula used here, lower PWV values represent greater sensitivity to drought, and vice versa).

Table 3 Drought sensitivity indexes for the parameters heading date, grain yield, plant height and PWV, by wheat variety and experimental year.

		Varieties					
Parameters	**Years**	**Gerek**	**Sonmez**	**Altay**	**Sultan**	**Yildiz**	**Bezostaja**
Heading	2005	0.44	0.53	0.40	0.00	0.00	-0.05
	2006	0.54	0.58	0.40	0.09	0.11	0.28
	Mean	0.49	0.56	0.40	0.04	0.05	0.11
Yield	2005	0.87	0.74	0.67	1.31	1.27	1.07
	2006	0.91	0.75	0.65	1.28	1.26	1.05
	Mean	0.89	0.75	0.66	1.29	1.26	1.06
Height	2005	0.73	0.71	0.81	0.84	0.65	0.66
	2006	0.55	0.65	0.75	0.72	0.53	0.60
	Mean	0.64	0.68	0.78	0.78	0.59	0.63
PWV	2005	-1.46	-1.11	-1.22	0.77	-0.19	0.25
	2006	-1.87	-0.92	-1.28	0.68	0.04	0.14
	Mean	-1.66	-1.02	-1.25	0.73	-0.08	0.19

Of all varieties tested, Sultan, a cultivar developed for irrigated conditions, showed the highest sensitivity to drought stress in terms of drought sensitivity index values both 2004-05 and 2005-06 (1.31 and 1.28, respectively), whereas Altay, which was developed for rainfed conditions, showed the highest tolerance in terms of drought sensitivity index values (0.67 and 0.65, respectively, for 2004-05 and 2005-06). Sonmez showed the highest tolerance to drought in terms of heading date in both 2004-05 and 2005-06. In terms of plant height, Sultan was the most drought-tolerant in 2004-2005, whereas Altay was the most drought-tolerant in 2005-06. According to PWV values, Gerek showed the highest drought tolerance in both 2004-2005 and 2005-2006 (-1.46 and -1.87, respectively), whereas Sultan showed the highest sensitivity to drought (0.77 and 0.68 in 2004-2005 and 2005-2006, respectively).

Grain yield was negatively associated with heading date (r=-0.746) (Figure 4). PWV was positively associated with grain yield and negatively associated with heading date (r=0.804 and r=-0.860; p<0.01, respectively); PWV was not associated with plant height.

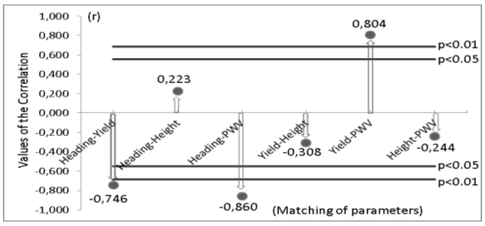

Figure 4 Relationships among heading date, grain yield, plant height and PWV.

Heading dates showed greater variation under rainfed and irrigated-conditions among drought-tolerant varieties (23.9%) in comparison to drought-sensitive varieties (4.7%) (Table 4). Plant height showed greater variation under rainfed and irrigated-conditions among drought-tolerant varieties (36%) in comparison to drought-sensitive varieties (34.3%). Grain yield showed greater variation under rainfed and irrigated-conditions among drought-sensitive varieties (39.3%) in comparison to drought- tolerant varieties (62.8%). PWV values showed greater variation under rainfed and irrigated-conditions among drought-tolerant varieties (65%) in comparison to drought-sensitive varieties (14.9%).

Gerek showed the lowest variation in PWV rates (-84.9%), followed by Altay (-64.9%) and Sonmez (-51.5%). Sultan showed the highest variation in grain yield rates (66.6%), followed by Yildiz (64.9%) and Bezostaja (54.6%).

Polynomial graphs of mean differences in 1.000-kernel weight by spikelet position between drought-sensitive and drought-tolerant cultivars exhibited inverted symmetry (Figure 5). Whereas polynomials of drought-tolerant varieties (Gerek, Sonmez and Altay) exhibited upward-curving graphs, those of drought-sensitive varieties (Sultan, Yildiz and Bezostaja) exhibited downward-curving graphs.

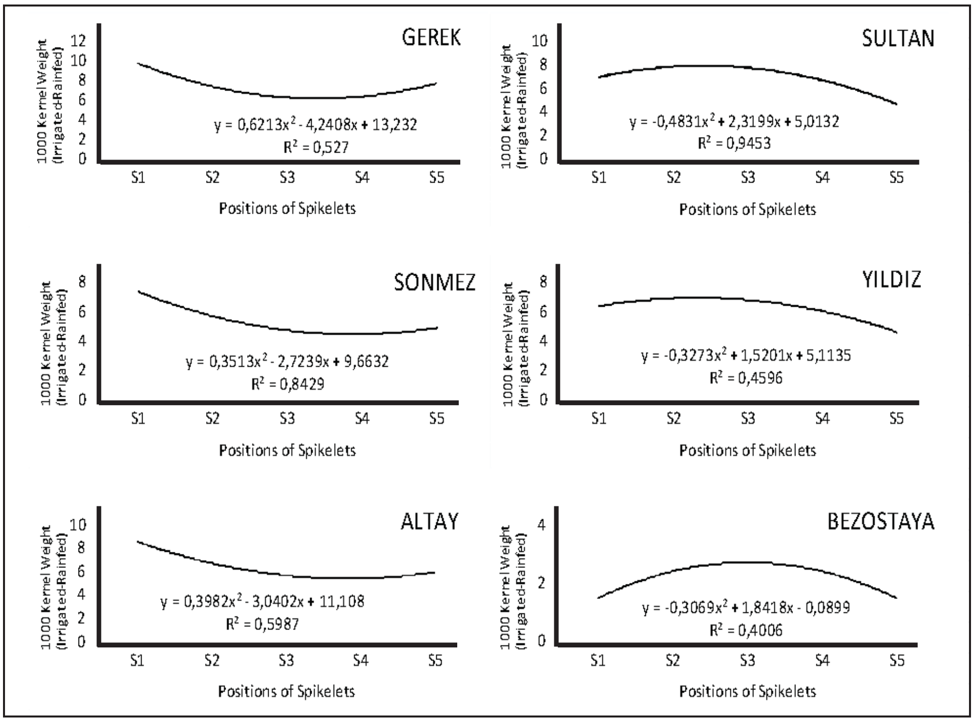

Figure 5 Differences in 1.000-kernel weight (DTKW) of spikelet positions between irrigated and Rainfed conditions for six wheat varieties.

Table 4 Mean differences in heading date, grain yield, plant height and PWV under irrigation vs rainfed conditions, by wheat variety.

Varieties	Heading Date		Grain Yield		Plant Height		PWV	
	I-R*	%#	I-R*	%#	I-R*	%#	I-R*	%#
Gerek (G)	5.7	24.8%	2.351	45.7%	36.1	32.9%	-7.9	-84.9%
Sonmez (Sn)	6.6	28.7%	2.067	38.4%	38.2	35.0%	-7.0	-51.5%
Altay (A)	5.2	20.8%	1.751	33.9%	44.3	40.1%	-7.2	-64.9%
Sultan (Sl)	1.0	3.3%	4.362	66.6%	40.5	40.1%	4.5	36.9%
Yildiz (Y)	0.8	2.8%	3.735	64.9%	30.1	30.4%	-0.5	-5.5%
Bezostaja (B)	1.6	6.2%	2.433	54.5%	34.1	32.4%	1.6	9.8%
Rainfed Character Varieties	5.7	23.9%	2.056	39.3%	39.5	36.0%	-7.4	-65.0%
Irrıgated Character Varieties	1.3	4.7%	3.510	62.8%	34.9	34.3%	1.9	14.9%

* Irrigated – Rainfed

(Irrigated – Rainfed) x 100 / Irrigated

Polynomial graphs of mean differences in spikelet positions of drought-sensitive and drought-tolerant cultivars exhibited inverted symmetry (Figure 6). Data for mean differences in 1.000-kernel weight by spikelet position is in line with drought sensitivity index data.

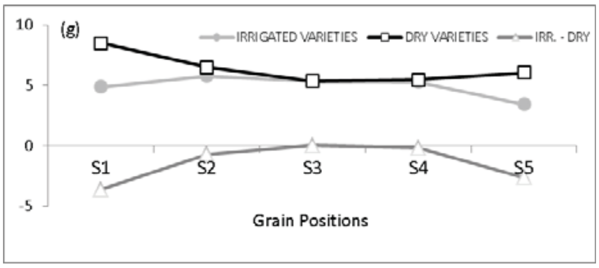

Figure 6 Mean differences in 1.000-kernel weight by spikelet positions between drought-tolerant (Gerek, Sonmez and Altay) and drought-sensitive varieties (Sultan, Yildiz and Bezostaja).

CONCLUSION

Water is the most important factor to influence wheat grain yields. Individual yield components such as fertile spikelets per spike and grain weight per spikelet differ in their responses to drought conditions and are used as indicators of water stress in breeding for drought tolerance. The grain filling rates of drought-tolerant varieties are optimal under drought conditions. Position weight variation (PWV) values of drought-tolerant varieties differ significantly from those of drought-sensitive varieties due to variations in the distribution of photosynthetic products among spikelets. In comparison to drought-sensitive cultivars, drought-tolerant cultivars distribute less photosynthetic products towards the ends of the spike under drought conditions. Drought-tolerant varieties maintain acceptable grain size in the middle of the spike; therefore, PWV can be used as a parameter in developing drought-tolerant wheat cultivars.

LITERATURE CITED

Acevedo, E., M. Nachit and G. Ortiz-Ferrara. 1991. Effects of heat stress on wheat and possible selection tools for use in breeding for tolerance. In: D.A Saunders, (ed) Wheat for the Nontraditional Warm Areas. Mexico, D.F.: CIMMYT. pp. 401-421.

Altay, F. 2006. Winter wheat yield statistics. Eskisehir Anatolian Agricultural Research Institute.

Anonymous. 1986. MSTAT-C Statistical Program. Michigan State. East Lansing, Michigan State University, USA.

Anonymous. 2003. Wheat varieties (irrigated & rainfed) and durum wheat varieties presentation catalog. Anatolian Agriculture Research Institute, Eskisehir.

Anonymous. 2004. Soil analysis report. Soil and Water Resources Research Institute, Eskisehir.

Anonymous. 2006. Weather report data from Eskisehir Anatolian Agricultural Research Institute.

Anonymous. 2009. Food and Agriculture Organization of the United Nations. Rome, www.fao.org

Anonymous. 2012a. Eskisehir Province latitude, longitude and altitude, and the General Directorate of State Meteorological, www.dmi.gov.tr.

Anonymous. 2012b. Microsoft Excel 2010. Microsoft Corporation. USA.

Atay, A.T. 2006. History of the Turkish seed breeding. Chapter 2, Seed File 4, the republic of seed breeding period. Agriculture and Engineering. 78-79: 45-50.

Bernardi, M. 2011. Understanding user needs for climate services in agriculture. Bulletin, Volume 60(2). http://www.wmo.int/pages.

Blum, A. 1998. Improving wheat grain filling under stress by stem reserve mobilization. In: H. J. Braun et al. (eds). Wheat: Prospects for Global Improvement. Kluwer Academic Puplishers. pp. 135-141.

Blum, A., G. Golan, J. Mayer, B. Sinmena, L. Shpiler and J. Bura. 1999. The drought response of landraces of wheat from the Northern Negev Desert in Israel. Euphytica. 43: 87-96.

Bremner, P.M. 1972. The accumulation of dry matter and nitrogen by grains in different position of the wheat ear, as influenced by shading and defoliation. Aust. J. Biol. Sci. 25: 657–668.

Brown, O. 2008. Migration and climate change. IOM Migration Research Series, No: 31. International Organization for Migration. ISSN 1607-338X.

Cekic , C. 2007. A study on physilogical parameters which can be used as selection criteria in breeding wheat (*Triticum aestivum* L.) for drought resistance. Ankara Univ. Institute of Natural Science. Phd Thesis.

Fischer, R.A. and R. Maurer. 1978. Drought resistance in spring wheat cultivars. I. grain yield responses. Austr. J. Agric. Res. 29: 897-912.

Forgone, A.G. 2009. Physiological indicators of drought tolerance of wheat. Biology PhD Program. University of Szeged Faculty of Science and Informatics Department of plant Biology, Szeged.

Garcia del Moral, L.F., Y. Rharrabti, D. Villegas and C. Royo. 2003. Evaluation of grain yield and its components in durum wheat under Mediterranean conditions: An onto genic approach. Agronomy Journal. 95: 266-274.

Gunes, A.M. 2010. Framework convention on climate change and the Kyoto Protocol which are legal developments in the international arena against global warming. Journal of the Bar Association of Turkey, 87:43.

Ilker, E., O. Tatar, F.A. Tonk and M. Tosun. 2011. Determination of tolerance level of some wheat genotypes to post-anthesis drought. Turkish Journal of Field Crops. 16: 59-63.

Li, A., Y. Hou and A. Trent. 2001. Effects of elevated atmospheric CO_2 and drought stress on individual grain filling rates and durations of the main stem in spring wheat. Agricultural and Forest Meteorology. 106: 289-301.

Madani, A., A. Shirani Rad, A. Pazoki, G. Nourmohammadi and R. Zarghami. 2010. Wheat (*Triticum aestivum* L.) grain filling and dry matter partitioning responses to source: sink modifications under post-anthesis water and nitrogen deficiency. Acta Scientiarum. Agronomy. Maringá. 32(1): 145-151.

Ozturk, A. and F. Aydin. 2004. Effect of water stress at various growth stages on some quality characteristics of winter wheat. J. Agronomy and Crop Sci. 190: 93-99.

Peterson, R.F. 1965. Wheat: Botany, cultivation and utilisation. Leonard Hill, London, pp. 448.

Rajaram, S., H.J. Braun, M. Van Ginkel and P.M.A. Tigerstedt. 1995. CIMMYT'S Approach to breed wheat for drought tolerance. Euphytica. 92(1-2): 147-153.

Rajaram, S. 2005. Role of conventional plant breeding and biotechnology in future wheat production. Turkish Journal Agric. Forestry. 29: 105-111.

Roder, M.S., X.Q. Huang and A. Borner. 2008. Fine mapping of the region on wheat chromosome 7D controlling grain weight. Funct. Integr. Genomics, 8: 79-86.

Rosenberg, M. 2012. Current world population and world population growth since the year One. http://geography.about.com/od/obtainpopulationdata/a/worldpopulation.htm

Sadiq, M.S., K.A. Siddiqui, C.R. Arain and A.R. Azami. 1994. Wheat breeding in water stressed environment. First delineation of drought tolerance and susceptibility. Plant Breeding. 113: 36-46.

Schmidt, J.W. 2003. Drought resistance and wheat breeding. Paper No. 6974, Journal series, Nebraska Agricultural Experiment Station. Department of Agronomy, University of Nebraska, USA.

Tirado, R. and J. Cotter. 2010. Ecological farming: Drought-resistant Agriculture Greenpeace Research Laboratories. GRL-TN 02/2010. www.greenpeace.org.

Yildirim, M. 2005. A study on heredity of some agronomical, physiological and quality characteristics in diallel F_1 off springs of selected six bread wheat (*Triticum aestivum* L.) cultivars. Natural Science of Cukurova Univ. PhD Thesis, register no: 893 pp.57.

Zadoks, J.C., T.T. Chang and C.F. Konzak. 1974. "A decimal code for the growth stages of cereals". Weed Res. 14: 415-421.