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Effects of drought stress condition on the yield and yield components of advanced wheat genotypes in Ardabil, Iran

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Abstract

In this research yield and yield components of 13 advanced winter and intermediate wheat genotypes obtained from the cold hardy wheat breeding stations of the country with two advanced genotypes as control were investigated under normal irrigation and after anthesis drought stress condition in a randomized complete block design experiment with three replications in Ardabil, Iran in 2006-2007. Combined analysis variance indicated that there were significant differences among the genotypes in their grain yield, 1000 grain weight, peduncle length, plant height, number and weight grain per spike and harvest index. Genotype SG-U7067 produced the highest yield under both normal irrigation and drought stress conditions. The yield reduction of this genotype was lowest under the drought stress conditions. Under normal irrigation no significant correlation was observed between the grain yield and other morphological characters, but under the drought stress conditions there were positive highly significant correlations between the grain yield and the 1000 grain weight and number of tillers per plant. Under both conditions there were a positive significant correlation between the number of tillers per plant and number of fertile tillers per plant.

Key words: Drought, stress, yield, wheat**.**

Introduction

Moisture deficiency, especially after anthesis, is one of the main constrains of wheat production in most part of central Asia and the Middle-East including Iran. Therefore, selection and breeding for drought tolerance has been the main challenge of wheat breeders and wheat scientists throughout the last 50 years.

Drought stress is the main problem of the wheat production in many parts of the world [1]. Iran, with about 220 mm of average annual rainfall is located in dry part of the world and except some northern provinces that are located in the vicinity of the Caspian Sea, in most areas of the country wheat crop encounters serious drought stress especially after anthesis [7]. Drought stress can reduce grain yield. Edmeades *et al*. [6] have estimated the average yield loss of 17 to 70% in grain yield due to drought stress. Drought stress may occur throughout the growing season, early or late season, but its effect on yield reduction is highest when it occurs after anthesis [3]. Morphological characters such as root length, tiller, number of spike per m^2, grain per spike number, fertile tillers per plant, 1000 grain weight, peduncle length, spike weight, stem weight, awn length, grain weight per spike etc. affect the wheat tolerance to the moisture shortage in the soil [3, 4, 13, 16-18, 23, 25, 26]. Also some physiological characters of the wheat cultivars, such as rate of root respiration increase in higher absisic acid and air CO_2 concentrations [15, 19, 22, 24, 31, 32] and phenological traits such as number of days to heading, anthesis and maturity influence the drought to tolerance of the wheat cultivars [2]. Selecting wheat genotypes that could tolerate drought stress and produce acceptable yield has been the major challenge for the wheat breeders in the past 50 years [20]. It has been found that under the drought stress conditions, those genotypes that show the highest harvest index and highest yield stability are drought tolerant [27].

In Iran water shortage is very common in the late season after the anthesis even in the irrigated lands. Therefore, the availability of wheat cultivars tolerant to the water shortage in the late season is very essential to the sustainable production of this important food crop. In this research thirteen advanced wheat genotypes obtained from cold hardy wheat stations of the country with two more advanced lines of C-73-20 and C-79-16 as control were studied for their drought stress tolerance after anthesis to delineate the most tolerant type.

Materials and Methods

This study was conducted at the Agriculture Research Station of Ardabil, Iran (48°20'N; 38°15'E) in 2006-2007. The soil texture at the experimental site is clay-loam. The average minimum, maximum and absolute temperatures during the experiment were 1.98, 15.18 and 21.58°C, respectively, and the long-term average rainfall of the region is 310 mm. The effective soil depth (A+B) is 70 cm and the drainage of the soil is considered to be very suitable and the level of underground water is very deep. Ardabil plain has a typical semi-arid cold climatic condition with a long dry summer and cold winter. The soil pH of the experimental site is 7.7 and its EC is 1 mmos. The P and K concentrations of the soil are 12 and 400 ppm respectively. Thirteen advanced winter and intermediate wheat genotypes were obtained from the cold hardy breeding stations

of the country with two advanced genotypes (Sahreeyar and C-79-16) as control to compare their tolerance to the late season drought stress. The experiment was conducted under two different irrigation conditions of (a): normal irrigation, where the plots were irrigated 6 times with an approximately 10 days intervals throughout the growing season, started at the end of rainfall season that coincided with the April 15th (Julian day 105); and (b): late season drought stress condition where the last two irrigations were cut off after the heading of the wheat. Each of two experiments was conducted in a randomized complete block design with three replications and 15 wheat genotypes. Each plot consisted of 6 rows of 2.5 m long and 30 cm apart. Plots were sampled twice during the growing season, first at the anthesis and later at the harvest. During the growth period some of characters were measured such as grain yield, 1000-grain weight, peduncle length, plant height, number and weight of grains per spike, harvest index and number of tillers and fertile tillers per plant. Also the number of days to heading, anthesis and maturity were recorded during the growing season for each genotype. Analysis of variance was carried out with MSTATC, and the results were used to evaluate the effect of drought stress, wheat genotype and the drought×genotype effects. The means were compared by Duncan's multiple range method using MSTATC software program.

Results and Discussion

The result of ANOVA indicated that the drought stress decreased the grain yield, 1000-grain weight, peduncle length, plant height, number and weight of grains per spike and harvest index. Also there were significant differences among wheat genotypes with respect to the number of grains per spike, 1000-grain weight, peduncle length, plant height and grain yield (Table 1).

Normal irrigation compared to drought stress increased the grain yield (4.14 ton ha^{-1}), plant height (7.5 cm), number of tillers per plant (1.16), number of fertile tillers per plant (1.09), 1000-grain weight (15.9 g), peduncle length (4.46 cm) and grain weight per spike (0.68 g) (Table 2). Therefore, it was concluded that if irrigation water is available, the crop must be irrigated after anthesis to obtain higher grain yield. Saxena and Saxena [29] have reported that the irrigation of wheat crop at drought development stage of the grains has increased the grain yield as much as 1340 kg ha^{-1}. Also Saxena *et al.* [30] found that 13 mm irrigation of the crop at anthesis has increased the grain yield 583 kg ha^{-1}. Ehdaie and Waines [8] concluded that the irrigation of wheat crop after anthesis has increased the grain yield 813 kg ha^{-1}.

The grain yield of any genotype is influenced by a complex of different morphological, physiological and phenological traits of that genotype which are in turn influenced by the soil moisture. Since the environmental conditions vary in different areas, therefore, the response of plant traits to the drought stress and expected grain yield also varies in different locations. Wheat genotypes that were evaluated in this study showed significant difference in their grain yield. The highest mean grain yield under two experimental conditions was obtained in genotypes SGU7067 (6.75 ton ha^{-1}), 885K4.1//MNG/SDV1/3/1D13.1/MLT (6.71 ton ha^{-1}) and C-79-16 (6.50 ton ha^{-1}). In these genotypes the average plant height was 77.17, 86.50 and 83.10 cm; the total number of tillers 3.33, 3.16 and 3.06; number of fertile tillers 3.05, 3.01 and 2.76; number of grains per spike 23.7, 21.98 and 22.20; weight of grains per spike 0.95, 0.89 and 0.74 g; 1000-grain weight 9.20, 39.72 and 33.01 g and peduncle length 26.64, 38.56 and 36 cm, respectively (Table 3). The average grain yield of genotypes was reduced about 50% under the drought stress condition. The highest yield reduction was in genotype Vee"s"/Bow"s"//40-71-23 and the lowest yield reduction in genotype SG-U7067. This genotype yielded higher than the other genotypes under both normal irrigation (8.479 ton ha^{-1}) and drought stress condition (5.020 ton ha^{-1}). Elhafid *et al.* [9] demonstrated that drought stress results in reduced pollination and reduces the number of grains per spike. Fischer [10] and Hassanpanah [11] also obtained similar results in their studies. Calderini *et al.* [5] concluded that increased number of grains per spike is the main yield component that influences the grain yield. In our studies we found a strong positive correlations between number of grains per spike and stem weight ($r = 0.61$, $P \leq 0.05$) under the drought stress condition and normal irrigation, but there was negative significant correlation between the number of grains per spike and plant height ($r = -0.58$, $P \leq 0.05$) under the drought stress condition. Machado *et al.* [21] concluded that the drought stress at anthesis reduces the flower fertilization and the grain set, and the drought stress at drought stage by reducing the allocation of photosynthetic material to the grains causes significant reduction in 1000-grain weight. Drought stress before the anthesis in spring wheat also reduces the number of grains per spike [12, 28].

Correlation coefficient analysis indicated that under the drought stress condition there were significant positive correlations between the grain yield and 1000-grain weight ($r = 0.64$, $P \leq 0.05$) and between the grain yield and the number of total tillers per plant ($r = 0.54$, $P \leq 0.05$). Under normal irrigation condition there were positive highly significant correlation between the grain weight per spike and number of grains per spike ($r = 0.85$, $P \leq 0.01$), but under the drought stress condition significant correlations were not detected between the grain weight per spike and the above traits and there was a negative significant correlation between the number of grains per spike and plant height ($r = -0.58$, $P \leq 0.05$). Under the drought stress there was a positive significant correlation between the 1000-grain weight and grain yield ($r = 0.64$, $P \leq 0.01$). Other researchers such as Passioura [25], Khan and Ashraf [14] and Hassanpanah [11] also have reported a positive significant correlation between the grain yield and 1000-grain weight, but Saxena and Saxena [29] found a negative correlation between these components.

Conclusions

Genotype SG-U7067 produced the highest yield under both normal irrigation and drought stress conditions. The yield reduction of this genotype was lowest under the drought stress conditions.

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Table 1. Mean squares of components of 15 advanced genotypes under normal irrigation and drought stress condition.

S.O.V.	D.F.	MS								
		Grain yield (ton ha^{-1})	Harvest index	1000- grain weight (g)	No. of tillers per plant	No. of fertile tillers per plant	Peduncle length	Plant height	No. of grains per spike	Grain weight per spike
Environment (E)	1	389.52 **	729.04**	5766.88**	30.195	22.11	547.008**	1266.3**	104176.04**	857.04**
Error 1	4	0.622	24.27	44.886	8.142	4.11	16.193	16.193	2446.289	7.847
Genotype (G)	14	0.857*	17.40	56.419*	0.11	0.153	84.805**	84.805**	5702.433**	7.411
G×E	14	0.420	9.99	15.465	0.10	0.09	17.923	17.923	1532.64	4.643
Error 2	56	0.321	13.12	16.014	0.21	0.144	17.752	17.752	1423.50	3.354
C.V. (%)	-	9.13	8.28	11.05	14.91	13.48	12.43	12.43	15.91	21.34

* and ** significant at 5% and 1% level of probability, respectively.

Table 2. Comparison of mean values for yield and yield components of 15 advanced genotypes under normal irrigation and drought stress condition.

Environmental condition	Grain yield (ton ha^{-1})	Harvest index (%)	1000-grain weight (g)	No. of tillers per plant	No. of fertile tillers per plant	Peduncle length (mm)	Plant height (cm)	No. of grains per spike	Grain weight per spike (g)
Normal irrigation	8.266	46.60	44.16	3.66	3.41	36.37	86.27	27.11	1.26
Drought stress	4.128	41.04	28.21	2.50	2.32	31.91	78.77	20.31	0.58
Difference	4.138	5.56	15.95	1.16	1.1	4.46	7.50	6.8	0.68

Table 3. Mean of yield components each genotype in normal irrigation and drought stress condition.

Genotype	Grain yield (ton ha^{-1})	Harvest index (%)	1000-grain weight (g)	No. of tillers per plant	No. of fertile tillers per plant	Peduncle length (mm)	Plant height (cm)	No. of grains per spike	Grain yield per spike (g)
Shareeyar (C-73-20)	6.044BCD+	42.63ABC	35.96ABC	3.103A	2.887A	35.19AB	88.38A	23.9BCD	0.893ABC
C-79-16	6.502ABC	44.93ABC	33.01BCD	3.067A	2.767A	36A	83.10ABC	22.2BCD	0.743BC
M-70-4…./K58/Tob/3/Wa	5.853BCD	43.42ABC	38.82A	3.272A	2.958A	35AB	84.06ABC	23.07BCD	0.928AB
MV17/Alvand	6.061ABCD	40.75C	32.84BCD	2.865A	2.570A	37.92A	84.78ABC	24.52BCD	0.842ABC
FDL4/NG8675//KINAC197	6.052ABCD	43.73ABC	36.40ABC	3.032A	2.688A	34.62AB	81.38BCD	26.4B	1.003AB
NA160/…/BUC/3/FALKE	6.409ABC	42.04ABC	38.64A	3.133A	2.788A	35.69A	73.72F	21.13CD	0.845ABC
885K4.1….1/MLT	6.705AB	42.86ABC	39.72A	3.160A	3.017A	38.56A	86.50AB	21.98BCD	0.899ABC
TAM200/KAUZ	6.252ABCD	45.70ABC	37.82AB	2.850A	2.588A	37.58A	82.62BC	20.25D	0.783BC
GKRABA	6.474ABC	46.71A	39.79A	3.050A	2.550A	26.95C	82.47BC	23.98BCD	0.957AB
Appolo/Mhdv	6.280ABC	43.86ABC	37.93AB	2.917A	2.767A	29.91BC	84.97ABC	24.1BCD	0.991AB
Vee"s"/Bow"s"//40-71-23	5.336D	43.80ABC	30.57D	3.067A	2.837A	32.92AB	75.40EF	32.55A	1.05A
FDL4/KAUZ	6.085ABCD	46.08AB	36.34ABC	3.033A	2.860A	33.23AB	80.17CDE	26.2BC	0.969AB
KARL//CTK/….01	6.236ABC	44.29ABC	34.94ABCD	3.093A	2.855A	34.18AB	86.49AB	20.93D	0.752BC
KRC66/SERI//KINAC197	5.836BCD	41.30BC	31.29CD	3.200A	2.983A	35.16AB	86.61AB	20.78D	0.6680C
SG-U7067	6.750A	45.25ABC	39.20A	3.333A	3.050A	26.64C	77.17DEF	23.7BCD	0.953A

+ Mean with the same letters in each column does not have significant difference at the 5% level of probability to according to value of LSD.

Table 4. Correlation coefficient yield components in advanced wheat genotypes under the drought stress condition.

Correlation	Grain yield	Harvest index	1000- grain weight	No. of tillers per plant	No. of fertile tillers per plant	Peduncle length	Plant height	No. of grains per spike	Grain weight per spike
Grain yield									
Harvest index	0.37								
1000-kernel weight	0.64**	0.73**							
No. of tillers per plant	0.54*	-0.14	0.30						
No. of fertile tillers per plant	0.18	-0.36	0.11	0.67**					
Peduncle length	-0.21	-0.52*	-0.43	-0.37	0.42				
Plant height	0.17	-0.22	0.01	0.09	0.36	0.44			
No. of grains per spike	-0.43	0.19	-0.03	-0.16	-0.25	-0.40	-0.58*		
Grain weight per spike	-0.37	0.04	0.03	-0.36	-0.05	0.13	-0.13	0.35	

* , ** and ns indicate significant, at 5% and 1% level probability and non-significant correlation between traits, respectively.

Table 5. Correlation coefficient yield components in advanced wheat genotypes under the normal irrigation condition.

Correlation	Grain yield	Harvest index	1000- grain weight	No. of tillers per plant	No. of fertile tillers per plant	Peduncle length	Plant height	No. of grains per spike	Grain weight per spike
Grain yield									
Harvest index	0.16								
1000- kernel weight	0.41	-0.10							
No. of tillers per plant	-0.21	-0.01	0.01						
No. of fertile tillers per plant	-0.01	-0.04	-0.11	0.76**					
Peduncle length	-0.30	-0.46	-0.15	-0.48	-0.40				
Plant height	-0.01	-0.23	-0.16	-0.10	0.03	0.01			
No. of grains per spike	-0.14	0.01	-0.36	0.19	0.05	-0.10	-0.13		
Grain weight per spike	-0.09	0.05	0.15	0.19	-0.01	-0.23	-0.15	0.85**	

∗ , ∗∗ and ns indicate significant, at 5% and 1% level probability and non-significant correlation between traits, respectively.