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EFFECT OF TERMINAL HEAT STRESS ON YIELD AND YIELD COMPONENTS OF SPRING BREAD WHEAT CULTIVARS IN AHWAZ, IRAN

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ABSTRACT: In order to study the effect of terminal heat stress on grain yield and yield components of spring bread wheat cultivars, a stripe block design was conducted using randomized complete block design with three replications in 35 Km north-east Ahwaz in 2007-2008 cropping season. The vertical plots included four sowing dates (06 Nov., 06 Dec., 05 Jan. and 04 Feb.) and 20 cultivars (Atrak, Arvand1, S-80-18, Star, Inia66, Bolani, Bayat, Pishtaz, Chamran, Chenab70, Darab, Dez, Roshan, Shoeleh, Kavir, Maroon, Hamoon, Hirman and Vee/Nac) were randomized in horizontal plots. The results showed that sowing date, cultivars and their interaction had significant effects on all measured traits. The highest grain yield (5.949 t/ha) was produced in sowing dates of 06 Dec. and the lowest grain yield (1.690 t/ha) was produced in sowing dates of 04 Feb. Chamran had the highest grain yield and Inia66 had the lowest grain yield. Maximum grain yield (7.039 t/ha) related to Chamran in 06 Dec. and the minimum grain yield (1.219 t/ha) belonged to Falat in 04 Feb.

Key words: wheat, terminal heat stress, sowing date, cultivars, grain yield.

INTRODUCTION

Wheat is traditionally grown as a cool-season crop, but with the increased availability of more widely adapted semi dwarf germplasm, wheat production has expanded into warmer regions where production had been restricted to higher altitudes or cooler latitudes (Badaruddin et al., 1999). Continuous high-temperature stress for wheat has been defined as when the mean average temperature of the coolest month is greater than 17.5° C (Fischer and Byerlee, 1991), but there are many areas worldwide that the coolest month temperature has not such conditions and these areas are exposed to terminal heat stress, since there is rise in temperatures in grain filling period (Rane et al., 2007). Several studies have confirmed that rise in temperature above a daily average temperature of 15° C during grain filling period reduced grain yield (Gibson and Paulson, 1999 and Mian et al., 2007). In Mediterranean environments such as the south western part of Iran, terminal heat stress during anthesis and grain filling period is an important constraint to grain yield limiting in winter sown spring wheat cultivars (Jalal Kamali and Duveiller, 2008). In these areas (province of Khouzestan) late planted wheat is exposed to high temperature at the reproductive stage resulting in average grain yield of 3 to 4 t/ha as compared to over 6 t/ha in cooler regions, because the temperatures often exceeds 30° C during grain filling period. Terminal or late heat stress during the last phases of wheat development especially from booting, heading, anthesis and grain filling stages of the spring wheat cultivars is considered as one of the major environmental constraints that drastically reduces grain number per spike and grain weight and consequently significant reduction in wheat grain yield throughout most of the bread wheat growing areas in this region and other warm and dry regions of Iran (Modhej et al., 2008). Many authors have reported a reduced crop stand, shorter life cycle, reduced tillering, less biomass production, reduced fertilization and grain development, reduced head size, reduction in number of spikes per m^2, number of grains per spike and grain weight as the consequences of heat stress, and all these changes are translated in reduction of grain yield under heat stress conditions (Gibson and Paulson, 1999, Ayeneh et al., 2002 and Irfaq et al., 2005). Post-anthesis heat stress in wheat induces several physiological effects which eventually result in smaller grain size due to reduced grain filling period and reduced grain filling rate or the combined effect of both (Hasan and Ahmed, 2005). Choosing a suitable planting date and cultivar with the appropriate phenology that matches crop growth to the climate conditions will lead to optimum grain yields (Chen et al., 2003). It has also been reported that different cultivars showed different response for number of grain per spike and grain weight when temperature increased in post-anthesis stage (Mian et al., 2007). Generally, cultivars are tested across space and time under field conditions by manipulation of date of sowing or choosing sites, which are featured by high temperature at grain filling (‘‘hot spots’’) (Rane and Nagarajan, 2004). Increased heat tolerance in late planted wheat is very essential to enhance and stabilize wheat productivity in the tropical and subtropical countries (Irfaq-Khan et al., 2007). The aim of this study was to evaluate the effect of terminal heat stress on grain yield and yield components of spring bread wheat cultivars in Ahwaz, a warm area in south west of Iran to determine the suitable cultivars for any sowing date. The suitable cultivars will then be used in wheat breeding programs for development of germplasm adapted to terminal heat stress conditions in the target environment.

MATERIALS AND METHODS

Experimental design and growing conditions: The experiment was conducted in the research field station of Ramin University of Agricultural and Natural Resources in Mollasani, Ahwaz (31º N, 48º E and 50 m above sea level) in south western Iran in 2008-2009 cropping season. Experimental factors were 4 sowing dates (06 Nov. (early), 06 Dec. (timely), 05 Jan. (late) and 04 Feb. (very late)) as vertical plots and 20 cultivars (Atrak, Arvand1, S-80-18, Star, Inia66, Bolani, Bayat, Pishtaz, Chamran, Chenab70, Darab, Dez, Roshan, Shoeleh, Kavir, Maroon, Hamoon, Hirman and Vee/Nac) as horizontal plots in strip block arrangement using a complete randomized block design with three replications. The soil was clay loam texture, pH=7.5 and EC=3 m mohs/m. Each horizontal plot had 10 rows with 20 cm row spacing and 2 m length. Seeds were sown by hand with a sowing density of 400 seeds per square meter. Horizontal plots were fertilized for each sowing time with 75 kg/ha Phosphorus (P_2O_5) from ammonium phosphate and 150 kg/ha Nitrogen (N) from urea sources, N was applied in two halves, first half at sowing time of each sowing date and the second half at the commencement of stem elongation. The experiment was optimally managed to avoid any water stress. Fungicides and pesticides were applied to control diseases development and insect infestation, and weeds were controlled manually and chemically.

Measurement of grain yield and yield components: Grain yield (GY) and biological yield (BY) were estimated after physiological maturity by harvesting all but the outer rows of each plot and excluding at least 0.5 m from either ends of the rows, as harvest area was 1.6 m^2. The spike no. per m^2 (SpkM) was measured from harvested area. The average number of grains per spike (GPS) was calculated based on 20 spikes. Thousand grains weight (TGW) was determined by counting 500 grain by an electronic counter and then weighed them and multiplied by two. Harvest index was calculated as the grain yield divided by the total above ground biomass.

Statistical analysis: Analysis of variance was performed by using general linear model (GLM) procedure of statistical analysis system (SAS version: 9.1). Mean comparison was carried using LSD test and LSmeans of SAS.

RESULT AND DISCUSSION

The results showed that sowing date, cultivars and their interaction effect had significant ($P<0.01$) effects on all measured traits (Table 1).

Table 1: Analysis of variance of Measured traits

Source	df	Means of squares					
		SpkM	GPS	TGW	GY	BY	HI
Replication	2	4571.4^{ns}	1.31^{ns}	8.80^{ns}	0.03^{ns}	0.62^{ns}	0.000017^{ns}
Sowing date (A)	3	675528.5**	3391.32**	4757.21**	222.21**	1167.59**	0.121379**
E_a	6	107.2	0.33	0.66	0.13	0.34	0.000161
Cultivars (B)	19	17570.2**	138.30**	122.55**	1.58**	12.07**	0.016188**
E_b	38	218.4	0.93	0.71	0.05	0.16	0.000189
A× B	57	5022.9**	19.93**	13.43**	0.76**	3.60**	0.001948**
E_c	114	171.5	0.58	0.59	0.04	0.21	0.000115

Ns: non-significant and **: Significant at the P<0.01.

Effect of terminal heat stress (sowing date): The result of mean comparison showed that delaying the sowing significantly decreased spike no.m^2, thousand grain weight and biological yield (Table 2). Reduction in spike no.m^2 is due mainly to higher tiller production in early sowing date which cooler temperatures the duration of vegetative phase, and decreasing in duration of vegetative phase in late sowing dates due to higher temperatures. This effect of sowing date on spike no.m^2 has also been reported by Ayeneh et al., (2002). Decreasing in thousand grain weight with delay in sowing date is also due to high temperatures in March, April and May when temperatures raised and terminal heat stress coincided with grain filling period. Lower thousand grain weight in late sowing has also been reported by Mian et al., (2007). Decrease in duration of crop life cycle with delay in sowing date and coincidence of terminal heat stress in grain filling period caused lower biological yield. This effect of late sowing has also been reported by Rane et al., (2007). However, grain no. per spike, grain yield and harvest index increased up to 06 Dec. sowing date and then significantly decreased. Grain number per spike, was greater in earlier sowing date and decreased in delayed sowings which could be associated with cooler temperatures in January, for early sowing date, and high temperatures in March and April, for late and very late sowing dates. This finding is in agreement with Khan et al., (2007). These findings indicate that 06 Dec. was the most suitable date of sowing. It also emphasizes the importance of the variation in grain number as main yield components to compensate for the effect of terminal heat stress on grain yield. Many authors have reported a reduced crop stand, shorter life cycle, reduced tillering, less biomass production, reduced fertilization and grain development, reduced head size, reduction in number of spikes in m^2, number of grains per spike and grain weight as a result of heat stress, and all of these changes will be translated in reduction of grain yield under heat stress conditions (Gibson and Paulson, 1999, Ayeneh et al., 2002 and Irfaq et al., 2005). Harvest index is also affected by delay in sowing date, this might be due to the effect of late sowing date and terminal heat stress on vegetative and reproductive phases, grain and biological yields and considered as their indirect effect on harvest index. This is also in agreement with Irfaq-Khan et al., (2007).

Table 2. Mean comparisons of some agronomic traits in different sowing dates.

Sowing dates	Mean					
	SpkM	GPS	TGW (g)	GY(t/ha)	BY(t/ha)	HI (%)
06 Nov.	479.0^a	41.64^b	44.07^a	5.474^b	15.358^a	35.82^b
06 Dec.	454.6^b	48.65^a	40.95^b	5.949^a	15.053^b	39.72^a
05 Jan.	351.5^c	36.98^c	30.22^c	3.833^c	11.473^c	33.43^c
04 Feb.	247.2^d	30.85^d	25.13^d	1.690^d	5.875^d	28.98^d

Means, in each column, followed by similar letter are not significantly different at the 5% probability level -using LSD

Effect of cultivar: Mean comparison of spike no.m^2 for cultivars showed that Shoeleh had the highest (468.1) and the lowest spike number per m^2 belonged to Maroon (340.0) (Table 3). The greatest grain number per spike belonged to Dez (45.22) and least number of grains per spike was for Arvand 1 (33.83). The heaviest thousand grain weight obtained from Maroon (39.93 g) and smallest grains belonged to Shoeleh (30.00 g). The highest grain yield produced by Chamran (4.941 t/ha) and Bayat (4.855 t/ha) and the lowest grain yield belonged to Inia 66 (3.490

t/ha). Roshan produced the greatest biological yield (13.985 t/ha) and the least biological yield was obtained from Inia 66 (10.383 t/ha). The highest harvest index was for Dez (42.11%) and lowest for Roshan (26.68%). Cultivar of Dez showed that there is no need too much biomass for reasonable grain yield, this cultivar could maintain its grain yield with fewer but more fertile tillers and higher grain number per spike. Synchronous tillerring pattern was accounted as the most common feature of many wheat cultivars susceptible to heat stress.

Table 3. Mean comparison of agronomic traits in bread wheat cultivars in 2007-2008 at Ahwaz

Cultivars	Mean					
	SpkM	GPS	TGW (g)	GY (t/ha)	BY (t/ha)	HI (%)
Atrak	398.8^{c}	44.38^{b}	30.42^{k}	4.178^{cde}	10.950^{h}	37.24^{c}
Arvand 1	444.3^{b}	33.83^{k}	38.85^{bc}	4.505^{b}	12.825^{c}	34.28^{gh}
S-80-18	385.0^{d}	38.21^{h}	32.39^{i}	4.261^{cd}	10.933^{h}	37.62^{bc}
Star	323.5^{i}	40.62^{ef}	39.26^{b}	4.279^{c}	11.925^{e}	33.63^{hij}
Inia 66	401.7^{c}	41.14^{e}	32.40^{i}	3.490^{j}	10.383^{j}	32.70^{j}
Bolani	351.3^{g}	38.29^{h}	36.99^{e}	4.019^{efg}	13.025^{bc}	28.92^{k}
Bayat	408.0^{c}	42.32^{d}	35.22^{f}	4.855^{a}	12.992^{bc}	35.92^{de}
Pishtaz	401.5^{c}	35.22^{j}	37.29^{e}	4.460^{b}	11.650^{efg}	37.33^{c}
Chamran	436.0^{b}	40.64^{ef}	32.89^{hi}	4.941^{a}	12.842^{c}	36.80^{cd}
Chenab 70	355.7^{fg}	39.41^{g}	35.56^{f}	4.100^{de}	11.733^{efg}	34.63^{fg}
Darab 2	374.7^{de}	40.75^{e}	33.19^{h}	3.924^{fgh}	10.767^{hi}	35.38^{ef}
Dez	350.8^{gh}	45.22^{a}	31.41^{i}	4.478^{b}	10.450^{ij}	42.11^{a}
Roshan	397.1^{d}	38.37^{j}	38.60^{cd}	3.919^{ghi}	13.985^{a}	26.68^{l}
Shoeleh	468.1^{a}	34.40^{k}	30.00^{k}	3.757^{i}	13.350^{b}	27.52^{l}
Falat	347.6^{gh}	40.82^{e}	33.11^{h}	4.266^{c}	11.483^{fg}	35.07^{efg}
Kavir	365.0^{ef}	43.77^{bc}	34.37^{g}	4.281^{c}	12.400^{d}	33.32^{ij}
Maroon	340.0^{h}	36.71^{i}	39.93^{a}	3.836^{hi}	11.408^{g}	33.20^{ij}
Hamoon	354.9^{fg}	36.36^{i}	38.04^{d}	4.085^{ef}	11.542^{ef}	33.69^{hi}
Hirmand	351.7^{g}	43.12^{c}	39.10^{bc}	4.479^{b}	12.350^{d}	35.34^{ef}
Vee/Nac	404.9^{c}	40.01^{fg}	32.96^{hi}	4.614^{b}	11.833^{ef}	38.39^{b}

Means, in each column, followed by similar letter (s) are not significantly different at the 5% probability level-using LSD

Effect of cultivarò sowing date: Mean comparisons of grain yield for cultivars in each sowing dates (Table 4) showed that highest grain yield for most of the cultivars observed in sowing date of 06 Dec., however, Star (6.554 t/ha), Bolani (6.517), Roshan (5.906) and Sholeh (5.376) (heat susceptible cultivars) had produced their greatest grain yield in 06 Nov., and the least grain yield for all cultivars observed in sowing date of 04 Feb. In 6 Dec. sowing date the highest grain yield obtained from Chamran (7.039 t/ha) and the lowest grain yield was produced by Inia 66 (4.521 t/ha), Shoeleh (4.655) and Maroon (4.703), whereas in sowing date of 04 Feb. the highest grain yield were produced by Maroon (2.222 t/ha), Virinak (2.213) and Arvand 1 (2.088) cultivars, and the lowest grain yield belonged to Falat (1.219 t/ha), Roshan (1.236), Hamoon (1.243) and Star (1.252) cultivars.

CONCLUSION

It is concluded that delay in sowing beyond the optimum window and high temperatures during grain filling period significantly reduces grain yield and yield components of wheat in Ahwaz region. In this study spike number per m^2, grains number per spike, thousand grains weight, grain yield, biological yield and harvest index were decreased with delay in sowing date, due mainly to rising temperatures. In Ahwaz conditions, the optimum sowing date for most of bread wheat cultivars was 06 Dec. For early sowing (06 Nov.) Star, Bolani, Chamran and Bayat, for timely sowing (06 Dec.) Chamran, for late sowing (05 Jan.) Chamran, Vee/Nac, Bayat, Hirmand, Pishtaz and Falat and for very late sowing (04 Feb.) Maroon, Vee/Nac and Arvand 1 could be recommended. This study confirmed that genetic variability for post anthesis heat tolerance exists between spring wheat cultivars of Iran, which could be utilized to develop high yielding and heat tolerant wheat lines. More analysis of these data with complicated statistical procedure could more brighten heat tolerance nature in Khouzestan conditions.

Table 4. Mean comparison of grain yield for bread wheat cultivars in different sowing dates and stress tolerance index (STI) for cultivars.

Cultivars	Mean Grain Yield (t/ha)			
	06 Nov.	06 Dec.	05 Jan.	04 Feb.
Atrak	4.900^{ef}	5.813^{ef}	4.054^{de}	1.949^{bc}
Arvand 1	5.250^{d}	6.531^{bc}	4.152^{cd}	2.088^{ab}
S-80-18	5.427^{cd}	6.148^{cd}	3.801^{ef}	1.666^{de}
Star	6.554^{a}	5.770^{fg}	3.539^{fg}	1.252^{f}
Inia 66	4.444^{g}	4.521^{h}	3.265^{h}	1.731^{cde}
Bolani	6.517^{a}	5.449^{fg}	2.572^{i}	1.536^{e}
Bayat	6.343^{a}	6.766^{ab}	4.456^{ab}	1.855^{bcd}
Pishtaz	5.453^{cd}	6.456^{bc}	4.343^{abc}	1.586^{e}
Chamran	6.355^{a}	7.039^{a}	4.516^{a}	1.853^{bcd}
Chenab 70	5.230^{d}	5.943^{de}	3.471^{gh}	1.756^{cde}
Darab 2	4.641^{fg}	5.334^{g}	4.144^{cd}	1.575^{e}
Dez	5.461^{cd}	6.469^{bc}	4.243^{bcd}	1.740^{cde}
Roshan	5.906^{b}	5.324^{g}	3.208^{h}	1.236^{f}
Shoeleh	5.376^{cd}	4.655^{h}	3.336^{gh}	1.659^{de}
Falat	5.229^{d}	6.345^{bcd}	4.270^{abcd}	1.219^{f}
Kavir	5.679^{bc}	6.446^{bc}	3.239^{h}	1.761^{cde}
Maroon	4.675^{fg}	4.703^{h}	3.745^{f}	2.222^{a}
Hamoon	5.216^{de}	6.424^{bc}	3.458^{gh}	1.243^{f}
Hirmand	5.433^{cd}	6.462^{bc}	4.366^{abc}	1.655^{de}
Vee/Nac	5.388^{cd}	6.374^{bcd}	4.482^{ab}	2.213^{a}

Means, in each column, followed by similar letter(s) are not significantly different at the 5% probability level- using LSmeans of SAS.

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