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Effects of Late-Season Drought Stress on some Physiological Traits, Yield and Yield Components of Wheat Genotypes

Masoud Aghanejad*, Siroos Mahfoozi** and Younes Sharghi*
**Department of Agronomy and Plant Breeding,*
Islamshahr Branch, Islamic Azad University, P.O. Box: 33135-369, Islamshahr, IRAN
***Department of Cereals Research,*
Seed and Plant Improvement Institute, P.O. Box: 31585-4119, Karaj, IRAN

(Corresponding author: Masoud Aghanejad)
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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. In order to investigate the effect of late season drought stress on some physiological traits, yield and yield components of seen wheat genotypes and experiment was conducted in Seed and Plant Improvement Institute, Karaj, Iran during 2012-2013 growing season. Six wheat lines and one cultivar as control (C-85-D8, C-85-D9, C-85-D13, C-88-D5, C-88-D6, C-85-D12 and Pishgam cultivar) were evaluated in two separate normal and drought stress conditions (no irrigation at 50% pollination stage) using a split plot layout based on randomized complete block design with three replications. According to the results, drought stress decreased 1000-seed weight, seed number per ear and final seed yield. In addition, drought stress was responsible for considerable reduction in chlorophyll content, photosynthesis rate, stomatal conductance and transpiration. Moreover, there was significant difference between wheat genotypes so that C-85D-13 and C-85D-9 genotypes showed the highest compatibility with drought stress conditions. In addition, the results showed that Pishgam cultivar was a suitable cultivar for both normal and stressed conditions.

Keywords: Drought stress, Physiological traits, Wheat, Yield,

INTRODUCTION

Drought stress has been defined as one of the environmental stresses, which is the most significant factor restricting plant growth and crop productivity in the majority of agricultural fields of the world (Tas and Tas, 2007). It is much more important in arid and semi-arid regions (Kirigwi *et al.,* 2004). About 33% of wheat fields in the world and about 55% in the developing countries are suffering from drought stress. In these regions, water deficit influences all developmental stages of wheat from germination to seed formation and finally yield (Trethowan *et al.,* 2001). Due to the complexity of drought as a stress factor, deciphering precise plant mechanisms for drought tolerance has remained a major challenge to plant biologists. The response of plants to drought stress is very complicated and they manage stress through stress avoidance approaches that depends on genotype (Ammar *et al.,* 2013). In general, drought is responsible for several metabolic processes of plants, with photosynthetic apparatus being one of the most important (Nayyar and Gupta, 2006). Besides changes in photosynthesis, such adverse effects on metabolism lead to growth inhibition, stomata closure with consecutive reduction of transpiration, which are considered necessary for coping with osmotic changes in their tissues (Lawlor and Cornic, 2002; Yordanov *et al.,* 2003; Zhu, 2002). In addition, some morphological characteristics in cereal such as root length, tillering, spike number, grain number, number of fertile tillers, 1000 grain weight, peduncle length, spike weight, stem weight and awn length are affected by moisture shortage in the soil (Blum, 2005). Wheat (*Triticum aestivum* L.) is one of the main crops consumed by humans and it is cultivated in different environments. Under the temperate zone early-summer droughts are increasingly frequent and limit grain yield since they coincide with the grain filling period of most cereals, including wheat. The most important parameter of the wheat for which genotypes are screened during the process of breeding is the grain yield. However determining grain yield is time-consuming as the wheat plants have to be bred until the maturity of the grains. Therefore the selection would be time and energy-saving if a standard test system were worked out based on the correlations of certain physiological parameters and the drought tolerance and grain yield (Guttieri *et al.,* 2000).

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 *et 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). Identification of the critical irrigation timing and scheduling of irrigation based on a timely and accurate basis to the crop is the key to conserving water and improving irrigation performance and sustainability of irrigated agriculture (Ngouajio *et al.*, 2007). Late season drought stress is one of the most important limiting factors in wheat yielding. Akbari-Moghaddam and co-workers (2002) determined that omitting water at spike production stage had the most effect on reducing grain yield (about 36%) and total yield (about 20%). Wheat crop needs water for whole growth period, but some stages are more vulnerable to water shortage and may result in significant yield losses. The shortage of irrigation water at crown root initiation, booting and early grain fill period results in significant yield losses (Anonymous, 2007). But it is considered that water stress is usually less detrimental to grain yield when occurring early in crop cycle (Blum, 1996). Zhang and Oweis (1998) reported that wheat crop was found to be more sensitive to water stress from stem elongation to heading and from heading to milking. Although sufficient research has been conducted on effect of drought on grain yield of plants and substantial losses in wheat grain yield have been reported due to water deficiency (Mary *et al.*, 2001), yet information on the effect of drought on biochemical constituents at successive stages of booting and grain filling is scanty. The main objective of this work was to investigate some physiological traits that are associated with drought stress in wheat genotypes and to find out the drought tolerant genotypes that could be used for yield improvement either by introducing these genotypes in rain fed area or using in wheat breeding programs.

MATERIALS AND METHODS

The current field research was conducted in Seed and Plant Improvement Institute, Karaj, Iran during 2012-2013 growing season. The study site was located in a place with longitude of 51° 6' Eastern, latitude of 35° 59' northern and altitude of 1321 m above sea level. This region with 226 mm long-term average annual rainfall was classified as a cold and semi-arid region. The farm soil structure according to soil experiment was loam-clay, desirable salinity, pH 7.4, high lime and lack of organic materials. The farm was ploughed (25 to 30 cm) in fall. Six wheat lines and one cultivar as control (C-85-D8, C-85-D9, C-85-D13, C-88-D5, C-88-D6, C-85-D12 and Pishgam cultivar) were evaluated in two separate normal and drought stress conditions (no irrigation at 50% pollination stage) using a split plot layout based on randomized complete block design with three replications. 80 kg ha^{-1} of triple super phosphate and 50 kg ha^{-1} potassium sulfate and 200 kg ha^{-1} urea was applied. Phosphorus and potassium and one third of urea fertilizers were applied at sowing and the remaining was applied during plants rapid growth stage. Each plot consists of four 6 m in length furrow, each 60 cm wide and three lines on each. One line gap was implanted between two plots. All plots were irrigated equally 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. At booting stage, photosynthesis, stomatal conductance and transpiration were recorded by a data logger (Meteodata-256, Geonica, Madrid, Spain) and then leaf samples were taken to determine chlorophyll content. Irrigation was stopped at 50% pollination stage in stressed plots. At maturity stage, by deleting 0.5 m from both sides of each line, 6 m^2 of each plot was harvested in order to determine plant height, yield and yield components as well as dry matter. Analysis of variance was done by SAS software. Duncan's Multiple Range Test (DMRT) at 5% probability was used for means comparison.

RESULTS AND DISCUSSION

Analysis of variance indicated that the effect of genotype was just significant on plant height (Table 1). Comparison of means showed that the highest and lowest plant heights were related to C-85-D 13 genotype and Pishgam cultivar, respectively (Table 3). Plant height is known as genetic characteristic which is also controlled by environmental factors. Significant reduction in plant height has been previously reported by many researchers (Kilic and Yagbasanlar 2010; Khayatnezhad *et al.*, 2010). In the current study, considering the fact that the last irrigation was performed at 50% pollination stage, therefore the drought stress could not be effective on plant height.

According to the analysis of variance the effect of genotype was significant on ear number per m^2 (Table 1). Amongst the genotypes, C-85-D9 and C-88-D5 produced the maximum ear number per m^2 (Table 3). By contrast, Pishgam cultivar showed the minimum ear number per m^2 (Table 3). Although ear number is a genetic dependent trait, there is a correlation between ear number and soil moisture content during pant growth period. Sachan and Singh (2003) also reported high heritability estimates for ear number which support the present findings. Heritability and genetic advance are important selection parameters. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone.

Table 1: Analysis of variance on some agronomic and physiologic traits of wheat genotypes as affected by drought stress and genotype.

Source of variations	d.f	Plant height	Ear number per m^2	1000-seed weight	Seed number per ear	Seed yield	Chlorophyll content	Photosynthesis	Stomatal conductance	Transpiration
Drought	1	1.93ns	1270.50ns	2027.32**	105.74ns	19598002.38**	250.64**	64.35**	2204.17*	117.04ns
Error *a*	4	20.50	5021.33	23.21	65.71	565405.17	9.34	2.56	142.83	186.67
Genotype	6	675.16**	50137.98**	33.71*	58.27**	4820622.55**	12.03ns	6.87*	4387.61**	247.38**
Drought × genotype	6	11.32ns	415.44ns	30.04*	21.44ns	593716.77**	6.36ns	2.26ns	272.28ns	6.71ns
Error	24	25.50	8462.25	9.75	12.61	151088.86	6.04	1.43	386.44	17.50
C.V (%)		4.86	11.46	9.12	13.24	7.58	5.63	7.63	14.35	2.89

*,** and ns significant at 0.05, 0.01 and no significant, respectively

Table 2: Main effect of drought stress on some traits of wheat.

Irrigation	Chlorophyll content	Photosynthesis	Stomatal conductance
Full irrigation	47.21a	17.21a	152.65a
Late season drought stress	41.12b	14.32b	127.51b

Values with similar letter are not statistically different

Table 3: Main effect of genotype on some traits of wheat.

Genotypes	Plant height	Ear number per m^2	Seed number per ear	Photosynthesis	Stomatal conductance	Transpiration
Pishgam	87.21c	648.56c	32.55a	15.66ab	142.23b	141.23b
C-85D-8	87.26c	789.25b	21.22c	14.32b	110.55c	137.56c
C-85D-9	108.56b	899.45a	25.66ab	14.65b	120.55bc	148.98a
C-85D-13	119.87a	725.99bc	24.88bc	16.54a	178.56a	149.78a
C-88D-5	109.56b	890.45a	24.65bc	13.12c	109.56c	129.25d
C-88D-6	110.49b	887.56ab	24.22bc	13.10c	108.65c	129.87d
C-88D-12	112.98b	785.22b	24.33bc	13.06c	10893c	128.45d

Values with similar letter are not statistically different

Table 4: Interaction between drought stress and genotype on some traits of wheat.

Irrigation	Genotype	1000-seed weight	Seed yield
Normal irrigation	Pishgam	42.23a	6954.55a
	C-85D-8	43.26a	5124.45def
	C-85D-9	37.56a	6984.56a
	C-85D-13	38.45a	68945.25ab
	C-88D-5	38.45a	4865.25ef
	C-88D-6	41.56a	5265.23cde
	C-88D-12	39.45a	6725.46bcd
Late season drought stress	Pishgam	21.44c	47652.33fg
	C-85D-8	26.78bc	3844.12h
	C-85D-9	21.89c	6745.26b
	C-85D-13	29.89b	6698.78bc
	C-88D-5	26.45bc	3812.23h
	C-88D-6	29.56b	3756.45h
	C-88D-12	30.12b	39884.23gh

Values with similar letter are not statistically different

The main effects of late season drought stress and genotype as well as interaction between them was significant on 1000-seed weight (Table 1). Comparison of means revealed that late season drought stress significantly reduced 1000-seed weight (Table 2). In addition, the heaviest seeds were obtained from C-88-D6 genotype, while the lightest seeds were collected from C-85-D9 genotype (Table 4). The late season drought stress reduces seed filling period due to chlorophyll degradation and suppressed photosynthesis which cause lower assimilate production rate. On the other hand, Kumar *et al.,* (2003) reported high heritability coupled with high genetic advance for1000-seed weight and number of days to 50% heading in wheat.

Seed number per ear was affected by genotype (Table 1). According to comparison of means the maximum and minimum seed number per ear were obtained from Pishgam cultivar and C-85-D8 genotype, respectively (Table 3). Shahryari *et al.,* (2011) in their study to examine the genetic diversity among 18 bread wheat genotypes in terms of phenological and morphological traits, demonstrated that the genotypes were genetically more diverse in terms of seed number per ear.

The results indicated that the effect of drought stress and genotype as well as their interaction were significant on seed yield. Furthermore, comparison of means demonstrated that the highest seed yield was related to Pishgam cultivar, C-85D-9 and C-85D-13 genotypes (Table 4). Our results are in agreement with findings of Chandler and Singh (2008) who reported that seed per ear decreased under drought stress. Water stress has been reported to affect all the yield components, mainly the number of grains per spike and the number of spikes per plant (Simane *et al.,* 1993). It has been recognized that decrease in yield and yield components under drought stress is a key concern in developing countries of the world (Guo *et al.,* 2004). Although stress typically depresses grain yield, it can elevate the value of other components of the economic yield, such as quality of grain protein (Guttieri *et al.,* 2000). Keshavarz (2002) reported that superior genotypes under optimum water stress conditions had higher grain yield under water stress, too. Grain yield is an important criterion for comparing wheat genotypes. However, yield is a trait that is controlled by a lot of genes (Keshavarz, 2002). According to the researchers comments, grain yield is affected by the interaction of environmental and genetic factors including soil type, planting date, planting method, plant density, fertilizer and irrigation time, row spacing, which has an important role in obtaining high yield (Shahin and Valiollah 2009).

Chlorophyll content was affected by drought stress (Table 1) and significantly decreased compared with normal irrigation conditions (Table 2). It seems that chlorophyll degradation would increase at the end of growing season on account of drought stress. 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.

Analysis of variance indicated that although the main effect of drought stress and genotype were significant on photosynthesis rate, the interaction between them was not significant (Table 1). Drought stress significantly decreased photosynthesis rate (Table 2). In addition, the highest photosynthesis rate was registered from C-85-D13 genotype (Table 3). Similar results were found in case of stomatal conductance, the main effects of drought stress and genotype were significant (Table 1). Drought stress decreased stomatal conductance in wheat plants (Table 2). Moreover, the highest and lowest stomatal conductance was found in C-85-D13 and C-85-D8 genotypes, respectively (Table 3). Literature (Ashraf *et al.,* 1994 and 2002) showed that many important physiological processes, such as stomatal conductance and photosynthetic activity are directly affected by drought stress. According to the results, transpiration decreased due to drought stress (Table 2). It has been reported that drought stress reduces transpiration rate, stomatal conductance, net photosynthesis and growth of crop plants (Scheuermann *et al.,* 1991).

CONCLUSION

Generally, the results indicated that drought stress affects yield and yield components as well as physiological traits of wheat genotypes. In addition, we have found that there is significant difference between wheat genotypes so that C-85D-13 and C-85D-9 genotypes showed the highest compatibility with drought stress conditions. In addition, the results showed that Pishgam cultivar is a suitable cultivar for both normal and stressed conditions.

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