Effects of post-anthesis heat stress and nitrogen levels on grain yield and grain growth of wheat (*T. durum* and *T. aestivum*) genotypes

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ABSTRACT

In order to study the effects of post-anthesis heat stress and nitrogen levels on grain yield and yield components of wheat genotypes, two separate field experiments were conducted in delayed and optimum sowing dates in Ahvaz, Iran in 2006-2007. The Ahvaz site is located in the south west of Iran (32°20' N, 40°20' E) with a subtropical climate. The experimental site had a moderate winter and dry, hot summer. Plants with delayed sowing date experienced heat stress post-anthesis. Each split-polt experiment had a randomized complete block design with three replicates. The N application rates were (50, 100, and 150 KgNha^{-1}) assigned in the main-plots. Sub-plots consisted of six bread and durum wheat genotypes. The results indicated that the grain yield was reduced in the 50 and 100 KgNha^{-1} compared treatments with 150 KgNha^{-1} treatments by 41% and 21% respectively under optimum conditions and by 44% and 26% under heat stress conditions. In all genotypes, the grain yield and 1000-grain weight (TGW) reduction under post-anthesis heat stress conditions was 33% and 42%, respectively compared with the non-stressed treatments. The highest and the lowest grain yield reduction due to heat stress were observed in Star (39%) and Vee/Nac (27%) genotypes. The grain yield reduction in low nitrogen and delayed sowing treatments was due reduced grain number and TGW, respectively. In low nitrogen treatments grain number per area was reduced due to a reduction in the number of fertile florets, spikelets^{-1}, spikes. m^{-2}, and spikelets. spike^{-1}. The grain growth period was 23 and 16 days under optimum and post-anthesis heat stress conditions, respectively. Heat stress after anthesis reduced the grain growth rate (12%) and grain growth period (30%) compared with optimum conditions. The indicated results show that agronomic efficiency (ANE) was greater with optimum sowing (2.1 kg per kg) compared with late sowing (1.2 kg per kg). Further research is recommended for a fuller understanding of the effects of heat stress and low N level on yield and yield components of recommended wheat genotypes under stressful conditions such as the south west of Iran.

INTRODUCTION

Wheat is traditionally grown as a cool-season crop, but with the increased availability of more widely adapted semi-dwarf cultivars, wheat production has expanded into warmer regions of countries, where production had previously been restricted to higher altitudes or cooler latitudes (Badrruuddin et al., 1999). Heat, drought and nutrient deficiency are the most important stresses that limit crop production (Entez and Fowler, 1990). Terminal heat stress is a problem in 40% of temperate environments, which cover 36 million ha (Reynolds et al, 2001). Under Mediterranean conditions such as the western part of Iran, heat stress after anthesis is the major grain yield limiting factor in winter sown wheat genotypes. Wheat crops are frequently faced with nitrogen (N) deficiency, due to low rates of N fertilizer application, organic farming practices, or a disjoing between the optimal time for N application, peak crop N demand.. Kernel number (KN), the principal determinant component of grain yield is reduced in crops subjected to pre-anthesis N deficiency (Jeuffroy and Bouchard, 1999). This study has three main aims: Describing the effects of N deficiency on wheat genotypes with different growth duration, evaluating the effect of post-anthesis heat stress on TGW and grain yield of these genotypes and determining interaction effects of this two important stresses on grain yield of six durum and bread wheat genotypes with different susceptibility to heat and N deficiency stresses.

MATERIALS AND METHODS

The experiment was conducted at Ahvaz, south-western of Iran, in the 2006-2007 growing season. The Ahvaz site is located at 20 m above sea level (32°20' N, 40°20' E). Wheat was sown on optimum (22nd Nov) or delayed (20nd Jan) sowing dates. Treatments of each individual experiment (sowing date) were arranged as a split-plot experiment in a randomized complete block design with three replications. Nitrogen rates (50, 100 and 150 kgNha^{-1}) were in main plots and wheat genotypes were in sub-plots. Plants in delayed sowing date experienced heat stress after anthesis. Six genotypes with different growth durations were used. The experiment site had a hot climate with a moderate winter and dry and hot summer. Mean temperature in grain growth period was 22 and 28°C, in optimum and delayed sowings, respectively. Total dry matter, relative grain yield and the harvest index (HI) and yield components were estimated after physiological maturity by harvesting interior rows. The harvest area was 1.2 m^{-2}. Grain yield in with heat stress after anthesis was investigated using the stress susceptibility index (SSI) recommended by Fischer and Maurer (1978) and stress tolerance index (STI) recommended by Fernandez (1992). SSI and STI were calculated as equation 1 and 2.

$$SSI = \frac{1 - \frac{Y_{Si}}{Y_{Pi}}}{1 - \frac{Y_S}{Y_P}} \quad \textbf{Eq. 1}$$

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

where Ysi, *Ypi*, *Ys*, *Yp* and Y^2p were grain yield of each cultivar under stress conditions, grain yield of each cultivar under optimum condition, mean of grain yield in all genotypes in stress and optimum conditions and square of mean grain yield in all genotypes under optimum conditions, respectively. A line of best fit for the linear phase of grain growth was determined as in earlier experiments and the slope of this line was used as an estimate of the grain growth rate (GGR). Effective grain growth duration (EGFD) was estimated by dividing final grain weight to GGR. The agronomic efficiency (ANE) was calculated as bellow:

ANE (kg per kg)= (grain yield at Nx - grain yield at N0) / N applied at Nx **Eq.3**

RESULTS

In the late sowing treatment, an increase of 6°C in the average temperature reduced TGW, grain yield (GY), biomass yield (BY) and HI approximately 42%, 33%, 32% and 11% compared to optimum sowing date, respectively. GY reduction was due to TGW decreasing (Table1). The highest and the lowest GY reduction with post-anthesis heat stress condition belonged to Star (long-season) and Vee/Nac (short-season) genotypes respectively. The highest and the lowest SSI were also in these two genotypes, respectively. Results indicated that, the highest and the lowest STI belonged to Showa and Vee/Nac genotypes, respectively. Modhej and Behdarvandi (2006) reported that, genotypes with high GY in optimum and post-anthesis heat stress conditions, had higher STI compared to other genotypes. They also suggested that, the problem with using SSI as a measure of adaptation to stress is that there are cases where SSI has been positively correlated with grain yield reduction in that genotypes whose yield was affected little by the stress also had very low yield potential. This means that the genotypes with low SSI also may have had low stress resistance yield and would not be useful for farmers. Generally, post-anthesis heat stress reduced GY 30%, 35% and 35% in short, middle and long season genotypes, respectively. In late sowing period, heat stress after anthesis reduced GY 32% and 34% in durum and bread wheat genotypes, respectively. BY reduction due to N fertilizer reduction was higher in optimum versus delayed sowing treatments, while the GY had same changes under both conditions, comparatively. Late-sown bread and durum wheat genotypes develop less extensive root systems and may be more vulnerable to drought and heat (Ehdaie and Waines, 2001). Less extensive root system due to delayed sowing may also lead to smaller N absorption and lower agronomic N efficiency. Generally, grain weight reduction with later sowing was due to grain growth duration and rate reduction. Although the grain weight reduction was associated with a shorter duration of grain development, the failure to obtain any compensating increase in the rate of dry matter accumulation, as occurs in the lower temperature ranges, was also considered important. In nitrogen deficiency treatments grain number per unit area is reduced due to reduction in the number of spikes, the number of spikes per spikelet and the number of fertile florets per spikelet.

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Table.1

Mean spike per m^{-2}, grain per spike (G.S^{-1}), grain growth rate (GGR), effective grain growth duration (EGGD), TGW, GY, BY and HI for N fertilizer treatments and wheat genotypes in optimum and late sowing date.

Treatments	Means															
	HI		BY (g. m^{-2})		GY (g. m^{-2})		TGW (g)		GGR (mg. grain^{-1} day^{-1})		EGFD (days)		G.S^{-1}		Spike.m^{-2}	
	LS	OS	LS	OS	LS	OS	LS	OS	LS	OS	LS	OS	LS	OS	LS	OS
N (kg ha^{-1})																
150	45^{a}	39^{b}	781^{a}	1303^{a}	354^{a}	512^{a}	27^{a}	45^{a}	1.42^{a}	1.70^{a}	15^{a}	26^{a}	41^{a}	42^{a}	415^{a}	420^{a}
100	39^{b}	40^{b}	667^{b}	1079^{b}	259^{b}	428^{b}	25^{a}	44^{a}	1.48^{a}	1.65^{a}	15^{a}	26^{a}	38^{a}	40^{a}	335^{b}	340^{b}
50	32^{c}	47^{a}	608^{b}	656^{c}	197^{c}	313^{c}	25^{a}	42^{a}	1.50^{a}	1.65^{a}	16^{a}	26^{a}	33^{b}	35^{b}	305^{b}	310^{b}
MS	819.26**	445.38**	139948**	1940978**	112864**	180149**	1.18^{ns}	53.68^{ns}	0.21^{ns}	0.09^{ns}	4.22^{ns}	0.66 ns	269.24**	269.24**	62367**	62328**
Genotypes																
Attila	36^{bcd}	41^{c}	673^{abc}	1059^{ab}	258^{ab}	414^{ab}	21^{e}	36^{d}	1.41^{d}	1.40^{d}	14^{d}	26^{b}	32^{c}	32^{c}	447^{a}	447^{a}
Vee/Nac	35^{cd}	36^{cd}	636^{bc}	964^{ab}	235^{ab}	325^{c}	23^{c}	39^{c}	1.85^{a}	2.00^{a}	17^{b}	26^{b}	37^{b}	37^{b}	345^{b}	345^{b}
Star	29^{d}	31^{d}	746^{ab}	1180^{a}	219^{b}	364^{bc}	22^{d}	40^{c}	1.66^{b}	1.75^{b}	18^{a}	26^{b}	37^{b}	37^{b}	305^{b}	304^{b}
Showa^{+}	41^{bc}	39^{cd}	760^{a}	1208^{a}	311^{a}	4690^{a}	31^{a}	51^{a}	1.50^{c}	1.71^{b}	17^{b}	28^{a}	35^{c}	35^{bc}	341^{b}	342^{b}
D-84-5^{+}	44^{ab}	58^{a}	677^{abc}	772^{b}	302^{a}	452^{a}	27^{b}	47^{b}	1.50^{c}	1.50^{c}	15^{c}	26^{b}	44^{a}	44^{a}	311^{b}	311^{b}
D-83-8^{+}	49^{a}	54^{b}	618^{c}	893^{ab}	309^{a}	453^{ab}	27^{b}	49^{a}	1.70^{b}	1.59^{c}	13^{d}	28^{a}	38^{b}	38^{b}	353^{b}	353^{b}
MS	442.64**	1292.78**	29810**	257109**	320.43**	35645**	177.53**	332.24**	0.44**	0.85**	29.6**	3.6**	12.88**	127.88**	23732**	23709**

Ns: Not significant **: significant at 1% probability level +: Durum genotypes MS: Mean square OS: Optimum Sowing LS: Late Sowing

Means in each column followed by similar letter (s) are not significantly different at 5% probability level using Duncan's Multiple Range Test.