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Effect of Canopy Temperature Depression on Grain Yield and Yield Components in Bread and Durum Wheat

BAHAR Bilge[1)], Mehmet YILDIRIM[2)], Celaleddin BARUTCULAR[3)], Ibrahim GENC[3)]

[1)]*Middle East Technical University, Department of Chemistry, Biochemistry and Biotechnology Research Programs, Inonu Blvd. Ankara, TR-06531, Turkey*

[2)]*University of Dicle, Faculty of Agriculture, Field Crops Department. Diyarbakir, TR-21280, Turkey, e-mail: mehmety@dicle.edu.tr*

[3)]*University of Cukurova, Faculty of Agriculture, Field Crops Department, Adana, TR-01330, Turkey*

Abstract

Relationships of CTD (Canopy Temperature Depression) with grain yield and its components were evaluated under Cukurova conditions, Turkey, in 2003 growth season. With this aim, six bread and five durum wheat genotypes were used as a material. CTD was measured three times during beginning of heading to full anthesis stages and only at the last measurements, both bread wheat and durum wheat genotypes showed significant differences. At the last measurements, CTD of bread wheat ranged between -0.22 and 0.57°C. On the other hand, CTD average values of durum wheat genotypes changed 0.63 to 1.23°C. This study showed that durum wheat was cooler than bread wheat in high temperature conditions. In addition, CTD was positively correlated with grain yield, spike yield, and grain numbers per spike. Overall, CTD has played an important role to search physiological basis of grain yield of wheat, and CTD can successfully use as a selection criterion in breeding programs.

Keywords: canopy temperature depression, drought stress, grain yield, heat, wheat

Introduction

Canopy Temperature Depression (CTD) is usually expressed as canopy temperature minus air temperature, and this value is higher and a positive number in a well irrigated wheat. Also, vapour pressure deficit has a large effect on CTD, while net radiation, air temperature, and wind speed have slight effects (Smith et al., 1986). CTD effected by biological and environmental factors like water status of soil, wind, evapotranspiration, cloudiness, conduction systems, plant metabolism, air temperature, relative humidity, and continuous radiation (Reynolds et al., 2001), has preferably been measured in high air temperature and low relative humidity because of high vapour pressure deficit conditions (Amani et al., 1996). At the end of 1980sh, Cimmyt began CTD measurements on different irrigated experiments in Northwest Mexico. Phenotypic correlations of CTD with grain yield were occasionally positive (Reynolds et al., 1994, Fischer et al., 1998). CTD has been used as a selection criteria for tolerance to drought and high temperature stress in wheat breeding and the used breeding method is generally mass selection in early generations like F_3. According to this method, firstly, bulks which show high CTD value (have cool canopy) are selected in F_3 generation. Later, single plants which show high stomata conductance (g) among bulks which show cool canopy at the same selection generation; thus, both of these traits are used at the same breeding programme (Reynolds et al., 2001). Munjal and Rena (2003) have reported that cool canopy during grain filling period in wheat is an important physiological principle for high temperature stress tolerance. In this study, our aim is to determine the relationships of CTD with grain yield and yield components in common commercial bread and durum wheat.

Materials and methods

Trial was conducted at Field Crops Research Area and department laboratories in Agricultural Faculty, Cukurova University, Adana, Turkey. In experiment, six bread wheat and five durum wheat genotypes were used as a material. Genotypes were sown in a randomized complete block design with four replicates. Plots were sown at a seeding rate of 450 seed m^{-2} by HEGE-80 trial drilling machine on 29 November in 2002. Plot size was eight rows, 5 m long, with 15 cm between rows. Fertilizers were applied: 80 kg ha^{-1} of nitrogen and 80 kg ha^{-1} of phosphorus as 20.20.0 compose fertilizer at planting time, 80 kg ha^{-1} of nitrogen as ammonium nitrate (half of the top dressed fertilizer) was given at tillering, and the other half of the top dressed fertilizer was given at swollen stage. No-disease was shown during growth season, and weed control was made by hand. After physiological maturity, plots were harvested by HEGE-125 C trial thrasher / harvester machine. Regional climatic data

Table 1 Average values of agronomical traits in bread and durum wheat genotypes

Genotypes	Grain yield (kg ha^{-1})	Spike yield (g spike^{-1})	Grain no. per spike (no spike^{-1})	Biomass (g m^{-2})	Harvest index (%)	Spike no. per square meter (no m^{-2})
A- Bread Wheat						
Genc-99	5720	1.178	42.0	1583	29.5	537
Balatilla	6230	1.066	38.3	1629	31.0	658
Seri-82	6060	1.176	44.0	1422	28.0	505
Panda	5180	1.167	38.0	1451	33.0	490
Golia	5100	0.896	38.0	1276	35.0	670
Adana-99	6500	1.255	40.8	1356	29.8	447
Average	5800	1.123	40.2	1453	31.0	551
LSD	603.5	N.S.	N.S.	N.S.	4.37	90.6
C.V. (%)	6.91	13.76	7.40	10.91	9.35	10.91
B- Durum Wheat						
Balcali-2000	6000	1.357	43.0	1422	31.5	445
Amanos-97	5910	1.129	39.0	1332	28.5	545
Dicle-74	4800	1.243	41.8	1473	28.0	564
NN-90.E-3-14	4850	1.045	38.8	1219	21.0	395
Porron 4/Yuan1	5410	1.388	53.6	1376	24.3	412
Average	5390	1.232	43.3	1364	26.7	472
LSD	783.7	N.S.	5.87	N.S.	3.27	98.1
C.V. (%)	9.43	16.03	8.80	13.49	7.97	18.74

during growth season (November to May) was like follow: (i) average monthly temperature according to months (Nov to May) was confirmed as 16.4, 8.8, 11.1, 8.2, 11.5, 17.1, 24.5 °C, respectively; (ii) total rain amount was respectively as 25.7, 77.9, 84.5, 111.7, 92.3, 61.1, 14.8 mm. Maximum air temperature at measurement dates (9, 12 and 30 April), was respectively 22.0, 27.3, 27.2°C. Average temperature was respectively 16.2, 18.4, and 19.9°C, and relative humidity was respectively 67.3, 54.9, 65.0 % on the same dates (Anonymous, 2003). CTD measurements were made by infrared thermometer (Model IRTS-P, Apogee Instrument, Inc., Logan, UT, USA) which was focused to 5:1 meter and at late morning to early afternoon cloudless periods (11:00 to 15:00 hours). As a similar to method of Fischer et al. (1998), the data for each plot were the mean of four readings, taken from the same side of each plot at an angle of approximately 30° to the horizontal in a range of directions such that they covered different regions of the plot and integrated many leaves. Also, measurements were at different three periods on 9th April (ZGS 5.0, emergence of the first spikelet), 12th April (ZGS 5.4, emergence of fifty percent of inflorescence), and 30th April (ZGS 6.9, completing of anthesis), and ZGS defines Zadoks Growth Scale (Zadoks et al., 1974). Variance analysis of all agronomical traits and CTD measurements on each growth stage were carried out and the significance of cultivar mean square determined by testing against the error (cultivar x replicate) mean square. Cultivars means over all dates were compared by the least significant difference method at P = 0.05 by MSTAT-C (1989) statistical packed program. Correlations between two traits were evaluated by MINITAB (1995).

Results and discussion

Means related with yield and yield components of bread and durum wheat were given in Table 1. Genotypic variance was significant for grain yield, harvest index and spike number in both species. In addition, significant genotypic variation was observed for grain number per spike in durum wheat. Bread wheat genotypes had higher grain yield, harvest index and spike number than durum wheat. The CTD measurements were taken at the stage of first spikelet of spike just visible (ZGS 5.0), half of spike visible (ZGS 5.4) and all of spikes are flowering (ZGS 6.9).

Genotypic differences were only detected at the last CTD measurements on both bread and durum wheat. Besides, all of CTD measurements of durum wheat had

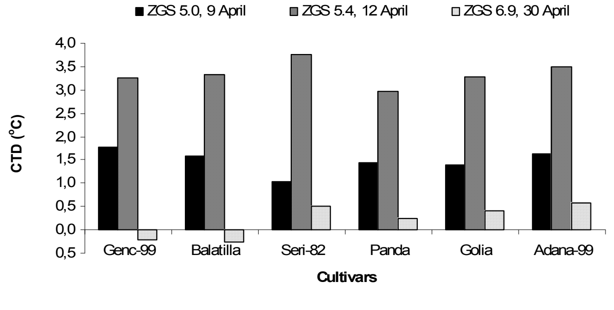

Figure 1 CTD (Canopy Temperature Depression) values of bread wheat genotypes

Table 2 Correlation coefficients between characters in bread and durum wheat genotypes

Character	Grain yield	Spike yield	Grain no. per spike	Biomass	Harvest index	Spike no. per square meter	CTD ZGS 5.0	CTD ZGS 5.4
CTD, ZGS 5.0[†]	-0.06[‡] -0.08	0.05 -0.26	0.15 -0.07	0.47* -0.36	0.15 -0.22	0.33 -0.18		
CTD, ZGS 5.4	0.45* -0.06	0.26 -0.15	0.40* -0.20	0.53** 0.25	-0.14 -0.31	0.35 0.14	0.38 0.24	
CTD, ZGS 6.9	0.39 0.17	0.35 -0.09	0.27 0.03	0.18 0.33	0.10 -0.38	0.07 0.09	0.00 0.00	0.70** 0.79**

* - shows significance level of 0.05 %, ** shows significance level of 0.01%.

† - Values of up lines explain bread wheat; values of down lines explain durum in the same cell.

‡ - ZGS 5.0, emergence of the first spikelet; ZGS 5.4, emergence of fifty percent of inflorescence; ZGS 6.9, completing of anthesis.

higher values than bread wheat. As shown in v, CTD of bread wheat genotypes between 1.03°C (Seri-82) genotypes and 1.77°C (Genc-99) at the stage of ZGS 5.0. CTD value changed between 2.96°C (Panda) and 3.75°C (Seri-82) at ZGS 5.4. At the last stage (ZGS 6.9), CTD values changed between -0.27°C (Balatilla) and 0.57°C (Adana-99).

Differences among genotypes have not been significantly out of 30th April measurements (ZGS 6.9). Rees et al. (1993) reported that CTD values have been changed between 3.54 and 5.10°C before anthesis, 3.16 to 4.61°C after anthesis in bread wheat. Reynolds et al. (1997) reported that CTD average values of heat stress tolerant genotypes in bread wheat were respectively 7.4, 9.0, and 6.5°C before heading, at heading and grain filling periods.

These values were respectively 7.1, 7.9, and 5.7°C at the same periods in susceptible genotypes. Also, Barma et al. (1997) showed that CTD values could have been changed -2.4 and -5.5 °C sometimes. In this study, it has been shown similar to this situation; for instance, CTD values have been observed such as -0.22°C in Genc-99 and -0.27°C in Balatilla. It has understood that these cultivars have hotter plant canopy than the other cultivars. In durum wheat, CTD values changed between 1.38°C (Porron4/Yuan1) and 2.02°C (Amanos-97) at the stage of ZGS 5.0 (Figure 2).

At the stage of ZGS 5.4, these values changed between 3.42°C (Porron4/Yuan1) and 4.13°C (NN-90.E-3-14). On 30th April (ZGS 6.9), CTD values changed between 0.53°C and 1.23°C (Balcali-2000 and Porron4/Yuan1).

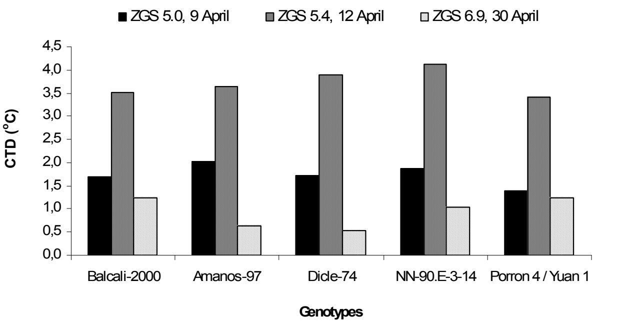

Figure 2 CTD (Canopy Temperature Depression) values of durum wheat genotypes

Differences between genotypes in durum wheat have not been significantly out of 30th April measurement (ZGS 6.9). Rees et al. (1993) reported that in durum wheat, CTD changed between 3.04 and 3.94°C after anthesis. It has been understood that in the latest two measurement dates, in other explanation, at fifty percent of inflorescence (ZGS 5.4) and full an thesis periods (ZGS 6.9), CTD values of bread wheat showed positive correlations with grain yield, spike yield and grain number per spike (Table 2). Also, at the stages of emergence of the first spikelet and fifty percent of inflorescence in bread wheat, CTD showed positive correlations with biological yield (biomass) and spike number per square meter. Non-significant negative correlations found between CTD and harvest index in durum wheat at all of three growth stages (emergence of the first spikelet, emergence of fifty percent of inflorescence, and completing of anthesis).

This study showed that durum wheat has stayed cooler than bread wheat in heat and drought stress conditions. At late periods of heading in bread wheat, CTD value positive correlations with grain yield, spike yield, and grain numbers per spike. Also, relations of CTD found positive with biomass and grain numbers per spike at head emergence and fifty percent of inflorescence. On the other hand, at the all of measurement periods, negative correlations found between CTD and harvest index in durum wheat genotypes. In this study, positive correlation between CTD and grain yield showed that CTD has been used for selection criteria in breeding programs.

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