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Full Length Research Paper

Evaluation of some morphological traits associated with wheat yield under terminal drought stress

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This study was carried out at the Seed and Plant Improvement Institute, Karaj (Iran) in 2007/2008 and 2008/2009 growing seasons to investigate the effects of two irrigation regimes (normal irrigation and no irrigation in post-anthesis growth stage) on grain yield of eight wheat cultivars (DM-81-6, DM-82-1, Bahar, DN-11, DN-7, Pishtaz, WS-82-9, and C-85-6). According to the results of variance analysis, it is clear that there is a significant difference among the testing cultivars in grain yield and yield components. It is a result of difference in grain yield reduction among genotypes under different irrigation regimes. DN-11 Genotype produced the highest grain yield under both irrigation regimes. The yield reduction of Bahar genotype was the highest under drought stress conditions. Based upon the result of stepwise regression analysis, the most important yield components were biological yield, harvest index, and 1000 grain yield.

Key words: Wheat, terminal drought stress, grain yield, components yield, stepwise regression.

INTRODUCTION

Dryness is the most important factor limiting the production of crops in the world Middle East, especially in semiarid Mediterranean (Samarah et al., 2009) such as Iran. This topic is more important in dry and semi-arid regions of the world (Kirigwi at al., 2004). Drought stress depends not only on the duration and intensity of water stress, but also on the developmental phase at which the stress was imposed. Drought stress at the grain filling period dramatically reduces grain yield (Ehdaie and Shakiba, 1996; Samarah et al., 2009; Alqudah et al., 2011). Since dry matter production after heading is the main source of grain yield in wheat (Saidi et al., 2008). This stage of plant growth has a critical importance in terms of drought (Alqudah et al., 2011). Selection of plant species with drought resistance has been considered to be an economic and efficient means of alleviating agricultural problems in dry areas (Ashraf et al., 1992). However, there is limited insight into the physiological basis of wheat drought resistance. A better understanding of the mechanisms that enable wheat plants to adapt to water stress and maintain growth, development and productivity during stress periods would help in breeding for drought resistance (Seropian and Planchon, 1984).

Reduction in yield and yield component due to water stress has been reported in both durum and bread wheat (Singh et al., 1986). Samara et al. (2009), studied the effect of late terminal drought stress on barley growth, yield and physiology, and they found that drought stress during grain filling period reduced grain yield by 73 to 87%, together with all the grain yield components. Barley grain yield under severe drought stress was positively correlated with grain filling duration and gross photosynthetic rate and negatively correlated with leaf water potential (Samarah et al., 2009). Reduction in crop yield under drought stress could be due to the accelerated days to flowering, shorter grain filling duration, lower accumulation of dry matter or by increase in the number of sterile floret and spike (Alqudah et al., 2011).

Although, the best option for crop production, yield

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improvement, and yield stability under soil moisture deficient conditions is to develop drought tolerant crop varieties (Siddique et al., 2000). In future years, breeding programs must consider and select from improved water use efficiency in newly released varieties. In this regard, screening for more drought tolerant wheat varieties, which are able to produce an acceptable yield under one or two irrigations after rainfall ceases in spring, has became a new strategy in cereal breeding research programs. To date, no variety has been released in this way, hence, recent efforts have commenced during the last few years (Najafian, 2003).

The main objective of this study was to determine the effect of terminal drought stress on yield and yield components of eight wheat cultivars and to study different traits related to yield under terminal drought stress conditions.

MATERIALS AND METHODS

This study was carried out at the Seed and Plant Improvement Institute, Karaj (Iran) in 2007/2008 and 2008/2009 growing seasons. Drought tolerance of eight genotypes of wheat was evaluated to study yield and yield components under terminal drought stress condition. Experimental design was split plot, based on randomized complete block design (RCBD) with three replications. The main plots were allocated to irrigation regimes (normal irrigation, where the plots were irrigated 6 times (50 mm per time) and no irrigation in post-anthesis growth stage (70 of the Zadoks), while the sub-plots were assigned for wheat cultivars (DM-81-6, DM-82-1, Bahar, DN-11, DN-7, Pishtaz, WS-82-9, and C-85-6). Each experimental unit consisted of three rows with distances of 20 cm and lengths of 6 m.

All plants of 6 m^2 area of each plot were harvested at maturity and for each treatment at each replicate. Grain weighed after drying for 48 h at 75°C provide grain yield in ton ha^{-1} at 14% moisture. Thousand grain weight was measured by using a Contador seed counter (Pfeuffer GmbH, Kitzingen, Germany). To determine the number of spikes per unit area and grains number per unit area, spikes of harvested area of each plot were counted. Biological yield was measured by harvesting the genotypes from the lowest part of the stem in each plot and the total aboveground part was weighed and converted to ton ha^{-1}. Harvest index was calculated as the ratio of grain weight to total sun-dried weight aboveground (grain yield + straw yield) × 100.

Data were analyzed using Statistical Package for Social Sciences (SPSS)-17 software program for analysis of variance (ANOVA). The means were compared by Duncan's multiple range method at 0.05 probability level. Correlation between grain yield and yield components was estimated by CORR PROC of SAS-9.3 software program.

RESULTS AND DISCUSSION

Within most wheat-bearing regions, especially those with Mediterranean climatic conditions, cultivating conventional wheat face drought and heat stresses during grain filling period and this terminal drought reduces grain yield in wheat (Ehdaie and Waines, 1989) and barley (Samarah et al., 2009).

The responses of eight selected wheat cultivar to terminal drought stress were evaluated. According to the results of variance analysis (Table 1), it is clear that there is a significant difference among the testing cultivars for gain yield, harvest index and 1000 grain weight in both years, but spike number per meter and grain number per meter in the second year and biological yield in both years was not affected by cultivars. Nazari and Pakniyat (2010) and Shahryari and Mollasadeghi (2011) in the investigation of wheat cultivars reported that there were significant differences for all traits among the genotype cultivars.

Therefore, DN-11 with a yield equal to 7.3 ton/ha produced the highest yield, but of Bahar with a yield equal to 5.7 ton/ha shows a significant difference with DN-11 as well as the values of harvest index and 1000 grains weight with the highest for DN-11.

According to Table 2 for terminal drought stress condition, grain yield, harvest index, 1000-grain weight, grain number per square meter in both years and bio-logical yield decreased only in the second year. Gupta et al. (2001) reported that during wheat anthesis period, drought stress reduced 1000 grain weight, grain yield and biological yield. Raynolds et al. (2000) reported that post anthesis drought stress reduces grain filling rate, resulting in reduction of 1000 grain weight, which is in agreement with the results of this experiment. Plaut et al. (2004) declared that weight of 1000 grains was sharply reduced by occurring drought stress in the post anthesis stage. Siddique et al. (1990) and Richards (1983) showed that in water stress conditions, the amount of harvest index depends on the amount of available water during the pollination period. Royo et al. (2000) showed that flowering-to-maturing water stress shortened the grain filling period for Triticale, therefore, decreasing the 1000 grain weight. Taheri et al. (2011) reported that during post-anthesis stage, water stress disrupted the flowing photosynthesis and transfer of stored substances into grains; this can be the cause of the decrease of weight and the number of grains. Raynolds et al. (2000) declared that terminal drought stress reduces grain filling rate, resulting in reduction of 1000 grain weight which is in agreement with the results of this experiment.

The number of grains per square meter of DM-82-1 and number of spike per square meter of DN-11 cultivar were significantly higher than other wheat cultivars. Increases the number of grains per square meter is an important yield component that influences the grain yield (Calderini et al., 1999).

Bahrani et al. (2009) reported that post-anthesis water deficit stress resulted in wheat grain yield reduction. Moussavi-Nik et al. (2007) working on wheat, obtained similar results where grain yield of wheat was decreased by no irrigation after pollination treatment.

Grain yield showed significant correlation with the number of spikes per square meter (r = 0.34**) in the second growing year and other traits studies (Table 3).

Table 1. Analysis of variance for studied traits.

Source of variance	DF	Means of square					
		Grain yield	Biological yield	Harvest index	1000 grains weight	Spike number per square meter	Grain number per square meter
2007-2008							
Replication	2	8.5	25.3	59.3	270.8	11868.9	79612258.4
Irrigation	1	16.3*	26.9^{ns}	91.1*	440.4**	38703.5^{ns}	196359272.8*
Replication*irrigation	2	1.9	2.4	39.0	24.6	8793.7	6356973.9
Cultivar	7	2.17**	31.6^{ns}	35.8**	155.8**	57644.9*	81127675.6*
Cultivar*irrigation	7	0.39	12.7	14.4	10.3	33343.0	41363239.6
Coefficient of variation		13.6	15.9	14.8	12.79	17.3	15.96
2008-2009							
Replication	2	1.4	236.6	115.3	11.5	302802.5	232032758
irrigation	1	125.7**	751*	386.2*	875.5**	121806.7^{ns}	274965280**
Replication*irrigation	2	2.8	12.4	87.2	4.5	1141.9	4534367
Cultivar	7	1.5*	22^{ns}	17.1*	78.2**	40731.7^{ns}	65545141^{ns}
Cultivar*irrigation	7	0.47	35.7	26.6	10.8	59892.2	144403466
Coefficient of variation		7.5	15.7	15.1	10.8	17.5	15.1

*, ** and ^{ns}Significant in 1 and 5% and non significant, respectively.

Table 2. Grain yield and yield components of different wheat cultivars and irrigation regimes.

Year	Cultivar	Grain yield (ton/ha)	Biological yield (ton/ha)	Harvest index	1000 grains weight (g)	Spike number per square meter	Grain number per square meter
2007-2008	DM-81-6	5.77^{bc}	26.89	21.36^{bc}	36.23^{b}	980.2b	21958b
	DM-82-1	6.9^{ab}	27	21.00^{bc}	35.90^{b}	1198.8^{ab}	34621^{a}
	Bahar	5.70^{c}	26.2	17.61^{c}	25.73^{d}	1152.2^{ab}	26818^{b}
	DN-11	7.37^{a}	29	25.97^{a}	42.70^{a}	1309.8^{a}	28510^{ab}
	DN-7	6.6^{abc}	28.22	21.01^{bc}	36.10^{b}	1183.3^{ab}	26837^{b}
	Pishtaz	6.8^{abc}	28.5	23.89^{bc}	32.10^{bc}	1143.3^{ab}	26948^{b}
	WS-82-9	6.5^{abc}	31.94	20.73^{bc}	33.03^{bc}	1084.5^{ab}	21958^{b}
	C-85-6	5.9^{bc}	28.27	21.62^{bc}	29.50^{cd}	1074.7^{ab}	26980^{b}
	Normal irrigation	7.04^{a}	30.9^{a}	24.03^{a}	36.94^{a}	1169.21^{a}	29075.5^{a}
	Terminal drought stress	5.87^{b}	29.4^{a}	19.27^{b}	30.88^{b}	1112.42^{a}	25048.3^{b}
2008-2009	DM-81-6	6.09^{cd}	28.61	21.65^{ab}	33.66^{bc}	1007	27733
	DM-82-1	6.18^{cd}	26.44	23.55^{ab}	31.86^{bc}	960.5	25275
	Bahar	5.74^{d}	25.65	23.19^{ab}	28.86^{c}	1041.7	25382
	DN-11	7.39^{a}	28.57	25.94^{a}	38.36^{a}	1118.2	18635
	DN-7	6.85^{ab}	26.44	22.68^{ab}	36.33^{ab}	1120.3	28619
	Pishtaz	6.59^{bc}	28.96	23.23^{ab}	31.03^{c}	1104.2	26429
	WS-82-9	6.32^{bcd}	31.65	19.98^{b}	38.93^{a}	930.5	21295
	C-85-6	6.50^{bc}	29.58	22.83^{ab}	32.36^{bc}	926	24770
	Normal irrigation	8.08^{a}	32.65^{a}	25.72^{a}	38.20^{a}	1076.41^{a}	27163.3^{a}
	Terminal drought stress	4.84^{b}	24.74^{b}	20.04^{b}	29.65^{b}	975.66^{a}	22376.4^{b}

Different letters in each column indicates significant difference at 5% level of probability according to value of Duncan’s multiple range.

The results of grain yield and yield components correlations show that, for all the cultivars, harvest index in the first year (r=0.71**) had the highest correlation with grain yield (Table 3). Other researchers such as Khan

Table 3. Correlation coefficients of grain yield with yield components in wheat.

Trait	Year	Biological yield	Harvest index	1000 grains weight	Spike number per square meter	Grain number per square meter
Grain yield	2007-2008	0.37 **	0.71**	0.41**	0.08^{ns}	0.46**
	2008-2009	0.62**	0.56**	0.69**	0.34**	0.21*

*, ** and ^{ns}Significant in 1 and 5% and non significant, respectively.

Table 4. Stepwise regression on the yield (dependent variables) and other traits (independent variables) under terminal drought stress and normal conditions.

Year	Model	Sum of squares	df	Mean square	F	Significance
2007-2008	Regression	87.89	2	85.50	2969.52	0.00
	Residual	85.78	93	0.02	-	-
	Total	173.68	95	-	-	-
2008-2009	Regression	306.21	3	102.02	883.18	0.00
	Residual	10.63	92	0.11	-	-
	Total	316.84	95	-	-	-

Table 5. Result of stepwise regression analysis for grain yield in wheat genotypes under terminal drought stress and normal conditions.

Year	Model	Unstandardized coefficient		Standardized coefficient	t	Significance	R^2	Adjusted R^2
		B	Standard error	Beta				
2007-2008	Constant	-5.92	0.161	-	36.75	0.00	0.985	0.984
	Biological yield	0.28	0.004	0.87	66.05	0.00		
	Harvest index	0.20	0.004	0.71	53.72	0.00		
	Final model	Grain yield = - 5.92 – 0.28 (Biological yield) + 0.20 (Harvest index)						
2008-2009	Constant	-5.18	0.230	-	22.57	0.00	0.966	0.965
	Biological yield	0.01	0.008	0.051	1.83	0.70		
	Harvest index	0.23	0.007	0.85	32.63	0.00		
	1000 grain weight	0.19	0.007	0.68	27.07	0.00		
	Final model	Grain yield = -5.18 + 0.01 (Biological yield) + 0.23 (Harvest index) + 0.19 (1000 grain weight)						

and Ashraf (1993), also reported a positive correlation between the grain yield and 1000-grains weight. Indicating the importance of harvest index in determining grain yield of testing cultivars; biological yield, 1000 grain weight, number of grain per square meter and number of spike per square meter were of subsequent importance. In the same trend, late terminal drought stress during grain filling under Mediterranean semi-arid region was negatively significant with barley grain yield and all grain yield components such as plant height, spike number per plant, grain number per spike, 1000-grain weight, straw yield, grain yield and harvest index (Samarah et al., 2009).

The results of stepwise regression analysis under both terminal drought stress and normal conditions were calculated by considering the yield as the dependent variable and other characters as the independent variables. In the first year, two characters; biological yield and harvest index were in turn, entered into the regression model which accounted for 0.98% of the yield changes (R^2 = 0.985). In the second year, biological yield, harvest index and 1000 grain weight remained in the final model, explaining 96% of variation in the yield (R^2 = 0.966) (Tables 4 and 5). According to these characters into the regression model, high percentage of yield changes was determined. Naderi et al. (2000), Hosseinpur et al. (2003) and Mollasadeghi et al. (2011a) in their researches indicated that through biological yield, we could have some

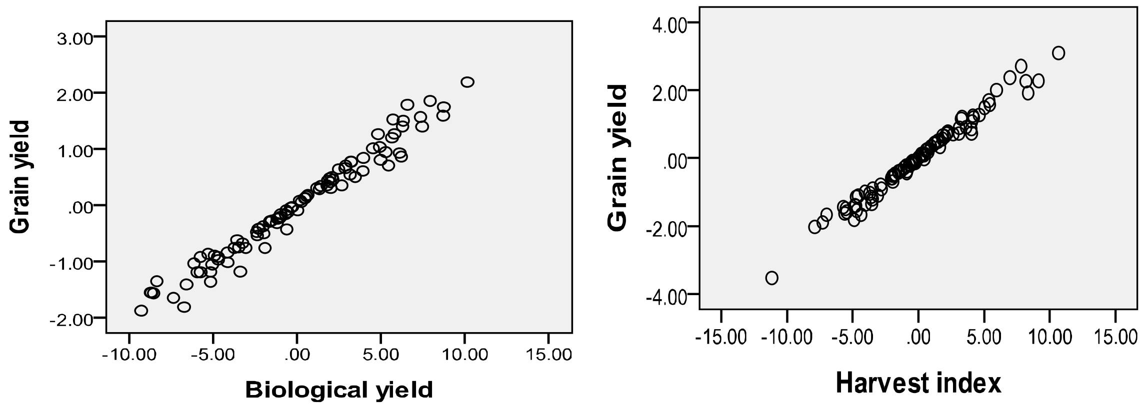

Figure 1. Relationships between grain yield (ton/ha) and characters entered into the regression model in the first growing season.

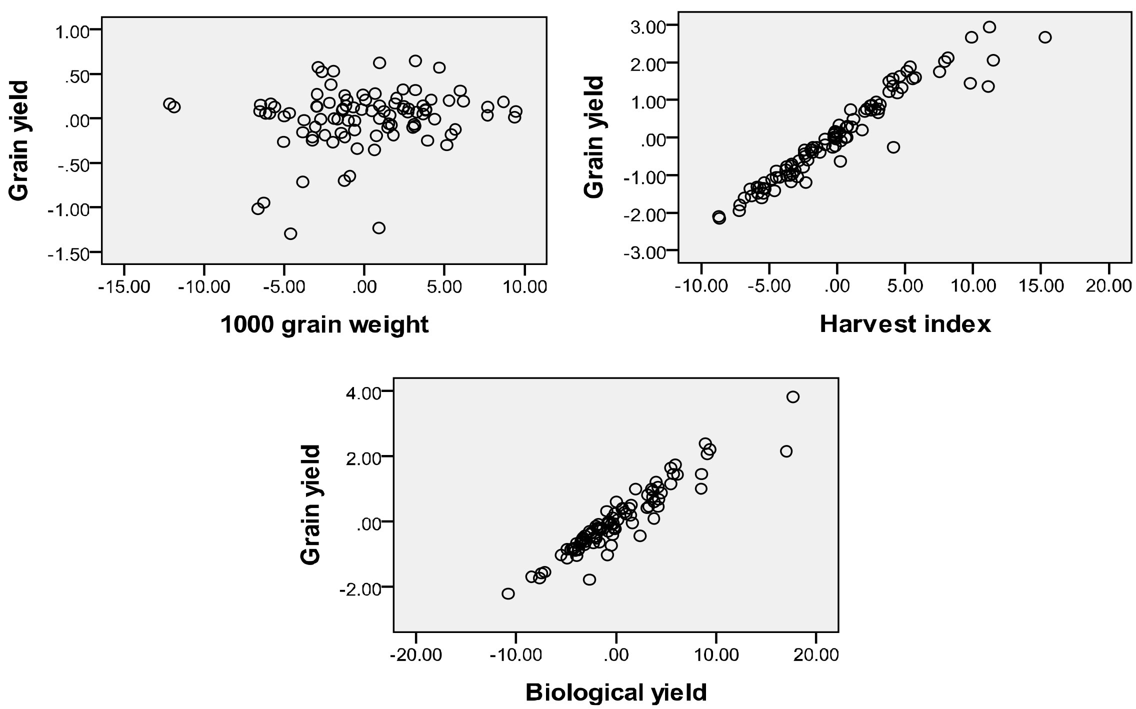

Figure 2. Relationships between grain yield (ton/ha) and characters entered into the regression model in second growing season.

yield changes. Leilah and Khateeb (2005) showed that five traits of harvest index, biological yield, number of spike per square meter, grain weight per spike and spike length were introduced into stepwise regression model.

Considering the positive and significant regression coefficient of mentioned characters, it could be stated that increase in the amount of these characters would increase the grain yield. Figures 1 and 2 show the relationship between grain yield, and characters can be entered into the regression model calculated for each year.

Conclusion

Based on the analysis of simple correlation and stepwise regression, biological yield, harvest index and 1000 grain weight had the highest effect on grain yield. Biological yield and harvest index, which account for a high degree of variation in grain yield, can be considered to improve wheat grain yield. High yield of DN-11 is associated with harvest index since this cultivar has retained superiority of its 1000 grain weight (Table 2). In general, these results confirm that DN-11 is one of the cultivars with high yield potential in moisture stress conditions, especially in terminal season drought stress conditions and it enjoys high stability of yield.

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