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Evaluation of some Wheat Genotypes under Water Stress Conditions in Upper Egypt

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ABSTRACT

Response of eighteen Egyptian wheat genotypes to both full irrigation (100%ETc) and deficit irrigation (60%ETc) were evaluated to identify water stress effects on yield and yield components. The field experiments were conducted in Assuit Research Station, Assuit Governorate, Egypt, during 2013/14 and 2014/15 winter growing seasons. Five stress tolerance indices were assessed, namely Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Tolerance (TOL), Stress Susceptibility Index (SSI) and Stress Tolerance Index (STI) to evaluate the response of the tested 18 wheat genotypes to imposed water stress. In addition, water productivity (WP), water consumptive use (WCU) and water use efficiency (WUE) for the studied genotypes were considered. The experimental design was stripe block design, where the irrigation treatments were in the main plots and genotypes were allocated in the sub plots. The obtained results indicate that all the evaluated characteristics responded significantly to the adopted irrigation treatments, genotypes and their interactions. The means of all genotypes significantly decreased for most characters in the two growing seasons under deficit irrigation. Based on drought indices MP, GMP, STI, Line 5 was identified as the suitable genotype under water stress conditions due to lower values for TOL and SSI indices. Total applied irrigation amount was 2722 m3fed-1 under full irrigation condition, and 1633 m3fed-1 under stress conditions, and the corresponding WCU values were 2042 and 1225 m3fed-1, respectively. WUE values exhibited a reverse trend, where higher values were recorded for deficit irrigation condition. It is evident that genotype 5 is potentially water use efficient. Furthermore, under full and deficit irrigation, genotype 5 expressed the highest yield and WP surpassing the commercial varieties. So, such genotype is more suitable for full irrigation and water stress conditions compared with other tested genotypes as well as possessing high values for MP, GMP, STI and expressed low values for SSI and TOL indices.

Keywords: Wheat genotypes, Water stress, Drought indices, Water productivity and Water Use Efficiency.

INTRODUCTION

Efficient water utilization for wheat production is of prime importance in order to reduce the gap between production and consumption and to conserve the available water resources as well. Limited water resources in Egypt are the major factor facing expansion of wheat growing areas. Additionally, climate changes are expected to increase risks of drought. Thus, breeding drought tolerance crops is vital to both mild and severe stress conditions. This implies a need for better characterization of crop biodiversity in order to understand their response to drought, and to develop better information on the physiological mechanisms crucial to increase production (Almeselmani *et al*., 2015).

Increasing wheat grain yield is correlated to the increase in yield components values, such as number of spikes m^{-2}, kernel weight and number of kernels spike-1. Number of kernels spike-1 is the most affected yield component with water stress and it has been proposed as an important selection criterion for drought tolerance (Shpiler and Blum 1991). Menshawey *et al*., (2006) found that number of kernels spike-1 is more drought sensitive compared with number of spikes per square meter. Moreover, Zafarnaderi *et al*. (2013) reported that path analysis indicated that number of grains spike-1, 1000-grain weight, number of fertile tillers and peduncle length were the most effective components on grain yield. Therefore, these traits could be used as important indices for selecting high yielding bread wheat genotypes. Moisture stress is known to reduce biomass, tillering ability, grains per spike and grain size at any stage when it occurs. So, the overall effect of moisture stress depends on intensity and length of stress (Bukhat, 2005). Water stress imposed during later stages might additionally cause a reduction in number of kernels ear-1 and kernel weight (Gupta *et al*., 2001). Moreover, Zareian and Hamidi (2014) reported that water stress through withholding irrigation at the ear emergence and grain filling phases reduced grain yield and its components. Esmail *et al*., (2016) evaluated 25 bread wheat genotypes under deficit water conditions and they found highly significant differences among the genotypes for all characters indicating the presence of considerable variability among them. Water stress not only affects the morphology but also severely affects the metabolism of the plant. The extent of modification depends upon the cultivar, growth stage, duration and intensity of stress (Mark and Antony 2005).

Selecting wheat cultivars based on their yield performance under drought conditions is a common approach, therefore, some drought stress indices or selection criteria have been suggested by different researches (Talebi *et al*., 2009 and Pireivatlou *et al*., 2010). This is because losses of yield are the main concern of plant breeders and they emphasis on yield performance under water stress conditions (Nazari and Pakinyat, 2010). Sio-Semardeh *et al*., (2006) used drought tolerant indices in wheat and found that under moderate stress, mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI) were more effective in identifying high yielding cultivars in both drought-stressed and irrigated conditions. Under severe stress, none of the indices used were able to identify high yielding cultivars group. Guttieri *et al*., (2001) used stress susceptibility index (SSI) criterion suggested that SSI value more than1.0 indicating above-average susceptibility and SSI value less than 1.0 indicated below-average susceptibility to drought stress. Singh *et al*., (2009) found that, grain yield and yield components of wheat were decreased with decreasing irrigation water amounts. Several studies reported that water use efficiency (WUE) values were higher under water deficit than high irrigation condition, especially when irrigation is applied in the critical growth stages of plant (Mandal *et al*., 2005). Haikel and El-Melegy, (2005) concluded that maximum grain yield and minimum water use efficiency of wheat was recorded by irrigation with recommended requirements under sandy soils conditions and sprinkler irrigation system. Water use efficiency (WUE) generally decreased linearly with increasing seasonal irrigation rates (Wang *et al*., 2012).

The objective of this study was a field evaluation of eighteen wheat genotypes under full irrigation and water stress to identify high-yielding genotypes under drought stress, with higher water use efficiency in order to utilize the Egypt's limited water resources efficiently.

MATERIALS AND METHODS

The present investigation was conducted at the experimental farm of Arab El-Awammer, Agriculture Research Center, Assuit Governorate, Egypt (latitude 27°, 11′ N and longitude 31°, 06′ E), during the two successive winter seasons of 2013/14 and 2014/15. Some chemical and soil – water constants of the experimental soil are presented in Table 1. In addition, soil particle size distribution, hydraulic conductivity, Organic matter and CaCO3 contents are shown in Table 2. Thirteen genotypes and five wheat cultivars were evaluated to drought tolerance under sprinkler irrigation system in sandy calcareous soil. Table 3 presents pedigree of the thirteen genotypes and five wheat cultivars used in the present study.

Table 1. Some soil chemical properties of the experimental site before cultivation

Soil depth (cm)	PH	EC dSm-1	Soluble cations (meq L-1)				Soluble anions (meq L-1)		Available P (ppm)	Total nitrogen (%)
			Ca++	Mg++	Na+	K+	CO3--+HCO3-	Cl-		
00-15	8.1	0.42	2.2	1.4	0.29	0.96	2.25	2.60	8.32	0.005
15-30	8.5	0.39	1.5	1.5	0.19	0.95	1.90	1.80	8.32	0.004
30-45	8.6	0.26	1.1	0.89	0.14	0.61	1.42	1.20	8.30	0.002
45-60	8.3	0.24	1.0	0.82	0.13	0.47	1.15	0.90	8.28	0.001
Mean	8.4	0.33	1.4	1.16	0.19	0.75	1.68	1.5	8.31	0.003

Soil depth (cm)	Moisture content (Volumetric %)			
	Saturation percentage	Field capacity	Wilting point	Available water
00 -15	25.2	12.5	4.9	7.6
15 -30	23.3	10.0	4.2	5.8
30 -45	21.7	9.50	4.0	5.6
45 -60	23.0	11.8	4.9	6.9
Mean	23.3	10.9	4.5	6.5

Table 2. Soil particle size distribution, hydraulic conductivity, organic matter and CaCO3 content before cultivation

Soil depth (cm)	Gravely (%)	Particle size distribution (%)			Textural class	Organic matter (%)	CaCO3 (%)	H.C (cm/h)
		Sand	Silt	Clay				
00-15	34.5	90.0	6.7	2.9		0.27	32.2	71.2
15-30	30.2	90.2	6.8	3.0		0.21	33.8	60.4
30-45	46.6	89.4	7.4	3.2	Sandy	0.17	25.4	46.8
45-60	46.3	89.0	7.5	3.5	calcareous	0.11	32.0	73.9
Mean	39.4	89.9	7.1	3.0		0.19	30.9	63.1

Table 3. Pedigree of the thirteen genotypes used in the study a long with the five commercial cultivars

No	Genotypes	Pedigree	Origin
1	Line1	Gemmeiza3* HD 2501	Egypt *India
2	Line2	Gemmeiza3* HD 2501	Egypt *India
3	Line3	Gemmeiza3* HD 2501	Egypt *India
4	Line4	Gemmeiza3* HD 2501	Egypt *India
5	Line5	Gemmeiza3* HD 2501	Egypt *India
6	Line6	Bb/7C*2//Y50E/Kal*3//SKh8/4/Prv/ww/5/3/BJ"S"//on*3/Bon	Egypt
7	Line7	HD2501	India
8	Line8	Vorona/Cno79*Sids 6	Mexico* Egypt
9	Line9	Vorona/Cno79*Sids 6	Mexico* Egypt
10	Line10	Vorona/Cno79*Sids 6	Mexico* Egypt
11	Line11	Vorona/Cno79*Sids 6	Mexico* Egypt
12	Line12	Vorona/Cno79*Sids 6	Mexico* Egypt
13	Line13	Vorona/Cno79	Mexico
14	Sids-6		Egypt
15	Shandaweel-1	STTE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC.	Egypt
16	Sahel-1		Egypt
17	Sakha 93	Sakha92/ TR 810328 S8871-1S-2S-1S-0S	Egypt
18	Sids-1	HD2172/Pavon "S"// 1158.58//Maya 74 "S" Sd 46-4Sd-2Sd-1Sd-0Sd	Egypt

Planting dates were on the 29th November and 8th December during 2013/2014 and 2014/2015 growing seasons, respectively. The soil was plowed to provide a satisfactory seed bed for planting. Calcium super phosphate (15.5%P2O5) was incorporated into the surface soil during land preparation at the rate of 200 kg fed-1. The plot area was 4.2 m2 and consisted of six wheat rows 20 cm in between and 3.5 m in length. Wheat seeds at the rate of 50 g plot-1 were hand drilled. Nitrogen fertilizer was added at the rate of 120 kgfed-1 in the form of ammonium nitrate (33.5%N) at five equal doses after planting. Other cultural practices were done as recommended for wheat production in newly reclaimed land. Number of days to heading and number of days to maturity were calculated during the growing season. Harvesting was done after 148 days and 141 days from sowing in 1st and 2nd growing seasons, respectively. Grain yield and its components namely plant height (cm), number of tillers/m2 were recorded and number of kernels spike-1 were estimated as the average of ten spikes taken randomly, 1000-kernel weight (g) was recorded as the average of two random samples of clean grains, biological yield/plot (kg) was estimated as total of above ground plants, and grain yield/plot (kg) was estimated. Both biological and grain yields were converted into ton fed-1.

Evapotranspiration (ETo) as estimated by CropWat model (Smith, 1991) and weather data for the experimental site during the two growing seasons are presented in Table 4.

Table 4. Monthly average of meteorological data during 2013/2014 and 2014/2015 winter growing seasons

Month	Temperature (oC) Max.	Temperature (oC) Min.	Relative humidity (%)	Wind speed (kmday-1)	Sunshine (hours)	ETo (mm)
			2013/2014			
November	27.5	12.1	49.3	208.8	9.4	4.1
December	23.2	8.10	52.3	254.4	9.0	3.6
January	22.0	6.20	47.5	211.2	8.9	3.3
February	23.6	7.10	37.5	259.2	9.7	4.6
March	25.0	9.20	37.2	362.4	9.9	6.0
April	32.1	15.5	30.5	343.2	10.3	6.5
			2014/2015			
December	23.2	7.90	54.9	208.0	9.0	3.2
January	24.0	7.70	49.4	255.4	8.9	3.8
February	26.9	10.5	39.6	318.0	9.7	5.5
March	29.4	13.3	40.0	358.0	9.9	6.7
April	32.8	16.5	32.0	296.0	10.3	7.9

The sprinkler irrigation system was fixed in square spacing pattern (12 m X 12m). The rotating sprinkler height was 1.0 m above the ground with flow rate of 1.2-1.4 m3/hour at 2-3 bars. The adopted irrigation treatments were:

full irrigation (FI) =100%ETc and

deficit irrigation (DI) = 60%ETc

The treatments were assessed in Strip Block Design with three replicates. The actual crop evapotranspiration (ETc) was estimated as follows:

ETc = Kc x ETo where:

ETc = actual crop evapotranspiration rate

Kc = crop coefficient

ETo = evapotranspiration rate for a grass reference crop

The used Kc values were 0.35, 0.75, 1.13 and 0.75 for initial, crop development, mid- season and late–season growth stages, respectively, (FAO 1984). The amounts of actual applied irrigation water requirement under each irrigation treatment were determined according to James (1988) using the following equation:

$$I.Ra = \frac{ETc + Lf}{Er}$$

Where:

I.Ra= Total irrigation water applied in 3- days interval, mm

ETc= Actual evapotranspiration, mm

Lf = leaching factor 10%

Er = irrigation system efficiency (86%).

Drought indices

The Drought tolerance indices vis. Mean Productivity, Geometric Mean Productivity, Stress Tolerance, Stress Susceptibility Index and Stress Tolerance Index were considered in the present investigation in order to verify the performance of the assessed wheat genotypes under the tested DI irrigation regime. Drought tolerance indices were calculated by the following formulae (Table 5).

Table 5. Drought tolerance indices

Index	Formula*	Reference
Mean Productivity	MP = (Yp + Ys) / 2	Hossain *et al* (1990)
Geometric Mean Productivity	GMP = (Yp x Ys) 0.5	Fernandez (1992)
Stress Tolerance	TOL = Yp – Ys	Hossain *et al* (1990)
Stress Susceptibility Index	SSI = [1-(Ys/ Yp)] / [1- (Ȳs/ Ȳp)]	Fischer and Maurer (1978)
Stress Tolerance Index	STI = (Yp + Ys)/ (Ȳp)2	Fernandez (1992)

***Yp, Ys are means grain yield of the same cultivar under potential irrigation (P) and stress irrigation (S) treatments, respectively. Where Ȳp and Ȳs are means of yield of all genotypes under P and Y under stress, respectively.**

Crop-water relations

Water productivity (WP)

Water productivity was estimated as crop yield per cubic meter of applied water according to (Ali *et al.* 2007) as follows:

WP = GY/ AW

Where:

WP= water productivity (kg grains m-3);

GY= grain yield (kgfed-1) …. and

AW= applied water throughout the growing season (m3fed-1).

Water use efficiency (WUE)

Water Use Efficiency (WUE) of Grain yields (WUEGY) was calculated as outlined by Hamed *et al*., (2015) as follows:

WUE = GY / WC

Where:

WUE is the water use efficiency (kg m-3), GY is the grain yield (kgfed-1) and WC is the total water consumption over the whole growing season (m3fed-1).

Water consumptive use efficiency (ECU %)

The consumptive use efficiency (Ecu) was calculated as described by Doornbos and Pruit (1975) as follows:

ECU= (ETc/Wa) X 100

Where:

Ecu= Consumptive use efficiency (%)

ETc= Total evapotranspiration' consumptive use (m3fed-1)

Wa= Seasonal water applied (m3fed-1).

Statistical analysis

All data were statistically analyzed according to the technique of analysis of variance (ANOVA) procedures for strip-plot design as published by Gomez and Gomez (1984). Means of the treatment were compared by the least significant difference (LSD) at 5% level of significance as developed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

1-Analysis of variance

The combined analysis of variance in Table 6 revealed highly significant differences between genotypes, under irrigation treatments, and years for all studied traits. This suggests the importance of the assessment of genotypes under deficit irrigation in order to identify the best genetic makeup under deficit irrigation. Similar results were obtained by Tawfelis (2006). The mean square of irrigation treatments explained most of the total variations for all characters in both growing season. Significant variations were detected due to interactions between genotypes and irrigation treatments for all characters. The variations due to genotypes were higher than those of interactions between genotypes and irrigation treatments. The significance of genotypes' variance for all characters under all conditions reflects the presence of sufficient genetic variability between these genotypes and provides the basis for genetic gain (Rajaram *et al*., 1994). Moreover, the significance of the interactions is a result of the different abilities of genotypes to adjust their characters to the irrigation regime and seasons, suggesting the importance of genotypes assessment under different irrigation treatments to identify the best ones for deficit irrigation.

Table 6. Means squares of the combined analysis of variance for the studied characters over all irrigation treatments and genotypes

S.O.V	D.F	Days to heading	Days to maturity	Plant height (cm)	plants No m-2	spikes No m-2	1000-Kernel weight (g)	Biological yield (tonfed-1)	Grain yield (tonfed-1)
Replications	2	54.3	42.4	83.4	448.1	5.056	44.268	2.08	0.019
G	17	248.3**	106.6**	226.1**	3332.1**	339.3**	73.981**	0.894**	0.240**
Rep./G (Error a)	34	11.2	10.9	26.7	271.7	11.3	11.142	0.162	0.012
I	1	504.2**	68.9**	7004.2**	122027.6**	1446.7**	11.718 ns	14.519**	9.028**
G x I	17	22.1**	13.4 ns	63.2**	1797.97**	187.1**	42.201**	0.832**	0.069**
Y	1	2802.2**	18629.8**	12000.5**	307360.7**	0.227 ns	1968.4**	10.756**	20.758**
G x Y	17	55.5**	22.6**	85.0**	1929.8**	362.96**	41.89**	0.846**	0.213**
I xY	1	284.7**	342.5**	600.0**	136.96 ns	94.7*	29.771	8.801**	4.629**
G x I x Y	17	8.6**	15.6 ns	61.5 ns	1277.4**	258.7**	41.771**	0.525**	0.058**
(Error b)	108	10.4**	9.1 ns	31.4 ns	260.91 ns	15.6 ns	8.228 ns	0.231**	0.012 ns

G= Genotypes; I= irrigation treatments; Y= year; NS =Non- significant, *= significant and ** = highly significant at 0.05 and 0.01 levels of probability respectively.

2-Mean performance

Data in Table 7 illustrate that the means of all wheat genotypes were decreased significantly under DI for all studied characters in the two seasons. Line4 and Line6 exhibited the earliest genotypes for days to heading, which comprised 80 and 80 days under FI, respectively, in 1st season and 71 and 71 days in 2nd season. Under DI, the same lines (Line4 and Line6) still exhibited the earliest values of days to heading e.g. 76 and 74 days in 1st season, and 73 and 71 days in 2nd season, respectively. Additionally, Line4 and Line6 possessed the shortest days to maturity values under either FI or DI in 1st and 2nd seasons. Days to maturity under FI were 125 and 126 days for Line 4 and Line 6 in 1st season and 103 and 103 days in 2nd season. The corresponding days to maturity under DI were 126 and 126 days in 1st season and 107 and 105 days in 2season, respectively, in the same order of wheat lines. The genotypes Line5, Shandaweel-1 were the latest genotypes for days to heading, with values reached to 96 and 97 days under FI in 1st season and 83 and87 days in 2nd season. With DI, line11 exhibited the longest value of days to heading e.g.94 days in 1st season, 83 days in 2nd season.

Respecting days to maturity trait, Line5 still exhibiting higher values under FI amounted to140 and 114 days, respectively, in 1st and 2nd seasons. Under DI, Line13 possessed higher days to maturity value (129 days) in 1st season, whereas both Shandaweel-1 and Sahel-1 genotypes exhibited higher values (115 and 115 days) in 2nd season, respectively. These findings could be used as a source of earliness in breeding program. Data in Table 7 indicate significant differences among genotypes for plant height and numbers of tillersm-2. Under FI, Line 11 exhibited the highest value of plant height reached to 93 cm in 1st season, whereas Line8 and Line11 possessed higher values comprised 75 and 75 cm in 2nd season. Sakha93 and Sids-1 genotypes possessed lower plant height values under FI in 1st season amounted to 60 and 65 cm, respectively. In 2nd season, Shandaweel-1 genotype possessed the lowest value of plant height that comprised 55 cm. Under DI, the highest plant height value i.e. 82 cm was recorded for Shandaweel-1 in 1st season, whereas in 2nd season the highest value (67 cm) was recorded for Line11 genotype. Regarding tillers No m-2 trait, under FI higher values e.g. 217 and 317 were attained by Line5 and Line6 in 1st and 2nd seasons, respectively. Under DI higher tillers No m-2 values i.e. 186 and 275 were observed with Line2 and Line3, respectively, in 1st and 2nd seasons. In this sense, Esmail *et al*., (2016) evaluated 25 bread wheat genotypes under deficit water conditions and found highly significant differences among the genotypes for all characters indicating presence of considerable variability among them.

Table 7. Effect of full and deficit irrigation on days to heading and days to maturity, plant height and number of tillers m-2of wheat genotypes in both growing seasons

Genotypes	Days to heading				Days to maturity				Plant height (cm)				tillers No m-2			
	1st season		2nd season		1st season		2nd season		1st season		2nd season		1st season		2nd season	
	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI
Line1	94	86	83	81	136	128	114	112	90	80	72	57	200	174	294	226
Line 2	92	85	81	77	133	125	111	113	85	58	60	58	211	186	297	264
Line 3	94	89	79	73	129	128	113	111	87	70	68	55	150	155	292	275
Line 4	80	76	71	73	125	126	103	107	90	67	65	60	184	146	288	213
Line 5	96	89	83	81	140	134	114	116	77	70	68	62	217	178	220	240
Line 6	80	74	71	71	126	126	103	105	93	75	58	63	213	109	317	199
Line 7	82	77	75	70	127	126	105	102	83	63	63	60	214	151	288	237
Line 8	82	85	79	82	128	128	114	111	92	68	75	55	191	136	249	263
Line 9	88	75	75	74	131	122	108	111	85	67	65	58	204	134	293	244
Line10	84	81	78	79	134	126	111	113	88	75	70	63	190	112	236	192
Line 11	91	94	81	83	135	134	112	113	97	78	75	67	193	137	253	222
Line 12	85	75	79	78	127	127	110	114	85	75	72	62	162	149	249	207
Line 13	88	82	82	83	130	129	112	113	87	68	78	63	150	146	280	185
Sids-6	86	79	84	84	130	127	112	114	90	78	73	58	186	133	244	189
Shandaweel-1	97	90	87	86	132	128	114	115	82	82	55	53	212	161	287	243
Sahel-1	96	90	82	82	137	130	111	115	82	75	68	60	174	111	273	188
Sakha93	92	88	77	77	131	129	108	112	70	60	58	52	214	153	213	197
Sids-1	92	86	80	80	135	126	112	114	78	65	67	60	210	118	228	191
Mean	89	83	79	79	131	128	110	112	86	71	67	59	193	144	267	221
F test																
C.V%	3.9				2.5				7.9				7.8			
A	***				***				***				***			
B	***				***				***				***			
A x B	**				NS				*				***			
C	***				***				***				***			
A x C	***				***				***				***			
B x C	***				***				***				***			
Ax B x C	***				NS				NS				***			

Genotypes (A); Irrigation treatments (B); Year (C); full irrigation (FI); deficit irrigation(DI)

Data in Table 8 Show significant increase in kernel No spikes-1 under full irrigation compared with deficit irrigation. It is worth to indicate that genotype Sids-6 surpassed the control checks, and exhibited the highest values of kernel No spikes-1 under FI reached to 73 and 59, respectively, in 1st and 2nd seasons. Under DI the highest kernel No spikes-1 e.g. 64 and 50 were recorded for Line10 and Line2, respectively, in 1st and 2nd seasons. These results agreed with the findings of Zhong-hu and Rajaram (1994), who found that kernel No spikes-1 is more drought sensitive trait compared with number of spike m-2.

Regarding 1000-kernel weight, the adopted irrigation treatments had significant effects on this character in both seasons (Table 8). Generally, 1000-kernel weight was adversely affected under deficit irrigation, where the highest 1000-kernel weight i.e. 44.3 and 43.1 g were found for line10 and line3 under FI, respectively, in 1st and 2nd seasons. Under deficit irrigation Line 3 and Line6 exhibited higher values of 1000-kernel weight comprised 41.9 and 34.6 g, respectively, in 1st 2nd seasons. The notable decreases in 1000-kernel weight under deficit irrigation for all wheat genotypes under study may be due to male sterility caused by drought stress (Saini and Aspinal 1981). The interaction effect between genotypes and irrigation treatments on 1000- kernel weight was highly significant in both growing season. Table 8 show that Line10 genotype exhibited good performance in 1000-kernel weight under both full irrigation (44.3 and 41.7 g) and deficit irrigation (35.7 and 32.5 g) in both growing seasons, respectively, which can be used as a source for breeding objectives.

Line1 exhibited higher biological yield values either with FI or DI, where under FI the values were 4.11 and 2.21 ton fed-1 and reached to 3.45 and 1.59 ton fed-1 under DI, respectively, in 1st and 2nd seasons. As for grain yield under FI, data reveal that the highest figures e.g. 2.75 and 0.60 ton fed-1 resulted from Line13 and line11, respectively, in 1st and 2nd seasons. Line5 exhibited the highest value of grain yield amounted to 2.44 ton fed-1 in 1st season, whereas in 2nd season, the highest value i.e. 0.48 tonfed-1 was recorded for Line10 genotype.

It is clear that values of grain yield in 1st season were higher than those obtained in 2nd one, and such finding was true under full and deficit irrigation treatments. The increases in grain yield in 1st season under FI and DI, over the genotypes average, were180 and 75%, respectively, comparable with those recorded in 2nd season. Such grain yield reduction in 2nd season could be attributed to late sowing date. In addition, higher temperature and wind speed values which were prevailing in January through April (Table 4) might be responsible for reducing the grain yield. In this sense, Ahmed *et al*., (1994) stated that high temperature in the post an-thesis period of late sown wheat shortened the grain filling period resulting in a smaller endosperm and lower grain weight. Additionally, Singh and Dhaliwal (2000) reported that high temperature and desiccating winds might cause forced maturity of late sown wheat, thus resulting in reduction of test weight.

Table 8. Effect of full and deficit irrigation on kernels No spikes-1, 1000-kernel weight, biological and grain yields in the two g rowing seasons

Genotypes	Kernels No spikes-1				1000-kernel weight (g)				Biological yield (tonfed-1)				Grain yield (tonfed-1)			
	1st season		2nd season		1st season		2nd season		1st season		2nd season		1st season		2nd season	
	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI
Line1	53	36	45	44	40.9	39.3	38.4	33.7	4.11	3.45	2.21	1.59	2.07	1.96	0.45	0.41
Line 2	36	36	50	50	44.2	41.4	34.0	25.7	3.41	2.80	1.80	0.99	2.12	2.10	0.46	0.38
Line 3	65	45	44	43	42.5	41.9	37.1	31.4	2.84	2.23	1.23	0.65	1.91	1.84	0.45	0.39
Line 4	42	32	53	44	42.7	35.4	33.6	31.6	3.17	2.21	1.39	0.75	2.43	1.83	0.56	0.40
Line 5	53	50	50	42	41.9	32.5	31.3	30.4	3.17	2.33	1.08	0.73	2.62	2.44	0.56	0.46
Line 6	34	26	58	35	37.3	33.2	35.6	34.6	2.43	1.77	1.16	0.6 1	1.87	1.54	0.37	0.37
Line 7	56	58	45	39	42.5	40.9	33.7	30.9	3.08	1.77	1.46	0.73	2.57	1.80	0.46	0.37
Line 8	54	33	46	44	41.8	40.6	43.1	30.9	3.92	1.40	1.40	0.56	2.24	1.79	0.56	0.41
Line 9	41	36	56	42	38.0	35.6	32.7	28.8	2.89	1.59	1.34	0.56	2.15	2.12	0.55	0.27
Line10	71	64	50	41	44.3	41.7	35.7	32.5	3.92	1.77	1.92	0.61	2.10	2.01	0.51	0.48
Line 11	70	36	48	47	41.3	36.7	35.5	29.3	3.27	1.60	1.79	0.70	2.43	2.38	0.60	0.41
Line 12	57	28	44	43	42.1	40.9	32.7	30.8	2.43	1.87	0.96	0.54	2.41	2.29	0.51	0.34
Line 13	51	40	49	47	40.9	40.8	36.3	33.7	2.80	2.07	1.40	0.45	2.75	2.12	0.47	0.39
Sids-6	73	44	59	40	43.9	34.6	30.9	24.7	2.43	1.63	1.23	0.55	2.40	1.96	0.46	0.29
Shandaweel-1	59	44	50	40	32.0	28.7	34.5	28.0	3.55	2.99	1.17	1.13	2.17	1.68	0.42	0.37
Sahel-1	43	38	42	38	32.8	29.8	31.0	29.7	2.43	1.67	1.25	0.51	1.73	1.54	0.42	0.35
Sakha93	36	38	41	32	41.1	34.9	35.2	33.2	3.17	1.31	1.39	0.56	1.82	1.73	0.50	0.35
Sids-1	34	25	48	47	42.3	29.1	32.4	29.6	2.89	1.21	1.12	0.45	2.29	2.10	0.48	0.29
Mean	49	42	47	44	39.2	38.0	32.7	32.4	3.00	2.100	2.20	2..00	1.40	0.70	0.50	0.40
F test																
C.V%	8.7				8.1				20.7				14.4			
A	***				***				***				***			
B	***				NS				***				***			
AXB	***				***				***				***			
C	***				***				***				***			
AXC	***				***				***				***			
BXC	**				NS				***				***			
AXBXC	***				***				**				***			

Genotypes (A); Irrigation treatments (B); Year (C); full irrigation (FI); deficit irrigation (DI).

3-Drought indices

Data in Table 9 reveal that the highest value of mean productivity (MP) was found with Line 5 genotype which had the highest yield under both normal and stress conditions, whereas the lowest value of MP (1.64) was recorded for Sahel-1 in 1st season and for Sids-6 in 2nd season that comprised 0.37. Even though for identification of high yielding and drought tolerant lines, the MP index was more favorable as reported by Ahmadzadeh (1990). However, Shirazi *et al*. (2009) stated that high yield in non-stress condition led the MP index to increase and cannot be a valid indicator to identify the tolerant genotypes. Regarding to GMP, similar trend to that of MP was indicated, where the highest value of GMP was recorded for Line 5 genotype, which reached to 2.53 and 0.51 in 1st and 2nd seasons, respectively. Sahel-1 genotype in 1st season, and both Sids-1, Sids-6 and Line 6 genotypes in 2nd season exhibited lower values of GMP, which comprised 0.37, 0.37 and 0.37, respectively.

Table 9. Drought tolerance indices of 18 wheat genotypes based on grain yield

Genotypes (G)	Grain yield (tonfed-1)													
	1st season							2nd season						
	(Yp)	(Ys)	MP	GMP	TOL	SSI	STI	(Yp)	(Ys)	MP	GMP	TOL	SSI	STI
Line1	2.07	1.96	2.02	2.01	0.11	0.44	0.81	0.45	0.41	0.43	0.43	0.04	0.36	3.58
Line 2	2.12	2.1	2.11	2.11	0.02	0.08	0.85	0.46	0.38	0.42	0.42	0.08	0.71	3.50
Line 3	1.91	1.84	1.88	1.87	0.07	0.30	0.76	0.45	0.39	0.42	0.42	0.06	0.54	3.50
Line 4	2.43	1.83	2.13	2.11	0.60	2.04	0.86	0.56	0.40	0.48	0.47	0.16	1.17	4.00
Line 5	2.62	2.44	2.53	2.53	0.18	0.57	1.02	0.56	0.46	0.51	0.51	0.10	0.73	4.25
Line 6	1.87	1.54	1.71	1.70	0.33	1.46	0.69	0.37	0.37	0.37	0.37	0.00	0.00	3.08
Line 7	2.57	1.80	2.19	2.15	0.77	2.48	0.88	0.46	0.37	0.42	0.41	0.09	0.80	3.46
Line 8	2.24	1.79	2.02	2.00	0.45	1.66	0.81	0.56	0.41	0.49	0.48	0.15	1.09	4.04
Line 9	2.15	2.12	2.14	2.13	0.03	0.12	0.86	0.55	0.27	0.41	0.39	0.28	2.08	3.42
Line10	2.1	2.01	2.06	2.05	0.09	0.35	0.83	0.51	0.48	0.50	0.49	0.03	0.24	4.12
Line 11	2.43	2.38	2.41	2.40	0.05	0.17	0.97	0.60	0.41	0.51	0.50	0.19	1.29	4.21
Line 12	2.41	2.29	2.35	2.35	0.12	0.41	0.95	0.51	0.34	0.43	0.42	0.17	1.36	3.54
Line 13	2.75	2.12	2.44	2.41	0.63	1.89	0.98	0.47	0.39	0.43	0.43	0.08	0.70	3.58
Sids-6	2.4	1.96	2.18	2.17	0.44	1.52	0.87	0.46	0.29	0.38	0.37	0.17	1.51	3.12
Shandaweel-1	2.17	1.68	1.93	1.91	0.49	1.87	0.78	0.42	0.37	0.40	0.39	0.05	0.49	3.29
Sahel-1	1.73	1.54	1.64	1.63	0.19	0.91	0.66	0.42	0.35	0.39	0.38	0.07	0.68	3.21
Sakha93	1.82	1.73	1.78	1.77	0.09	0.41	0.72	0.50	0.35	0.43	0.42	0.15	1.23	3.54
Sids-1	2.29	2.1	2.20	2.19	0.19	0.69	0.89	0.48	0.29	0.39	0.37	0.19	1.62	3.21
Sum	40.1	35.2	37.7	37.6	4.86	17.35	15.2	8.8	6.7	7.8	7.7	2.1	0.0	64.6
Mean	2.23	1.96	2.09	2.08	0.27	0.96	0.84	0.49	0.37	0.43	0.43	0.11	0.42	3.59

(G) =Genotypes; (Yp) = Grain yield (tonfed-1) under optimal irrigation100%ETo; (Ys) = Grain yield (tonfed-1) under deficit irrigation 60%ETo; (MP)= Mean Productivity; (GMP)= Geometric Mean Productivity; (TOL) =Stress Tolerance; (SSI)= Stress Susceptibility Index and = (STI) Stress Tolerance Index.

Regarding TOL index, the higher value of this index referrers to more sensitive genotypes to drought stress. Zangi, (2005) indicated that the low value of Ys or high value of Yp leads to an increase in TOL value, therefore, genotypes with high TOL have higher sensitivity to drought stress. So, genotypes with lower value of TOL are favored for selection. Results in Table 9 show that Line 2 and Line 6 in 1st season gave lower values of TOL, which comprised 0.02 and 0.00 in 1st and 2nd seasons, respectively. So, such lines could be recognized as the best genotypes based TOL index. Nevertheless, Sio-Semardeh *et al*., (2006) and Dorostkar *et al*., 2014 TOL failed to recognize the best genotypes, because this parameter would tend to select for low-yielding genotypes which, consequently, means that TOL by itself is not a good index to screen drought tolerant genotypes.

Genotypes with low SSI values were considered as stress tolerant, because such genotypes showed a lower reduction in grain yield under drought stress compared to non-stress condition. SSI has been widely used by researchers to identify sensitive and resistant genotypes (Winter *et al*., 1988). In this concern, Guttieri *et al*., (2001) indicated that SSI >1 refers to above-average susceptibility, while SSI <1 indicates below-average susceptibility to drought stress. In respect in the current study, the lowest value of SSI belonged to line 2 and line 6 the 1st season and 2nd season respectively, whereas genotype 7 and line 9 had the highest SSI in 1st season and 2nd season respectively (Table 9). SSI appeared to be a suitable selection index to distinguish drought -resistant genotypes. STI was more useful index to select the proper cultivars under drought stress and full irrigation conditions as stated by Moghaddam and Hadizadeh (2002). Genotypes had high values of STI showed high MP and GMP indices but lower values of SSI and TOL. Results in Table 9 show that line 5 had the highest value for STI, MP and GMP being 1.02, 2.53, and 2.53, respectively in the 1st season and comparable values in 2nd season were 4.25, 0.51 and 0.51, respectively. It's interesting that genotypes 5 surpassed in performance to water deficit conditions the commercials cultivars Sids-6, Shandweel-1, Sahel-1 Sakha93 and Sids-1.

4-Water relationships

Applied irrigation water (AW) and water consumptive use (WCU)

Data in Table 10 illustrated that the highest values of seasonal water applied were observed at mid-season growth stage, and amounted to 61.5 and 63.9% out of total applied water, respectively, under full and deficit irrigation regimes. Such growing stage is matching higher crop water requirement due to higher growth rate and higher evaporative demands as well. The maximum crop water need is reached at the end of the crop development stage which is the beginning of the mid-season stage that extended to the beginning of late-season stage (FAO, Irrigation Water Management, Training manual No. 3, 1986).

Applied irrigation water, regardless the assessed wheat genotypes, under non-stressed treatment was averaged higher value e.g. 2722 m3fed-1, compared with stressed one 1634 m3fed-1 (Table 10). In this respect, Sallam (2014) studied the effect of DI and RDI (Regular Deficit Irrigation) techniques on the productivity of wheat crop in sandy soils, and found that the amounts of applied water (based on class A pan records) were 6534 and 5151 m3/ha with full and 75% ETc irrigation regimes, respectively. Likely, the present data indicate that WCU values exhibited similar trend, where higher average figures e.g. 2042 m3fed-1 was attained with full irrigation, whereas with deficit irrigation the value was reduced and being 1225 m3fed-1. In this sense, Bukhat (2005) stated that, exposing wheat crop to water stress depresses seasonal consumptive use.

Table 10. Applied water and water consumptive use under full and deficit irrigation at different wheat growth stages during both growing seasons

Growth stages	AW (m3fed-1)						WCU (m3fed-1)					
	1st season		2nd season		Average		1st season		2nd season		Average	
	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI	FI	DI
Initial	130	78	99	59	114	69	97	58	74	44	86	51
Development	247	148	233	140	240	144	186	111	175	105	180	108
Mid-season	1583	950	1763	1058	1673	1004	1187	712	1322	793	1255	753
Late-season	721	432	670	402	695	417	540	324	502	301	521	313
Total	2681	1608	2765	1759	2722	1634	2010	1206	2073	1243	2042	1225

(FI) full irrigation (100%ETO); (DI) deficit irrigation (60%ETo); (AW) Applied irrigation water (m3fed-1) and (WCU) Water consumptive use (m3fed-1)

Water productivity and water use efficiency

Data in Table 11 show that both Water Productivity (WP) and Water Use Efficiency (WUE) had the same trend, and being higher for deficit irrigation. Deficit Irrigation averaged 46.99 and 27.78% higher than Full Irrigation, respectively, in 1st and 2nd seasons. Likely, WUE exhibited higher values with DI, which reached to 45.95 and 25.00% in 1st and 2nd higher than those with FI, respectively. Higher WUE values under DI were previously reported by Zhang *et al*., (2005) who reported that wheat grown under the Regular DI had 26% greater WUE compared with the control. In addition, Wang *et al*. (2012) found low irrigation treatment had a higher WUE than that with high irrigation over the 2 years.

Based on the average over the tested genotypes, it is notable that WP under FI and DI in 1st season were higher by 361.11 and 430.43% than those in 2nd season, respectively. In addition, WUE exhibited the same trend, where the values under FI and DI in 1st season exceeded those in 2nd season by 362.5 and 4400%, respectively. The highest WP and WUE in 1st season compared with 2nd season are attributable to the drastic reduction in grain yield in 2nd season, whereas WCU did not greatly differ.

Water Consumptive Use Efficiency (ECU%)

Data in Table 12 indicate that water consumptive use efficiency% under full and deficit irrigation at different wheat growth stages and seasonally did not greatly alter due to the adopted irrigation treatments, and the obtained values ranged between 74.2 and 76.9% in 1st and 2nd seasons. It clear that not less than 24% of applied irrigation is lost, however, decreasing the losses of applied water could be achieved through reducing runoff and percolation losses due to over-irrigation. Furthermore, avoiding midday sprinkling to reduce direct evaporation and avoiding excessive cultivation to reduce deep water percolation and proper planting time as well are advisable practices to accomplish efficient water use.

Table 11. Water Productivity (WP) and Water Use Efficiency (WUE) as affected by FI and DI in the two growing seasons

Genotypes	WP (kgm3fed-1)				WUE (kg m3fed-1)			
	1st season		2nd season		1st season		2nd season	
	FI	DI	FI	DI	FI	DI	FI	DI
Line1	0.77	1.22	0.16	0.25	1.03	1.63	0.22	0.33
Line 2	0.79	1.31	0.17	0.23	1.05	1.74	0.22	0.31
Line 3	0.71	1.14	0.16	0.24	0.95	1.53	0.22	0.31
Line 4	0.91	1.14	0.20	0.24	1.21	1.52	0.27	0.32
Line 5	0.98	1.52	0.20	0.28	1.30	2.02	0.27	0.37
Line 6	0.70	0.96	0.13	0.22	0.93	1.28	0.18	0.30
Line 7	0.96	1.12	0.17	0.22	1.28	1.49	0.22	0.30
Line 8	0.84	1.11	0.20	0.25	1.11	1.48	0.27	0.33
Line 9	0.80	1.32	0.20	0.16	1.07	1.76	0.27	0.22
Line10	0.78	1.25	0.18	0.29	1.04	1.67	0.25	0.39
Line 11	0.91	1.48	0.22	0.25	1.21	1.97	0.29	0.33
Line 12	0.90	1.42	0.18	0.20	1.20	1.90	0.25	0.27
Line 13	1.03	1.32	0.17	0.24	1.37	1.76	0.23	0.31
Sids-6	0.90	1.22	0.17	0.17	1.19	1.63	0.22	0.23
Shandaweel-1	0.81	1.04	0.15	0.22	1.08	1.39	0.20	0.30
Sahel-1	0.65	0.96	0.15	0.21	0.86	1.28	0.20	0.28
Sakha 93	0.68	1.08	0.18	0.21	0.91	1.43	0.24	0.28
Sids-1	0.85	1.31	0.17	0.17	1.14	1.74	0.23	0.23
Average	0.83	1.22	0.18	0.23	1.11	1.62	0.24	0.30

Table 12. Water consumptive use efficiency% under full and deficit irrigation at different wheat growth stages and seasonally during both growing seasons

Growth stage	1st season		2nd season	
	FI	DI	FI	DI
Initial	76.9	74.4	74.7	74.6
Development	75.3	75.0	75.1	75.0
Mid-season	75.0	74.9	74.9	74.9
Late-season	74.9	75.0	74.9	74.9
Total	74.2	75.0	75.0	74.9

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تقييم بعض التراكيب الوراثية للقمح تحت ظروف نقص مياه الرى فى مصر العليا

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هدفت هذه الدراسة تقييم استجابة ثمانية عشر تركيبا وراثيا من القمح المصري للري العادى (100%ETc) ونقص مياه الري (60%ETc) وتأثيره على المحصول ومكوناته. أجريت التجارب الحقلية في محطة بحوث أسيوط خلال عامي 2014/2013 و 2015/2014. تم تقييم خمسة دلائل لتحمل الإجهاد وهى (MP, GMP, TOL, STI, SSI)، كما تم حساب الاستهلاك المائي (WCU) وإنتاجية المياه (WP)، ، وكفاءة استخدام المياه (WUE) للتراكيب الوراثية المدروسة. وكان التصميم المستخدم الشرائح المنشقة موزعة فيها معاملات الرى فى القطعة الرئيسية وفى القطع المنشقة السلالات، ولقد تأثرت جميع الصفات المدروسة معنويا للتراكيب الوراثية المدروسة بمعاملات الري والتفاعل بينهما. ولقد تاثرت سلبيا جميع الصفات المدروسة فى كلا الموسمين تحت نقص مياه الرى، وبناءا على حساب دلالات الاجهاد (MP, GMP, TOL, STI, SSI) فان السلالة 5 اظهرت تفوقا تحت ظروف نقص المياه حيت اعطت ارقام منخفضة (TOL and SSI) وعليه فان دلالات الاجهاد (MP, GMP, TOL, STI, SSI) يمكن ان تستخدم للتعرف على السلالات المتحملة للاجهاد المائى مع المحصول العالى تحت ظروف الرى العادى ونقص المياه . كانت كمية المياه المضافة 2722 م3 ف-1 تحت ظروف الرى العادى مقارنة 1633 م3 ف-1 تحت ظروف نقص المياه، ولقد وجد أيضا ان قيم WCU 2042 م3 ف-1 و 1225 م3 ف-1 تحت ظروفي الرى العادى ونقص المياه. وأظهرت WUE نفس الاتجاه. ويتضح من ذلك ان السلالة رقم 5 اكثرهم كفاءة فى استخدام مياه الرى حيث انه تحت ظروف الرى العادى وأيضا مع نقص المياه فانها تعطى أعلى محصول وأعلى انتاجية للمياه متفوقة فى ذلك على الأصناف التجارية.