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Canopy Cover Temperature & Drought Tolerance Indices in Durum Wheat (*Triticum durum* Desf.) Genotypes under Semi-arid Condition in Algeria

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Abstract

This experiment was carried out at Setif Agricultural Experimental Station in Algeria during 2017–2018 crop season using five cultivars (*Triticum durum* Desf.) to determine differences in the relationship between (CT and drought resistance indices values based on their difference in yielding under irrigated and non-irrigated conditions and sown in a random block design with three replications. Our study aim to determine differences in the relationship between CT and drought resistance indices values and grain yield GY under both conditions to evaluate the effect of canopy temperature in drought tolerance of durum wheat. Five durum wheat (*Triticum durum* Desf.) genotypes were studied based on their difference in yielding under irrigated and non-irrigated conditions in conception of a random block design with three replications. The following measurements were applied: GY, CT canopy cover temperature depression CTD and seven drought tolerance indices (HM-SSI-GMP-STI-YSI-MP-TOL). ANOVA showed that genotype effect and irrigation regime effect were highly and significantly on CT and CTD under both stressed (s) and watered (i) conditions. The interaction Genotype×irrigation regime was significant for CT and CTD. PCA showed that CTDs was related with HM, GMP, STI, and MP in indication of drought tolerance, where CTDi was related with TOL and SSI in indication of drought sensitivity. A negative correlation showed between CT and CTD, higher values of CT compared to environmental temperature implies negative values of CTD which indicates drought sensitivity; on the other hand, CT values lower than environmental temperature implies positive CTD values indicating drought tolerance.

Keywords: Durum wheat, canopy temperature, drought tolerance, semi-arid

1. Introduction

Durum wheat (*Triticum turgidum* subsp. *durum* Desf.) is a minor cereal crop representing 5% of the total wheat crop cultivated worldwide (about 17 mha) (Xynias et al., 2020). Among cereal crops, durum wheat (*Triticum durum* Desf.) is widely cultivated in the Mediterranean region and other semi-arid areas of the World (Ahmed et al., 2019). Durum wheat occupies an important place among the cereals in the world (Anonymous, 2019). Total food use of wheat is forecast to approach 518 mt, up 1.1% and rising in close tandem with world population growth. However, large supplies and competitive prices are likely to drive up feed use of wheat by 2.8%, a faster rate than was projected earlier, while industrial use is also anticipated to register strong growth (Anonymous, 2019). Durum

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wheat production represents 5% of total wheat production with a planting area of 16 mha globally (Anonymous, 2020a). In Algeria, the actual production of cereals during the period 2010–2017 is estimated at 4.12 mt on average, an increase of 26% compared to the decade 2000–2009 when production is estimated on average at 3.26 mt. Production consists mainly of durum wheat and barley, which respectively represent 51% and 29% of all cereal production on average 2010–2017 (Anonymous, 2018). An estimate by the UN-FAO indicates that, by 2050, the global demand for agricultural products will have risen by 50%. Meeting this demand will require traditional development of improved cultivars coupled with modern best management practices as well as innovations that are transformational (Beres et al., 2020). The emission of harmful gases such as CO_2 is the main cause of the greenhouse effect and warmer global temperatures (Raza et al., 2019). The 2-degree increase in global average surface temperature that has occurred since the pre-industrial era (1880-1900) might seem small, but it means a significant increase in accumulated heat. That extra heat is driving regional and seasonal temperature extremes, reducing snow cover and sea ice, intensifying heavy rainfall, and changing habitat ranges for plants and animals—expanding some and shrinking others (Lindsey and Dahlman., 2020). Canopy temperature is a promising trait for identifying drought tolerance and canopy temperature depression (CTD) has been shown to correlate well with the transpiration status in crops like rice, wheat and sugar beet (Kumar et al., 2015). The relationship between stomatal conductance and yield potential in C_3 crops over the last 50 years was recently highlighted in a review (Roche, 2015). Further, under yield potential conditions, cooler CT has been associated with genetic gains in wheat yield (Aisawi et al., 2015). Further opportunities include improving the heritability estimate of grain yield by using CT measurements to improve spatial and site characterization for variation in soil water, and subsoil constraints including root disease (Araus et al., 2018). The issues relating to determining the optimal CTD depend on sampling time and obtaining the maximum genetic discrimination was seldom addressed (Purushothaman et al., 2015). Drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions are a good means for detecting drought tolerant genotypes (Frih et al., 2021). Therefore, the objectives of our study to determine the relationship between the temperature of the canopy CT and the depression of the temperature of the canopy CTD with the value of indices of drought resistance and yield of durum wheat (*Triticum durum* Desf.) under both conditions to assess the effect of canopy temperature and canopy temperature depression on the drought tolerance of some durum wheat (*Triticum durum* Desf.) genotypes.

2. Materials and Methods

2.1. study area

The experimental material used in this study consists of 5 cultivars (*Triticum durum* Desf.) mentioned in Table 1 and based on their difference in yielding under irrigated and non-irrigated conditions. Cultivars were sowing in 15 November 2017 during the 2017–2018 crop season in Setif Agricultural Experimental Station (ITGC-AES, 36° 12’ N and 05° 24’ E and 1.081 m asl, Algeria), in a random block design with three replications. Each plot consisted of 2 rows of 2.5 m long spaced of 20 cm. Irrigated plots were watered in 05 and 15 May 2018, non-irrigated plots were grown under rain-fed conditions. No specific treatment has been assigned.

Table 1: Origin of the five genotypes studied

Cultivar	Name	Abbreviation	Origine
1	Boussellem	Bouss	ICARDA
2	Mohamed Ben Bachir	MBB	Algeria
3	Oum Rabie	Mrb5	ICARDA
4	Ofanto	Ofa	Italia
5	Waha	Waha	ICARDA

2.2. Method of data collection

The cereal yield performances in dry (GYs) and irrigated (GYi) conditions of the different cultivars were measured at maturity in tonnes per hectare (t ha^{-1}) by measuring the weight of the grains in a linear meter. The temperature of the canopy was measured using an infrared thermometer (Model AG-42, Teletemp Crop, Fullerton, CA.) used by Oulmi et al. (2020). The canopy temperature (CT) was taken on 05/06/2018 between 1:30 p.m. and 2:00 p.m. on a completely sunny day (daily temperature and time of measurement 24°C). Canopy temperature was taken for all genotypes studied, in all plots and under both conditions at nearly 50 cm above the canopy with an angle of 30° to the horizontal. The data presented for each treatment were the average of three sets of measurements. Canopy temperature depression is the difference between environnemental temperature and canopy temperature, it can calculate from formula:

CTD =Ta– CT used by Sofi et al. (2019) where Ta: environmental temperature at time of taking CT

Drought resistance indices used by Frih et al. (2021) were calculated using the following relationships were mentioned in Table 2.

2.3. Statistical analysis

All statistical analyses will be performed by (Anonymous, 2020b) and (Anonymous, 1998). (For analysis of variance, Fisher’s LSD multiple ranges test was employed for the mean comparisons.

3. Results and Discussion

3.1. Analyse of variance (ANOVA)

The results of the 2-way ANOVA in Table 3 show that the genotype effect was highly significant with the variables: CT and CTD while the irrigation effect was highly significant with

Table 2: drought tolerance and resistance indices, relationships and references

N°	Drought tolerance indices	Relationships	Author developer	Year
01	Harmonic mean (HM)	HM=2 (GYi×GYs) / (GYi + GYs)	Kristin et al.	1997
02	Stress susceptibility index (SSI)	SSI=1 – (GYs/GYi) / SI SI=1 – (GŶs/GŶi)	Fischer and Maurer	1978
03	Geometric mean productivity (GMP)	GMP=√(GYi×GYs)	Fernandez Kristin et al.	1992; 1997
04	Stress tolerance index (STI)	STI=(GYi×GYs)/(GŶi) 2	Fernandez Kristin et al	1992; 1997
05	Yield stability index (YSI)	YSI=GYs/GYi	Bouslama and Schapaugh	1984
06	Mean productivity (MP)	MP=(GYi+GYs)/2	Hossain et al.	1990
07	Tolerance intensity (TOL)	TOL=GYi-GYs	Rosielle and Hamblin	1981

GYs and GYi: yield of each cultivar under stressed and non-stressed, respectively. SI: stress intensity, GŶs and GŶi : means of all genotypes under stress and well watered conditions, respectively

Table 3: 2-way ANOVA of GY, CT and CTD with the factors genotype and irrigation regime

	DF	Mean of squares		
		GY	CT	CTD
Genotype	4	ns	6^{***}	6^{***}
Irrigation regime	1	84.54^{***}	86.02^{***}	86.02^{***}
Genotype×IR	4	ns	4.86^{***}	4.86^{***}
CV%	-	23.85	3.68	27.86

GY, CT and CTD. The Interaction (genotype×irrigation regime) was with canopy temperature variables (CT and CTD).

The ranking of the different variables under both conditions (stressed and irrigated) were presented in Table 4

3.1.1. *Grain yield (GY)*

GY takes the values of 6.02 t ha^{-1} for the Waha genotype to 7.86 t ha^{-1} of the Mrb5 genotype with an average of 6.88 t ha^{-1} for all the genotypes studied, this takes place under rain-fed conditions. Under irrigation, GY increases yield by taking the values of 9.18 t ha^{-1} for Waha to 11.35 t ha^{-1} for Ofa with a genotypic average of 10.24 t ha^{-1}. The difference between the two conditions is 32.78% showed at table 4 and in favor of irrigation condition (Figure 1). Durum wheat genotypes were significantly affected by drought stress for grain yield and several agronomic and morpho-physiological traits. This resulted in considerable variation in the measured traits and drought tolerance in these genotypes that should be considered for durum wheat breeding (Pour-Aboughadareh et al., 2020). A thorough understanding of the effect of drought on wheat metabolism is essential to develop drought tolerant wheat varieties (Itam et al., 2020).

3.1.2. *Canopy temperature and (CT)*

In this experiment, the environnemental temperature at the time of CT taken was 24°C. under rain-fed condition CT were ranged between 22.13°C for Ofa to 24.13 °C for Waha with an average of 22.89°C over all genotypes. under irrigation, there is decrease in the values where ranged from 17.44°C for Ofa to 21.93°C for Bous with an average of 19.51°C over all genotypes. The difference the tow conditions was 14.79 % (Table 4) in favor of rain-fed condition (Figure 2). This result is very consistent with the work of Oulmi et al., 2020 who reported that the increase in canopy temperature causes a decrease in grain yield. Canopy temperature (CT) is an indirect measure of transpiration rate and stomatal conductance and may be valuable in distinguishing differences among genotypes in response to drought (Bazze and larry, 2020). Remotely sensed canopy temperature was also reported to be a powerful indicator in screening for drought-tolerant wheat genotypes due to its correlation with leaf water

Table 4: Ranking of tested genotypes for the different variables measured

	GYs (t ha^{-1})	GYi (t ha^{-1})	CTs°C	CTi°C	CTDs°C	CTDi°C
Bous	7.56	10.45	22.20	21.93	1.80	2.07
MBB	6.31	9.67	22.47	18.87	1.53	5.13
Mrb5	7.86	10.53	23.53	19.00	0.47	5.00
Ofa	6.66	11.35	22.13	17.47	1.87	6.53
Waha	6.02	9.19	24.13	20.27	-0.13	3.73
Mean	6.88	10.24	22.89	19.51	1.11	4.49
Min	6.02	9.19	22.13	17.47	-0.13	2.07
Max	7.86	11.35	24.13	21.93	1.87	6.53
CV%	15.19	24.87	3.78	3.66	78.29	15.90
LSD (*p* =0.05%)	1.97	4.80	1.63	1.35	1.63	1.35
G effect	ns		***		***	
Irr effect	***		***		***	
G×Irr	ns		***		***	
% of dif	32.78 ↑		14.79 ↓		7.54 ↓	

ns: o significant;*significant at (*p*=0.05);**significant (*p*=0.01);*** significant at (*p*=0.001)

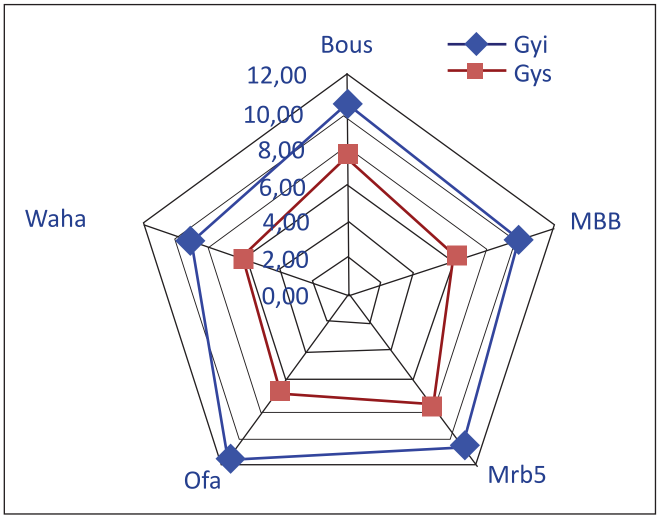

Figure 1: Interaction of genotype×irrigation regime on the grain yield

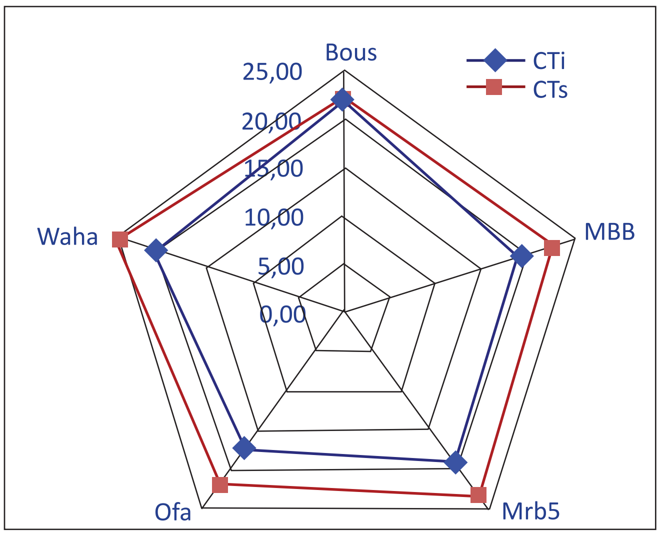

Figure 2: Interaction of genotype×irrigation regime on the canopy temperature

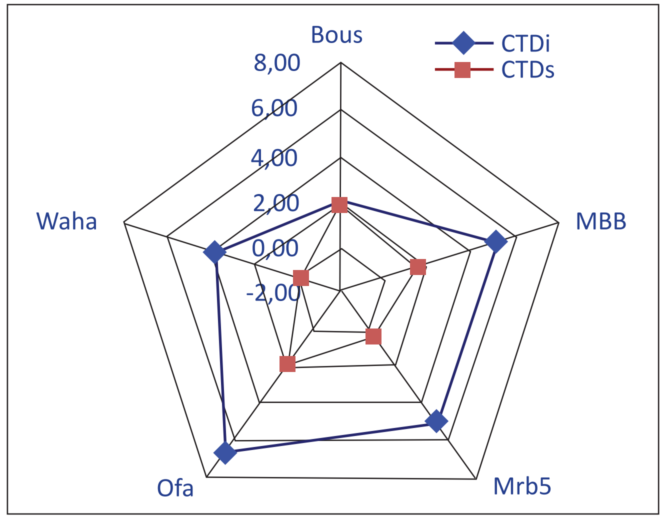

Figure 3: Interaction of genotype×irrigation regime on the canopy temperature depression

potentials under moisture stress. Researchers found that lower canopy temperatures were accompanied by higher leaf water potentials (Blum et al., 2001 in Lan, 2020).

3.1.3. Canopy temperature depression (CTD)

The values of Canopy temperature depression (CTD) ranged between -0.13°C for Waha to 1.87°C for Ofa with an average of 1.11°C over all genotypes under rain-fed condition. Under irrigation CTD varied from 2.07°C for Bous to 6.53°C for Ofa with an average of 4.49°C over all genotypes tested with a decrease of 7.54% in table 4 in favor of irrigation condition (Figure 3). At the whole crop level, leaf temperatures decrease below air temperature when water evaporates (Chaudhary et al., 2020). Estimating yield from a small number of short-term CTD measurements seems much more dubious, however, since short-term CTD and transpiration rate are related to temporally variable environmental properties including irradiance, air temperature, wind speed and vapour pressure deficit (Jokar et al., 2018). In light of substantial experimental evidence that a fairly positive relationship exists between yield and CTD under both stressed and non-stressed conditions, it is essential to incorporate CTD as effective complementary trait in selection program aimed at developing climate resilient varieties (Sofi et al., 2019).

3.1.4. Drought tolerance indices

The intensity of stress in our study SI=33%. Table 5 shows that the high values of the MP, GMP, STI and YSI indices are indicative of stress tolerances, this results were very consistent with the work of Semcheddinne et al. (2017) showed high significant difference between genotypes for the indices: STI, MP, GMP and HMP, this suggests the possibility of using them to evaluate drought tolerance in durum wheat genotypes. Table 5 also shows that the lowest values of SSI and TOL also indicate stress tolerance; therefore Mrb5 and Bous always remain the most suitable genotypes for stress. The other genotypes were more sensitive to drought stress. The yield-based drought and susceptible indices revealed that stress tolerance index (STI), geometric mean productivity (GMP), mean productivity (MP), and harmonic mean (HM) were positively and significantly correlated with grain yields in both conditions (Pour-Aboughadareh et al., 2020).

3.2. Principal component analysis (PCA)

PCA showed that the tow axes respectively explain 44.78 and 33.13% (table 6), they explain the majority of the information by cumulating a percentage of 77.91%. CTDs was significantly and positively correlated with PC1 (r=0.60) (Table 6), it was regrouped with GY under both conditions, HM, GMP, STI, and MP (Figure 4), this result qualified PC1 as yield potential and drought tolerance factor, the genotypes related with this axis Mrb5 and Bous (coordinates=1.98 and 1.97) (Table 7) were qualified as high potentials yield and high drought

Table 5: Estimation of sensitivity rate of 5 durum wheat genotypes by different drought tolerance indices under normal and stressed conditions

	HM	SSI	GMP	STI	YSI	MP	TOL
Bouss	8.68	0.76	8.84	0.75	0.75	9.01	2.90
MBB	8.99	1.01	7.78	0.59	0.43	7.99	3.36
Mrb5	8.93	0.72	9.06	0.78	0.76	9.20	2.67
Ofa	8.18	0.98	8.58	0.73	0.68	9.01	4.69
Waha	6.93	0.84	7.25	0.50	0.72	7.60	3.16
Mean	8.34	0.86	8.30	0.67	0.67	8.56	3.36
Min	6.93	0.72	7.25	0.50	0.43	7.60	2.67
Max	8.99	1.01	9.06	0.78	0.76	9.20	4.69
CV (%)	15.35	96.52	12.47	102.52	48.51	14.13	90.86
LSD (5%)	2.41	1.57	1.95	1.77	0.61	2.28	4.45

Table 6: Correlations of variables measured with 2 first's components

Components	% of var	Variables												
		GYs	GYi	HM	SSI	GMP	STI	YSI	MP	TOL	CTs	CTi	CTDs	CTDi
PC1	44.78	0.85	0.87	0.70	-0.30	0.98	0.99	0.33	0.98	-0.08	-0.60	-0.09	0.60	0.09
PC2	33.13	-0.50	0.33	0.14	0.94	-0.17	-0.10	-0.67	0.08	0.86	-0.56	-0.77	0.56	0.77

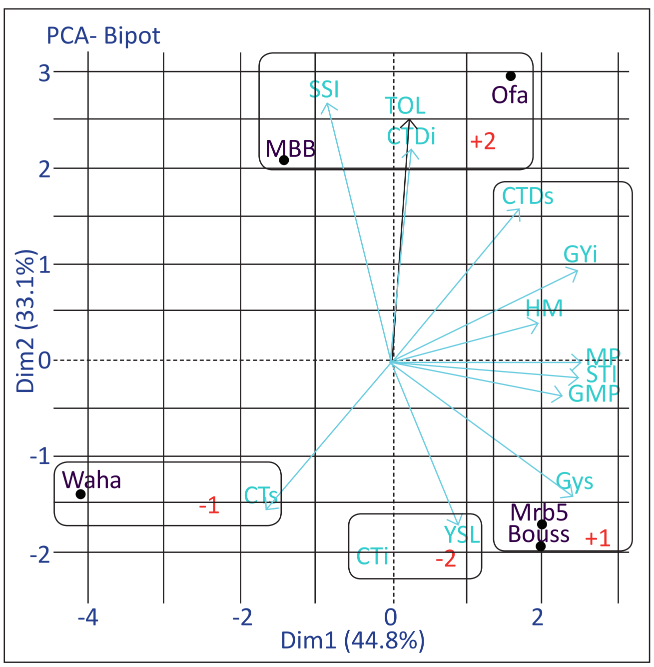

Figure 4: Biplot of variables measured and genotypes with first's 2 components

resistant, the high values of CTDs indicate drought tolerance. PC1 is also negatively correlated with CTs (r=-0.60) in table 6, the high values of CTs indicate drought sensitivity. Waha genotype negatively related to PC2 (coordinate=-4.10) (Figure 4) was showed as drought sensitive genotype. CTDi is significantly and positively correlated with PC2 (r=0.77) in table 6, it was regrouped with TOL and SSI, this result qualified

Table 7: Coordinates of genotypes studied in 2 first's components

Components	Genotypes				
	Bous	MBB	Mrb5	Ofa	Waha
PC1	1.97	-1.42	1.98	1.57	- 4.10
PC2	-1.90	2.07	-1.77	2.95	-1.35

PC2 as drought sensitive factor, the genotypes related with this axis Ofa and MBB (coordinates=2.95 and 2.07) in Table 7 were showed as high drought sensitive genotypes (Figure 4), according to these result we can say that the high values of CTDi indicate drought sensitivity. PC2 is also negatively correlated with CTi (r=-0.77) (table 6), we can say that the high values of CTi indicate drought sensitivity. Figure 4 showed a negative correlation between CT and CTD, higher values of CT compared to environmental temperature imply negative values of CTD which indicates drought sensitivity; on the other hand, CT values lower than environmental temperature implies positive CTD values indicating stress tolerance. Kumar et al. (2017) reported that CTD, an important trait that indicates canopy cooling capacity of the plants, can explain the genetic variation in seed yield of soybean geno-types grown both under well-watered and water-stressed conditions. CTD can be a reliable indicator of crop performance under both irrigated and drought stress condition (Sofi et al., 2019). CT is an important tool for studying plant physiological responses to drought stress, because it integrates many physiological responses into a single low-cost measurement (Mason and Singh, 2014).

4. Conclusion

ANOVA showed that genotype effect and irrigation regime effect were highly and significantly on CT and CTD under both stressed and watred conditions. Interaction Genotype X irrigation rigime was significant for CT and CTD. PCA showed that CTDs was related with HM, GMP, STI, and MP in indication of drought tolerance. A negative correlation showed between CT and CTD, higher values of CT compared to environmental temperature implies negative values of CTD which indicates drought sensitivity.

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