Journal of Agriculture and Sustainability

Volume 1 (2012) , Number 1, 23-38.

Canopy Temperature Efficiency as Indicators for Drought Tolerance in Durum Wheat (*Triticum Durum* Desf.) in Semi Arid Conditions.

A. Guendouz (Corresponding author)

National Institute of Agronomic Research of Algeria, Research Unit of Sétif (INRAA)

S. Guessoum

Department of Agronomy, Ferhat ABBAS University of Sétif (Algeria)

K. Maamri

Department of Agronomy, Ferhat ABBAS University of Sétif (Algeria)

M. Benidir

National Institute of Agronomic Research of Algeria, Research Unit of Sétif (INRAA)

M. Hafsi

Department of Agronomy, Ferhat ABBAS University of Sétif (Algeria)

Abstract

Durum wheat (*Triticum durum* Desf.) is one of the more widely cultivated crops in the Mediterranean basin, where drought is the main abiotic stress limiting its production. This study was conducted on the experimental site of station ITGC in Setif, Algeria. The objectives of this study were (i) to determine differences in canopy temperature (CT) and canopy temperature depression (CTD) of different durum wheat under both well-watered and moisture stressed conditions and (ii) to correlate canopy temperature (CT) and canopy temperature depression (CTD) with drought resistance indices value and yield of durum wheat (Triticum durum Desf.) under both conditions. The results of study showed a significant difference between CT and CTD under both conditions and among

genotypes. Under dryland conditions, grain yield and mean CTD were correlated positively (r = 0.32**), this correlation is similar to other studies (Blum et al., 1989; Royo et al., 2002). Similar results of correlation between canopy temperature (CT), canopy temperature depression (CTD) and grain yield suggest that the use of CT and CTD in screening for highly tolerant varieties to drought is similar. The significant correlation of CT and CTD with Mean productivity (MP) and Stress tolerance index (STI) suggests that CTD and/or CT can be favorite selection criteria in plant breeding for drought tolerance.
Keywords: Durum wheat, Canopy temperature, Canopy temperature depression, Drought resistance indices

INTRODUCTION

Wheat production in Mediterranean region is often limited by sub-optimal moisture conditions. Visible syndromes of plant exposure to drought in the vegetative phase are leaf wilting, decrease of plant height, number and area of leaves and delay in accuracy of buds and flowers (Boyer, 1982; Passioura et al., 1993). Durum wheat is grown on 10% of the world wheat area. It occupies approximately 11 million ha in the Mediterranean basin. The world's durum wheat acreage is concentrated in the Middle East, North Africa, Russia, the North American Great Plains, India, and Mediterranean Europe(Golabadi et al., 2006).Water deficit is one of the most important factors limiting crop yield, and the monitoring of crop water status has prime importance for reasonable irrigation and water saving cultivation. Breeding for resistance to drought is complicated by the lack of fast, reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions where large amount genotypes can be evaluated efficiently (Ramirez and Kelly, 1998). Achieving genetic increase in yield in these environments has been recognized to be difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards et al., 2002). Thus, drought indices which provide a measure of drought based on loss of yield under drought condition in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). These indices are either based on drought resistance or susceptibility of genotypes (Fernandez, 1992). Canopy temperature measurements have been widely used in recent years to study genotypic response to drought. Blum et al., (1989) used canopy temperatures of drought stresses wheat genotypes to characterize yield stability under various moisture conditions.A positive correlation was found between a drought susceptibility index and canopy temperature in stressed environments. Drought-susceptible genotypes which suffered relatively greater yield loss under stress tended to have warmer canopies at midday. Result from several recent studies show that canopy temperatures under well-watered conditions also provide an indication of potential yield performance during drought and could effectively be used as a technique to assess genotypic response to drought. Rashid et al., (1999) reported that significant correlation between canopy temperature and yield under moisture-stress conditions and stress susceptibility index values indicated the potential for screening wheat genotypes for drought response.Canopy temperature depression, the difference between air temperature (Ta) and canopy temperature (Tc), is positive when the canopy is cooler than the air (CTD = Ta – Tc). It has been used in various practical applications including evaluation of plant response to environmental stress (Ehrler et al., 1978; Idso, 1982; Howell et al., 1986), irrigation scheduling (Hatfield, 1982), and to evaluate cultivars for water use (Pinter et al., 1990), tolerance to heat (Amani et al., 1996), and drought (Blum et al., 1989; Rashid et al., 1999). In general, CTD has been used to assess plant water status because it represents an overall, integrated physiological response to drought and high temperature (Amani et al., 1996).Overall, the existing literature suggests that dominant mechanisms that increase CTD vary with environment and crop species. 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). Therefore, the objectives of this study were (i) to determine differences in canopy temperature (CT) and canopy temperature depression (CTD) of different durum wheat under both well-watered and moisture stressed conditions and (ii) to correlate canopy temperature (CT) and canopy temperature depression (CTD) with drought resistance indices value and yield of durum wheat (*Triticum durum*Desf.) under both conditions.

MATERIALS AND METHODS

Ten durum wheat (*Triticum durum* Desf.) were chosen for study based on their reputed differences in yield performance under irrigated and non-irrigated conditions (Table 1). Experiments were conducted at experimental field of ITGC (Technical Institute of Field Crops) station of Setif, Algeria (5°20'E, 36°8'N, 958 m above mean sea level) during the 2011/2012 cropping year. Genotypes were grown in randomized block design with four replicates. Plots were 2.5 m × 6 rows with 0.20 m row spacing and sowing density was adjusted to 300 g m^{-2}. All plots of the irrigation experiment were irrigated by using a Sprinklers system and the volume of water input for each plot was controlled. Two irrigation regimes were applied; the first irrigation (15 mm) was performed at the time of heading (50 Zadoks cods), and the second irrigation (25 mm) was applied at grain filling period (70 Zadoks cods). A handheld infrared thermometer (Model TECPEL 513, TAIWAN), with a field of view of 100 mm to 1000 mm, was used to measure CT (°C). The data were taken from the same side of each plot at 1m distance from the edge and approximately 50 cm above the canopy at an angle of 30° to the horizontal. Readings were made between 1300 and 1500 h on sunny days.

At harvest, grain yield were recorded under two conditions irrigated and non irrigated. Drought resistance indices were calculated using the following relationships:

1. Harmonic mean (HM) (Kristin et al., 1997):

$$HM = 2 (GYp * GYs) / (GYp + GYs)$$

GYp and GYs were the yield of each cultivars, non stressed and stressed, respectively.

2. Geometric mean productivity (GMP) and **3.** Stress tolerance index (STI) (Fernandez, 1992; Kristin et al., 1997):

$$GMP = (GYp * GYs)^{½} \qquad STI = (GYp * GYs) / (G\hat{Y}p)^2$$

4. Mean productivity (MP) (Hossain et al., 1990):

$$(GYp + GYs) / 2$$

Data were analyzed using SAS for analysis of variance and Fisher's LSD multiple range test was employed for the mean comparisons.

RESULTS AND DISCUSSION

Grain yield (GY):

The results of the present study indicated that the tow different conditions of growth (stressed and non stressed conditions) had different considerable effects on grain yield. Data concerning grain yield is given in Table 1 and Figure 1, the grain yield of ten genotypes tested ranged between 21.45-36.87 q/ha in stressed condition and 26.62-58.56 q/ha in well-watered condition. Drought resistance is usually quantified by grain yield under drought. Wheat grain yield under drought, however, depends on yield potential as well as the phenology of the genotype (Acevedo, 1991). In this study the difference between grain yield under stressed and non stressed conditions equal 29.88%. Severe water stress from the seedling stage to maturity reportedly reduced all grain yield components, particularly the number of fertile ears per unit area by 60%, grain number per head by 48% (Garcia del Moral et al., 1991) and grain yield by 12.42% (Guendouz et al., 2012).

Canopy temperature (CT) and Canopy temperature depression (CTD):

Means related with canopy temperature and canopy temperature depression were given in Table 1 and Figure 2, 3. Genotypic variance was significant for CT and CTD under both conditions. The values of canopy temperature (CT) under irrigated condition were ranged between 23.83°C for Sooty to 28°C for Hoggarwith an average of 25.99°C over all genotypes, but under stressed condition there is augmentation in the values where ranged from 27°C for Polonicum to 30.66°C for Altar with an average of 28.77°C over all genotypes. The difference between CT under stressed and irrigated conditions equal 10.69%, this result is in agreement with the finding of Talebi (2011), water stress affect positively canopy temperature.Blum et al., (1989) used canopy temperatures of drought stresses wheat genotypes to characterize yield stability under various moisture conditions.

Values of Canopy temperature depression (CTD) ranged between -0.36 for Mexicali to 2.8 for Polonicum with an average of 1.016 over all genotypes in stressed conditions. Under irrigated conditions CTD varied from 1.8 for Hoggar to 5.96 for Sooty with an average of 3.79 over all genotypes tested. Drought stressed plants displayed higher canopy temperatures than well-watered plants (Siddique et al., 2000). High CTD has been used as a selection criterion to improve tolerance to drought and heat (Amani et al., 1996; Ayeneh et al., 2002). The genotypes with negative values of CTD suggest that these genotypes it's very sensitive to water stress. CTD as a tool for predicting performance (Reynolds et al., 1997). Increase in CTD might have occurred due to increased respiration and decreased transpiration resulting from stomatal closure (Siddique et al., 2000).

Drought resistance indices (DRIs):

In this study, the stress intensity (SI) was 27.11 %. It is essential to say that this index is just to measure drought stress intensity in experiment and it has no efficiency to measure stress intensity in varieties (Fisher and Maurer, 1978). Achieved results from calculation of drought tolerance and drought sensitive indices (Table 2) shows that the higher value of MP, GMP and STI indicated stress tolerance. Under both conditions values of GMP, HM and MP ranged between 23-44. The best index to select varieties, is stress tolerance index (STI), as it can separate varieties which has high yield in both stressed and non-stressed conditions (group A) from two groups of varieties which have just relatively batter yield under non-stressed (group B) or stressed (group C) conditions (Fernandez, 1992).

Correlations between CTD, CT and grain yield:

Under dryland conditions, grain yield and mean CTD were correlated positively (r = 0.32**), this correlation is similar to other studies (Blum et al., 1989; Royo et al., 2002); but under irrigated condition CTD correlated negatively with grain yield (r = -0.41**) (Table 3). In this study, positive correlation between CTD and grain yield suggests that CTD has been used for selection criteria in breeding programs. Blum (1988) and Balota et al. (2007) proposed CTD as a selection criterion for drought tolerance. Under stressed condition canopy temperature (CT) correlated negatively with grain yield (r = -0.32**). Similar results were reported by Hirayama et al., (2006) for rice and by Talebi (2011) in Durum wheat. In addition, Fischer et al., (1998) reported that stomatal conductance, photosynthesis and canopy temperature were closely related with yield in spring wheat. The evaluations and line selection of drought tolerance based on the canopy temperature could also be effective in durum wheat to develop highly tolerant varieties to drought (Talebi, 2011). Similar results of correlation between canopy temperature (CT), canopy temperature depression (CTD) and grain yield suggest that the use of CT and CTD in screening for highly tolerant varieties to drought is similar.

Correlations between CTD, CT and Drought resistance indices:

Selection for drought tolerance in wheat could be conducted for high MP, GMP and STI under rainfed and supplementary irrigation environments (Golabadi et al., 2006). Selection of different genotypes under environmental stress conditions is one of the main tasks of plant breeders for exploiting the genetic variations to improve the stress-tolerant cultivars (Clarke et al., 1984).

Tolerance indices including STI and MP were able to identify cultivars producing high yield under both conditions (Stressed and non stressed conditions) (Shefazadeh et al., 2012). As shown in Table 3, and under both conditions canopy temperature depression (CTD) and Canopy temperature (CT) correlated significantly with Mean productivity (MP) and Stress tolerance index (STI). This significant correlation suggests that CTD and/or CT can be favorite selection criteria in plant breeding for drought tolerance.

CONCLUSIONS

This study showed that the irrigation affect significantly canopy temperature (CT), canopy temperature depression (CTD) and grain yield. Significant correlation between canopy temperature depression, canopy temperature and grain yield suggests that CTD and/or CT has been used for selection criteria in breeding programs. In addition, similar results of the correlation between canopy temperature (CT), canopy temperature depression (CTD) and grain yield suggest that the use of CT or CTD in screening for highly tolerant varieties to drought is identical, and the significant correlation of CT and CTD with Mean productivity (MP) and Stress tolerance index (STI) suggests that CTD and/or CT can be favorite selection criteria in plant breeding for drought tolerance.

References

[1] Acevedo, E. (1991). Improvement of winter cereal crops in Mediterranean environments: use yield, morphological and physiological traits. In E. Acevedo, A.P. Conesa, P. Monneveux and P. Srivastava, eds. Physiology Breeding of Winter Cereals for Stressed Mediterranean Environments, 273- 305. INRA, France.

[2] Amani, I., Fischer, R.A. and Reynolds, M.P. (1996). Canopy temperature depression association with yield of irrigated spring wheat cultivars in hot climate. J. Agron. Crop Sci., 176:119–129.

[3] Ayeneh, A., Ginkel, M., Reynolds, M.P. and Ammar, K. (2002). Comparison of leaf, spike, peduncle, and canopy temperature depression in wheat under heat stress. Field Crops Res., 79: 173-184.

[4] Balota, M., Payne, W.A., Evett, S.R., Lazar, M.D. (2007). Canopy temperature depression sampling to assess grain yield variation and genotypic differentiation in winter wheat. Crop Sci., 47:1518-1529.

[5] Blum, A. (1988). Plant breeding for stress environments. CRC Press, Boca Raton, FL.

[6] Blum, A., Shipiler, L., Golan, G. and Mayer, J. (1989). Yield stability and canopy temperature of wheat genotypes under drought stress. Field Crops Res., 22: 289-296.

[7] Boyer, J.S. (1982). Plant productivity and environment. Science., 218: 443-448.

[8] Clarke, J.M., Towenley-Smith, T.M., McCaig, T.N. and Green, D.G. (1984). Growth

analysis of spring wheat cultivars of varying drought resistance. Crop Sci., 24: 537-541.

[9] Ehrler, W.L., Idso, S.B., Jackson, R.D. and Reginato, R.J. (1978). Diurnal changes in plant water potential and canopy temperature of wheat as affected by drought. Agron. J., 70: 999–1004.

[10] Fernandez, G.C.J. (1992). Effective selection criteria for assessing stress tolerance. In, Kuo CG (Ed.) Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, Publication, Tainan, Taiwan.

[11] Fischer, R.A. and Maurer, R. (1978). Drought resistance in spring wheat cultivars. 1. Grain yield response. Aust. J. of Agric. Res., 29: 897-912.

[12] Fischer, R.A., Rees, D., Sayre, K.D., Lu, Z.M., Condon, A.G., Larque-Saavedra, A. (1998). Wheat yield progress is associated with higher stomatal conductance and photosynthetic rate, and cooler canopies. Crop Sci., 38(6): 1467-1475.

[13] Garcia del Moral, L.F., Ramos, J.M., Garcia del Moral, M.B. and Jimenez-Tejada, P. (1991). Ontogenetic approach to grain production in spring barley based on path-coefficient analysis. Crop Science., 31: 1179-1185.

[14] Golabadi, M., Arzani, A. and Maibody, S.A.M. (2006). Assessment of drought tolerance in segregating populations in durum wheat. Afr J Agric Res., 5: 162-171.

[15] Guendouz, A., Guessoum, S., Maamari, K. and Hafsi, M. (2012). The Effect of Supplementary Irrigation on Grain Yield, Yield Components and Some Morphological Traits of Durum Wheat (Triticum Durum Desf.) Cultivars. Advances in Environmental Biology., 6(2): 564-572.

[16] Hatfield, J.L. (1982). The utilization of thermal infrared inputs from grain sorghum as methods of assessing irrigation requirements. Irrig. Sci., 3: 259–268.

[17] Hirayama, M., Wada, Y. and Nemoto, H. (2006). Estimation of drought tolerance based on leaf temperature in upland rice breeding. Breed. Sci., 56: 47-54.

[18] Hossain, A.B.S., A.G. Sears, T.S. Cox and Paulsen, G.M. (1990). Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. Crop Sci., 30: 622-627.

[19] Howell, T.A., Musick, J.T. and Talk, J.A. (1986). Canopy temperature of irrigated winter wheat. Trans. ASAE., 29: 1692–1699.

[20] Idso, S.B. (1982). Non-water-stressed baseline: A key to measuring and interpreting plant water stress. Agric. For. Meteorol., 27:59–70.

[21] Kristin, A.S., R.R. Senra, F.I. Perez, B.C. Enriquez, J.A.A. Gallegos, P.R. Vallego, N. Wassimi and Kelley, J.D. (1997). Improving common bean performance under drought stress. Crop Sci., 37: 43-50.

[22] Mitra, J. (2001). Genetics and genetic improvement of drought tolerance in crop plants. Curr Sci., 80: 758-762.

[23] Passioura, J.B., Condon, A.G. and Richards, R.A. (1993). water deficits, the development of leaf area and crop productivity. In: Smith J.A.C., Griffiths H.(eds). Water deficits plant responses from cell to community. BIOS Scientific Publishers limited, Oxford, 253-264.

[24] Pinter, P.J., Zipoli, Jr.G.,Reginato, R.J., Jackson, R.D., Idso, S.B. and Hohman, J.P. (1990). Canopy temperature as an indicator of differential water use and yield performance among wheat cultivars. Agric. Water Manage., 18: 35–48.

[25] Ramirez, P. and Kelly, J.D. (1998). Traits related to drought tolerance in common bean. Euphytica., 99: 127-136.

[26] Rashid, A., Stark, J.C., Tanveer, A. and Mustafa, T. (1999). Use of canopy temperature measurements as a screening tool for drought tolerance in spring wheat. J Agron Crop Sci., 182: 231-237.

[27] Reynolds, M.P., Singh, R.P., Ibrahim, A., Ageeb, O.A.A., Larque-Saavedra, A. and Quick, J.S. (1997). Evaluating Physiological Traits to Complement Empirical Selection for Wheat in Warm Environments. Proceedings of the 5th International Wheat Conference, Ankara, Turkey.

[28] Reynolds, M.P., Ortiz-Monasterio, J.I. and A. McNab (ed.). (2001). Application of physiology in wheat breeding. CIMMYT, El Batan, Mexico.

[29] Richards, R.A., Rebetzke, G.J., Condon, A.G. and Herwaarden, A.F. (2002). Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci., 42: 111-121.

[30] Royo, C., Villegas, D., Garcia Del Moral, L.F., Elhani, S., Aparicio, N., Rharrabti, Y. and Araus, J.L. (2002). Comparative performance of carbon isotope discrimination and canopy temperature depression as predictors of genotypes differences in durum wheat yield in Spain. Aust J Agric Res., 53: 561-569.

[31] Shefazadeh, M.K., Karimizadeh, R., Mohammadi, M. and SaeediSuq, H. (2012). Using flag leaf chlorophyll content and canopy temperature depression for determining drought resistant durum wheat genotypes. Journal of Food, Agriculture & Environment., 10(1): 509-515.

[32] Siddique, M.R.B., Hamid, A. and Islam, M.S. (2000). Drought stress effects on water relations of wheat. Bot. Bull. Acad. Sin., 41: 35-39.

[33] Talebi, R. (2011). Evaluation of Chlorophyll Content and Canopy Temperature As Indicators For Drought Tolerance In Durum Wheat (*Triticum durum* Desf.). Australian Journal of Basic and Applied Sciences, 5: 1457-1462.

Table 1.Ranking of tested genotypes for Canopy Temperature Depression (CTD), Canopy temperature (CT) and Grain Yield (GY).

	Canopy Temperature Depression		Canopy Temperature		Grain Yield	
Genotype	Stressed	Irrigated	Stressed	Irrigated	Stressed	Irrigated
OuedZenati	1,13 abcd	3,96 ab	28,66 abcd	25,83 ab	21,45 b	26,62 c
Altar	-0,86d	2,3 ab	30,66 a	27,5 ab	24,86 ab	43,04 abc
Sooty	1,63 abc	5,96 a	28,16 bcd	23,83 b	27,33 ab	44,08 abc
Polonucum	2,8a	4,13 ab	27 d	25,66 ab	32,68 ab	44,82 abc
Waha	1,96ab	4,3 ab	27,83 cd	25,5 ab	35,24 a	49,11 ab
Dukem	1,46 abcd	5,3 ab	28,33 abcd	24,5 ab	29,75 ab	33,67 bc
Mexicali	-0,36 bcd	2,96 ab	30,16 abc	26,83 ab	32,90 ab	45,80 abc
Kucuk	2,3a	4,96 ab	27,5 d	24,83 ab	36,87 a	47,08 ab
Hoggar	-0,53 cd	1,8 b	30,33 ab	28 a	30,23 ab	58,56 a
Bousselem	0,63 abcd	2,3 ab	29,16 abcd	27,5 ab	36,87 a	46,66 ab
Mean	1,016	3,797	28,779	25,998	30,818	43,944
Min	0,36	1,8	27	23,83	21,45	26,62
Max	2,8	5,96	30,66	28	36,87	58,56
LSD 0,05	2.47	3,89	2,47	3,89	13,6	19,65

Means followed by the same latter are not significantly different at p<0.05.

Table 2. Estimation of sensitivity rate of 10 durum wheat genotypes by differentdrought tolerance indices under normal and stressed conditions.

	GMP	HM	MP	STI
OuedZenati	23,83 b	23,65 b	24,03 c	0,315 b
Altar	32,64 ab	31,39 ab	33,95 abc	0,619 ab
Sooty	34,05 ab	32,53 ab	35,71 abc	0,623 ab
Polonucum	38,23 a	37,71 a	38,75 ab	0,794 a
Waha	41,08 a	40,03 a	42,17 ab	0,957 a
Dukem	31,60 ab	31,52 ab	31,71 bc	0,551 ab
Mexicali	38,56 a	37,80 a	39,35 ab	0,873 a
Kucuk	41,52 a	41,07 a	41,98 ab	0,972 a
Hoggar	40,81 a	37,78 a	44,40 a	0,902 a
Bousselem	41,17 a	40,59 a	41,77 ab	0,922 a
Mean	36,349	35,407	37,382	0,7528
Min	23,83	23,65	24,03	0,315
Max	41,52	41,07	44,4	0,972
LSD 0,05	11,77	12,25	11,89	0,45

Means followed by the same latter are not significantly different at $p<0.05$; GMP: Geometrie mean productivity; HM: Harmonic mean, MP: Mean productivity and STI: Stress tolerance index

Table 3. Correlation between CTD, CT, GY and drought tolerance indices under stressed andirrigated conditions

	GYs	GYi	GMP	HM	MP	STI
CTDs	0,32**	-0,21	0,07	0,15	-0,01	0,05
CTDi	-0,02	-0,41**	-0,24	-0,18	-0,30**	-0,27**
CTs	-0,32**	0,21	-0,07	-0,15	0,02	-0,05
CTi	0,02	0,41**	0,24	0,18	0,30**	0,27**

CTD: Canopy Temperature Depression, CT: Canopy Temperature, GY: Grain Yield, GMP:Geometrie mean productivity; HM: Harmonic mean, MP: Mean productivity and STI: Stress tolerance index.

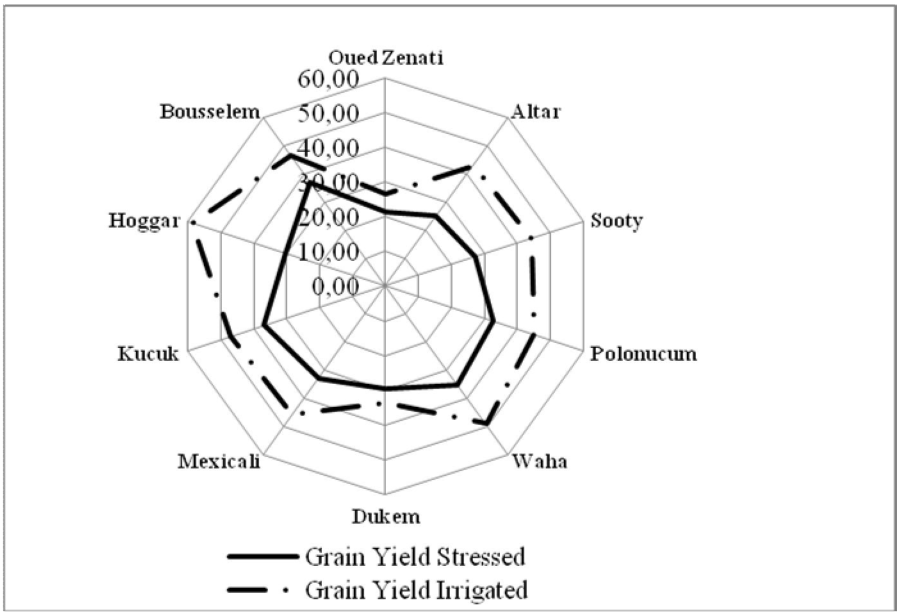

Figure 1.Interaction effect of irrigation regime × genotype on the grain yield.

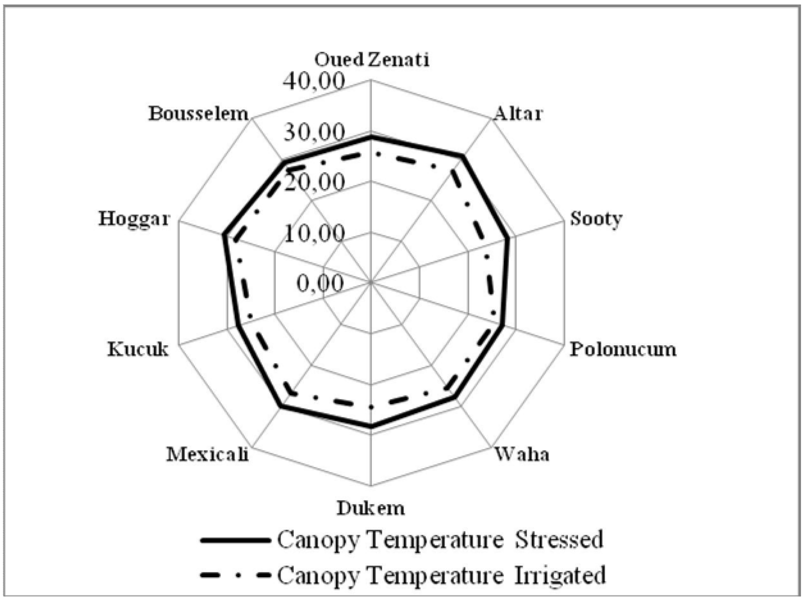

Figure 2. Interaction effect of irrigation regime × genotype on Canopy Temperature

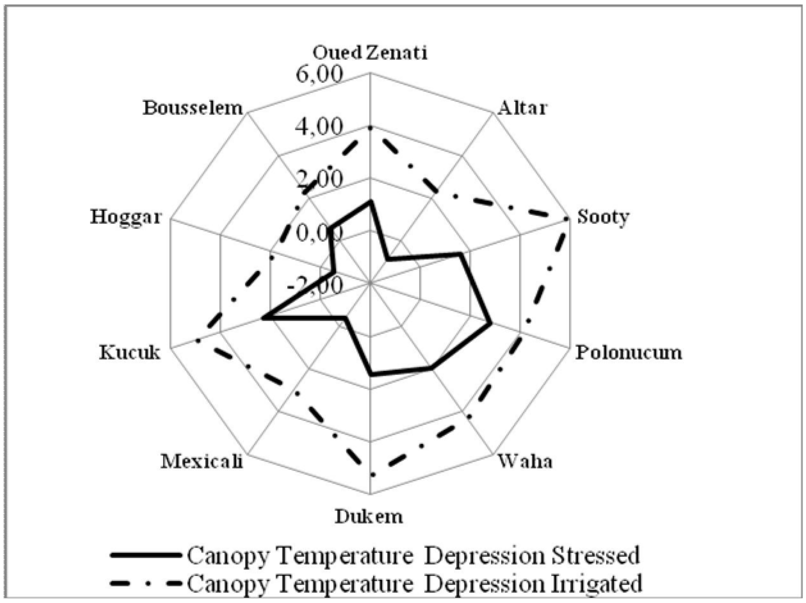

Figure 3. Interaction effect of irrigation regime × genotype on Canopy Temperature Depression