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Physiological Traits and Drought Tolerance Indices in Advanced Genotypes of Bread Wheat (*Triticum aestivum* L)

H. M. Fouad
Department of Agronomy, Faculty of Agriculture, Minia University, Minia, Egypt.

TWO FIELD experiments were carried out at Fac. Agric. Edu. Farm, Minia University, Egypt, during the two successive seasons of 2015/2016 and 2016/2017 under irrigation and drought conditions. Thirty nine genotypes of bread wheat were evaluated to estimate physiological traits related to water stress, tolerance indices, and to determine the best drought tolerant genotypes. The combined analysis revealed significant differences for environments, genotypes, years, environments x genotypes and years x genotypes interactions for all studied traits. Under irrigation, three genotypes No. 39, No. 42 and No.68 were significantly higher than the better parent in excised leaf water retention and grain yield. Under drought stress condition, genotypes No. 13, No. 42 and No. 246 exceeded the better parent in relative water content, leaf water content, specific leaf weight and grain yield. Under normal irrigation, relative water content showed negative and significant ($P \leq 0.01$) correlation with leaf water loss (-0.86), with leaf area (-0.36), and positive correlation with grain yield ($P \leq 005$), while under drought stress, excised leaf water retention showed negative and significant ($P \leq 0.01$) correlation with leaf water loss (-0.85), and negative correlation with both of leaf area (-0.25) and grain yield. Ranking method indicated that genotypes No. 13, No.296 and No.379 were the most drought tolerant genotypes, while genotypes No. 1, No.74, No.95 and No.129 were the most sensitive to drought condition.

Keywords: Drought stress, Excised leaf water retention, Relative water content, Leaf water loss, *Triticum aestivum* L.

Introduction

Wheat is the most important cereal grain crop in the world. World's wheat production was about 751.36 million tons. Egypt ranked the sixth in world wheat production per unit area with average yield of 6.43ton/ha. According to the recent reports, wheat cultivated more than 1.26 million hectares and its total production was about 8.1 million tons in Egypt during cropping season of 2015/2016 (USDA, 2016).

Drought stress is the most significant environmental stress in agriculture worldwide and improving yield under drought is a major goal of plant breeding (Cattivelli et al., 2008 and Talebi et al., 2009).

Relative water content (RWC) was the best criterion for plant water status. RWC related with cell volume, indicate the balance between absorbed water and loosed by transpiration in plant. It is revealed that varieties, with higher leaf turgor and RWC under stress conditions are more drought tolerant and gave higher yield than others (Schonfeld et al., 1988, Gunes et al., 2008, Akram, 2011 and Khakwani et al., 2011). Likewise, low excised leaf water loss (LWL) has been suggested as important indicators of water status (Gunes et al., 2008). Moreover, Amiri et al. (2013), Allahverdiyev et al. (2015) and Dabiry et al. (2015) showed effect of drought on reduction in grain yield, relative water content, leaf water content (LWC) and excised leaf water retention (ELWR), whereas increased of leaf water loss and leaf specific mass in dryland conditions.

Mahdy et al. (2015) showed higher phenotypic and genotypic coefficient of variation for grain yield/plant. Besides, Khakwani et al. (2012), Amiri et al. (2013) and Mursalova et al. (2015) observed high significant differences for all studied traits among genotypes in both irrigated and drought conditions.

Corresponding author email: hassan.mostafa@mu.edu.eg
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Lonbani et al. (2011) and Aharizad et al. (2012) revealed that combined analyses of variances indicated significant differences among genotypes and genotype × environment interaction for RWC, ELWR, rate of water loss, initial water content and leaf area. Meanwhile, Rashidi et al. (2011) and Dabiry et al. (2015) indicated that genotype and environment significantly affect the yield and the most of the other evaluated traits whereas, the interaction between genotype and environment was significant for grain yield.

Lonbani et al. (2011) stated significant negative correlation between ELWR and grain yield under drought environments, while was significant positive under normal environments. This correlation indicated that ELWR had a valuable effect on grain yield under both environments. Though, Dabiry et al. (2015) noticed negative correlation between ELWR and LWL under complementary irrigation (r = -0.265) and dryland (r = -0.533*) conditions. Jager et al. (2014) found that drought tolerance was correlated with narrow flag leaf and RWC.

Several drought indices have been used for screening drought tolerant genotypes based on yield under drought and normal environments (Talebi et al., 2009 and Mursalova et al., 2015) such as: Stress susceptibility index (SSI) (Fischer & Maurer, 1978), stress tolerance index (STI), geometric mean productivity (GMP) (Fernandez, 1992), mean productivity (MP), tolerance index (TI) (Rosielle & Hamblin, 1981), yield stability index (YSI) (Bouslama & Schapaugh, 1984), harmonic mean (HM) (Chakherchaman et al., 2009), sensitivity drought index (SDI) (Farshadfar & Javadinia, 2011), drought resistance index (DRI) (Lan, 1988) and relative drought index (RDI) (Fischer et al., 1998). Consequently, Mohammadi et al. (2012), Mursalova et al. (2015) and Ali & El-Sadek (2016) indicated that GMP, MP and STI were more efficient indices for recognizing high performance genotypes under diverse moisture stress. Likewise, Akçura et al. (2011) and Khakwani et al. (2011) revealed that RWC, MP, STI, SSI and TOL are recognized as beneficial drought tolerance indicators for selecting stress tolerant genotypes.

Farshadfar et al. (2012) and Ershadimanesh & Shiravani (2014) used mean rank, standard deviation of ranks and rank sum to screen drought tolerant genotypes.

The present work aims to estimate physiological traits, correlation between the studied traits, and study drought tolerance indices to determine the best genotypes in drought tolerance from 37 genotypes and the two parents cultivars of bread wheat under normal irrigation and drought stress conditions.

Materials and methods

The 37 genotypes were in the F_6-generation derived from the population (Giza 168 x Sids 4) in addition to the two parents were grown in two separated experiments; normal irrigation (irrigated 6 times) and drought stress condition (irrigated only one time three weeks after planting irrigation) along with the two parents on November 20th in the two successive seasons of 2015/2016 (F_7-generation) and 2016/2017 (F_8-generation) at Fac. Agric. Edu. Farm, Minia University, Egypt. These materials were derived from the materials of Ph.D. study of the author. A randomized complete block design with three replications was used. The plot size was eight rows, 1.5m length, and 0.2m row spacing. Seeds were sown by hand 5cm within a row. The recommended cultural practices for wheat production were adopted throughout the growing seasons. The pedigree of the parents is given in Table 1.

TABLE 1. The pedigree of the parents of the wheat genotypes.

Parental cultivars	Pedigree
Giza 168	MIL/Buc//Seri CM93046-8M-04-0M-2Y-0B
Sids 4	Maya (S)/Man (S)//CMH 74A-592/3/Giza 157*2

Studied traits

Relative water content (RWC)

It was determined according to Schonfeld et al. (1988). Five flag leaves from each genotype were preserved in plastic bags and fresh wieght (FW) determined within 1h after transferred to the laboratory. Turgid weight (TW) was obtained after soaking the leaves for 24h in distilled water under 4°C in dark. After soaking, leaves were quickly and carefully blotted dry with a tissue paper prior to determine of turgid weight. Dry weight (DW) was obtained after drying the leaves sample for 72h at 70°C. Relative water content was calculated from the following equation:

RWC(%) = [(FW-DW)/(TW-DW)] x 100.

Excised leaf water retention (ELWR)

It was measured according to Clarke & McCaig (1982) method.

ELWR % = [(1 – ((FW-ADW)/DW))] x 100.

where, FW = Fresh leaf weight; ADW = Weight of leaves after 24h under room temperature (wilt leaf) and DW = Leaves placed in an oven at 72h at 70°C and re-weighed.

Leaf water loss (LWL)

It was measured according to Xing et al. (2004) method:

LWL % = [(FW-ADW)/DW)] x 100

Leaf water content (LWC)

It was calculated using Clarke & McCaig (1982) method:

LWC % = [(FW-DW)/FW)] x 100

Leaf specific weight (LSW)

It was measured from leaf dry weight per unit leaf area, gm/cm^2.

Flag leaf area (LA) in cm^2

LA = Flag leaf length x flag leaf weidth x 0.75 according to Radford (1967).

Grain yield (GY) in gm

It was determined from five middle rows with 1m long and expressed as ton per hectare (ton ha^{-1}).

Drought tolerance indices

Ten drought tolerance indices were calculated based on grain yield under drought (Ys), irrigated (Yp) conditions and the stress intensity SI = 1− (Ys/Yp).

1- Stress susceptibility index (SSI) = [1- (Ys/Yp)]/SI (Fischer & Maurer, 1978)

2- Stress tolerance index (STI) = Ys.Yp/(Yp)^2 (Fernandez, 1992)

3- Mean productivity (MP) = (Ys + Yp)/2 (Rosielle & Hamblin, 1981)

4- Geometric mean productivity (GMP) = $\sqrt{(Ys \times Yp)}$ (Fernandez 1992)

5- Tolerance index (TOL) = Yp – Ys (Rosielle & Hamblin, 1981)

6- Yield stability index (YSI) = Ys/Yp (Bouslama & Schapaugh, 1984)

7- Harmonic mean (HM) = [2(Yp Ys)]/(Yp + Ys) (Chakherchaman et al., 2009)

8- Sensitivity drought index (SDI) = (Yp - Ys)/Yp (Farshadfar & Javadinia, 2011)

9- Drought resistance index (DI) = [Ys(Ys/Yp)]/Ys (Lan, 1988)

10- Relative drought index (RDI) = (Ys/Yp) (Ys/Yp) (Fischer et al., 1998)

Statistical procedures

Analysis of variance was performed on the different traits on plot mean basis as out genotyped by Steel & Torrie (1980).

The phenotypic (pcv %) and genotypic (gcv %) coefficients of variability were calculated as $\sigma p/\bar{x} * 100$ and $\sigma g/\bar{x} * 100$; respectively as outgenotyped by Burton (1952).

where: σp and σg are the phenotypic and genotypic standard deviation of the genotypes mean; respectively, and $\bar{x}$ is genotypes mean for a given trait.

Mean comparisons were calculated using revised least significant difference (RLSD) according to El-Rawi & Khalafalla (1980) as follows:

RLSD of Genotypes= $t^{\backslash}.\sqrt{2Mse/r}$ to compare genotypes.

where r: Number of replicates, $t^{\backslash}$: The t value from "minimum-average-risk t-table" at F-value of treatments, d.f: Degree of freedom for treatments and degree of freedom for experimental error.

Standard deviation of ranks (SDR) was measured as:

$$S_i^2 = \frac{\sum_{j=1}^{m}(Rij - \overline{R}i.)^2}{l-1}$$

where: Rij is the rank of drought tolerance indicator and $\overline{R}$i is the mean rank across all drought tolerance indicators for the i[th] genotypes and SDR= $(S_i^2)^{0.5}$.

Rank sum (RS) = Rank mean ($\overline{R}$) + Standard deviation of rank (SDR) (Farshadfar & Elyasi, 2012).

Results and Discussion

The results of the analysis of variance for the studied traits, heritability in broad sense (H), genotypic (gcv %) and phenotypic (pcv %) coefficients of variability are presented in Table 2. Mean squares of all the studied traits were significant (P<0.01) under the two environments in the two seasons, indicating presence of variability. Similar results found by Mahdy et al. (2012), Khakwani et al. (2012), Amiri et al. (2013) and Mursalova et al. (2015).

TABLE 2. Analysis of variance, heritability in broad sense (H%), genotypic (gcv %), phenotypic (pcv %) coefficient of variation for studied traits for genotypes under two conditions in the two seasons.

Year	Envir	S.V	df	RWC%	ELWR%	LWC%	LWL%	LA	SLW	GY
2015/2016	Irrigation	Rep	2	376.7	106.99	104.68	115.38	132.87	2.89	0.32
		Genotype	38	12.94**	174.50**	20.96**	148.19**	604.07**	10.56**	2.41**
		Error	76	2.3	1.36	1.24	0.91	1.39	0.1	0.08
		H%		82.24	99.22	94.07	99.38	99.77	99.01	96.58
		gcv%		2.16	14.87	3.73	15.57	26.15	51.44	11.71
		pcv%		2.38	14.93	3.84	15.62	26.18	51.69	11.91
	Drought	Rep	2	279.12	95.96	115.43	110.72	190.3	2.42	0.1
		Genotype	38	41.26**	116.89**	49.72**	133.57**	630.84**	4.10**	2.54**
		Error	76	1.64	1.35	1.39	1.94	1.94	0.04	0.04
		H%		96.03	98.85	97.2	98.55	99.69	99.12	98.23
		gcv%		4.34	14.51	6.15	12.39	29.61	29.66	15.74
		pcv%		4.43	14.6	6.23	12.48	29.65	29.79	15.88
2016/2017	Irrigation	Rep	2	75.14	4.18	0.64	0.6	1.81	0.17	2.47
		Genotype	38	11.49**	152.08**	20.88**	142.10**	675.52**	11.25**	1.67**
		Error	76	3.52	7.82	4.38	6.22	5.31	0.16	0.13
		H%		69.41	94.86	79.04	95.64	99.21	98.56	92.03
		gcv%		1.78	13.15	3.32	14.32	26.65	48.01	9.91
		pcv%		2.14	13.5	3.73	14.64	26.76	48.36	10.33
	Drought	Rep	2	17.26	10.87	2.51	2.85	90.65	0.03	1.96
		Genotype	38	31.19**	86.55**	16.80**	110.37**	539.70**	3.60**	0.80**
		Error	76	4.5	6.67	5.47	6.53	65.68	0.06	0.09
		H%		85.59	92.29	67.45	94.08	87.83	98.27	88.75
		gcv%		3.36	11.46	2.87	10.67	24.94	25.61	8.65
		pcv%		3.63	11.93	3.49	11.01	26.61	25.83	9.19

** Significant at 0.01 level of probability.

TABLE 3. Combined analysis of variance for studied traits under two conditions in two seasons.

S.V	d.f	RWC	ELWR	LWC	LWL	LA	SLW	GY
Env	1	1150**	7529.34**	1191.66**	7929.28**	3525.18**	8.25**	322.11**
Rep(Env)	4	138.76	49.16	49.21	62.15	151.54	0.96	0.45
Year (Yr)	1	2602.4**	451.87**	552.44**	412.87**	333.49**	13.84**	6.05**
Env*Yr	1	6.96	11.12	10.84	7.12	3.96	0.11	0.47
Rep*Yr*Env	4	235.35	59.83	62.42	52.63	56.28	1.8	1.39
Genot	38	50.57**	290.07**	50.09**	307.479**	1886.05**	16.61**	7.34**
Env*Genot	38	36.5**	222.46**	42.18**	207.34**	516.28**	12.57**	0.96**
Yr* Genot	38	4.9*	6.402**	5.39**	10.34**	20.78	0.18**	0.17**
Env*Yr* Genot	38	4.93*	11.09**	10.71**	9.86**	27.05**	0.5**	0.11
Error	304	2.99	4.3	3.12	3.9	18.58	0.09	0.09

* and ** Significant at 0.05 and 0.01 level of probability, respectively.

Estimates of gcv and pcv % (Table 3) were high and closest to each other, which resulted high values of heritability in broad sense in most of the studied traits. It ranged from 67.45% for LWC% under drought in the second season to 99.77% for LA under normal irrigation in the first season. RWC and LWC showed moderate value of heritability 69.41 and 79.04%; respectively, under irrigation in the second season. Mahdy et al. (2015) showed higher phenotypic and genotypic coefficient of variation for grain yield/plant.

The combined analysis over the two years (Table 3) revealed that environments, genotypes, years, environments x genotypes and years x genotypes interactions exhibited significant differences for all studied traits except leaf area in years x genotypes interaction. These results indicated different response of the genotypes for two conditions and presence genetic variation among genotypes. These results are in agreement with these obtained by Lonbani et al. (2011), Rashidi et al. (2011), Aharizad et al. (2012) and Dabiry et al. (2015).

RWC showed positive correlation coefficient with each of LWC, LA and SLW under the two environments. Correlation between RWC and grain yield was negative under irrigation, while convert to positive correlation under drought stress condition.

ELWR showed positive correlation coefficient with specific leaf weight and grain yield under normal irrigation (Table 4). The correlation coefficient between ELWR and GY was positive under irrigation, while it was negative under drought stress. Lonbani et al. (2011) showed significant and negative correlation for ELWR with grain yield under drought stress conditions, while their correlation was significant and positive under non-stress conditions.

Means of the studied traits for genotypes under the two conditions averaged across the two seasons are presented in Supplemental Table 1.

Average of RWC under irrigation was 89.33%, and ranged from 86.23% for genotype No.170 to 92.57% for genotype No. 378. All the genotypes not surpassed the better parent Sids 4 (94.19%). Ten genotypes (No. 1, No.13, No.39, No.92, No.245, No.246, No.306, No.352, No.378 and No.459) exceeded the mid parents (90.66%) in RWC. Under drought stress, the average of RWC was 86.34 and ranged from 73.44% for genotype No.343 to 90.83% for genotype No.389, and most of genotypes were higher than the better parent. The best two genotypes in RWC under drought were genotypes No.389 and No.395 with means 90.83 and 89.99%; respectively.

Average of excised leaf water retention (ELWR) was 51.91 and 43.69% under irrigation and drought conditions, respectively. The best genotype in ELWR under irrigation was No. 95 with mean of 70.12% and under drought was genotype No. 202 with mean 60.62%.

TABLE 4. Simple correlation among the studied traits under irrigation (below diagonal) and drought (above diagonal) conditions across two seasons.

Trait	RWC	ELWR	LWC	LWL	LA	SLW	GY
RWC	-	-0.13	0.59**	0.05	0.09	0.21	0.07
ELWR	-0.23	-	0.03	-0.85**	-0.25	0.27	-0.06
LWC	0.36*	0.10	-	-0.07	0.04	0.00	0.15
LWL	0.09	-0.86**	-0.11	-	0.25	-0.28	0.08
LA	0.08	-0.36*	-0.30	0.32*	-	-0.06	-0.18
SLW	0.14	0.12	0.24	-0.18	-0.11	-	-0.03
GY	-0.13	0.04	-0.17	-0.05	-0.21	-0.05	-

Average LWC was 69.75% and the best genotype was No. 246 with mean 77.37% under irrigation, while under drought the average was 66.59% and the best genotype was No. 300 with mean of 71.82%.

Averages LWL, LA and SLW were 46.12%, 54.49cm and 3.77g/cm^2 under irrigation and 54.38%, 49.58cm and 4.11g/cm^2 under drought, respectively. The best genotype in each of LWL, LA and SLW were No. 95, No.13 and No.39 with mean of 28.31%, 93.74cm and 8.89g/cm^2 under normal irrigation, respectively, while under drought the best genotypes were No.202, No.139 and No.245 with mean of 36.66%, 76.51cm and 6.08g/cm^2, respectively.

Averages of grain yield were 7.47 and 5.77ton/ha, under normal irrigation and drought conditions, respectively. All genotypes except one under irrigation, and twelve genotypes under drought stress were higher than the better parent in grain yield.

Genotypes No.13, No.39 and No.42 surpassed the better parent in RWC, SLW and GY with mean of 87.13% for RWC, 4.45gm/cm^2 for SLW in No.39 and 5.57ton/ha for GY in genotype No.42 under drought condition. Also, these three genotypes surpassed the better parent in GY, in addition to genotype No.68 was higher than the better parent in ELWR and LA under irrigation condition.

Under normal irrigation, three genotypes No.39, No.42 and No.68 were significantly higher than the better parent in ELWR and GY. Also, genotypes No.95, No.170, No.202, No.245, No.246 and No.296 exceeded the better parent in ELWR, LWC, LWL and GY. Four genotypes No.13, No.63, No.68 and No.74 exceeded the better parent in LA and GY. Genotypes No.39, No.68 and No.104 were higher than the better parent in ELWR, LWL and GY.

Results under drought stress condition showed that genotypes No.13, No.42 and No.246 exceeded the better parent in RWC, LWC, SLW and GY. Genotypes No.209 and No.397 were higher than the better parent in RWC and GY.

According to mean of the studied traits for genotypes averaged across two seasons (Supplemental Table 1), genotypes No.95 had the highest ELWR of 70.12%, but had the lowest LWL (28.31%) under irrigation and genotype No.202 had the highest ELWR (60.62%%), and had the lowest LWL (36.66%) under drought. This means that these genotypes had the ability to maintain water and decrease of leaf water loss under drought. This associations are confirmed by correlation coefficients results (Table 4), in which ELWR showed negative and significant ($P<0.01$) correlation with LWL (-0.86) and significant correlation ($P<0.05$) with LA (-0.36) under normal irrigation, also under drought stress ELWR showed negative and significant ($P<0.01$) correlation with LWL (-0.85) and negative correlation with LA (-0.25). Dabiry et al. (2015) found negative correlation between ELWR and LWL under complementary irrigation (r = -0.265) and dryland (r = -0.533*) conditions.

Results of screening drought tolerant genotypes based on yield under drought stress and normal irrigation environments (Supplemental Table 2) revealed that genotypes No. 296, No.378, No.379 and No.463 were the drought tolerant genotypes based on STI, MP and GMP. Based on the same three indices genotypes No.74, No.150 and No.459 were the most susceptible genotypes. Therefore, STI, MP and GMP considered as more efficient indices in identify high yielding genotypes under normal and drought stress conditions. Similar resulted were reported by many authors; Mohammadi et al. (2012), Mursalova et al. (2015), Sahar et al. (2016) and Ali & El-Sadek (2016).

Based on SSI, TOL, YSI, SDI and RDI, genotypes No.13, No.296 and No.395 were the most tolerant genotypes (Supplemental Table 2). Moreover, genotypes No.95 and No.129 were the least tolerant genotypes. No.395 was the best tolerant based SSI, TOL, YSI, SDI, DI and RDI, but its performance under irrigation was low so couldn't be drought tolerant. In contrasting, No.379 was superior in STI and considered a promising genotype in breeding programs.

Ranking method carried out for all drought tolerance indices to determine higher and lower drought tolerance genotypes (Table 5) indicated that genotypes No.13, No.296 and No.395 were the lowest ranking sum, hence they were the most drought tolerance genotypes, while genotypes No.1, No.74, No.95 and No.129 were the most sensitive to drought condition. These results were in accordance with those obtained by Farshadfar et al. (2012).

TABLE 5. Ranks ($\overline{R}$), ranks mean (R), standard deviation of ranks (SDR) and rank sum (RS) of drought tolerance indicator.

Genotype No.	Yp ton/ha	Ys ton/ha	SSI	STI	MP	GMP	TOL	YSI	HM	SDI	DI	RDI	R	SDR	RS
1	9	30	2	20	19	19	39	36	22	38	34	36	25.33	12.07	37.40
13	16	6	4	8	8	8	3	3	7	3	5	3	6.17	3.74	9.90
39	11	26	34	18	17	18	36	33	18	33	29	33	25.50	8.61	34.11
42	7	21	33	15	13	15	35	32	16	32	27	32	23.17	9.72	32.89
48	33	35	28	34	34	34	22	27	35	27	30	27	30.50	4.25	34.75
62	12	9	17	10	10	10	17	16	9	16	10	16	12.67	3.39	16.06
63	27	31	30	29	29	29	27	29	29	29	28	29	28.83	1.11	29.95
68	6	14	26	9	9	9	30	25	10	25	20	25	17.33	8.64	25.97
74	36	38	39	38	37	38	31	39	38	39	39	39	37.58	2.27	39.86
92	17	25	31	21	21	21	32	30	19	30	26	30	25.25	5.29	30.54
95	10	28	37	19	18	20	38	37	21	36	33	37	27.83	9.77	37.60
104	20	32	36	30	28	30	34	35	30	35	35	35	31.67	4.54	36.21
124	24	19	20	22	23	22	21	19	20	19	21	19	20.75	1.71	22.46
129	19	33	38	28	26	28	37	38	31	37	36	38	32.42	6.11	38.53
139	14	13	18	12	12	12	19	17	12	17	13	17	14.67	2.71	17.37
145	30	29	22	32	32	32	20	21	32	21	25	21	26.42	5.18	31.59
150	35	37	35	36	36	36	28	34	36	34	37	34	34.83	2.41	37.24
151	29	17	12	25	25	25	10	11	25	11	15	11	18.00	7.22	25.22
170	15	10	16	11	11	11	15	15	11	15	9	15	12.83	2.52	15.35
202	23	8	7	13	14	13	6	6	13	6	7	6	10.17	5.20	15.37
206	13	16	25	14	15	14	26	24	15	24	22	24	19.33	5.18	24.51
209	26	15	14	17	20	17	13	13	17	13	12	13	15.83	4.00	19.83
245	28	34	32	33	33	33	29	31	33	31	32	31	31.67	1.78	33.44
246	31	18	9	26	27	26	7	8	26	8	14	8	17.33	9.32	26.65
296	8	3	3	4	4	4	4	2	4	2	3	2	3.58	1.62	5.20
300	25	12	6	16	16	16	5	5	14	5	8	5	11.08	6.46	17.54

TABLE 5. Cont.

Genotype No.	Yp ton/ ha	Ys ton/ ha	SSI	STI	MP	GMP	TOL	YSI	HM	SDI	DI	RDI	R	SDR	RS
306	5	7	21	7	7	7	24	20	8	20	11	20	13.08	7.19	20.27
343	22	23	24	24	24	24	23	23	24	23	23	23	23.33	0.65	23.98
352	34	22	11	31	31	31	8	10	28	10	16	10	20.17	10.30	30.47
378	4	4	15	3	3	3	18	14	3	14	6	14	8.42	5.96	14.38
379	1	1	8	1	1	1	14	7	1	7	2	7	4.25	4.27	8.52
389	21	24	27	23	22	23	25	26	23	26	24	26	24.17	1.85	26.02
395	18	5	1	6	6	6	1	1	5	1	1	1	4.33	4.89	9.22
397	3	11	29	5	5	5	33	28	6	28	19	28	16.67	11.87	28.54
423	32	20	13	27	30	27	9	12	27	12	17	12	19.83	8.32	28.15
459	38	36	19	37	38	37	11	18	37	18	31	18	28.17	10.38	38.55
463	2	2	10	2	2	2	16	9	2	9	4	9	5.75	4.69	10.44
Sids 4	39	39	23	39	39	39	12	22	39	22	38	22	31.08	10.00	41.09
Giza168	37	27	5	35	35	35	2	4	34	4	18	4	20.00	15.17	35.17

Conclusion

Under irrigation three genotypes No.39, No.42 and No.68 were significantly higher than the better parent in excised leaf water retention and grain yield. Under drought stress condition genotypes No.13, No.42 and No.246 exceeded the better parent in relative water content, leaf water content, specific leaf weight and grain yield. Genotypes No.13, No.296 and No.395 were the most drought tolerance genotypes.

References

Aharizad, S., Fard. A.K., Mohammadi, S.A. and Sedaghat, S. (2012) Evaluation of bread wheat recombinant inbred genotypes under drought conditions. *Annals of Biol Res.* **3**(12), 5744-5747.

Akçura, M., Partigoç, F. and Kaya, Y. (2011) Evaluating of drought stress tolerance based on selection indices in Turkish bread wheat landraces. *J. of Animal & Plant Sci.* **21**(4), 700-709.

Akram, M. (2011) Growth and yield components of wheat under water stress of different growth stages. *Bangladesh J. Agril. Res.* **36**(3), 455-468.

Ali, M.B. and El-Sadek, A.N. (2016) Evaluation of drought tolerance indices for wheat (*Triticum aestivum* L) under irrigated and rainfed conditions. *Com in Biometry & Crop Sci.* **11**(1), 77-89.

Allahverdiyev, T.I. (2015) Physiological traits of durum wheat (*Triticum durum* Desf.) and bread wheat (*Triticum aestivum* L) genotypes under drought stress. *Agric. Sci.* **6**, 848-859.

Amiri, R., Bahraminejad, S. and Honarmand, S.J. (2013) Effect of terminal drought stress on grain yield and some morphological traits in 80 bread wheat genotypes. *Intl. J. Agric. Crop Sci.* **5**(10), 1145-1153.

Bouslama, M. and Schapaugh,W.T. (1984) Stress tolerance in soybean. Part 1: Evaluation of three screening techniques for heat and drought tolerance. *Crop Science,* **24**, 933-937.

Burton, G.W. (1952) Quantitative inheritance in grasses. *6th Internat. Grassland Cong. Proc.* **1**, 227-283.

Cattivelli, L., Rizza, F., Badeck, F.W., Mazzucotelli, E., Mastrangelo, A.M., Francia, E., Mare, C., Tondelli, A. and Stanca, A.M. (2008) Drought tolerance improvement in crop plants: An integrated view from breeding to genomics. *Field Crop Res.* **105**, 1-4.

Chakherchaman, S.A., Mostafaei, H., Imanparast, L. and Eivazian, M.R. (2009) Evaluation of drought tolerance in lentil advanced genotypes in Ardabil region, *Iran J. Food Agric. Env.* **7**(3-4), 283-288.

Clarke, J.M. and McCaig, T.N. (1982) Excised leaf water retention capability as an indicator of drought resistance of *Triticum* genotypes. *Canadian J. of Plant Scie.* **62**, 571-578.

Dabiry, S., Esmaeili, M.A., Haghparast, R. and Ghajarsepanlo, M. (2015) Drought tolerance of advanced bread wheat genotypes based on different drought tolerance criteria. *Biological Forum – An Inter. J.* **7**(1), 230-241.

El-Rawi, K. and Khalafala, A.M. (1980) "*Design and Analysis of Agricultural Experiments*". El-Mousel Univ. pp.79-80, Iraq.

Ershadimanesh, K. and Shiravani, H. (2014) Application of integrated selection index and morpho-physiological traits for screening drought tolerant genotypes in bread wheat. *Agric. Sci. Dev.* **3**(11), 375-380.

Farshadfar, E. and Javadinia, J. (2011) Evaluation of Chickpea (*Cicer arietinum* L) genotypes for drought tolerance. *Seed & Plant Improvement J.* **27**(4), 517-537.

Farshadfar, E., Jalali, S. and Saeidi, M. (2012) Introduction of a new selection index for improvement of drought tolerance in common wheat (*Triticum aestivum* L) *European J. of Exp. Biol.* **2**(4), 1181-1187.

Farshadfar, E. and Elyasi, P. (2012) Screening quantitative indicators of drought tolerance in bread wheat (*T. aestivum*) landraces. Pelagia Res. Library. *Eur. J. Exp. Biol.* **2**(3), 577-584.

Fernandez, G.C.J. (1992) Effective selection criteria for assessing plant stress tolerance. In: *Proceeding of the International Symposium on adaptation of vegetable and other food crops in temperature and water stress*. Publication, Taiwan, pp. 257-270.

Fischer, R.A. and Maurer, R. (1978) Drought resistance in spring wheat cultivars. I. Grain responses. *Australian Journal of Crop Sci.* **29**, 897-912.

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

Gunes, A., Inal, A., Adak, M.S., Bagci, E.G., Cicek, N. and Eraslan, F. (2008) Effect of drought stress implemented at pre or post anthesis stage on some physiological parameters as screening criteria in chickpea cultivars. *Russ. J. Plant Physiol.* **55**, 59-67.

Jager, K., Fabian, A., Eitel, G., Szabc, L., Deak, C., Barnabas, B. and Papp, I. (2014) A morpho-physiological approach differentiates bread wheat cultivars of contrasting tolerance under cyclic water stress. *J. of Plant Physiology,* **171**, 1256-1266.

Khakwani, A.A., Dennett, M.D. and Munir, M. (2011) Drought tolerance screening of wheat varieties by inducing water stress conditions. *Songklanakarin J. of Sci & Technology,* **33**(2), 135-142.

Khakwani, A.A., Dennett, M.D., Munir, M. and Abid, M. (2012) Growth and yield response of wheat varieties to water stress at booting and anthesis stages of development. *Pakistan J. Botany,* **44**(3), 879-886.

Lan, J. (1998) Comparison of evaluating methods for agronomic drought resistance in crops. *Acta Agriculturae Boreali-Occidentalis Sinica,* **7**, 85-87.

Lonbani, M and Arzani, A. (2011) Morpho-physiological traits associated with terminal drought stress tolerance in triticale and wheat. *Agronomy Res.* **9**(1–2), 315-329.

Mahdy, E.E., El-Karamity, A.E., Mokadem, S.A., Abd-Elmawgood, A.L. and Fouad, H.M. (2012) Selection for grain yield and its components in two segregating populations of bread wheat *Triticum aestivum* L. *Minia Inter Conf for Agric and Irrigation in the Nile Basin Countries*, 26th - 29th March, pp. 595-604. El-Minia, Egypt.

Mahdy, E.E., El-Karamity, A.E., Mokadem, S.A. and Fouad, H.M. (2015) Selection for grain yield in bread wheat under normal irrigation and drought stress conditions. *J. Plant Production, Mansoura Univ.* **6**(4), 547-562.

Mohammadi, S., Mohammadi, M.J., Javanmard, A., Sabaghnia, N., Rezaie, M. and Yezadansepas, A. (2012) Assesment of drought tolerance indices in bread wheat genotypes under different sowing dates. *Cercetări Agronomice în Moldova,* **3** (151), 25-39.

Mursalova, J., Akparov, Z., Ojaghi, J., Eldaro, M., Belen, S., Gummadov, N. and Morgounov, A. (2015) Evaluation of drought tolerance of winter bread wheat genotypes under drip irrigation and rain-fed conditions. *Turkish J. Agric & Forestry,* **39**, 1-8.

Radford, P.J. (1967) Growth analysis formulae their use and abuse. *Crop Science,* **7**, 171-175.

Rashidi, V., Yani, S.C. and Tarinejad, A.R. (2011) Evaluation of drought tolerance in promising genotypes and cultivars of bread wheat (Triticum aestivum L). *J. of Food, Agric & Environ.* **9**(2), 423-427.

Rosielle, A.A. and Hamblin, J. (1981) Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Sci.* **21**, 943-946.

Schonfeld, M.A., Johnson, R.C., Carwer, B.F. and Mornhinweg, D.W. (1988) Water relations in winter wheat as drought resistance indicators. *Crop. Sci.* **28**, 526-531.

Steel, R.G.D. and Torrie, J.H. (1980) "*Principle and Procedures of Statistics. A Biometrical Approach*" 2nd ed., McGraw-Hill Book Company, New York. U.S. A.

Talebi, R., Fayaz, F. and Naji, A.M. (2009) Effective selection criteria for assessing drought stress tolerance in durum wheat (*Triticum durum* Desf.). Gen. *Appl. Plant Physiol.* **35**, 64-74.

USDA (2016) United State Department of Agriculture. Foreign Agricultural Service. January 2016.

Xing, H., Tan, L., An, L., Zhao, Z., Wang, S. and Zhang, C. (2004) Evidence for the involvement of nitric oxide and reactive oxygen species in osmotic stress tolerance of wheat seedlings: Inverse correlation between leaf abscisic acid accumulation and leaf water loss. *Plant Growth Regulation,* **42**, 61-68.

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الصفات الفسيولوجية ودلائل تحمل الجفاف في بعض التراكيب الوراثية المتقدمة من قمح الخبز

حسن محمد فؤاد
قسم المحاصيل – كلية الزراعة – جامعة المنيا – المنيا – مصر.

أجريت تجربتان حقليتان في المزرعة التعليمية بكلية الزراعة – جامعة المنيا – مصر – خلال موسمين زراعيين متتاليين 2016/2015، 2017/2016 تحت ظروف الري والجفاف. حيث تم تقييم 93 تركيب وراثى من قمح الخبز لتقدير الصفات الفسيولوجية المرتبطة بالإجهاد المائى. وأدلة تحمل الإجهاد المائى وتحديد التراكيب الوراثية الأكثر تحملاً للجفاف، وأظهرت نتائج التحليل المشترك وجود اختلافات معنوية بين البيئات والتراكيب الوراثية والسنوات والتفاعل بين البيئات والتراكيب الوراثية والتفاعل بين السنوات والتراكيب الوراثية لكل الصفات تحت الدراسة. وتحت ظروف الري كان هناك ثلاثة تراكيب وراثية أرقام 39، 42، 68 عالية معنوياً عن الأب الأفضل في صفات قوة حفظ الأوراق المقطوعة للماء ومحصول الحبوب. وتحت ظروف الجفاف تجاوزت التراكيب الوراثية أرقام 13، 42، 246 الأب الأفضل في صفات المحتوى المائي النسبي والمحتوى المائي للورقة والوزن النوعي للورقة ومحصول الحبوب. وتحت ظروف الرى العادى أظهر المحتوى المائى النسبى ارتباط سالب عالى المعنوية مع الماء المفقود من الورقة (0.86-) ومع مساحة الورقة (0.36-) وارتباط موجب معنوى مع محصول الحبوب، بينما تحت ظروف الجفاف أظهرت صفة قوة حفظ الأوراق المقطوعة للماء أرتباط سالب عالي المعنوية مع صفة الماء المفقود من الورقة (0.85-) وارتباط سالب معنوي مع كلاً من مساحة الورقة (0.25-) ومحصول الحبوب. كما أوضحت طريقة ترتيب التراكيب الوراثية أن التراكيب أرقام 13، 296، 379 كانت هي الأكثر تحملاً للجفاف بينما التراكيب أرقام 1، 74، 95، 129كانت الأكثر حساسية لظروف الجفاف.