

## EFFECTIVE APPLICATION OF CANOPY TEMPERATURE FOR WHEAT GENOTYPES SCREENING UNDER DIFFERENT WATER AVAILABILITY IN WARM ENVIRONMENTS

M. MOHAMMADI<sup>1\*</sup>, R. KARIMIZADEH<sup>1</sup>, N. SABAGHNIA<sup>2</sup> and M. K. SHEFAZADEH<sup>3</sup>

<sup>1</sup> *Dryland Agricultural Research Institute (DARI), Gachsaran, Iran*

<sup>2</sup> *Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Maragheh, Maragheh, Iran*

<sup>3</sup> *Department of Agronomy, Yasooj branch, Islamic Azad University, Yasooj, Iran*

### Abstract

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High temperature and drought are the most important abiotic stress factors which influence the wheat production in major parts of the wheat grown areas in Iran. This study was conducted to identify the proper criteria (morphological or physiological markers) for screening the heat and drought tolerant wheat genotypes under field conditions as well as to find out the sources of terminal heat and drought tolerance for utilization in the breeding programs. Under dryland, supplemental and full irrigation (exposed to high temperatures after anthesis), nine bread wheat genotypes were evaluated in three separate experiments at Gachsaran agricultural research station which is located in southwest of Iran in 2010-2011. This study showed the strong association between yield and canopy temperature under different intensity of drought (\*P < 0.05, and \*\*P < 0.01 under dryland and supplemental irrigation conditions respectively), and heat (\*\*P < 0.01) stresses, indicating the trait potential as an indirect selected criterion for achieving genetic gains in heat and drought adaptation. It was concluded that the combined heat and drought stresses, considerably, reduced grain yield more than by either stress alone, but not with additive effects. Some genotypes, in particular, genotype 7 (T.AEST/SPRW'S//CA8055/3/ BACANORA86) was identified as low CT value and high grain yield in all environments. This genotype was released through Agricultural Research, Education and Extension Organization (AREO) under the name of "Karim" in Iran in 2011.

*Key words:* drought, grain-filling period, heat, leaf chlorophyll content, tolerance

*Abbreviations:* CT\_ canopy temperature, EGV\_ early growth vigor, GYD\_ grain yield, KL\_ kernel length, KPS\_ kernels per spike, LCC\_ leaf chlorophyll content, LL\_ flag leaf length, PLH: plant height, PL: peduncle length, S/ M<sup>2</sup>: spikes per meter square, TKW: \_thousand kernel weight and TW: test weight, WL: width leaf

### Introduction

Heat and drought are the major abiotic constraints, which determine the yield and quality of wheat. Prevalence and great losses associated with abiotic, biotic and socio economic constraints to wheat production in-

dicating that heat stress is the factor, which influences the largest area, but water constraints are associated with largest economic losses (Kosina et al., 2007).

Terminal heat caused by high temperatures during wheat kernel development is an important constraint to wheat production (Rane et al., 2000; Sharma et al.,

2007). During grain filling, high temperatures drastically reduce the grain-filling period, particularly under delayed seeding (Sharma, 1992). Heat affects grain yield and quality of wheat through sink strength and source capacity. Wheat genotypes express a differential response to chronic heat as well as a heat shock (Yang et al., 2002).

Under changing ambient temperatures, plant water status is the most important variable (Mazorra et al., 2002). In general, plants, regardless temperature, tend to maintain stable tissue water status when moisture is ample; however, high temperatures severely impair this tendency when water is limiting (Machado and Paulsen, 2001).

A major challenge in traditional breeding for heat and drought tolerance is the identification of reliable screening methods and effective selection criteria to facilitate detection of heat/drought tolerant genotypes. Several screening methods and selection criteria have been developed/ proposed by different researchers.

Under water-limited conditions, the efficiency in the selection of drought-tolerant genotypes is restricted, based on empirical selection for yields per se, by the low heritability of yield as well as by a large genotype by environment interaction (Trethowan et al., 2002). In addition, yield evaluation in early generations is difficult because per plant yield may not be related to crop yield. Progress through plant breeding has been achieved by using physiological traits in the selection process to complement conventional breeding for yield (Araus, 1996, 2003; Condon et al., 2002; Richards 1996; Richards et al., 2002 and Reynolds et al., 2009).

Multidisciplinary research involving genetic resources enhancement and crop physiology at CIMMYT have led to a physiological trait-based approach to breed for abiotic stress, which has merit over breeding for yield per se by increasing the probability of successful crosses resulting from additive gene action. Advances have already been made in the drought-breeding program (Reynolds and Borlaug, 2006 and Ortiz et al., 2007), and this strategy is used to breed wheat for the high temperature-stressed environments. However, there is always uncertainty associated with the inherent genetic and environmental complexity, especially in water-limited environments (Lopes et al., 2010).

Physiological traits can be used to dissect stress adaptation into some of its components. Such physiological traits represent the closest approximation available to genetic markers, assuming they are applied to a restricted range of environments within which the traits show acceptable levels of heritability.

Research in the Yaqui Valley has demonstrated that high wheat yields are strongly associated with low average temperatures (especially low average minimum temperatures; Lobell et al., 2005).

Canopy temperature (CT) has been used as a screening tool for predicting high wheat yield in rain fed environments (Araus et al., 2002, 2003; Blum et al. 1989; Condon and Richards, 1992 and Olivares-Villegas et al., 2007). Since leaf temperature is depressed below air temperature when water evaporates, CT is an indirect measure of the (instantaneous) transpiration at the whole-crop level (Reynolds et al., 2001) and plant water status (Araus et al., 2003). Genotypic variation has been reported for CT in wheat (Amani et al., 1996; Ayeneh et al., 2002; Blum et al., 1989; Fischer et al., 1998; Karimizadeh and Mohammadi, 2011 and Reynolds et al., 1994).

The above results suggest that new sources of genetic variation combined with more efficient selection method/criteria must be pursued further to ensure significant increases in genetic yield potential for spring bread wheat cultivars.

The main objectives of this study are to identify selection criteria, which may be correlated with heat and drought tolerance during reproductive stages and to evaluate, the response of some wheat genotypes facing high temperatures during and after anthesis under field conditions.

## **Materials and Methods**

Nine bread wheat genotypes were exposed to three different sowing dates: normal (6<sup>th</sup> December 2010 under supplemental irrigation) and late sowing, to assure high temperatures and more drought stress (7<sup>th</sup> January 2011) during and/or after anthesis, at Gachsaran Agricultural Research Station (30° 20'N, 50° 50'E, 710 masl) that is located in southwest of Iran, on a silty clay loam soil. All experiments were planted in a random-

ized complete block design with four replications. Plot size of 6.3 m<sup>2</sup> consisted of six rows, 17.5 cm apart and 6 m long.

For irrigated experiments, crop management was optimal in terms of fertilization, irrigation, and weed and pest control, exclude irrigation for supplemental irrigation experiment, which was done twice in anthesis and grain filling period.

Yield components were calculated through using standard protocols (Sayre et al. 1997). Days to anthesis was determined when 50% of the spikes had half florets with anther extrusion starting from sowing date; and days to maturity were recorded when 50% of the spikes showed total loss of green color. Grain filling duration was recorded as the difference between days to maturity and days to anthesis.

Measurements of canopy temperature (CT) were taken with the infrared thermometer (Model LT-300, Sixth sense) held 0.5-1 m from the edge of the plot and approximately 50 cm above the canopy at a 30 angle from the horizon. The presented data are means of three sets of measurements, which was taken, between 12 and 16 h (Reynolds et al., 1994).

Leaf chlorophyll content (LCC) was measured at 50% anthesis through using a self-calibrating chlorophyll meter (Minolta SPAD model 502). Five random leaves from five random plants were measured and averaged in each plot (Reynolds et al., 1998) and the SPAD value recorded.

Data on early growth vigor (EGV), plant height (PLH), peduncle length (PL), flag leaf length (LL) and width (WL), spikes per m<sup>2</sup> (S/M<sup>2</sup>), kernels per spike (KPS), canopy temperature (CT), Leaf chlorophyll content (LCC),

grain yield (GYD), kernel length (KL), thousand kernel weight (TKW) and test weight (TW) were recorded and analyzed statistically by SAS and SYSTAT softwares.

## Results

Comparison between three the best and the weakest CT value for different traits under various environmental conditions showed that, these two groups had highly difference in view of grain filling period, grain yield and plant height in dry land condition. Grain filling period, grain yield, thousand-kernel weight and width leaf were more different in comparison to other traits in top and bottom value for CT under supplemental condition. These two groups showed highly difference between grain yield, thousand kernel weight and test weight in more heated environment (Table 1).

There was a negative correlation between CT and grain yield (full irrigated:  $r = -0.87$ ; drought:  $r = -0.72$ , and supplemental irrigation:  $r = -0.71$ ). The founded relationship between CT and grain yield was proved to be repeatable across diverse environments (Figure 1), which is in agreement with the results of previous studies on the robustness of the association between this physiological character and grain yield (Balota et al., 2007; Blum et al., 1989 and Olivares- Villegas et al., 2007).

Highly significant correlations were also found between LCC and CT in supplemental irrigation and heat environments. Canopy temperature showed partially high correlation with width leaf under diverse conditions, particularly in supplemental irrigation and heated environments (Table 2).

**Table 1**  
**Standard deviation (SD) and significance at 5% probability level (Prob) for various traits of three the best and weakest selected genotypes in response to canopy temperature**

Environment		DHE	GFP	DMA	CT	CC	GYD	TKW	TW	PLH	KPS	WL
Dryland	SD	2,615	0,651	3,175	0,513	2,858	41,549	1,7	3,453	1,206	5,052	0,115
	Prob	0,576	0,01	0,279	0,009	0,574	0,006	0,266	0,761	0,031	0,368	0,423
Supplemental Irri.	SD	3,6	0,321	3,351	0,115	1,646	319,26	0,755	1,234	9,531	2,931	0,1
	Prob	0,271	0,006	0,102	0,001	0,73	0,149	0,04	0,686	0,86	0,469	0,074
Heat	SD	1,872	1,266	2,517	1,332	3,604	602,89	5,278	0,416	6,768	7,477	0,2
	Prob	0,956	0,78	0,84	0,071	0,311	0,085	0,184	0,013	0,317	0,43	0,478

In view of phenological traits, grain filling period showed high negative significant correlation with CT under dry land condition (Table 2). It means that high temperature reduces duration time between heading and maturity. It is expected, the longer duration of grain filling results in less kernel weight and grain yield in dry land environment. However, grain-filling duration is adversely directed in heated (full irrigation) environment. Thousand-kernel weight is highly correlated with CT in dry land and heat conditions but not in supplemental irrigation environment. Mean while CT had high significant correlation with test weight (hectoliter) in facing to heat.

The trend of wheat yield genotypes in dry land condition in facing heat was not similar to response of the same genotypes in supplemental irrigation. As it is expected, association between dry land environment and heat condition was less in comparison to supplemental irrigation in facing heat (Figure 2). For example: Genotype no. 8 (G8) had the best rank for grain yield under dry land condition, but it had the least rank in heat condition. G5. However, G7 (T.AEST/SPRW'S//CA8055/3/BACANORA86 ICW92-0477-1AP-1AP-4-AP-1AP-0AP) showed the second rank in dry land and

heat environments and forth in supplemental irrigation with the lowest standard deviation of its rank. Genotype no. 4 showed medium rank in all environments, although, G5 had the optimum response in supplemental and full irrigation (Heat) conditions (Table 3).

## Discussion

Obtained results indicated that the productivity of wheat genotypes reduced more by the combined stresses than by heat stress alone; however, the combined effects of heat and drought are not necessarily additive ones. In the case of the kernel weight at maturity, for example, high temperature because of the reduction in the duration of grain filling reduced the effect of post-anthesis drought. It is in agreement with the results that reported by Wardlaw (2002).

Grain yield was positively correlated with CT both under timely and late seeding, which indicates that CT always influenced grain yield. This finding is in agreement with the previous reports from the studies conducted in. However, higher correlation coefficient under late seeding condition showed that CT influence grain yield more strongly in the presence of heat

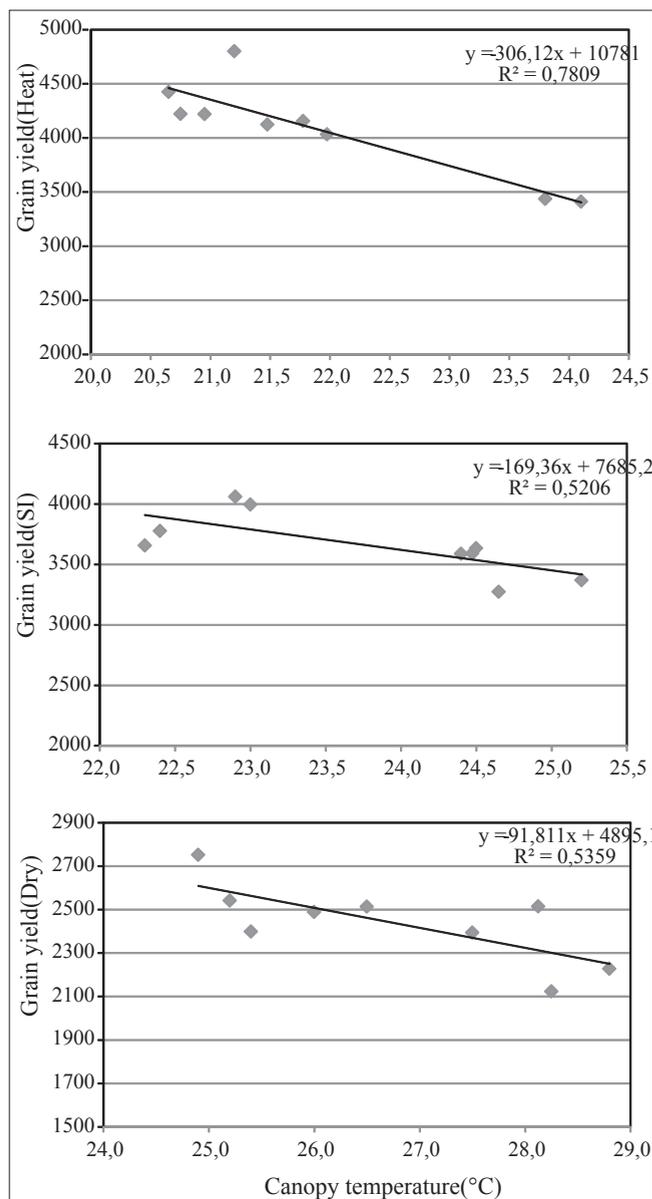
**Table 2**  
Mean trait values and correlation coefficient between CT and physio-morphological traits under different environmental conditions

Traits	Dryland		Supplemental irrigation		Heat (full irrigation)	
	Corr.	Value	Corr.	Value	Corr.	Value
Early growth vigor	0.648**	3,6	0,146	3,8	0,477	3,8
Days to heading	0,172	80,6	0,253	77,3	-0,069	94,4
Grain filling period	-0.752**	39	0,224	45,3	0,099	34,5
Days to maturity	-0,389	119,6	0,279	122,6	-0,013	128,9
Chlorophyll content	0,2	47,9	-0.588**	45,1	-0.834***	49,5
Grain yield	-0. 720**	2440	-0.712**	3663	-0871***	4091
Thousand kernel weight	-0.504*	23	-0,013	33,1	-0.671**	34,8
Test weight	0,07	68,6	-0,246	76,5	-0.733**	78,5
Plant height	-0,219	89,9	0,256	98,1	0,467	81,5
Peduncle	-0,295	46,5	0,273	50,9	-0,112	30
Tiller/M <sup>2</sup>	-0,04	340	0.629**	269	0.483*	411
Kernel length	0,012	6,4	-0,298	6,6	0.498*	6,8
Number of kernel per spike	-0.556*	51,6	0,092	52,1	-0,134	47,1
Length of leaf	-0,085	20,5	0.566*	25,9	0,33	24,3
Width of leaf	-0,406	1,5	-0.589**	1,7	-0.493*	1,6

Significant correlations are indicated: \*,  $P < 0.10$ ; \*\*,  $P < 0.05$ ; \*\*\*,  $P < 0.01$

stress. It seems that a few days longer in grain development could be an important determinant in improving grain yield in the heat stress environment in contrary to drought condition.

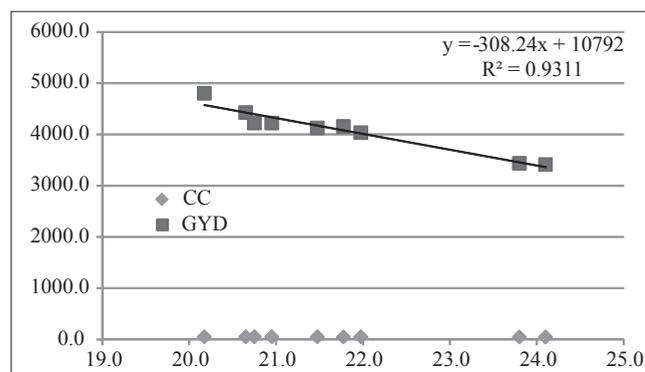
The difficulty of selecting for improved adaptation to abiotic stresses makes the use of indirect measures attractive to plant breeders. A good example is canopy



**Fig. 1. Phenotypic association between canopy and grain yield in heat (top), supplemental irrigation (middle) and dryland conditions (bottom)**

temperature, for which measurement is quick (10 seconds), easy (aim and pull the trigger) and inexpensive. Previous studies have shown that less CT has been associated with increased wheat yield under irrigated, hot environments (Amani et al., 1996; Reynolds et al., 1994; Reynolds, 2002; Fischer et al., 1998), but also under dryland environments (Blum, 1988 and Balota et al., 2007). Under favorable soil-water conditions, less CT and yield have been attributed to increased stomatal conductance and crop water use (Amani et al., 1996; Fischer et al., 1998 and Pinter et al., 1990). Therefore, CT has been used as a selection criterion to improve adaptation to drought and heat stresses. The CT is a result of the leaf's energy balance, which includes determined terms by environment and physiological traits (Balota et al., 2008). Many studies have shown that root traits are important adaptive attributes of drought (Sinclair and Muchow 2001; Manschadi et al., 2006, 2008; Reynolds et al., 2007 and Christopher et al., 2008). However, root traits are notoriously difficult to measure in realistic field situations and, therefore, cooler canopy temperature has been suggested as a surrogate indicating a genotype ability to maintain transpiration through access of roots to water deep in the soil profile.

It was found that leaf chlorophyll content was correlated with grain yield. Such sources of alleles coupled with some of the other traits can provide means for genetically enhanced wheat by designing in heat-prone environments. In this regard, data from extensive in-



**Fig. 2. Comparison between grain yield in dryland (top) and supplemental irrigation (bottom) to heat condition**

**Table 3**  
**Mean and standard deviation of grain yield ranks for nine bread wheat genotypes under different environmental conditions**

No.	Name/Cross	Dry	SI	Heat	$\bar{R}$	SDR
1	BHRIKUTINL623-0NPL	2514(4)	4061(1)	4032(7)	3	3
2	FRTL /2*PIFED CMSS96M05650M-040Y-050M-050SY-040SY-030M-27SY-010M-0Y-0SY	2400(6)	3370(8)	4222(3)	7,5	2,5
3	CN079//PF70354/MUS/3/PASTOR/4/BABAX CMSS97 M02936T-040Y-030M-040SY-030M-040SY-26M-0Y	2124(9)	3274(9)	3436(8)	9	0,6
4	SKAUZ/BAV92//PASTOR CMSS97Y06166T-040M-8Y-010M-010SY-010M-8SY-010M-0Y-0SY	2489(5)	3995(2)	4156(5)	3	1,7
5	CS/TH.SC//3*PVN/3/MIRLO/BUC/4/MILAN/5/TILHI CMSS97M04005T-040Y-020Y-030M-020Y-040M-28Y-1M-0Y	2228(8)	3779(3)	4801(1)	3	3,6
6	CS/TH.SC//3*PVN/3/MIRLO/BUC/4/MILAN/5/TILHI CMSS97M04005T-040Y-020Y-030M-020Y-040M-28Y-3M-0Y	2394(7)	3592(6)	4219(4)	7,5	1,5
7	T.AEST/SPRW'S//CA8055/3/BACANORA86 ICW92-0477-1AP-1AP-4AP-1AP-0AP	2542(2)	3658(4)	4423(2)	1	1,2
8	CHEN/AEGILOPSSQUARROSA(TAUS)//BCN/3/VEE#7//BOW/4/PASTOR CMSS93 B01854T- 040Y-8Y-010M-010Y-010M-10Y-0M-4KBY-0KBY-0M-0HTY	2753(1)	3635(5)	3411(9)	5	4
9	KOUHDASHT	2515(3)	3589(7)	4124(6)	6	2,1

ternational yield trials in more marginal environments indicate even greater grain yield progress (2–3% per annum) in both semi-arid and heat stressed environments between 1979 and 1995 (Trethowan et al., 2002). Mamnouie et al. (2006) reported that Chlorophyll content is positively correlated with the photosynthesis rate and soluble proteins.

Potential parents are characterized for a range of morpho-physiological traits, thereby allowing plant breeders to combine these traits in a strategic manner in crosses. Genotype no.7 (KARIM: T.AEST/SPRW'S//CA8055/3/BACANORA86) is recently released for cultivation in semi-tropical dry land of Iran.

## Conclusion

Heat stress, alone or in combination with drought, is a common constraint during grain filling stages for wheat production in many regions. Heat tolerance may have additive or opposite effects on drought stress.

The present study showed that the lower canopy temperature under different availability water conditions caused higher grain yield. Therefore, CT has been used as a selected criterion for tolerance in drought and high temperature stresses.

Some genotypes such as G7 and G4 are potentially useful sources for improving in the combined heat and drought tolerance in addition to G5 as a heat tolerant line.

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