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RESEARCH ARTICLE

SCREENING OF TOLERANT AND SUSCEPTIBLE BREAD WHEAT (*TRITICUM AESTIVUM* L.) ACCESSIONS TO WATER STRESS UNDER FIELD CONDITIONS IN MOGRAN, ZAGHOUAN ENVIRONMENT

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flag leaf area (FLA), grain yield/spike (GY/S), 1000 kernel weight (TKW) plant height (PH), root length (RL) and root volume (RV), spike length (SL), spikelet number (SN/S).

ABSTRACT

A field experiment, in a split-split plot design with three replications, was conducted, during 2009/2010 growing season in semi arid region Mogran belongs Zaghouan governorate, to evaluate the response of eleven bread wheat (*Triticum aestivum* L.) genotypes under four water stress treatments (T0: rainfall, T1: rainfall + 10 mm, T2: rainfall + 20 mm, T3: rainfall + 30 mm applied at each stage). The evaluation was based on eight agro-morphological traits: flag leaf area (FLA), plant height (PH), spike length (SL), spikelet number/spike (SN/S), 1000 kernel weight (TKW), grain yield/spike (GY/S), root length (RL) and root volume (RV). Variance analysis revealed a high significant ($p<0.01$) effect of water treatments and genotypes for all traits except spikelet number/spike. Water supply had a positive effect on yield and yield related traits. In fact, greatest values were obtained under T3 for PH, SL, SN/S, TKW and GY/S. Accession 10 gave the highest spikelet number/ spike, 1000 kernel weight and grain yield/spike which appeared to be the most drought tolerant genotype. Grain yield/spike was significantly and positively correlated with PH ($r = 0.25$), SL ($r = 0.32$), SN/S ($r = 0.75$), and TKW ($r = 0.88$) which indicated that effective selection can be done on these traits through breeding programs.

INTRODUCTION

Bread Wheat (*Triticum aestivum* L.) is among the major important crops due to its area and production in the world (Johari-pireivatlou, 2014). It is cultivated on about 217 million ha, and production about 651 million tons by year (FAO, 2012). Yasir *et al.* (2013) reported that, face to the increase of population, estimated to reach 8.3 billion in 2025, wheat production must annually increase about 2%. However, drought is a limiting factor of wheat production in the world (Ilker *et al.,* 2011; Farshadfar *et al.,* 2013; Harb and Lahham, 2013). In fact, about 32% of the wheat areas in developing countries are face to water stress during the growth season (Rajaram, and Van Ginkel, 1996).

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In fact, grain yield is the result of different developmental processes during croping season (Nakhforoosh *et al.,* 2015). In Mediterranean Basin especially in arid and semi arid region, where rainfall had a variant distribution, drought stress seriously decrease yield (Ilker *et al.,* 2011 and Mollasadeghi *et al*., 201, Allahverdiyev, 2015). Grain yield decrease could be a result of photosynthesis activity and translocation reduction caused by the decrease of spikelet number/spike, grain number/spike and 1000 kernel weight, biomass, tiller number and grain size (Khan and Naqvi, 2011; Sokoto and Singh, 2013). In addition, Lonbani and Arzani (2011) reported that wheat respond to drought stress by leaf (area, shape, expansion, orientation, senescence, pubescence) and root (length, density, dry weight). Photosynthesis of the flag leaf is among main factors of grain yield formation (Saeidi and Abdoli, 2015). In wheat, it contributes about 30% to 50% of the assimilates for grain filling (Sylvester-Bradley *et al.,* 1990).). To new tolerant and adapted varieties with high performance under unfavorable environments remain a challenge for bread wheat breeder (Kumar *et al*., 2014; Noorka and Tabasum, 2015). Under drought conditions, screening wheat lines using yield and morphological traits related to yield is an important common approach because of the relative high heritability of these quantitative characters (Gholmani *et al*., 2011; Ilker *et al.,* 2011; Lonbani and Arzani, 2011.). This study aims to evaluate the response of eleven bread wheat accessions under water stress and to select the most tolerant accession based on eight agro-morphological traits.

MATERIALS AND METHODS

Plant material and experimental design

The plant material consisted of a common variety Salambo and ten bread wheat (*Triticum aestivum* L.) accessions collected by genebank were used in this study. In a randomized split-split design with three replication, a field experiment was conducted in Higher Agriculture School of Mogran, Zaghouan (36° 21' 07" Nord and 10° 06' 43" Est), a tunisian semi arid region in 2009-2010 growing season under four water treatments allocated as a main plot. Mean temperature, weed speed, relative humidity, evaporation and rainfall were mentioned in table 2. The soil at this site is calcic-magnesium carbonate, brown limestone on deposit encrusted: limestone crust of about 60 cm profounder with fine loamy to clayey silt. Seedbed has been prepared by a means plowing followed by a pseudo-plowing. Sowing was done by hand of five rows of 1 m length and 20 cm apart. Seeding rate was 350 grains/m^2. All plots were immediately irrigated to facilitate germination by suitable moisture around seeds. It was hand weeded during growth season. Nitrogen fertilization (100 kg/ha) with ammonitrate (33%) were applied at three leaves, tillering and bolting stages.

Treatment and parameters assessed

To assess the tolerance and susceptibility of bread wheat accessions, three water treatments were applied in different growth stages according Zadoks *et al*., (1974) scale. Water treatment was shown in Table 1.

Eight traits: plant height (cm), spike length (cm), spikelet number, 1000 kernel weight (g), grain yield/spike (g), were measured for ten plant/plots of each bread wheat genotype. Also, other traits were recorded:

- Flag leaf area (cm^2) = flag leaf width x flag leaf length x 0.74 (Muller, 1991)
- Root length (cm): measured from the base of shoot to the tip of the root (Khan et al., 2010),
- Root volume (cm^3): determined by the immersion way as described by Musick et al. (1965).

Statistical data analysis

Variance analysis (ANOVA), mean comparison and correlation coefficient were carried out by Duncan's multiple range test ($p<0.05$, $p<0.01$ and $p<0.001$) using SPSS software ver. 16.0 (IBM SPSS Statistics; SPSS Inc., SPSS for Windows, 2007, Chicago, USA) software.

RESULTS AND DISCUSSION

The results obtained from mean comparison analysis of all parameters tested are shown in Table 3. A highly significant ($p<0.01$) effect of water treatments and genotypes was observed for all parameters. Also, there was a highly significant ($p<0.05$, $p<0.01$, $p<0.001$) interaction between water treatment and accession for traits except spikelet number/spike. The effect of water treatment and the response of the eleven accessions for all traits measured were resuming in table 4. A significant difference between the 04 treatment and between accessions was observed.

Flag leaf area

The flag leaf area decrease significantly with the increase of irrigated treatment (Table 4). For almost accessions smallest leaf area was obtained under the well watered treatment (T3) (Figure 1). It opposes the finding of Lonbani and Arzani (2011) in 41 triticale genotypes and a bread wheat cultivar while flag leaf area did not significantly change under water stress. Also these results corroborates with those obtained by Bazzaz *et al*. (2014) in 11 wheat genotypes. A high difference among accessions for flag leaf area was observed. Accessions 3 and 6 had the lowest flag leaf area (14.70 and 11.46 cm). Smaller leaf area can be helpful in moisture conservation by reducing transpiration (Ahmed et al., 2004). Bhutta *et al*. (2006) reported that leaves of drought tolerant genotypes are smaller than genotypes adapted to adequate moisture environments. Leaf area of a crop affects the amount of solar radiation intercepted by the crop canopy, which in turn affects photosynthesis, evapo-transpiration and final grain yield.

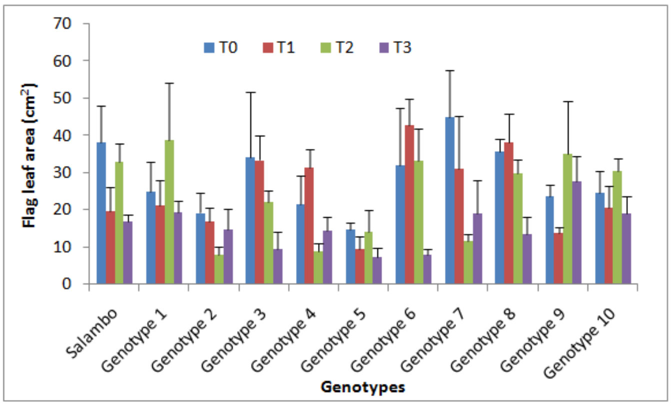


Figure 1. Flag leaf area of eleven bread wheat genotypes under four water treatments

Plant height

The effect of different water deficit levels was clear on plant height of all 11 accessions (Figure 2). The smallest plant height (54.07 cm) was obtained under T1 (rainfall + 10 mm at each stage), and in accessions 1 and 6 (51.65 and 53.40 cm) (Table 2). Singh *et al*. (2001) showed that less reduction in plant height in stress conditions could be an important adaptive mechanism for drought environments. Yazdanseta *et al*. (2014) reported that in response to water stress the reduction in plant high explained by a decrease in turgidity and dehydration of protoplasm, which is related to the lessen expansion of cell and cell division.

Table 1. Treatments and quantities of water supply at each stages

Stages	Seedling growth (1.0)	Tillering (2.0)	Steam elongation (3.0)	Booting (4.0)	Ear emergence (5.0)	Flowering (6.0)	Milk development (7.0)	Dough development (8.0)	Total water supply + rainfall
Treatmant 1 (mm)	10	10	10	10	10	10	10	10	242.3
Treatment 2 (mm)	20	20	20	20	20	20	20	20	252.3
Treatment 3(mm)	30	30	30	30	30	30	30	30	262.3

Table 2. Weather data of the experimental site from metrological station of Mogran during the cropping season 2009-2010

Months	January	February	March	April	May
Minimum temperature (°C)	7.21	7.23	8.71	11.47	13.46
Maximum temperature (°C)	16.61	19.12	19.95	23.04	26.20
Average temperature	11.78	12.63	13.68	16.59	19.54
Wing speed (m/s)	4.00	4.30	3.50	3.20	4.20
Relative humidity (%)	75.80	71.50	78.00	81.00	67.20
Evaporation (mm)	84.70	103.40	93.30	81.60	156.60
Rainfall (mm)	36.60	29.60	75.00	64.00	27.10

Table 3. Analysis of variance (F value) of flag leaf area (FLA), plant height (PH), spike length (SL), spikelet number (SN/S), 1000 kernel weight (TKW), grain yield/spike (GY/S), root length (RL) and root volume (RV) of eleven bread wheat genotypes for different water treatments used

Sources of variation	df	FLA (cm^2)	PH (cm)	SL (cm)	SN/S	TKW (g)	GY/S	RL (cm)	RV (cm^3)
Water treatments	3	18.93 ***	10.11***	4.34**	7.23***	26.94***	14.39***	18.06***	270.60***
Genotypes	10	7.49***	19.28***	2.65**	2.81**	36.25***	9.80***	7.35***	34.01***
Water treatments × genotypes	30	4.20***	11.24***	1.79*	0.97ns	20.65***	3.17***	37.65***	53.97***

df: degree freedom,
Level of signification: *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$; ns: non significant

Table 4. Flag leaf area (FLA), plant height (PH), spike length (SL), spikelet number (SN/S), 1000 kernel weight (TKW), grain yield/spike (GY/S), root length (RL) and root volume (RV) of eleven bread wheat genotypes under four water treatments

Source of variation		FLA (cm^2)	PH (cm)	SL (cm)	SN/S	TKW (g)	GY/S (g)	RL (cm)	RV (cm^3)
Water treatments	T0	28.54 a	56.98 a	11.35 ab	17.64 b	35.49 b	1.25 bc	13.69 c	3.64 c
	T1	25.33 ab	54.07 b	10.76 b	17.27 b	34.53c	1.19 c	13.59 c	3.27d
	T2	24.17 b	57.57 a	11.72 a	18.00 b	35.99 b	1.30 b	15.19 a	6.50 a
	T3	15.46 c	58.13 a	12.05 a	19.12 a	38.47 a	1.47 a	14.58 b	5.55 b
Genotypes	Salambo	23.74 ab	61.60 a	11.02 abcd	19.25 a	39.20 b	1.51 ab	15.05 ab	4.00 d
	Genotype1	26.99 a	51.65 d	11.87 abc	16.75 c	33.27 e	1.12 e	13.97 cde	5.50 b
	Genotype 2	26.12 a	57.37 bc	11.98 ab	18.00 abc	39.37 b	1.41 bc	13.17 def	3.50 e
	Genotype 3	14.70 cd	60.05 ab	12.15 ab	17.00 bc	36.16 d	1.23 de	14.50 bcd	5.00 c
	Genotype 4	24.80 ab	58.57 bc	11.48 abcd	18.00 abc	32.62 e	1.17 e	14.75 bc	5.50 b
	Genotype 5	19.08 bc	56.35 c	10.85 bcd	17.08 bc	32.97 e	1.13 e	13.30 ef	3.50 e
	Genotype 6	11.46 d	53.40 d	12.23 ab	18.05 ab	36.47 cd	1.35 cd	12.87 f	5.50 b
	Genotype 7	29.05 a	59.12 abc	11.47 abcd	18.25 abc	32.11 e	1.17 e	14.67 bc	5.38bc
	Genotype 8	26.68 a	47.75 e	12.34 a	18.00 abc	35.32 d	1.26 cde	14.00 cde	4.00 d
	Genotype 9	29.35 a	58.42 bc	10.48 cd	18.00 abc	37.80 bc	1.36 bcd	14.37 bcd	4.25 d
	Genotype10	25.13 ab	59.30 abc	10.30 d	19.25 a	42.02 a	1.62 a	15.71 a	6.00 a

Table 5. Correlation coefficients among different measured traits

	FLA (cm^2)	PH (cm)	SL (cm)	SN/S	TKW (g)	GY /S (g)	RL (cm)	RV (cm^3)
FLA (cm^2)	1	0.028	-0.026	-0.006	-0.134	-0.100	-0.092	-0.093
PH (cm)		1	0.106	0.206^{*}	0.215^{*}	0.254^{**}	0.182^{*}	0.043
SL (cm)			1	0.595^{**}	0.065	0.329^{**}	0.173^{*}	0.127
SN/S				1	0.363^{**}	0.752^{**}	0.143	0.124
TKW (g)					1	0.884^{**}	0.092	0.140
GY /S (g)						1	0.138	0.164
RL (cm)							1	0.393^{**}
RV (cm^3)								1

Yield and yield related traits

Grain yield depends on spike length, fertile spikelets, grain number per spike and 1000-grain weight) (Akram, 2011).Water supply had a positive effect on yield and yield related traits (Table 4). In general, under the well watered treatment (T3), traits were higher than those under T0, T1 and T2 (Figure 2).

Yield and yield related traits had a significantly differences among genotypes. Accession 10 had the highest grain yield/spike which not significantly differs to Salambo variety. It might be due to its less reduction in other yield contributing factor: spikelet number/spike, 1000 kernel weight. According to, Shirazi *et al.* (2014) water stress affects grain yield by reducing grain number per spike, spike number and grain size.

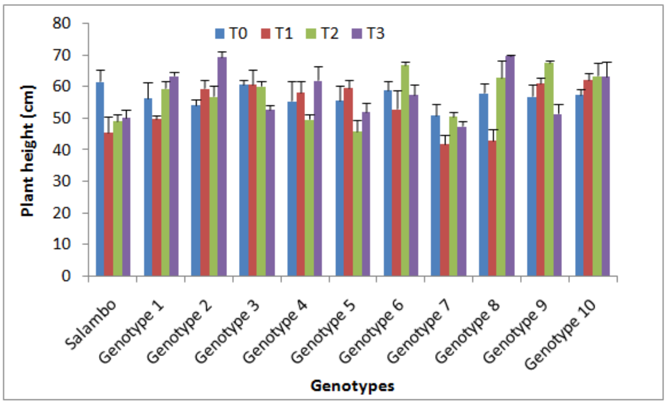


Figure 2. Effects of water treatments on plant height of eleven bread wheat genotypes

Sokoto and Singh (2013) found that water stress at tillering and flowering stages cause a decrease of the number of spikelets/spike, it is explain by a few number of spikelets formed at tillering stage or attributed to floret death at the terminal and basal end of the spike during stem extension.

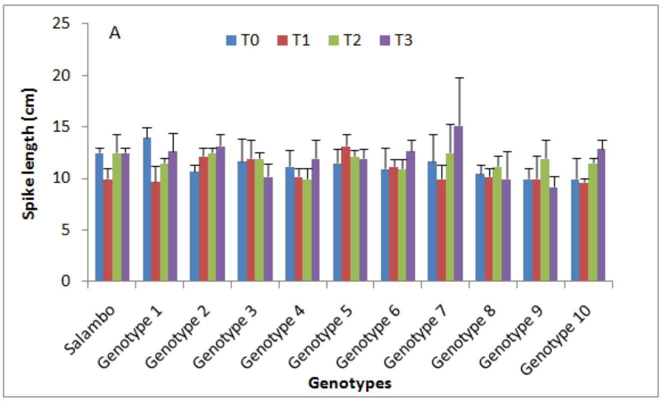
Root traits

A significant reduction of root traits was observed in response to water stress. Lowest root traits ware obtained under T0 (rainfed conditions) and T1 (10 mm of water supply at each stage) (Table 4). Similar results were obtained by Atta *et al.* (2013) in fifteen wheat genotypes under high and low moisture regimes (Comas et al. (2013) these authors reported that as shoot functioning, root system characteristics could determine plant access to water. In comparison to all studied accessions, accession 10 had the greatest RL (15.71 cm) and RV (6 cm^3) (Table 4). Under stressed conditions, accession 8 had the lowest RL (10.5 cm) and RV (1 cm^3) (Figure 4 A and B). Bazzaz *et al*. (2014) reported that drought tolerant genotypes had significantly higher roots than susceptible genotypes.

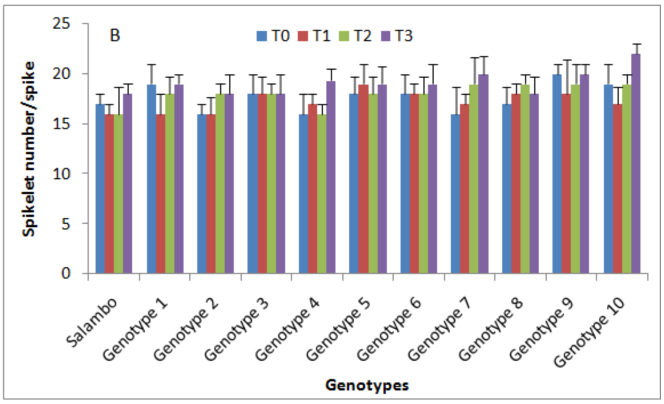
Correlation coefficient among studied traits

Grain yield/spike was significantly and positively correlated with PH (r = 0.254), SL (r = 0.329), SN/S (r = 0.752), and TKW (r = 882) (Table 5). They can discriminate drought tolerant genotypes with high grain yield. Johari-Pireivatlou *et al.* (2011) found that grain yield had a positive-significant correlation with spike number/m^2, 1000 kernel weight, grain number/spike and plant height.

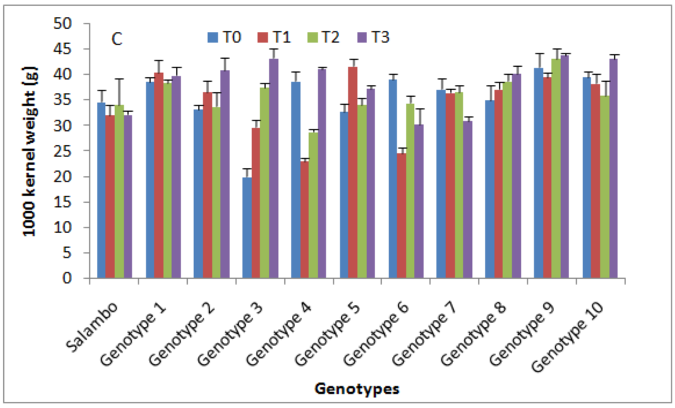
Root length had a significant and positive correlation with PH (r = 0.182), SL (r = 0.173) and RV(r = 0.393). Significant associations were detected also between all three root traits assessed at different depths in the whole soil profile (0-60 cm) and number of grains per spike and number of kernels per spikelet (Table 5). Similar results were obtained by Atta *et al.* (2013). These correlations coefficients are helpful to plant breeders programs to improve drought tolerance. They might be used as indirect selection tools to improve wheat performance under water stress.



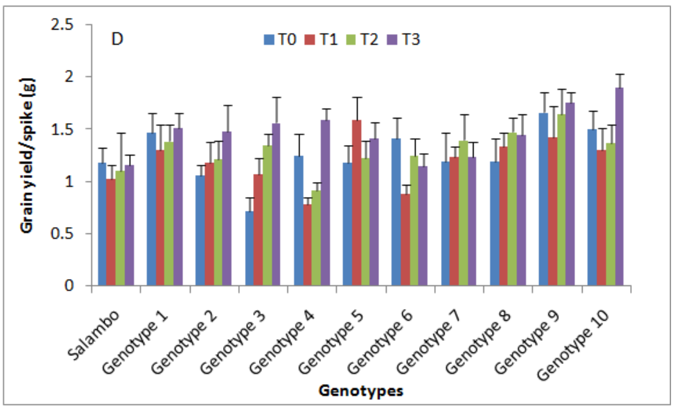
(A)



(B)



(C)



(D)

Figure 3. Spike length (A), spikelets number/spike (B), and 1000-grain weight (C) grain yield/spike (D) of eleven bread wheat genotypes under for water treatments

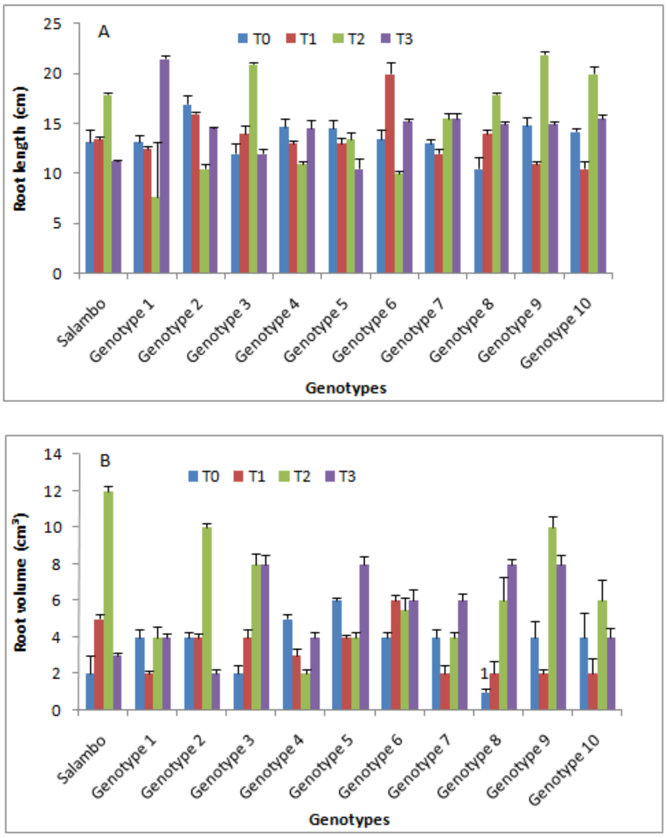


Figure 4. Effects of different water treatments on root growth: root length (A) and root volume (B) of eleven bread wheat accessions

Conclusion

It is concluded that water stress significantly altered most bread wheat performances (spike length, spikelet number/spike, grain number /spike and grain yield/ spike). Results suggest that, accession 10 was the most suitable for drought environment. Therefore, it is advised to develop this accession of bread wheat in land areas with limited precipitations.

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