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Effect of Post Anthesis Heat Stress on Head Traits of Wheat

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ABSTRACT

Heat stress is a major environmental stress limiting wheat productivity in most cereal growing areas of the world. The effect of post anthesis heat stress on important traits of head was studied in a recombinant inbred line population of wheat. Seedlings were grown in greenhouse and a week after anthesis moved to growh chamber with 35/30 ºC day/night for three days. Grain filling duration, head weight, kernel number, kernel weight were measured and compared to the controls. The results showed a significant difference among RILs for all of the traits in stress and control conditions. Heat shock reduced grain filling duration, kernel weight and head weight of lines, but did not change kernel number. All of the traits under study were correlated. The highest correlation was between kernel weight and head weight (0.946) and the lowest correlation between kernel weight and grain filling duration (-0.159). Grain filling duration had the highest heritability both in control and stress environments with 70.06 and 61.8%, respectively and kernel weight under stress had the lowest heritability (20%). It was concluded that kernel weight and kernel weight reduction are best measurements of heat tolerance and can be used for the studies such as QTL mapping.

Key Words: Heat tolerance; Wheat; Head traits

INTRODUCTION

Heat stress is a major limitation to wheat (*Triticum aestivum* L.) productivity in arid, semiarid, tropical, and subtropical regions of the world (Fischer, 1986). Consequently, development of heat-tolerant cultivars is of major concern in wheat breeding programs. A detailed understanding of the genetics and physiology of heat tolerance as well as the use of the proper germplasm and selection methods will facilitate the development of heat tolerant cultivars.

Exposure to higher than optimal temperatures reduces yield and decreases quality of cereals (Fokar *et al*., 1998; Maestri *et al*., 2002; Wardlaw *et al*., 2002). Decreased yield may be due to a wide range of interrelated processes, including accelerated development (Al-Khatib & Paulsen, 1984). reduced photosynthesis, either via damage to photosystem II (Paulsen, 1994) or inhibition of Rubisco activase (Law & Crafts-Brandner, 1999), increased respiration (Berry & Bjorkman, 1980) or disruptions to the respiratory mechanism (Lin & Markhart, 1990) and decreased starch synthesis in developing grain (Bhullar & Jenner, 1985). The nature and severity of the yield depression depends on the developmental stage at which the stress occurs (Acevedo *et al*., 1991; Paulsen, 1994). High temperatures during floral initiation and spikelet development (a period of several weeks preceding anthesis) reduce the potential number of grains, thus determining maximum yield potential. Heat stress during the post-anthesis grain-filling stage affects availability and translocation of photosynthates to the developing kernel, and starch synthesis and deposition within the kernel, thus resulting in lower grain weight and altered grain quality (Bhullar & Jenner, 1985).

Direct experimentation and yield models show an optimal temperature of 25ºC or lower for wheat from anthesis to maturity (Feyerherm & Paulsen, 1981). Ambient field temperature of 35 to 40ºC are not unusual , however, in many wheat-producing areas during that period. Acevedo *et al*. (1991) reported a 4% reduction in grain weight for each °C increase in mean air temperature during grain-filling, over a range of 17 to 24°C. Earliness, leaf rolling, early ground cover, shortness and stay green are known to be associated with heat tolerance (Blum & Neguyen, 1997; Reynolds *et al*., 2001).

Cell membrane stability (Ibrahim *et al*., 2001), canopy temperaute depression (Reynolds *et al.,* 1994) and stomatal conductance (Reynolds *et al*., 2001) have been used as physiological screening techinques for heat tolerance. Yield and yield components in stress condition, however, are still the most effective tools for stress evaluation (Ozkan *et al*., 1998). Grain filling duration was also used as a measurement of heat tolerance (Fokar *et al*., 1998). Genetic diversity for heat tolerance in wheat is well established (Al-Khatib & Paulsen, 1990; Wardlaw *et al.,* 1989; Reynolds *et al*., 2001).

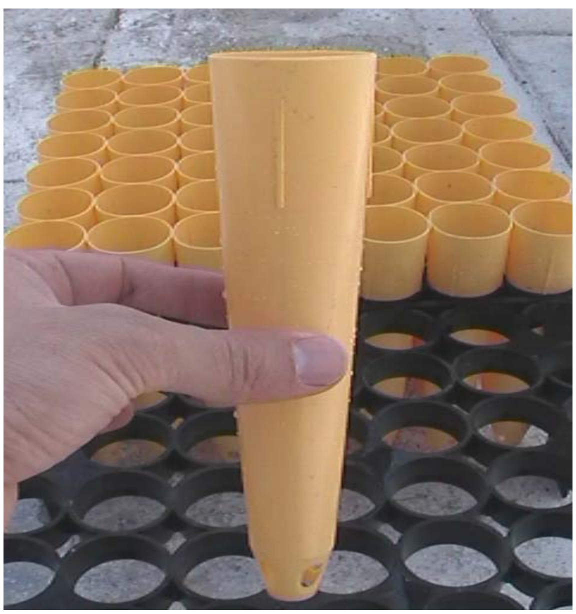
The objectives of this study were: 1) to asses the impact of post anthesis heat stress on grain filling duration, head weight as well as kernel weight and number, and 2) to evaluate the genetic variation of a recombinat inbred line population for heat tolerance and to find a trait indicating heat tolerance to be employed in QTL analysis.

MATERIALS AND METHODS

Previous studies demonstrated that Kauz, developed at CIMMYT/ Mexico, and MTRWA116, developed at Montana State University (USA), were thermotolerant and thermosensitive, respectively (Ibrahim & Quick., 2001). The initial cross was made between Kauz and MTRWA116 and generations were advanced by single seed descent until F6. Seeds of 144 recombinant inbred lines (RILs) were increased through a field planting up to F9.

Seedlings were germinated and grown in Metro - Mix2000® growing medium (consisting of horticultural vermiculie, Canadian sphagnum, peat moss, horticultural perlite, washed sand) in greenhouse with 20-25ºC in a special pots called Conetainer® (Fig. 1). The experimental design was randomized complete block with four replications. Plants were watered in proper time and fertilized with a complete sollution of PETER-Professional® containing N (20%), P_2O_5 (20%), K_2O (20%) and small amount of Mg, B, Cu, Fe, Mn, Mo and Zn. One week after the first anther extrusion was observed , the pots of two replications, each containing one seedling, were moved to a controlled environment chamber for heat shock. Chamber was set at 35/30ºC and 14/10 h day/night, 50/70 % relative humidity and illumination of 335 µmol m^{-2} S^{-2}. Plants were exposed to this high temperature for three days and then moved back to the greenhouse. Since the lines anthesis - date were different, they were moved to chamber in different times.When the color of peduncle turned to yellow, physiological maturity, plant head was excised and incubated in 40ºC for three days. Head weight, kernel number, kernel weight were,then, measured. Grain filling duration (GFD) was determined as the days from anthesis to physiological maturity.

Fig. 1. Conetainer® special pots used for the experiment



Analysis of variance and t-test assuming unequal variance were conducted for each of the measurements and means were compared by least significant difference (LSD).

RESULTS AND DISCUSSION

Comparison of means (Table I) demonstreated that the parents of population are different in their response to heat stress. Kauz has longer Grain filling period than MTRWA116 in both control and stress conditions. t-test showed also that kernel weight of MTRWA116 has decreased more than Kauz under stress. Kernel number of MTRWA116 decreased under stress while Kauz didn't change significantly. Head weight could not show the parent's difference in themotolerance.

Aalysis of variance showed there is a significant difference among RILs for all of the traits in stress and control conditions (Table II). Replications do not differ significantly from each other showing that the environmental conditions have been similar in greenhouse or growth chamber. Heat shock reduced grain filling duration, kernel weight and head weight of lines, while kernel number did not change significantly (Table I) . It makes sense because RILs were exposed to high temperature a week after anthesis and kernel number has been determined by then (Bhullar & Jenner, 1985).

Table I. Mean of the traits for the parents and the RILs in stress and control conditions

	GFD		Kernel weight		Kernel No		Head weight	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
Kauz	47.250	44.278	1.074	0.797	27.552	29.429	1.401	1.147
MTRWA116	37.240	33.833	1.206	0.612	35.385	26.741	1.592	1.038
RILs	43.539	39.878*	1.035	0.648**	29.330	26.418	1.405	1.023**

*, **, Significantly differenet from control at 5% and 1% level, respectively

Table II. Mean square of the traits in stress and control conditions

	GFD		Kernel weight		Kernel Number		Head weight	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
Reps	14.45	112.022	0.047	0.047	31.736	5.626	0.003	0.021
RILs	249.66**	164.801**	0.386**	0.146*	263.925**	180.292**	0.556**	0.274**

*, **, Significant at 5% and 1% level, respectively

Tolerance index were calculated for the traits affected by heat stress. Analysis of variance revealed very significant difference among entries for grain filling duration, kernel weight and head weight (Table III) showing that RILs are different in their response to heat stress.

All of the traits under study were correlated with each other (Table IV). The highest correlation was seen between kernel weight and head weight (0.946) and the lowest correlation between kernel weight and grain filling duration (-0.159). Head weight is highly correlated with kernel number and kernel weight because these two traits are components of head weight. Grain filling duration is adversely correlated with the other traits particularly kernel weight. It is expected, however, the longer duration of grain filling result in more kernel weight (Fokar *et al*., 1998a). So grain filling duration cannot be a good measurement of heat tolerance in this population.

Heritability of the traits in stress and control conditions are outlined in Table V. It should be noted that this heritability is almost narrow sense heritability as the lines are nearly homozygous and there is no dominance effect in genetic variation. Grain filling duration had the highest heritability both in control and stress environments with 70.06 and 61.8%. Kernel weight under stress had the lowest heritability(20%).Heritability in stress condition is lower than controls for all of the traits suggesting that environmental variation accounts for more of the variation in stressed plants.

Although head weight had significant variation in RILs, it is not recommended for QTL analysis. Grain filling duration was adversely correlated with kernel weight and kernel number did not show significant variation among RILs. We conclude, therefore, that kernel weight and kernel weight reduction (tolerance index) are the best indicator of heat tolerance and are recommended to be used for QTL studies.

Table III. Mean square of toleranc index for different traits

	GFD	Kernel weight	Head weight
Reps	0.9313	0.0003	0.0004
RILs	46.177**	0.246**	0.253**

**, Significant at 5% and 1% level, respectively.

Table IV. Pearson Correlation coefficients for the traits under study

Trait	Kernel No.	Kernel weight	GFD
Head weight	0.831**	0.946**	-0.299**
Kernel No		0.818**	-0.307**
Kernel weight			-0.159**

** Correlation is significant at the 0.01 level

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Table V. Hertability(%) of the traits in stress and control condition

	GFD		Kernel weight		Kernel No		Head weight	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
Hertability	70.06	61.8	53	20	52	45	54	41