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INVESTIGATION ON SELECTION CRITERIA FOR DROUGHT TOLERANCE OF BREAD WHEAT *(Triticum aestivum* L.) IN THE NORTH-WEST TURKEY

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Abstract

This study was carried out with 27 bread wheat genotypes during two crop seasons. The great variations were determined between first and second year means of genotypes for all characters. The correlation between grain yield and rate of water losses at heading stage, number of stomata and days to flowering in the first year were found significant and negative. The correlation only between grain yield and days to maturity was positive and significant in the second year. The highest direct positive effects on grain yield were computed for plant height in two years. Although rate of water losses at heading stage showed negative direct effect on grain yield in the first year, it influenced the grain yield positively in the second year. It can be concluded that plant height, days to flowering, maturity, and rate of water losses at heading stage might be effective selection criteria for drought tolerance in semi-arid regions, such as Tekirdağ.

Keywords: Bread wheat, flag leaf area, rate of water loss, glaucousness, stomata, grain yield.

Introduction

Wheat is an important main food crop and source of almost 20% of total calories of the world population. It is grown mostly under rainfed conditions in Thrace region of Turkey like in many countries. The region produces about 10% of national wheat production of the country. Baer *et al*. (2004) found that water consumption of wheat was changed between 566-593 mm during growing period in Thrace region. Average annual precipitation in the region was about 575 mm, with more than 70% of it falling during September to March. There is very limited water loss with evapo-transpiration during the mentioned cooler months. After this period, rainfall is about to stop, crop starts to use residual soil moisture and consume it before May. In other words, even though annual precipitation should be adequate but there is lacking rainfall at critical growth stages resulting reduced yield. Under these conditions, there are two types of choice for farmers. First is to select drought tolerant genotypes and second is to make the irrigation. In the near future, limited water resources will only be available for drinking water due to effect of global warming. For this reason, the most accurate choice is to develop varieties which can tolerate drought hazards. But it is prerequisite to

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determine the drought related criterion for variety improvement program in the region. Drought tolerance of a plant genotype is a product of many physiological and morphological characters for which effective selection criteria have not yet been developed (Ludlow and Muchow, 1990). The multitude factors involved in plant response to water stress make it difficult to provide a test of drought tolerance (Moustafa *et al.*, 1996).

As a major crop, wheat has gained special attention in respect to morphological and physiological characters affecting drought tolerance, including stomata number, leaf area, relative water content, etc. Some agronomic traits, such as grain yield and its components have also served as criterion for drought tolerance (Dencic *et al*., 2000). The objective of this study was to determine response of bread wheat genotypes to rigid fluctuations in soil moisture and climate and the effect on changes in yield and some drought-related characters in semi-arid regions as Tekirdag Conditions of Turkey.

Materials and Method

Plant material: Eight bread wheat cultivars and 19 advanced bread wheat lines selected from the CIMMYT collection were used as genetic material. These lines originated from 30th ISWYN (1995-96), 27th TBWSN (1995-96), EPCME2HR (1995-96), and EPCME7WF (1995-96).

Location and crop management: The experiments were conducted at Experimental Field of Tekirdağ Agricultural Faculty at latitude 40^0 36'-40^0 31' and longitude 26° 43'-28° 08'and altitude 10 m during 1998-1999 and 1999-2000 (hereafter referred to as 1999 and 2000). The soil type in the sowing area is generally clay soil (44% clay, 30% silt, and 26% sand) with a depth of about 0.5 m and the available water holding capacity within 0.90 m of the soil profile is about 131 mm. The experiment was carried out in randomized block design with 3 replicates. Each genotype was sown in a plot of 6 rows. The seeding rate was 500 seeds per square meter of plot (Gençtan *et al*., 1992). The plots were planted in mid October each year and a total of 120 kg/ha N and 50 kg/ha P_2O_5 were applied at sowing, tillering, and pre-anthesis periods in both years.

Weather conditions and seasonal effects: The central part of Thrace is under the influence of continental climate, along with Mediterranean and Black Sea climate, with lover temperatures during winters and hot, dry summers. Average long-term seasonal precipitation is 466 mm, which is irregularly distributed. A total of 518.9 mm of rain was recorded in the period November-June 1999, compared with 482.0 mm for same period in 2000.

Table 1. Distribution of rainfall and temperature regimes during the crop seasons and long- term average (LTA).

Period	Mean temperature (°C)			Rainfall (mm)			Crop growth stage
	1999	2000	LTA	1999	2000	LTA	
1-30 Nov.	10.8	10.8	11.4	121.2(16)	94.5(7)	81.3 (9)	Germination
1-31 Dec.	4.7	9.5	7.2	95.6(13)	117.6 (12)	86.2 (12)	Seedling
1-31 Jan.	5.9	2.4	4.4	34.2 (7)	24.4 (8)	69.9 (13)	Tillering
1-28 Feb.	5.3	5.7	5.3	111.4 (15)	67.3 (9)	54.7 (10)	Jointing
1-31 March	8.4	7.2	6.8	82.2 (10)	50.9 (8)	55.6 (10)	Jointing
1-30 April	13.6	14.0	11.5	16.7 (6)	5 48.5 (18)	42.9 (9)	Anthesis
1-31 May	17.2	16.6	16.6	39.7 (6)	67.0 (6)	37.6 (8)	Grain filling
1-30 June	22.4	20.9	28.9	17.9 (9)	11 .8 (3)	37.8 (6)	Dough stage and maturity
Total				518.9	482.0	466.0	

Values in parenthesis indicate number of rainy days in both crop seasons, respectively.

The amount and distribution of rainfall in first year were found to differ from that of second year. Especially, spring rainfall (April-May) was equal to 56.4 mm within 12 days in the first season, and 115.5 mm within 24 days in the second, and 80.5 mm within 17 days in long-term average. The totally received precipitation during grain filling period, which is the most important critical stage in the region was considerably lower in the first year than the second and long-term. The both season mean temperatures were similar to long-term mean. Only, mean temperature of growing seasons were below than the long-term mean during dough stage.

Methods

Data were recorded for plant height, days to flowering and maturity, flag leaf area, gloucousness, number of stomata, leaf water potential (at 4-5 leaves and heading state) and grain yield related drought resistance. Flag leaf area was calculated by measuring flag leaf length and width of 10 randomly selected plants and multiplying by 0.68 (Fowler and Rasmusson, 1969). Gloucousness was scored visually just at anthesis on a scale of 1.3, 5.7, and 9, with 1 being nongloucous, 3 lightly gloucous, 5 moderately gloucous, 7 gloucous and 9 highly glaucous on the appearance of flag leaf, peduncle, and spike (Anonymous, 1985). Number of stomata was measured by the impression method using clear nail polish described by Wang and Clarke (1992). Samples were taken from 5 to 10 fully developed leaves for each genotype. Four to 100 microscopic fields of view (0.04 mm^2) were randomly selected from the middle of the adaxial surface for each sample. Rate of leaf water loss from the excitedleaves was measured once or twice, depending on available time, at 4-5 leaf stage and heading in each genotype and year, using the technique described by Clarke and McCaig (1982). Ten of the youngest, fully expanded leaves were sampled from each plot. Samples were immediately taken to the laboratory and weighed. The samples were weighed again after wilting for 2 h at 30 °C, and again after oven-drying to constant weight. The analysis of variance for each character was measured followed by LSD to test significance difference between means (Steel and Torrie, 1960), and simple correlation coefficient and path analysis, which is the direct and indirect effects of each character was performed as per method of Dewey and Lu (1959).

Results and Discussion

The final general rule, which is important for identifying the most likely characters to improve yield is to know the nature of the target area. Areas may range from Mediterranean-like, where rainfall is highest during the winter and then declines to almost zero in summer, to areas where summer rainfall is probable and winter rainfall is rare, and a full spectrum in between (Richards, 1996). But, the most important among them are arid and semi-arid areas for wheat production. The combination of several phenomenons like heat chocks, water deficit, low air hygrometry, insolation and salinity lead to different types of drought (Monneveux and Beihassen, 1996). So, careful consideration was also being given on how important a specific character will be in both areas because of their different attributions. Certain characters which are important for arid regions may limit the yield in semi-arid regions. For this reason. it became necessary to determine a considerable number of selection criteria under natural conditions of semi-arid regions like Tekirda.

Even in areas, such as Thrace where annual rainfall is high, uneven distribution often exposes plants to periodic soil drying (Liang and Zhang, 1999). For improving yields and stability of production under those conditions, the development of new wheat cultivars with high grain yield potential and yield stability through identifying drought tolerance mechanism is of great significance (Rajaram *et al.,* 1996).

The results of variance analyses and significance tests showed that the differences between genotypes were significant in terms of investigated characters, except for rate of water loss at heading in the first year and glaucousness. This might be attributed to experimental material, changing spring rainfall and other environmental conditions.

Plant height of genotypes varied between 75.0-105.0 cm and 82.3-115.7 cm in 1^{st} and 2^{nd} seasons, respectively. The genotypes means of second year was calculated partially high than the first year. The differences of plant height between two seasons were about 8 cm (Table 2). Plant height showed positive and significant correlation with days to maturity in year ($p = 0.01$) and 2^{nd} year ($p = 0.05$). The interesting relation between plant height and days to flowering

Table 2. Mean values and significance test for plant height (PH), days to flowering (DF), days to maturity (DM), flag leaf area (FLA), glaucousness (G) number of stomata (SN), rate of water loss (RWL) and grain yield (GY) in bread wheat.

Genotypes	PH (cm)		DF (days)		DM (days)		FLA (cm^2)	
	1999	2000	1999	2000	1999	2000	1999	2000
ISWYN 50	80.0 hi	86.0 i	168.0 efg	178.7 1	43.67 fg	50.33 bcd	27.203 abc	29.930 a-e
IBWSN 17	90.0 efg	100.3 d	168.0 efg	182.3 fg	43.67 fg	44.00 hi	27.470 ab	34.967 abc
IBWSN 71	85.0 gh	82.3 i	168.3 efg	176.7 n	43.00 gh	47.00 g	21.000 b-f	19.100 h
IBWSN 2	102.0 b	100.3 d	168.0 efg	177.7 n	43.67 fg	50.33 bcd	19.403 def	21.400 gh
ISWYN 30	103.0 b	98.3 de	170.0 ab	180.7 ii	40.33 ij	40.33 i	26.893 a-d	29.167 b-f
ISWYN 1	104.0 b	99.3 de	169.7 bcd	184.3 bc	40.33 l	43.33 i	21.000 b-f	22.503 fgh
ISWYN 38	100.0 bc	94.7 fg	166.0 i	177.3 mn	45.43 cd	48.66 ef	19.067 ef	22.307 fgh
ISWYN 21	110.0 a	100.3 d	168.0 efg	181.0 hii	43.67 fg	48.33 fg	23.900 b-f	24.850 e-h
ISWYN46	96.0 cd	96.7 ef	166.7 hi	178.7 1	45.33 d	51.00 bc	20.900 b-f	30.013 a-e
Mv 04/87	105.0 ab	107.0 c	170.3 ab	183.7 cd	40.00 l	49.00 def	23.900 a-f	35.633 ab
ISWYN 14	103.0 b	91.3 gh	167.3 gh	183.3 de	40.33 kl	44.66 h	20.513 b-f	28.743 b-g
EPCME2HR 3	83.0 h	93.3 fgh	168.7 def	179.3 kl	41.00 jk	54.33 a	24.600 a-f	33.863 abc
IBWSN-43	75.0 i	99.3 de	170.3 ab	180.7 ii	40.33 kl	51.00 bc	26.213 a-f	28.607 b-g
EPCME7WF 289	100.0 bc	112.7 ab	168.7 def	183.7 cd	44.66 de	49.00 def	21.110 b-f	25.543 d-h
IBWSN-41	95.0 cde	108.3 c	167.7 fgh	181.7 gh	44.11 ef	49.66 c-f	20.270 b-f	21.083 gh
EPCME7WF 275	88.7 fg	98.7 de	170.0 bc	185.7 a	34.33 m	51.00 bc	24.950 a-f	36.560 a
IBWSN 4	100.0 bc	91.0 h	162.7 i	178.7 l	47.00 b	48.66 ef	21.610 b-f	25.773 d-h
IBWSN 78	90.3 ef	86.0 i	166.7 hi	182.3 fg	44.66 de	48.33 fg	18.4671 f	21.940 fgh
ISWYN 24	96.0 cd	92.3 gh	I65.7 i	179.7 jk	45.00 de	50.00 b-e	20.413 b-f	35.110 abc
Kristal	90.0 efg	101.3 d	168.0 efg	182.7 ef	42.67 hi	51.33 b	19.037 ef	19.923 h
Pehlivan	92.0 def	106.3 c	168.0 efg	181.7 gh	43.00 gh	49.66 c-f	21.900 b-f	21.963 fgh
Todora	80.7 h	98.3 de	170.3 ab	184.3 bc	42.00 ii	48.33 fg	19.000 a-f	19.560 h
Flamura 85	100.0 bc	115.7 a	168.7 def	181.7 gh	48.66 a	54.66 a	30.833 a	34.363 abc
Saraybosna	75.0 i	83.3 ii	171.3 a	184.7 b	40.00 l	44.33 h	19.900 c-f	26.407 d-h
Flamura 80	90.0 efg	108.0 c	168.7 def	186.3 a	43.67 fg	45.33 hi	24.450 a-f	32.843 abc
Katea I	102.0 b	109.7 bc	165.7 i	181.3 hi	46.33 bc	48.33 fg	18.093 f	27.810 d-g
Miryana	96.0 cd	109.7 bc	170.3 ab	180.3 ii	45.00 de	50.00 c-f	20.000 b-f	22.123 fgh
P≤0.05	5.295	3.662	1.067	0.930	0.928	1.528	7.499	6.763

Table 2. Cont'd.

Genotypes	G		SN (no.)		RWL (at 4-5 leaf stage) ($g/H_20/g$)		RWL (at heading stage) $g/H_20/g$)		GY (t/ha)	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
ISWYN 50	5.00	5.00	3.33 h	5.67 f-i	0.028 b-h	0.020 fgh	0.140	0.140 f-i	3.930 j	5.133 de
IBWSN 17	7.00	4.00	5.83 a-e	8.33 ab	0.018 fgh	0.034 b-g	0.143	0.140 f-i	3.660 m	7.296 ab
IBWSN 71	7.00	5.00	4.50 d-h	5.33 ghi	0.022 c-h	0.041 bcd	0.217	0.220 a-e	4.670 d	6.173 b-e
IBWSN 2	3.00	3.00	5.33 a-g	5.00 hi	0.022 c-h	0.019 gh	0.100	0.153 e-i	4.853 bc	5.873 b-e
ISWYN 30	5.00	1.50	5.33 a-g	8.67 a	0.016 gh	0.038 b-f	0.140	0.087 i	4.570 ef	6.850 abc
ISWYN 1	3.00	3.00	3.33 h	5.67 f-i	0.022 c-h	0.044 abc	0.173	0.173 c-h	4.530 fg	5.993 b-e
ISWYN 38	1.50	1.00	5.33 a-g	7.00 cde	0.021 d-h	0.018 gh	0.150	0.147 f-i	4.950 a	6.803 abc
ISWYN 21	5.00	1.50	7.00 a	7.67 abc	0.038 a-d	0.019 gh	0.177	0.183 b-g	3.850 jk	5.533 cde
ISWYN46	3.10	3.00	4.67 c-h	7.33 bcd	0.021 d-h	0.039 b-e	0.200	0.237 a-d	2.923 o	5.120 de
Mv 04/87	9.00	5.00	5.33 a-g	7.67 abc	0.035 a-f	0.015 h	0.147	0.137 f-i	3.760 1	6.323 a-e
ISWYN 14	3.00	3.00	5.67 a-f	6.67 c-f	0.016 gh	0.023 d-h	0.157	0.193 b-g	4.470 h	5.896 b-c
EPCME2HR 3	5.00	3.00	3.67 gh	6.67 c-f	0.040 abc	0.022 e-h	0.183	0.207 a-f	3.850 jk	5.186 de
IBWSN-43	3.00	3.00	5.33 a-g	4.67 i	0.037 a-c	0.0l7 gh	0.167	0.167 d-h	4.140 i	7.760 a
EPCME7WF 289	3.00	3.00	6.33 abc	5.67 f-i	0.019 e-h	0.061 a	0.193	0.243 abc	2.330 or	5.603 cde
IBWSN-41	7.00	5.00	5.00 b-h	5.00 hi	0.043 ab	0.025 c-h	0.107	0.107 hi	4.310 h	5.500 cde
EPCME7WF 275	5.00	3.00	4.00 fgh	5.67 f-i	0.020 d-h	0.028 c-h	0.153	0.160 e-h	4.500 fg	5.520 ede
IBWSN 4	9.00	7.00	4.33 d-h	6.00 c-h	0.017 fgh	0.050 ab	0.167	0.200 a-g	4.800 c	6.850 abc
IBWSN 78	5.00	1.50	5.00 b-h	5.00 hi	0.023 c-h	0.024 d-h	0.160	0.160 e-h	4.900 ab	6.540 a-d
ISWYN 24	5.00	1.50	4.17 e-h	5.33 ghi	0.035 a-g	0.027 c-h	0.163	0.163 e-h	4.650 de	5.690 cde
Kristal	5.00	5.00	5.33 a-g	6.33 d-g	0.020 d-h	0.021 c-h	0.153	0.147 f-i	4.150 i	5.667 cde
Pehlivan	7.00	3.00	6.33 abc	8.33 ab	0.019 e-h	0.018 gh	0.177	0.200 a-g	3.830 kl	6.773 abc
Todora	5.00	5.00	6.67 ab	6.66 c-f	0.016 gh	0.016 gh	0.157	0.200 a-g	4.116 ii	5.700 cde
Flamura 85	5.00	5.00	6.67 ab	7.00 cde	0.019 e-h	0.023 d-h	0.173	0.173 c-g	4.043 i	6.030 b-e
Saraybosna	3.00	5.00	6.67 ab	6.67 c-f	0.014 h	0.039 b-e	0.193	0.250 ab	2.660 p	4.866 e
Flamura 80	7.00	5.00	6.67 ab	6.67 c-f	0.013 h	0.023 d-h	0.130	0.150 e-i	4.480 ef	6.850 abc
Katea I	7.00	5.00	5.67 a-f	7.00 cde	0.012 h	0.024 d-h	0.127	0.130 ghi	2.800 ö	6.250 a-e
Miryana	5.00	5.00	6.00 a-d	6.33 d-g	0.048 a	0.030 c-h	0.160	0.267 a	3.370 n	6.246 a-e
P≤0.05			1.695	1.196	0.019	0.019		0.02	0.087	0.156

was observed. Although there was negative and significant correlation between two characters in first year, this relation changed into positive and significant in following year. The positive and insignificant correlation coefficient between plant height and grain yield (Paul *et al.,* 2006) indicates that very short plant height might not be actually appropriate for high yield in Tekirdag conditions. The correlations between plant height and days to flowering denoted that rising plant height caused in decreases days to flowering in first year, and this is verified for indirect effects of plant height via same character. Views of direct and indirect effects of plant height suggest that it can be direct selection criterion in the region.

For most annual plants, the main adaptation of the cycle is the earliness, called days to flowering. In drought conditions, early annuals which close their reproductive period for drought seasons will be favoured. Mean days to flowering of genotypes ranged from 162.7 to 171.3 days and 176.7 to 186.3 days in 1999 and 2000, respectively. Days to maturity values of initial season varied from 34.33 to 48.66 days. These values ranged between 40.33 and 54.66 days in following season. Days to flowering demonstrated negative and significant correlations with days to maturity in two years. Their relations with gloucousness in second year and with number of stomata in first year were positive and significant at 0.05 levels. Days to maturity had significant positive correlation with gloucousness and significant negative correlation with rate of water losses at heading stage in second year at 0.05 levels. The high negative and significant correlation between days to flowering and days to maturity and their relation with grain yield indicate that these characters are to be absolutely evaluated together. It is necessary to select earlier genotypes to avoid water stress effect in stress conditions, but with long filling period, the genotypes were suitable for non-water stress conditions in Tekirdag conditions.

Leaf area is the main determinant of photosynthesis, however, it is also a common adaptive trait for drought tolerance effecting plant transpiration (Tardieu *et al.*, 2004). Water loss at the plant level largely depends on the size of the evaporating area. Watson (1952) pointed out that flag leaf area during filling-period was more influential on yield than net assimilation rate. For the trait, there were significant differences between genotypes in both years; flag leaf area varied between 18.093 and 36.560 mm^2 (Table 2). In the second year, there were significant increases in flag leaf area. Highly significant and positive correlation was computed between flag leaf area and gloucousness in second year. Cedola *et al.* (1994) stated that water stress conditions may cause diminishing of leaf area. Flag leaf area reduced due to water-stress, and reduces gloucousness resulted in rises of stomata number. And this rises caused in decreased yield and the variation in yield reduction depended upon genotypes in the first year experiment. The findings of Cedola *et al.* (1994) partially support our result.

Glaucousness, the waxy bloom on the surface of plants, has been associated with improved yields in wheat (Johnson *et al.,* 1983). Quantitative estimate of waxes affects the rate of water loss through the cuticle (Jordan *et al.,* 1984) or susceptibility to leaf disease (Troughton and Hall, 1967). The glaucousness is an important feature which effects rate of water loss through the cuticle in arid region. Thus, selection for or against glaucousness may be a goal in breeding programs. Thrace region is called as semi-arid region because of rainfall, which is adequate but erratic. No differences of glaucousness were found important, and it is pointed out that the glaucousness is not an important selection feature in semi-arid region like Thrace. In first year, scale value of glaucousness had higher than the second year. But, the difference was not important. Since, the direct effect on yield of glaucousness were highly negative and correlation coefficient between glaucousness and grain yield was negative in second year, it was concluded that glaucousness has an inhibiting influence on yield under water stress conditions. For this reason, glaucousness suggests that it may not be appropriate selection criterion for Tekirdag condition. Results of Clarke (1987) also stated that glaucousness is not an effective selection criterion.

The stomatal transpiration is the main way of water loss in the plant. Stomata characteristics affecting the water-use efficiency of plants are the important factors in evaluation of genotypes for drought stress. Restriction of water loss from leaf surface during periods of severe water-stress is an important drought survival mechanism. There was variation among the genotypes in terms of number of stomata. An average number of stomata were 3.33-7.00 in the first year and 4.67-8.67 in the second year (Table 2). The less water was received in first year than the second, which caused that plants were exposed to water stress condition. And, stomata numbers of genotypes were lower in the initial year than the following. But, it may not be explained enough these differences according to only stomata number. However, stomata characteristics, such as stomatal frequency size, stomatal aperture, stomatal conductivity etc. should be evaluated together for more healthy comments. Correlation and path analysis results denote that number of stomata has a limiting character like glaucousness to yield in water stress conditions.

Water content in a whole plant and water potential of its tissue and cells affect tolerance of genotypes to drought. Under stress conditions, a slow down of biological activities is quickly observed at different level of metabolism, growth, rigidity. The drought tolerant genotypes lose less water and maintain water levels for a longer period than drought susceptible genotypes (Clarke, 1987). Clarke *et al.* (1991) found that rate of water loss at two stages (4-5 leaves and heading) is an important selection criterion for drought tolerance. In general, rate of water loss of the plants in the first year was less than in the other year.

Table 3. Correlation coefficients among plant height (1) days to flowering (days) (2), days to maturity (days) (3), flag leaf area (mm^2) (4), glaucousness (5), number of stomata (no.) (6), rate of water loss (RWL) at 4-5 leaves stage (7) and at heading stage (8) and grain yield (t/ha) (9) and path analysis showing direct and indirect effects of drought-related traits in 1999 and 2000 years on grain yield (t/ha).

Characters		Years	Correlation coefficients							
			Plant height (1)	Days to flowering (days) (2)	Days to maturity (3)	Flag leaf area (mm^2) **(4)**	Glaucousness	No. of stomata (6)	Rate of water loss (g)	
									At 4-5 leaves stage (7)	At heading stage (8)
1		1999	1.000							
		2000	1.000							
2		1999	0.306**							
		2000	0.301**							
3		1999	0.33 1**	- 0.558**						
		2000	0.250*	-0.317**						
4		1999	0.013	0.060	0 163					
		2000	0.020	-0.029	- 0.029					
5		1999	0.084	- 0.152	0.045	0.131				
		2000	0.160	0.211*	0.211*	0.403**				
6		1999	0.072	0.202*	0.103	-0.248*	0.011			
		2000	0.127	0.088	0.088	-0.002	0.152			
RWL	7	1999	-0.022	0.063	0.033	-0.074	0.014	-0.202*		
		2000	-0.071	-0.001	-0.001	0.021	0.222*	-0.155		
	8	1999	-0.130	0.073	0.086	-0.071	-0.169	0.023	-0.013	
		2000	-0.208*	-0.065	-0.250*	0.004	0.183	0.038	0.281**	
9		1999	0.089	-0.240*	-0.065	-0.106	0.045	-0.272**	0.021	-0.344**
		2000	0.120	-0.114	0.212*	-0.146	-0.143	-0.121	-0.142	0.105

* and ** significant at $P \leq 0.05$ and 0.01, respectively. r ($P \leq 0.05$) 0.195 and r ($P \leq 0.05$) 001) = 0.254

Table 3. Cont'd.

Characters	Years	Direct and indirect effects							
		1	2	3	4	5	6	RWL (g)	
								7	8
1	1999	**0.0602**	0.0819	-0.0720	0.0403	-0.0007	-0.0182	0.0006	-0.0182
	2000	**0.2645**	-0.0637	-0.0006	-0.0021	-0.0213	-0.0230	0.0131	-0.0467
2	1999	-0.0184	**-0.2676**	0.1212	-0.0013	0.0012	-0.0511	-0.0016	-0.0227
	2000	0.0797	**-0.2114**	0.0008	0.0029	-0.0280	-0.0158	0.0003	-0.0056
3	1999	0.0199	0.1492	**-0.2173**	0.0368	-0.0004	-0.0262	-0.0008	-0.0267
	2000	0.0685	0.0670	**-0.0025**	-0.0034	-0.0093	0.0323	0.0486	0.0111
4	1999	0.0008	-0.0015	0.0353	**-0.2261**	-0.0010	0.0628	0.0019	0.0218
	2000	0.0054	0.0061	-0.0001	**-0.1011**	-0.0536	0.0003	-0.0038	0.0009
5	1999	0.0064	0.0406	-0.0097	-0.0190	**-0.0078**	-0.0029	-0.0004	-0.0100
	2000	0.0424	-0.0445	-0.0002	-0.0407	**-0.1330**	-0.0057	0.0200	-0.0220
6	1999	0.0043	-0.0539	-0.0224	0.0560	-0.0001	**-0.2536**	0.0051	-0.0072
	2000	0.0337	-0.0186	0.0004	0.0002	0.0239	**-0.1803**	0.0286	0.0002
RWL 7	1999	-0.0014	-0.0169	-0.0071	0.0167	-0.0001	0.0513	**-0.0254**	0.0040
	2000	-0.0188	0.0003	0.0007	-0.0021	-0.0296	0.0280	**-0.1840**	0.0631
RWL 8	1999	-0.0079	-0.0196	0.0188	0.0160	0.0013	-0.0059	0.0003	**-0.3091**
	2000	-0.0551	0.0053	-0.0001	-0.0004	-0.0244	0.0069	-0.0518	**0.2243**
9	1999								
	2000								

The reason of this is the water stress which occurred because of low rainfall in first year. Previous investigations carried out by several researchers showed that water stress occurring at the beginning of heading stage affects grain yield more than earlier growth stages (Cetin *et al.,* 1999). The results of correlation and path coefficient confirm these statements. Rate of water loss at 4-5 leaves stage was 0.012-0.048 g/H_2Og^{-1} and 0.015-0.061 g/H_2Og^{-1} in 1st and 2[nd] years, respectively. The high negative direct effects at heading stages rate of water loss on grain yield and its high negative correlation with grain yield are explained that bread wheat genotypes with low water loss may be the high grain yield ability in stress condition. This result indicates that rate of water loss at heading stages can be used as important selection criterion for drought tolerance studies.

Several investigations on wheat grown under water stress showed that different characters had inhibitory effects on grain yield at different levels (Leithold *et al.,* 1997). Especially, water stress from anthesis to physiological maturity reduces grain yield (Stone and Nicolas, 1995) through reduction in the rate and duration of grain filling (Al-Khatih and Paulsen, 1984). Spring rainfalls (April-May) among these stages increased grain yield considerably in the second season (Table 1). Grain yield of the 27 bread wheat genotypes varied between 2.33 and 4.95 t/ha in the first year and 4.87 and 7.76 t/ha in the second year (Table 2).

The correlation between grain yield and days to maturity was positive and significant (P= 0.05) in second year (Table 3). All of the significant correlations were negative with grain yield in first year. These correlations were computed as 0.344**, -0.272**, and -0.240* for rate of water losses at heading stage, number of stomata, and days to flowering, respectively. The highest direct positive effects on grain yield were computed for plant height in two years for rate of water losses at heading stage in second year. The highest negative direct effect was obtained from rate of water losses at heading stage with a value of -0.3091. Our results are supported by findings of Sankarapandian and Bangarusamy (1996).

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