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Study of Drought Tolerance of Some Durum Wheat (*Triticum durum* Desf.) Genotypes Growing under Semi-arid Conditions in Algeria

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Abstract

The aim of this study was to test the behavior of 5 genotypes cultivated in normal and irrigated conditions with regard to drought stress. We used seven indices of tolerance and resistance to drought stress. Analyze of variance showed that the geometric mean productivity, mean productivity, stress tolerance index, yield stability index, stress sensitivity tolerance and tolerance intensity were effective in judging tolerance to water stress, Boussellem and Oum Rabie was the best at water stress resistance genotypes. Correlation analysis showed that GMP is both an indicator of high performance under both conditions and of resistance to stress (r=0.56* in a stress state and r=0.82*** in a non-stress state) . Boussellem and Oum Rabie were the strongest in yield and the most adapted to water stress thanks to their values for this index (8.84 and 9.06 respectively). SSI testified to the high yield in non-stress condition (r=0.82***), therefore Ofanto was a good cultivar in non-stess condition. PCA classified the genotypes Bousselem and Oum Rabie on the first component which combined the performance in yield under both conditions with the mean productivity, geometric mean productivity, and stress tolerance index. In conclusion, the Oum Rabie and Bousselem genotypes were the best performing under both conditions and the best adapted to drought stress, while Ofanto was a good cultivar in non-stress conditions. MP, GMP and STI indices was the best to judge the adaptability of our genotypes to drought stress.

Keywords: Durum wheat, drought, drought tolerance indices, semi-arid, Algeria

1. Introduction

Climate changes recorded changes in the composition and geographic redistribution of ecosystems in Algeria. This situation has resulted in a shift towards the north of the arid zones, until then confined between the Sahara and the high cereal plains (Haffaf et al., 2003). Durum wheat (*Triticum durum* Desf.) is one of the most cultivated cereals in the Mediterranean basin, where drought is a limiting factor for its production (Royo et al., 1998). It is mostly grown under rain-fed conditions, where drought and heat stress usually constrain yield potential during the grain filling period (Simane et al., 1993). Drought tolerance is the ability to which a plant maintains its biomass production during arid or drought conditions (Ashraf, 2010). The terms 'Drought' and 'Water Deficit' are badly used between them, the term 'drought' should be used much more to describe environmental or agronomic situations, on the other hand that the term 'water deficit' is the preferred

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term to denote the lack of irrigation or the experiments which related to the simulation of the drought. Plants can be subjected to slowly developing water shortages (i.e., taking days, weeks, or months), or they may face short-term water deficits (i.e., hours to days) (Ogbaga et al., 2020). The negative impact of drought on grain yields is a major problem in many developed and developing countries around the World (Guo, 2004; Passioura, 2007). The complexity of selecting drought-resistant genotypes is mainly due to the lack of rapid and reproducible screening techniques supplemented by the inability to systematically create defined and repeatable water stress conditions. (Ramirez and Kelly, 1998). Thus, 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 (Mitra, 2001). Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (GYs) and non-stress (GYi) environments and mean productivity (MP) as the average yield of GYs and GYp. Fischer and Maurer (1978) demonstrated the stress sensitivity index (SSI). Fernandez (1992) proposed the index (IST = Stress tolerance index), it is used to screen for genotypes that perform well under stress as well as under non-stress conditions. Other yield based estimates of drought resistance are geometric mean (GM). Our objective was to evaluate the selection criteria to identify the drought tolerance of durum wheat genotypes, to give recommendations for cultivation in semi-arid zones of Algeria.

2. Materials and Methods

2.1. Study site

The field experiment was conducted during 2017-2018 crop season at Setif Agricultural Experimental Station (ITGC-AES), Algeria with 5 cultivars of Durum wheat (*Triticum durum Desf.*) (Table 1) selected based on their difference in yielding under irrigated and non-irrigated conditions. The location was situated at 36 ° 12’N and 05 ° 24’E and 1.081 m asl. 36 ° 12’N and 05 ° 24’E and 1.081 m asl). Cultivars were sown on 15 November 2017 in a random block design with three replications. Each plot consisted of 2 rows of 2.5m long spaced of 20 cm. Irrigated plots were watered in 05 and 15 May 2018, non-irrigated plots were grown under rain-fed conditions.

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 tons per hectare (tons.ha^{-1}) by measure the grain yield in one linear meter and convert to tones per hectare.

Drought resistance indices were calculated using the following relationships:

• Harmonic mean (HM): (Kristin et al., 1997) *(HM=2(GYi× GYs)/(GYi+GYs)*

GYi and GYs were the yield of each cultivar, none stressed and stressed, respectively.

• Stress sensitivity index (SSI): (Fisher and Maurer, 1978)

SSI =1–(GYs / GYi)/SIwhileSI=1–(GŶs/GŶi)

SI: stress intensity,*GŶs* and *GŶi* are the means of all genotypes under stress and well watered conditions, respectively.

• Geometric mean productivity (GMP) (Fernandez, 1992; Kristin et al., 1997)

GMP=√(GYi×GYs)

• Stress toleranceindex (STI) (Fernandez, 1992; Kristin et al., 1997)

STI=(GYi×GYs)/(GŶi) ^{2}

• Yield Stability Index (YSI): (Bouslama and Schapaugh, 1984)

YSI=GYs/GYi

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

MP=(GYi+GYs)/2

• Tolerance intensity (TOL): (Rosielle and Hamblin , 1981)

TOL=GYi–Gys

2.3. Statistical analysis

All statistical analyses will be performed as per the standard format (Anonymous, 2020).

• *Analysis of variance (ANOVA)*

ANOVA is a statistical tool used to detect differences between experimental group means. (Sawyer, 2009).

(For analysis of variance, Fisher’s LSD multiple ranges test was employed for the mean comparisons.)

• *Simple linear correlation (SLC)*

SLC is used under the condition where there is only one predictor variable, the correlations between the grain yield and its components have been calculated according to the formula given by Snedecor and Cochran (1981).

$$r(x,y)= \frac{(\sum xy-(\sum x)(\sum y)/n)}{\sqrt{(\sum x^2-(\sum x)^2/n)(\sum y^2-(\sum y)^2/n)}}$$

r: correlation coefficient, x: first character, y: second character, n: total of number of observation

• *Principal components analysis (PCA)*

PCA is a mathematical procedure used to classify a large number of variables (items) into major components and determine their contribution to the total variation. The first principal component is accounted for the highest variability in the data, and each succeeding component accounts for the highest remaining variability as possible (Everitt and Dunn, 1992).

3. Results and Discussion

3.1. Analysis of variance (ANOVA)

Table 2 showed that the high values of the MP, GMP, STI and YSI indices were indicative of stress tolerances, the Mrb5 (GYs =7.86 t ha^{-1}) and Bous (GYi=7.56 t ha^{-1}) genotypes showing the highest values were shown to be resistant to water stress, Ofa, MBB and Waha with (GYs=6.66; 6.31; 6.06 t ha^{-1} respectively) showing the lowest values of these indices were shown to be more sensitive to stress. Table 2 also showed that the lowest values of SSI (the intensity of stress in our study SI=33%) and TOL also indicated stress tolerance, therefore Mrb5 and Boss always remained the most suitable genotypes for stress, the other genotypes were more sensitive. Stress sensitive index (SSI) value with less than one indicated high tolerance of variety to stress (Choukan et al., 2006). In our study HM did not give us clear information on the behavior of our varieties with respect to tolerance or resistance to water stress, our results were very similar to the work of Guendouz et al. (2012) who reported that MP, GMP and STI were the best indices for inferring resistance or sensitivity to water stress.

Table 2: Sensitivity rate of the 5 genotypes studied with the different tolerance indices for drought and under stress and non-stress conditions

	GYs (t ha^{-1})	GYi (t ha^{-1})	HM	SSI	GMP	STI	YSI	MP	TOL
Bouss	7.56	10.46	8.68	0.76	8.84	0.75	0.75	9.01	2.90
MBB	6.31	9.68	8.99	1.01	7.78	0.59	0.43	7.99	3.36
Mrb5	7.86	10.54	8.93	0.72	9.06	0.78	0.76	9.20	2.67
Ofa	6.66	11.35	8.18	0.98	8.58	0.73	0.68	9.01	4.69
Waha	6.02	9.19	6.93	0.84	7.25	0.50	0.72	7.60	3.16
Mean	6.88	10.24	8.34	0.86	8.30	0.67	0.67	8.56	3.36
Min	6.02	9.19	6.93	0.72	7.25	0.50	0.43	7.60	2.67
Max	7.86	11.35	8.99	1.01	9.06	0.78	0.76	9.20	4.69
CV (%)	15.19	24.87	15.35	96.52	12.47	102.52	48.51	14.13	90.86
LSD (5%)	1.97	4.80	2.41	1.57	1.95	1.77	0.61	2.28	4.45

GYs: grain yield under stress conditions, GYi: grain yield under irrigated conditions, HM: harmonic mean, SSI: stress susceptibility index, GMP: geometric mean productivity, STI: stress tolerance index, YSI: yield susceptibility index, MP: mean productivity, TOL: tolerance intensity

3.2. Simple linear correlations(SLC)

The correlation analysis (Table 3) showed that the performance in terms of yield under the two conditions GYs and GYi were significantly and positively correlated with GMP (r=0.54*; 0.82*** respectively), the high values of this index are indicative of yield potential and drought tolerance

Table 3: Matrix of correlations between grain yields under stress and non-stress conditions and various drought tolerance indices

	HM	SSI	GMP	STI	YSI	MP	TOL
GYs	ns	-0.56*	0.54*	ns	0.62*	ns	ns
GYi	ns	0.82***	0.82***	ns	ns	0.90***	0.91***

ns: non significatif, *: significatif at (p= 0.05), **: significatif at (p= 0.01), ***: significatif at (p= 0.001)

SSI was significantly and negatively correlated with GYs and strongly positively and significantly correlated with GYi, the high values of this index were significant of high GYi and low GYs; this index was a potential yield indicator in a non-stress state, were similar with that of Guendouz et al. (2012). YSI was significantly and positively correlated with GYs, the high values of this index were indicative of potential yield in a state of drought (Ladoui et al., 2020). This index was an index of drought tolerance. MP and TOL were strongly and positively correlated only with the performance in a non-stress state GYi, the high values of this index were indicative of performance in a non-stress state. This index was a performance indicator in a non-stress state. These results agreed with the work of Ladoui et al. (2020) who reported that the high values of TOL were indicative of potential yield in the absence of water stress. Rosielle and Hamblin (1981) showed that in a majority of comparative experiments, the correlation of yield between MP and GYi, and MP and GYs were positive. According to their reports, selection on the basis of MP generally caused to increasing yield in both normal and stressed conditions.

3.3. Principal components analysis (PCA)

Principal component analysis showed that the first three axes respectively explained 59.94; 25.20 and 14.85% (Table

Table 4: Correlations of variables measured with 3 first's components

Components	% of var	Variables								
		GYs	GYi	HM	SSI	GMP	STI	YSI	MP	TOL
PC1	59.94	0.956	0.759	0.608	-0.556	0.993	0.982	0.537	0.975	-0.158
PC2	25.20	-0.245	0.574	0.315	0.820	0.113	0.189	-0.533	0.201	0.857
PC3	14.84	-0.162	0.307	-0.729	-0.086	-0.038	-0.008	0.653	0.091	0.491

4). They explained all of the information by cumulating a percentage of 99.99. Table 4 showed that PC1 was significantly, strongly and positively correlated with GYs, GYi, GMP and MP (r=0.956; 0.759; 0.993; 0.982 and 0.975 respectively). PC2 was significantly, strongly and positively correlated with SSI and TOL (r=0.820; 0.857 respectively), while PC3 was positively correlated with YSI (r=0.729) and negatively correlated with HM (r=-0.653). these results indicated that PC1 was an axis of yield potential and drought tolerance while PC2 and PC3 were axes of drought tolerance only with respect to (SSI;TOL), (YSI;HM) indices respectively. The genotypes represented on PC1 positively Bous, and Mrb5 with the scores (2.763; 1.963 respectively) (Table 5) were said

Table 5: Coordinates of genotypes studied in 3 first's components

Components	Genotypes				
	Bous	MBB	Mrb5	Ofa	Waha
PC1	1.963	-2.135	2.763	0.650	-3.241
PC2	-0.791	1.140	-1.054	2.359	--1.655
PC3	-0.142	-1.857	-0.435	1.389	1.045

to be high yield potential and drought tolerance genotypes. Waha and MBB genotypes negatively represented in PC1 (-3.241;-2.135 respectively) were less yield potential and less drought tolerant. Ofa genotype strongly represented in PC2 (2.359) with TOL and SSI indices, it had a higher value of TOL (4.69) and SSI less than 1 (0.98) which made it a very sensitive genotype under water stress conditions. Guendouz et al (2012), Farshadfar et al. (2001), Mardeh et al. (2006) and Golabadi et al. (2006) obtained similar trends in multivariate analysis of drought tolerance in different crops. The results of the principal component analysis were summarized in figure 1. In figure 2, we had classified our genotypes in relation to their performance in a stress state (GYs) and according to their performance in a non-stress state (GYi). This graph reinforced our results by classifying the genotypes Bous and Mrb5 as the better performing resistance by placing above the average means. Their performance in the state of stress was the best. Waha and MBB had been shown to be more sensitive under stress, only Ofa was a good cultivar under non-stress conditions.

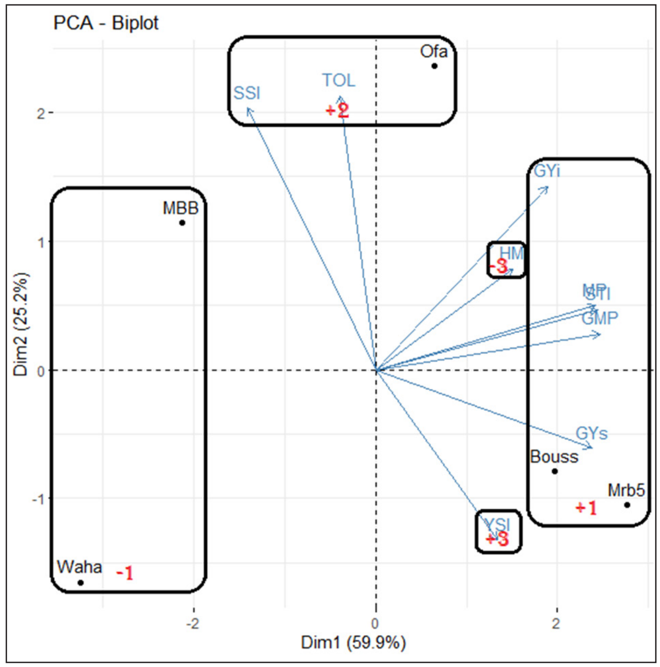

Figure 1: Biplot of variables measured and genotypes with first's 3 components

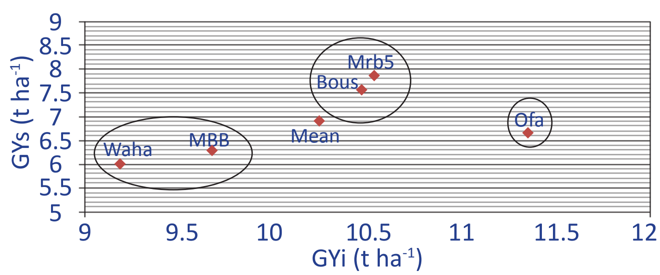

Figure 2: Classification of varieties evaluated by their performance comparatively averages of the effect of water stress

4. Conclusion

ANOVA showed that the GMP, MP, STI, YSI, SSI and TOL indices were effective in judging tolerance to water stress, PCA classifies Boussellem and Oum Rabie as genotypes of better yield and better resistance to water stress. Correlation analysis showed that GMP was a good indicator of drought resistance (r=0.56* stress r=0.82*** stress free). SSI demonstrates high yield under stress-free conditions (r=0.82***), so Ofanto was a good cultivar in stress-free condition.

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