Journal of Scientific Research and Development 2 (6): 127-131, 2015
Available online at www.jsrad.org
ISSN 1115-7569

Effect of post-anthesis heat stress on grain yield of barley, durum and bread wheat genotypes

Adel Modhej [1,*], Rozbeh Farhoudi [1], Ali Afrous [2]

[1]*Department of Agronomy, Susangerd Branch, Islamic Azad University, Susangerd, Iran*
[2]*Young Researchers and Elite Club, Andimeshk Branch, Islamic Azad University, Andimeshk, Iran*

Abstract: In order to study the effects of heat stress after anthesis on grain yield and yield components of two barley (six and two row) and six wheat genotypes, two field experiments were conducted in optimum and delayed sowing dates. With delayed sowing plants experienced heat stress in the growth stages after anthesis. Stress tolerance index (STI) and stress susceptibility index (SSI) for grain yield and 1000-grain weight indicated that Jonoob (six row barley) and Stork (durum wheat) had the highest and the lowest STI for grain yield, respectively. Barley genotypes had a higher tolerance to post-anthesis heat stress than wheat genotypes. Average grain yield reduction in barley and wheat genotypes exposed to heat stress after anthesis was 17% and 24%, respectively. Higher SSI for 1000-grain weight in late maturity genotypes was related to delay in anthesis and contact of grain growth period with heat stress. In early maturity genotypes with early anthesis, grain growth period took place before heat stress.

Key words: Barely; Wheat; Post-anthesis heat stress

1. Introduction

Barley and wheat are traditionally grown as cool-season crops, but with the increased availability of more widely adapted semi dwarf cultivars, barley and wheat production has expanded into warmer regions of countries, where production had been restricted to higher altitudes or cooler latitudes (Badrruuddin et al., 1999). Heat and drought are the most important stresses that limit crop production (Entez and Flower, 1990; Rawson, 1988). Optimal crop growth requires a non-limiting supply of resources (water, nutrients, and radiation) and, as temperature rises, the demand for growth resources increases due to higher rates of metabolism, development, and evapotranspiration (Rawson 1988). In Mediterranean conditions such Khozestan, the Western part of Iran, heat stress after anthesis is the major factor limiting grain yield in winter sown barley and wheat. The optimum temperature range to achieve maximum kernel weight is 15-18°C; higher temperatures (up to 30°C) reduce the duration of grain filling and this reduction is not compensated by the increase in rate of assimilate accumulation (Wardlaw et al. 1980; 1989; Stone et al. 1995). Heat stress during the growth stages following anthesis mainly affect assimilate availability, translocation of photosynthates to the grain and starch synthesis and deposition in the developing grain. The net result is a lower grain yield due to a lower thousand 1000-grain weight (Gibson and Paulsen 1999; Rao et al. 2002; Modhej and Behdarvandi, 2006). Some studies indicated that barley genotypes had higher tolerance to post-anthesis heat stress (Modhej et al., 2005 and 2003). Modhej et al. (2005) showed that the higher heat stress tolerance of barley after anthesis was due to its shorter crop growth duration compared to wheat. As in this study the barley genotypes used were early, the grain growth period occurred before the heat stress.

The objective of this experiment was to examine the effects of high temperature stress during grain filling period on the grain yield of barley and wheat genotypes and also to identify heat stress after anthesis on tolerant and sensitive genotypes using the stress tolerance index (STI) recommended by Fernandez et al. (1992) and the stress susceptibility index (SSI) recommended by Fischer and Maurer (1978).

2. Materials and methods

The experiment was conducted at Ahvaz, in the South-West of Iran, in 2005-2006 growing season. Ahvaz is located at 20 m above sea level (32°20ˈ N, 40°20ˈ E). Wheat was sown on optimum (22nd Nov) and delayed (20th Jan) sowing dates. Wheat and barley genotypes were sown on optimum (22 November) and delayed (22 December) sowing dates. Plants in delayed sowing date experienced heat stress in the growth stages after anthesis. Two short-season barley cultivars and six wheat cultivars with different growth durations were used (Table 1). Treatments of each individual experiment (sowing date) were arranged as a randomized complete block

* Corresponding Author.

design with three replications. The soil was clay loam in texture, alkaline in reaction, pH 8.0 with low organic carbon (less than 1%), moderate phosphorus (7.2 ppm) and high potassium (220 ppm) status. The experimental site had a hot climate with mild winters and dry and hot summers.

Table 1: Characteristics of the examined wheat genotypes

Crop	Genotypes	Growth Duration
Barley	Jonoob (six row)	Short-season
Bread wheat	Sarasary (two row) Fong	Short-season Short-season
	Chamran	Middle-season
	Star	Long-season
Durum wheat	Showa/malt	Middle-season
	Stork	Short-season
	Green	Long-season

Mean temperatures during grain growth period were 22°C and 28°C, in optimum and delayed sowings, respectively (Fig. 1).

Normal cultural and management practices (fertilizers, irrigation and pest control) of wheat plants were used. Plot size was 1.2 m by 3.0 m and based on research recommendation and different tillering capacity of the barley and bread and durum wheat genotypes, seeds were drilled in 18 cm rows at about 350, 400 and 500 seeds/m^2 for barley, bread and durum genotypes, respectively. There were 8 rows in each plot. Yield and yield components were estimated by harvesting after physiological maturity excluding border rows and at least 0.5 m from either end of the rows. The harvested area was 1.2 m^{-2}. 1000-grain weight was estimated on a sample of 200 grains.

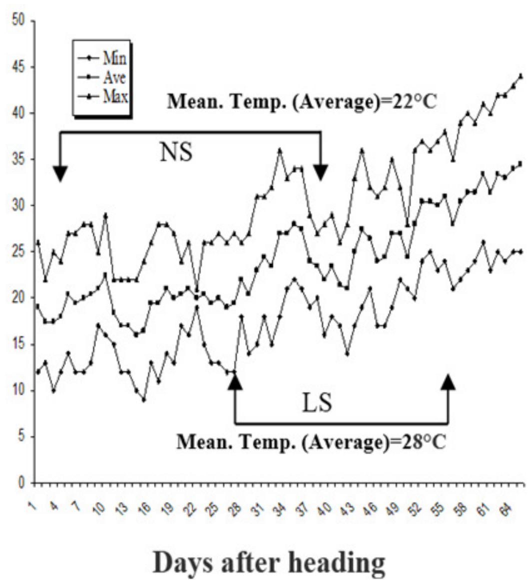

Fig. 1: Maximum daily air temperature (°C) during heading and grain growth. NS= normal sowing date and LS= late sowing date. Arrows indicate the beginning and ending of grain filling period for each sowing date.

Grain yield and individual 1000-grain weight in heat stress after anthesis were investigated with stress susceptibility index (SSI) recommended by Fischer and Maurer (1978) and stress tolerance index (STI) recommended by Fernandez (1992). SSI was calculated as below:

$$SSI = \frac{1 - \frac{Y_{Si}}{Y_{Pi}}}{1 - \frac{Y_S}{Y_P}}$$

Where *Ysi*, *Ypi*, *Ys* and *Yp* are the grain yield or TGW of each cultivar in stress condition, grain yield or TGW of each cultivar in optimum condition and the mean grain yield in all the genotypes in stress and optimum conditions, respectively. STI was calculated as following formula:

$$STI = \frac{Y_{Si}.Y_{Pi}}{Y^2{}_P}$$

Where *Ysi*, *Ypi* and Y^2p are the grain yield or TGW of each genotype in stress condition, in optimum condition and the mean square of grain yield of all the genotypes in optimum condition. Statistical analysis was conducted with the SPSS statistical program.

3. Results and discussion

3.1. Optimum sowing date (optimum conditions)

Results indicated that the differences between genotypes for grain yield in the optimum sowing date were not significant (Table 2). However, Jonoob (six-row barley) and Fong (bread wheat) tended to be the highest and the lowest grain yield in optimum conditions, respectively, but the difference was not significant (Table 3).Mean grain yield in barley, bread wheat and durum wheat genotypes under optimum conditions was 515, 473 and 479 respectively (Table 3). Statistical differences for spike per unit area, spikelet per spike and TGW were significant in 1% probability level (Table 2). Jonoob and Fong had the highest and the lowest number of spikes per m^{-2}. Jonoob and Chamran (bread wheat) did not differ significantly for number of spikes per m^{-2}. Among the wheat genotypes, Chamran had the highest number of spikes per unit area. Green (durum wheat) had the highest and Jonoob and Chamran genotypes had the lowest TGW under optimum, sowing date period (Table 3). Modhej et al

(2008) indicated that there was negative correlation between grain number per spike and TGW in durum and bread wheat genotypes. Sattore and Slafer (2000) reported that yield components were correlated with each other and changes in one character may lead to changes in the other. The mean of TGW in durum wheat was higher than in bread and barley (Table 3).

Table 2: ANOVA for grain yield GY), number of spikes per m-2 (S), 1000-grain weight (TGW) and number of grains per spike (GS) in optimum sowing date g.m-2

S.O.V	df	Mean of square				
		GY	S	TGW	$s.S^{-1}$	$G.S^{-1}$
R	2	372999	357	2.50	0.13	6.5
G	7	261531ns	14421**	61.23**	2.02ns	67.2ns
Error	14	377016	1110	2.25	0.01	18
CV (%)		1.6	6.5	3.3	5.8	13.5

** Significant at 1% probability level; ns = non-significant; GY, $S.m^{-2}$, TGW, s.S-1, $G.S^{-1}$ grain yield, spike per m^{-2}, 1000-grain weight and grain per spike, respectively

3.2. Late sowing date (post-anthesis heat stress conditions)

Results indicated that the differences between genotypes for grain yield in late sowing date were not significant (Table 4**).**

TGW showed significant difference between genotypes in post-anthesis heat stress conditions (Table 4). 6 Sarasary (two-row early maturing barley), Fong and Showa (durum wheat) had the highest TGW in the late sowing date (Table 3). Modhej et al. (2008) reported that TGW in had a strong relation with grain yield under post-anthesis heat stress conditions. They also reported that, in optimum sowing date the highest correlation was between grain yield and grain number per unit area.

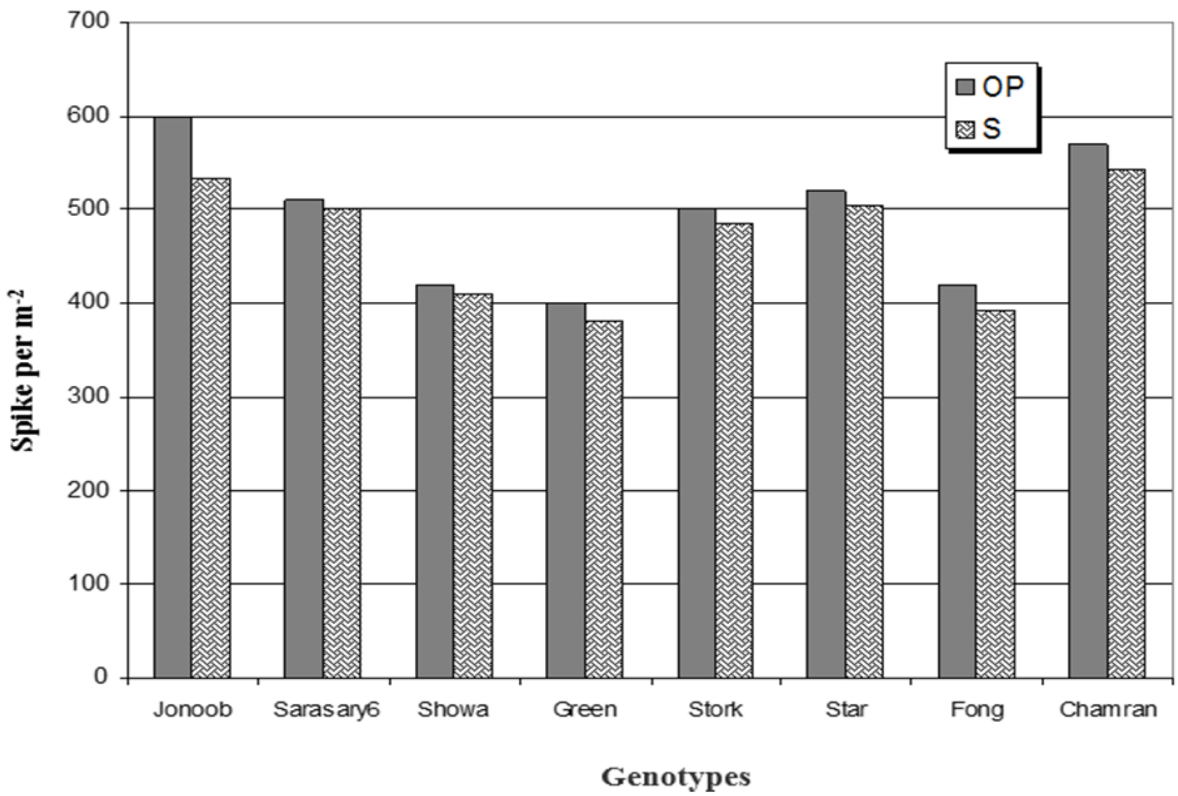

Fig. 2: Mean spike number/m² under optimum and late sowing dates

4. Comparison of the two environments

The combined ANOVA indicated that the effect of the treatment (sowing date) on spike per unit area (Fig. 2), grain number per spike and fertile floret per spikelet characteristic was not significant. The treatment effect was significant for GY and TGW at P = 1%. In the late sowing, an average increase of 6 °C in the average temperatures reduced TGW and GY by approximately 34% and 30% compared with the optimum sowing date, respectively. GY reduction was due to significant reduction in TGW (Table 3).

Stork (durum wheat) and Jonoob had the highest and the lowest SSI for TGW were in genotypes, respectively (Table 3). SSI for individual TGW was highly correlated (P<0.01) with final individual TGW reduction in heat stress (r = 0.99**) than with TGW in optimum condition (data not shown).

Table 3: Grain yield (GY), 1000-grain weight (TGW), stress susceptibility and tolerance indices for barley and wheat genotypes under optimum and late sowing dates

Genotypes	STI Gw	SSI Gw	TGW (g/m^2)	TGW(OP) (g/m^2)		STI Gy	SSI Gy	GY(S) (g/m^2)	GY(OP) (g/m^2)
Barley									
Jonoob	0.63c	0.78c	31ab	41e		1.06	0.63de	461a	535a
6 Sarasary	0.71bc	0.80c	33a	44cde		0.76	0.72d	387a	495a
Mean	0.67	0.79	32	42		0.91	0.67	424	515
Durum wheat									
Showa	0.84ab	1.03bc	34a	50e		0.78b	1.34b	358a	504a
Green	0.88a	1.25ab	33a	54a		0.71c	1.23b	434a	473a
Stork	0.59c	1.4a	26c	46c		0.66d	1.00c	346a	442a
Mean	0.77	1.22	31	50		0.71	1.19	379	473
Bread wheat									
Star	0.60c	0.91bc	30b	42de		0.70c	1.50a	332a	492a
Fong	0.73bc	0.80c	33a	45cd		0.71c	0.53e	383a	432a
Chamran	0.61c	0.86bc	30b	41e		0.90a	0.97c	405a	513a
Mean	0.64	0.85	31	42		0.77	1.00	373	479

Means in each column followed by similar letter (s) are not significantly different at 5% probability level using Duncan's Multiple Range Test. S = Stress; OP = Optimum; SSI = Stress susceptibility index STI = Stress tolerance index

Table 4: ANOVA for grain yield GY), number of spikes/m2 (S), 1000-grain weight (TGW) and number of grains per spike (GS) in the late sowing date

S.O.V	df	Mean of square				
		GY	S	TGW	s.S-1	G.S-1
R	2	616479	2686.6	23.0	6.4	5.8
G	7	815120**	11331.4**	28.3**	212.2**	71.3ns
Error	14	292511	735.2	5.5	4.9	13.0
CV (%)		13	5.6	7.5	12.2	13.8

** and ns, significant in 1% probability level and non-significant, respectively
GY, S/m^2, TGW, G/S, grain yield, spike/m^2, 1000-grain weight and grain per spike, respectively

Green and Fong had the highest and the lowest STI for TGW (Table 3). STI for TGW was highly correlated (P<0.01) with final individual TGW in optimum condition (r = 0.99**) (data not shown). Modhej and Behdarvandi (2006) reported that, genotypes with high TGW in optimum and post-anthesis heat stress had higher STI compared to other genotypes.

The values of stress tolerance index (STI) and stress susceptibility index (SSI) for grain yield indicated that Jonoob (six-row barley) and Stork (durum wheat cultivar) had the highest and the lowest STI for grain yield, respectively (Table 3). Star (late maturing genotype) had the highest and Fong (early maturing genotype) had the lowest SSI for grain yield, respectively (Table 3). There wasn't significant difference between Fong and Jonoob (six-row, early maturing barley) for SSI in grain yield (Table 3). However, Star had the highest grain yield reduction in stress condition (Table 3). The problem with using SSI as a measure of adaptation to the stress is that there are cases where SSI is positively correlated with 1000-grain weight reduction in those genotypes whose yield was affected little by the stress but also had a very low yield potential (Modhej, 2006). This means that genotypes with low SSI also may have low stress resistance yield and would not be useful to farmers (Modhej et al., 2005).

Generally, among all the entries, barley genotypes had higher tolerance to post-anthesis heat stress compared with wheat genotypes. The average reduction of grain yield in barley, durum wheat and bread wheat genotypes under after anthesis heat stress was 17% and 20% and 23%, respectively. Higher SSI for 1000-grain weight in late maturity genotypes was related to delay in anthesis and overlapping of grain growth period with the heat stress. In early maturing genotypes with early anthesis, grain growth period occurred before heat stress developed.

References

Badrruuddin M, Reynolds, M, and Ageeb, O (1999) Wheat management in warm environments: Effect of organic and inorganic fertilizers, irrigation frequency and mulching. Agron J 91, 975-983.

Entez MH and Flower DB (1990) Differential agronomic response of wheat cultivars to environmental stress. Crop Sci 30, 1119-1123.

Fernandez GJ (1992) Effective selection criteria for assessing plant stress tolerance. pp. 257-270. In: Proceeding of the International Symposium on Adaptation of vegetables and other food crops in temperate and water stress. Taiwan.

Fischer R, Maurer A (1978) Drought resistance in spring wheat genotypes. I. Grain yield response. Aust J Agric Res 29, 897-912.

Gibson LR, Paulsen GM (1999) Yield components of wheat grown under high temperature stress during reproductive growth. Crop Sci 39, 1841-1846.

Modhej A (2006) Effect of heat stress after anthesis on grain yield of wheat and barley genotypes. Conference of German Genetics Society and the German Society for Plant Breeding, 95.

Modhej A, Behdarvandi B (2006) Effect of heat stress after anthesis on source limitation and grain yield in bread wheat (*Triticum aestivum* L.) genotypes. 24th annual meeting of ESCB, Belgium, 29.

Modhej A, Nadery A, Siadat A (2003) Effect of heat stress after anthesis on source limitation and grain yield among wheat and barley cultivars. 7th Iranian conference of agriculture and plant breeding, Iran, 606.

Modhej A, Nadery A, Siadat A (2005) Effect of heat stress after anthesis on grain yield of wheat and barley cultivars. Scientific J of Agric 72, 82-99.

Modhej, A, Naderi A, Emam Y, Aynehband A and Normohamadi G (2008) Effects of post-anthesis heat stress and nitrogen levels on grain yield in wheat genotypes. International Journal of Plant Production. 2 (3), 257-268.

Rao VS, Singh G, Misra SC (2002) Wheat: Technologies for warmer areas. Anamaya Publishers, 322.

Rawson HM (1988) Effect of high temperatures on the development and yield of wheat and practices to reduce deleterious effects. In: Klatt A. R., ed. Wheat production constrains in tropical environments. Mexico City: CIMMYT, 44-62.

Sattore HE, Slafer GA (2000) Wheat, Ecology and Physiology of yield determination. Published by Food Product Press, 503.

Stone PJ, Savin R, Wardlaw IF, Nicolas ME (1995) The influence of recovery temperature on the effects of brief heat shock on wheat. I. Grain growth. Aus J Plant Physiol 22, 945-954.

Wardlaw IF, Dawson IA, Munibi P, Fewster R (1989) The tolerance of wheat to high temperature during productive growth. Survey procedures and general response patterns. Aust J Agric Res 40, 1-13.

Wardlaw IF, Sofield I, Cartwright PM (1980) Factors limiting the rate of dry matter accumulation in the grain of wheat grown at high temperature. Aust. J. Plant Physiol. 7, 387-400.