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Response of Different Bread Wheat (*Triticum aestivum* L.) Genotypes to Post-Anthesis Water Deficit

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Abstract

Resources of water are limited in many agricultural areas of West Asia. Therefore, effective use of this scarce resource is very important in this region. So, this research was conducted in 2009-2010 growing season at Research Farm of Agricultural Researches Center of Khuzestan, Iran, to investigate the effects of two irrigation regime (I_1: normal irrigation and I_2: no irrigation in post-anthesis growth stage) on grain yield of five wheat cultivars ('Chamran', 'S-78-11', 'A', 'S-80-18' and 'S-82-10'). A split plot experiment based on randomized complete block design in three replications was used, with the irrigation regime in main plots and wheat cultivars in subplots. The results showed that 1000-grain weight, grains per spikelet and grain yield were decreased by water limitation. Despite of their significant differences ($P<0.05$) in 1000-grain weight, spikelets per spike and grains per spike, the grain yield of wheat cultivars was not significantly different. It was resulted by different grain yield reduction of genotypes under different irrigation regimes. Genotypes 'S-80-18' and 'S-78-11' produced highest yield under normal irrigation and drought stress conditions, respectively. The yield reduction of 'S-80-18' genotype was highest under drought stress conditions. 'S-78-11' was the most tolerant genotype to water deficit occurrence.

Keywords: agronomic traits, drought stress, wheat grain yield, yield components

Introduction

Water limitation, especially after anthesis, is a major abiotic stress which severely affects 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 (Lopes *et al.*, 2003).

Wheat is an important crop in southwest Iran, especially, Khuzestan, where low precipitation and high temperature occur during grain filling period of wheat growth in April and May (Modhej, 2006). Therefore, yield is lowered. The ability of a cultivar to produce high yield over a wide range of environmental condition 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). Drought stress may occur throughout the growing season, early or late season, but its effect on yield reduction is high when it occurs after anthesis (Nouri-Ganbalani *et al.*, 2009). Drought stress after anthesis usually result in smaller grain size (Jamieson *et al.*, 1995) both from direct effects on the grain and also because of accelerated flag leaf senescence (Hafsi *et al.*, 2000)

Morphological characters such as root length, spike number per m^2, grain number per spike, 1000-gain weight, awn length (Moustafa *et al.*, 1996; Boyer, 1996; Plaut *et al.*, 2004; Blum, 2005), physiological traits such as rate of root respiration (Liu *et al.*, 2004) and phonological characters such as number of days to heading, anthesis and maturity (Austin, 1987) affect wheat tolerance to the moisture shortage in the soil. Under different drought treatment, Guinata *et al.* (1993) suggested that grain number per spike and spikes per unit area were the wheat yield components most sensitive to drought stress. Other studies have indicated that variation in grain yield between moisture regimes was predominantly associated with variation in spikes per unit area and grains per spike (Simane *et al.*, 1993).

In Iran, water shortage is very common in late season after the anthesis, even in irrigated lands. Therefore, the availability of wheat cultivars tolerant to the water deficit in the late season is essential to the sustainable production of this important crop. Thus, the present study was aimed screening out drought tolerant varieties of wheat, which can adapt to the drought conditions in Iran, particularly in the southwest region.

Materials and methods

The experiment was conducted at research Farm of Agricultural Researches Center of Khuzestan, Iran (latitude 32°20′N, longitude 48°20′E, altitude 50 m above sea level) in 2009-2010 growing season. The climate is characterized by mean annual precipitation of 240 mm, mean annual temperature of 25°C, annual maximum tempera-

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ture of 51.2°C and mean annual minimum temperature of -1°C. Soil type was clay-loam with EC of 2.8 dsm^{-1} and pH of 7.6.

Seeds were hand sown in 4 cm depth with density of 400 m^{-2} on 6 November 2009. Each plot consisted of 6 rows with 2.5 m length, spaced 30 cm apart. Experimental design was split plot, based on RCB design with three replications. The main plots were allocated to irrigation regimes (I_1: 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 in Mach; and I_2: no irrigation in post-anthesis growth stage), while the sub-plots were assigned for wheat cultivars ('Chmaran', 'S-78-11', 'A', 'S-80-18' and 'S-82-10'). All plots were fertilized with the same amount of fertilizer. The fertilizers containing N 50, P_2O_5 90 and K_2O 50 kg ha^{-1} were broadcast before sowing. An additional 50 kg of N ha^{-1} were applied at two growth stages of after tillering and the beginning of flowering. Weeds were chemically controlled, using Topik (1lit ha^{-1}) and Granstar (15 g ha^{-1}) herbicides.

At maturity, all plants of 6 m^2 area of each plot were harvested and then, grains per spikelets, spikelets per spike, grains per spike, spikes per unit area, 1000-grains weight and grain yield per unit area for each treatment at each replicate were determined.

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 at 0.05 probability level, using MSTATC software program.

Results and discussions

Grains per spike and 1000-grains weight were significantly (P=0.05) affected by irrigation regimes and cultivars (Tab. 1). The effect of irrigation on grain yield was also significant (P=0.01), but cultivar had not significant effect on this trait (Tab. 1). Spikes per unit area and spikelets per spikes were not significantly affected by water supply, but the effect of cultivars on these traits was significant (Tab. 1).

Generally, the number of grains per spike, 1000-grain weight and grain yield per unit area decreased with deceasing water availability (Tab. 3). Mean spikelets per spike and grains per spike of 'Chamran' cultivar were significantly (P<0.05) lower than that of the other wheat cultivars, but it produced the highest spikes per unit area (Tab. 2). The largest grains were produced by 'S-82-10', followed by 'A' cultivar (Tab. 2).

The interaction of irrigation × cultivar for 1000-grains weight, grain yield, spikelets per spike and grains per spike was significant (P=0.05) (Tab. 1). Even though the highest grain yield was observed under normal irrigation regime (I_1) for 'S-80-18' cultivar. However, 'S-80-18' cultivar had the lowest grain yield under water deficit condition, indicating that 'S-80-18', with 31% grain yield reduction, is the most sensitive cultivar to post-anthesis water shortage (Tab. 3). 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. 'S-78-11' cultivar had the highest number of spikelets per spike and grains per spike under normal irrigation regime, but it had the lowest 1000-grains weight under two irrigation regimes. 'S-78-11' cultivar, with 4% grain yield reduction, had the highest resistance to post-anthesis drought stress (Tab. 3).

Tab. 1. Interactive effect of treatments, grain yields (kg ha^{-1}) and yield components

Source of variance	Df	Grain yield	Spike per unit area	Spikelet per spike	Grain per spike	Grain per spikelets	1000-grains weight
Replication	2	358579^{*}	47626^{*}	1.9^{*}	12.2^{ns}	0.006^{ns}	6.7^{*}
Irrigation	1	5012706^{**}	2521^{ns}	2.1^{ns}	90.1^{*}	0.065^{ns}	30.0^{**}
Error	2	937924	2286	1.2	58.6	0.15	6.3
Cultivar	4	100815^{ns}	37839^{*}	6.8^{**}	97.8^{**}	0.075^{ns}	54.5^{**}
Irrigation × cultivar	4	696863^{*}	6623^{ns}	2.7^{**}	33.0^{**}	0.025^{ns}	1.7^{*}
Error 2	16	336418	22833	1.1	32.3	0.062	4.7

* and ** indicate significance at 5% and 1% level of probability, respectively; ns: not significant

Tab. 2. Grain yield (kg ha^{-1}) and yield components of different wheat cultivars

Cultivar	Spike per unit area	Spikelet per spike	Grain per spike	Grain per spikelets	1000-grains weight
'Chamran'	615a	13b	37b	2.6a	41.0bc
'S-78-11'	432b	16a	44ab	2.7a	36.6d
'A'	494ab	16a	46a	2.8a	43.0ab
'S-80-18'	525ab	15a	39ab	2.5a	39.8c
'S-82-10'	418b	16a	45a	2.7a	44.5a

Different letters in each column indicates significant difference at 5% level of probability according to value of LSD

The grain yield of any genotype is influenced by a complex of different morphological, physiological and phonological traits of that genotype which are in turn influenced by soil moisture. Since the environmental conditions vary in different areas, the response of plant traits to drought stress and expected grain yield also varies in different locations. Normal irrigation compared to drought stress increased the grains number per spike, 1000-grains weight and grain yield (Tab. 3). Therefore, it could be concluded that if irrigation water is available, the crop must be irrigated, particularly after anthesis to obtain higher grain yield as was similarly reported by Saxena and Saxena (1990) that the irrigation of wheat crop at drought development stage of grains has increased the grain yield as much as 1340 kg ha^{-1}. Also, Saxena *et al.* (1989) found that 13 mm irrigation of the crop at anthesis stage has increased the grain

Tab. 3. Mean yield and yield components of wheat cultivars under different irrigation treatments

Irrigation regime	Cultivar	Grain yield (kg ha^{-1})	Spike per unit area	Spikelet per spike	Grain per spike	Grain per spikelets	1000-grains weight
I_1	'Chamran'	5666ab	603.3a	13.3c	39.6ab	2.6a	41.6bc
	'S-78-11'	4958abc	411.6a	17.0a	41.6ab	2.8a	38.3cd
	'A'	5720ab	521.6a	16.0ab	48.0a	2.9a	43.6ab
	'S-80-18'	6086a	541.6a	16.3ab	49.0a	2.5a	40.3bc
	'S-82-10'	5430abc	410.0a	16.6a	48.0a	2.8a	46.0a
	Mean	5572a	497.0a	15.8a	44.0a	2.7a	42.0a
I_2	'Chamran'	4722bc	628.3a	14.3c	35.0b	2.7a	39.3bc
	'S-78-11'	4906abc	420.0a	15.0b	36.6b	2.6a	35.0cd
	'A'	4833bc	500.0a	16.6a	45.3ab	2.7a	41.3abc
	'S-80-18'	4278c	508.3a	14.3c	40.3ab	2.5a	38.3bc
	'S-82-10'	4930abc	430.0a	16.0ab	43.0ab	2.6a	43.0ab
	Mean	4734b	497.0a	15.2a	41.0b	2.6a	39.0b

Different letters in each column indicates significant difference at 5% level of probability according to value of LSD

yield 583 kg ha^{-1}. Ehdaie and Waines (1989) concluded that irrigation of wheat crop after anthesis increased the grain yield to 813 kg ha^{-1}.

the two yield related traits reduced significantly by water deficit. There was a positive significant correlation between 1000-grains weight and grain yield ($r = 0.61$, $P \leq 0.05$) (Tab. 4). Other researchers such as Passioura (1977), Khan and Ashraf (1993) have also reported a positive correlation between the grain yield and 1000-grains weight. Machado *et al.* (1993) concluded that drought stress reduced the allocation of photosynthetic material to the grains and, thus, caused significant reduction in 1000-grains weight. Royo *et al.* (1999) reported that water deficit and high temperature in late season reduced grain filling period and, thus, grain weight. Royo *et al.* (2000), also out found that drought stress in grain formation and filling period reduced grain weight of triticale.

Increased number of grains per spike is an important yield component that influences the grain yield (Calderini *et al.*, 1999). In this experiment, water deficit reduced grains per spike (Tab. 3). Positive correlation between grain yield and grain nymber per spike (Tab. 4) shows that sufficient irrigation results in higher grain yield by increasing grain number per spike. Similar results have been reported by other researchers. Elhafid *et al.* (1998) demonstrated that drought stress results in reduced pollination and reduced the number of grains per spike. Fisher (1985) and Nouri-Ganbalani *et al.* (2009) also obtained similar results in their studies. Mirbahar *et al.* (2009) reported the significant suppressive effect of post-flowering drought on number of grains per spike in wheat.

Tab. 4. Correlation coefficient between grain yield and yield components of wheat genotypes

	Grain yield	Spike per unit area	Spikelets per spike	Grain per spike	1000-grains weight
Grain yield	1				
Spike per unit area	0.06	1			
Spikelets per spike	0.32	-0.20	1		
Grain per spike	0.66*	0.24	0.70*	1	
1000-grain weight	0.61*	0.20	-0.11	-0.07	1

* indicates significance at 0.05 probability level

Conclusions

Genotype 'S-80-18' and 'S-78-11' produced highest yield under normal irrigation and drought stress conditions, respectively. The yield reduction of 'S-80-18' genotype was highest under drought stress conditions. 'S-78-11' was the most tolerant genotype to water deficit occurrence. Kindly describe what characteristics or attributes of 'S-80-18' could make it that tolerant.

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