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Response of some Bread Wheat Genotypes to Less Irrigation Water

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ABSTRACT

This study was performed at Sakha Agricultural Research Station, Kafer El-Sheikh, Egypt, in 2014/2015 and 2015/2016 seasons under normal (five irrigation) and reduced irrigation (only one irrigation after planting one) regimes. Eighteen bread wheat genotypes were used to study the agronomic and morpho-physiological characters and tolerance indices to distinguish wheat high yielding genotypes under reduced irrigation. The used genotypes were evaluated using randomized complete block design. The results revealed that reduced irrigation caused noticeable reduction in earliness, yield and yield components, harvest index and morpho-physiological in both growing seasons except 1000 kernels weight. Lines 3, 4 and 5 were the earliest ones for earliness characters and could be used in breeding program for earliness. It is obvious that lines 1 and 9 recorded the maximum values for most studied characters, especially, grain yield. Lines 1, 4, 6, 9, 10 and cultivar Misr 1, Giza 171 and shandweel1 had the highest relative water content and rate of water loss in both seasons. Also, Line 1 and Line 9 recorded the highest values for water use efficiency. Based on drought tolerance indices of mean productivity, geometric mean of productivity, stress tolerance index, yield index, harmonic mean and modified stress tolerance index, Line 1 and Line 9 were identified as suitable genotypes under well-watered and water deficit conditions. Misr 1, Misr 2, Giza 171, Lines 2, 6, 8, 10, 11, 12 and 13 were moderate for drought tolerance index and the others wheat genotypes were sensitive for water deficit.

Keywords: *Triticum aestivum* L, Earliness, Relative water content, Drought tolerance indices, Water use efficiency

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most grown crops worldwide and provides more than a quarter of the total world cereal output. In Egypt, wheat is one of the oldest and highest important cereal crops and it is considered the first food grain for urban and rural societies and the main source of straw yield for animals. In addition, wheat is on the top of the list of cereal crops in terms of area and production. However, its productivity varies from year to year and from region to region, due to various factors, including nutritional deficiency, diseases, pests, soil fertility, climate changes and limitation of water resources. Egypt is one of the countries fronting great challenges, due to its a fixed share of limited Nile water. Water shortage is a major environmental problem which affects agricultural land in Egypt. Therefore, water shortage events have gained increasing importance in both the scientific and political agendas. Water reduction is the most significant environmental stress in agriculture worldwide and improving yield under drought conditions is a major goal of plant breeding (Cattivelli *et al.*, 2008).

The better crop management and developing for high yielding cultivars characterized by tolerance to biotic and abiotic stress, so, efforts have been made for a long time to develop such crop cultivars which could cope against biotic and abiotic stress and give more production. The stable yield performance of genotypes under both favorable and drought circumstances is vital for plant breeders to identify drought tolerant genotypes (Pirayvatlou 2001). Since the recognition of the analytical approach to crop improvement under water-limiting conditions, the use of physiological traits is extensively advocated. Therefore, the use of physiological traits as an indirect selection would be important in augmenting yield-based selection procedures. Selection efficiency could be improved if particular physiological and morphological attributes related to yield under a stress environment could be identified and employed as selection criteria for complementing traditional plant breeding (Acevedo, 1991). These efforts have been focused mostly on exploiting high yield potential and genotype selection for morphological, physiological and agronomic traits indicative of drought tolerance in field conditions (Dhanda *et al.*, 2004). Early maturity period is one of the important traits that help genotypes in different ways to cope with various abiotic and biotic stresses (Al-Otayk, 2019).

Generally, different strategies have been proposed for the selection of relative drought tolerance. So, some researchers proposed selection under non-stress conditions (Rajaram and Van Ginkle, 2001), others have suggested selection in the target stress conditions (Ceccarelli and Grando, 2000). Many studies used drought indices to select stable genotypes according to their performance under favorable and stress conditions (Mursalova *et al.*, 2015).

Maximizing water use efficiency will be essential in areas where water is the most limiting factor for wheat production. On a global scale the water use efficiency of wheat ranges typically from 0.4 to 2.0 kg/m^3, but there are substantial differences between the regions. As reported in some works, the values of water use efficiency were greater under reduced than normal irrigation conditions (Wang *et al.*, 2012).

There are differences among researchers in terms of their assessment to face the risk of water shortage. Also,

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studying all available methods, whether at the level of water deficit, wheat genotypes, early and late maturity, high yielding and important physiological characteristics are vital steps to get high yielding and drought tolerance genotypes.

This work aimed to evaluate the response of agronomic, morph-physiological, drought indices and yield characters for 18 wheat genotypes at normal and reduced water irrigation.

MATERIALS AND METHODS

Eighteen bread wheat genotypes (Table 1), including five high yielding cultivars and 13 promising lines selected form Sakha wheat breeding program different in early heading, maturity, plant height, leaves erection, size and also, grain yield were used in this study. The used genotypes were evaluated under two irrigation regime experiments in 2014/ 2015 and 2015 /2016 seasons at the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt. The first water regime, representing normal irrigation, was irrigated four times after planting irrigation (5 irrigations in the season) while the second regime was water deficit treatment and represented by one irrigation after planting (only two irrigations in the season). A wide border (20 m) was used to minimize the underground water permeability surrounded each experiment. In each treatment, the aimed entries were experimented in a randomized complete block design (RCBD) with three replications. The experimental plot area was 4.8 m^2. Each plot contained of 6 rows, 4 m-long and 20 cm apart. The harvested area was 3.2 m^2 included the four guarded rows. Sowing dates were 28th November and 1st December in 1st and 2nd seasons, respectively. The soil was a clay and pH of 7.8 and 8.2 in both seasons, respectively. The pervious crop was maize in the two seasons.

Table 1. Name and pedigree of used bread wheat genotypes.

No.	Name	Pedigree and selection history
1	Misr1	OASIS/SKAUZ//4*BCN/3/2*PASTOR CMSS00Y01881T-050M- 030Y-030M- 030WGY- 33M-0Y-0S
2	Misr2	SKAUZ / BAV92 CMSS96M03611S-1M- 010SY- 010M- 010SY-8M-0Y-0S
3	Giza 171	SAKHA93 /GEMMEIZA 9 S.6-1GZ- 4GZ- 1GZ- 2GZ-0S
4	Gemmeiza 11	BOW"S"/ KVZ"S"// 7C/ SER182/3 / GIZA168/ SAKHA61 GM7892-2GM-1GM- 2GM-1GM-0GM
5	Shandweel 1	SITE/ MO/4/ NAC/ TH.AC//3* PVN/3/MIRLO/ BUC CMSS93B00567S-72Y-010M -010Y-010M-3Y- 0M- 0HTY-0SH
6	Line 1	ATTILA*2/ PBW65*2 //KACHU. CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y- 099M-10WGY-0B- 0EGY.
7	Line 2	BAV92//IRENA/KAUZ/3/HUITES/4/GONDO/TNMU/5/ BAV92//IRENA/KAUZ/3/HUITES CMSS06B00918T-099TOPY-099ZTM-099Y-0FUS-6WGY-0B-0EGY
8	Line 3	ATTILA*2/PBW65 /4/CHEN / AEGILOPS SQUARROSA (TAUS) // BCN/3/ 2*KAUZ. S.16233-01S-06S-5S-0S.
9	Line 4	ATTILA*2/ PBW65 /4/CHEN / AEGILOPS SQUARROSA (TAUS) // BCN/3/ 2*KAUZ. S.16233-01S-08S-0SY-1S-0S.
10	Line 5	SIDS1/ ATTILA// GOUMRIA-17 S. 16498-042S-013S-15S -0S
11	Line 6	TACUPETO F2001*2 /BRAMBLING// KIRITATI/ 2*TRCH CMSS08Y00140S -099Y-099M- 099NJ-29WGY-0B
12	Line 7	TACUPETOF2001*2 /BRAMBLING/3/KIRITATI// PBW65/2* SERI.1B /4/ TACUPETO F2001*2/BRAMBLING CMSS08Y00675T-099TOPM-099Y-099M-099Y-3M-0WGY
13	Line 8	WBLL1*2/ BRAMBLING/5/BABAX/LR42// BABAX*2/4/SNI/ TRAP #1/3/ KAUZ* 2/TRAP//KAUZ CMSS08B00196S-099M-099NJ-099NJ-18RGY-0B
14	Line 9	WBLL1*2/BRAMBLING/5/BABAX/LR42//BABAX* 2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ CMSS08B00196S-099M-099NJ-099NJ-20RGY-0B
15	Line 10	MUTUS*2/JUCHI CMSS07Y00982T-099TOPM-099Y-099M-099NJ-099NJ-17WGY-0B
16	Line 11	SUP15 2/VILLA JUAREZ F2009 CMSS07B00144S-099M-099Y-099M-5WGY-0B
17	Line 12	PCAFLR/KINGBIRD #1//KIRITATI/2*TRCH CMSS07B00594T-099TOPY-099M-099Y-099M-5WGY-0B
18	Line 13	FRANCOLIN #1*2/MUU CMSS07Y00938T-099TOPM-099Y-099M-099NJ-099NJ-1WGY-0B

According to the data of Wheat Research Department, ARC.

Nitrogen fertilizer (N) was added as recommended in two splits dose; one third after sowing and before the planting irrigation and two third before the first irrigation. All other cultural practices were applied as recommended for wheat cultivation in North Delta Region. The meteorological data for 2014/015 and 2015/016 winter seasons is given in Table 2. The amount of applied irrigation water, rainfall and seasonal water applied in each irrigation treatments in the two seasons were calculated and shown in Table 3.

Agronomical characters

In both growing seasons, collected data were recorded for all plots including earliness characters., days to 50% heading (DTH, day), days to 50 % anthesis (DTA, day), days to 50 % maturity (DTM, day) and grain filling period (GFP, day), equal to the number of days from anthesis to maturity, as well as grain filling rate (GFR, kg fed^{-1} day^{-1}), equal to grain yield (kg) per feddan divided by grain filling period. The previous earliness characters were recorded on plot basis. At harvest, data on grain yield and its attributes were recorded as follows: number of spikes m^{-2} (NSm^{-2}), 1000-kernel weight (1000 KW; g), number of kernels $spike^{-1}$ (NKS^{-1}), spike length (SL, cm), biological yield (BY, ton fed^{-1}), straw yield (SY, ton fed^{-1}), harvest index (HI) and grain yield (GY, ardab feddan, Ardab =150 kg).

Table 2. Monthly mean of air temperatures (AT, C), relative humidity (RH %) and rainfall (mm /month) in winter seasons of 2014/2015 and 2015/2016 at Sakha location.

Month	Temperature				RH%		Rainfall (mm)	
	2014/15		2015/16					
	Max.	Min.	Max.	Min.	2014 /15	2015 /16	2014 /15	2015 /16
Nov	24.30	13.79	24.75	14.42	74.15	75.62	24.60	12.15
Dec	22.27	9.72	20.36	8.33	76.05	78.27	5.70	25.00
Jan	18.70	6.46	18.40	6.30	74.60	74.10	52.55	42.70
Feb	19.01	7.65	23.53	6.70	74.75	70.00	38.80	-
Mar	22.69	11.69	23.67	11.61	70.59	69.76	6.25	13.20
Apr	27.64	13.70	30.03	14.22	63.40	61.72	23.90	-
May	30.19	18.79	31.15	19.0	61.70	58.33	-	-

Max = maximum temperature, Min = minimum temperature

Morpho-physiological characters

Plant height (PH, cm), flag leaf area (FLA, cm^2), relative water content (RWC %) according to Ritchie *et al.*, (1990) and rate of water loss (RWL) according to Yang *et al.*, (1991).

Water measurements

1- Amount of irrigation water applied for each treatment m^3/fed.: This amount was measured using water counter. Total amount of applied water for each treatment was calculated by adding amount of irrigation water plus the total rainfall amount (Table 3).

2 - **Water use efficiency (kg/m^3):** This formula was expressed as the weight of grain yield in kg of water transpired and evaporated (m^3) during the growing seasons. It was computed according to Doorenbos and Pruitt (1975) as follows:

WUE = Total yield, (kg) / Total applied water, (m^3).

Table 3. Calculated applied irrigation water, total rainfall and seasonal water delivered to each irrigation treatment during the two-growing season, 2014/15 and 2015/16.

	Season			
	2014/2015		2015/2016	
Treatment	**NI**	**RI**	**NI**	**RI**
Irrigation water (m^3 feddan)	1898	797	1927	808
Total rainfall (m^3 feddan)	534.24	534.24	339.78	339.78
Seasonal water applied	2432.24	1331.24	2266.78	1147.78

NI= Normal irrigation and RI= reduced irrigation

Drought tolerance indices

For each genotype, six indices of tolerance were estimated using the average grain yield under normal (Y_n) and water deficit stress (Y_s) treatments under the two seasons. Table 4 shows names, equations and references of the tolerance indices. One samples t-test or t-confidence interval was performed to obtain the significance differences among six stress tolerance indices as proposed by Gomez and Gomez (1984).

Statistical analysis

Data were analyzed in individual and combined manner over the two cultivated trials (normal irrigation and water shortage) for each season (Gomez and Gomez, 1984). The homogeneity of individual error terms was performed according to Levene (1960) prior to the combined analysis. The significance of the differences among the genotypes was tested using least significant difference (LSD) at probability level (0.05).

Table 4. The names, equations and references of six drought indices.

No.	Name	Formula	Reference
	The high values of these indices indicated to drought tolerance		
1	Mean productivity (MP)	$(Y_n+Y_s)/2$	(Rosielle and Hamblin, 1981)
2	Harmonic mean (HM)	$(2*Y_n*Y_s)/(Y_n+Y_s)$	(Jafari *et al.*, 2009)
3	Geometric mean productivity (GMP)	$(Y_n*Y_s)^{0.5}$	(Fernandez, 1992)
4	Stress tolerance index (STI)	$(Y_n \times Y_s)/(\bar{Y}_n)^2$	(Fernandez, 1992)
5	Yield index (YI)	$Y_s/\bar{Y}_s$	(Gavuzzi *et al.*, 1997)
6	Modified stress tolerance index (MSTI)	$(YI)^2*STI$	(Farshadfar and Sutka, 2002)

- Y_n and Y_s indicate to average grain yield of each genotype under normal and stress conditions respectively, $\bar{Y}_n$ and $\bar{Y}_s$ indicate to average grain yield overall genotypes under normal and stress conditions respectively.

RESULTS AND DISCUSSION

The weather conditions

The weather conditions, minimum and maximum temperatures (ºC) reached during each month in 1st and 2nd seasons are given in Table 2. Seasonal rainfall was 127.20 and 80.90 mm in the first and second growing sea in 1st and 2nd seasons, respectively. The 2014/ 2015 season was characterized by less average temperature during the period from Feb. to May. compared with 2015/2016 season. Whereas the second (2015-2016) season was considered extremely dry due to low rainfall and high temperatures by the end of season. This result is considered one of factors that affect on all agronomic traits, especially, earliness characters i.e., days to heading and maturity.

Earliness characters

Levene test (1960) proved the homogeneity of separate error variances for all studied traits that permits to apply combined analysis. Our results (Table; 5) indicated that reduced number of irrigations from five to two recorded the lowest values for all earliness characters in both growing seasons. Abd El-Rahman and Hammad (2014) and Farhat (2015) indicated that reduced irrigation from 5 to 2 irrigations decreased all earliness characters. This may be due to the water deficit was occur in end of elongation stage and relatively high temperature until early flowering and speed up maturation. These results coincide with the findings of El Hag (2017) and Noreldin and Mahmoud (2017).

The results (Table 5) indicated highly significant differences among the 18 bread wheat genotypes under study in all earliness characters in both growing seasons.

These variations among the studied genotypes might referred to their different genetic backgrounds. The timing of heading and maturity are among the major traits that related to the adaptation of wheat genotypes under dominant field conditions in particular areas. Generally, Lines 5, 3 and 4 were the earliest wheat genotypes for days to heading, anthesis, maturity and have long grain filling period. On the other hand, Misr 2 cultivar was the latest one for these characters in both growing seasons. Gab Alla *et al.*, (2018) and Al-Otayk (2019) revealed that the earliest wheat genotypes for days to heading might be usually the earliest for days to maturity, also, indicated that the early maturing genotypes had long grain filling period and the reverse for late genotypes. The results indicated that Lines 5, 3 and 4 (Early lines) recorded the longest grain filling period. While, Line 1 recorded the lowest values for grain filling period in the two growing seasons. Gemmeiza 11 had recorder the lowest values for grain filling rate in the two seasons. Line 1 and Line 9 recorded the highest values for grain filling rate in both seasons, respectively. Pireivatlou *et.al.*, (2011) reported that, the short effective grain filling period and high grain filling rate are major factors for producing higher grain yield in wheat. These results indicate the possibility of superiority of these genotypes under some abiotic stresses especially heat stress conditions (Gab Alla *et al.*, 2018). The wheat breeders prefer to select the wheat plants that characterized by short grain filling period and high grain filling rate. These results were in line with Abd El-Rahman and Hammad (2014), Farhat (2015), El Hag (2017), Noreldin and Mahmoud (2017) and Al-Otayk (2019).

Table 5. Effect of irrigation treatments, bread wheat genotypes and their interaction on days to heading, anthesis, maturity, grain filling period and grain filling rate during 2014/2015 and 2015/2016 seasons.

Factor	Earliness characters									
	Days to heading (day)		Days to anthesis (day)		Days to maturity (day)		Grain filling period (day)		Grain filling rate (Kg/fed/day)	
Irrigation (I)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal irrigation	97.80	94.17	107.91	102.46	149.69	142.17	41.78	39.70	90.84	89.23
Water deficit	96.09	92.50	105.78	100.43	144.89	138.15	39.11	37.72	85.09	83.29
F -Test	**	**	**	**	**	**	**	**	**	**
Wheat genotype (G)										
Misr 1	99.00	95.17	108.33	102.00	148.67	139.33	40.33	37.33	89.28	93.15
Misr 2	101.67	98.50	112.00	107.50	152.17	144.17	40.17	36.67	84.99	88.59
Giza 171	98.83	95.67	109.67	103.17	151.67	143.50	42.00	40.33	82.51	82.95
Gemmeiza 11	96.67	96.00	107.00	104.00	148.33	142.50	41.33	38.50	71.19	68.92
Shandaweel 1	98.00	96.83	110.00	103.50	151.67	144.17	41.67	40.67	75.46	78.49
Line 1	99.83	95.50	109.50	102.67	147.83	138.67	38.33	36.00	109.42	109.19
Line 2	98.83	94.50	109.17	103.00	151.67	142.67	42.50	39.67	87.77	89.33
Line 3	90.50	85.67	100.00	94.83	141.17	135.17	41.17	40.33	82.76	77.43
Line 4	89.83	85.83	98.17	93.83	141.00	135.50	42.83	41.67	73.23	71.023
Line 5	87.17	82.33	96.00	93.17	138.83	133.67	42.83	40.50	81.69	76.037
Line 6	97.83	94.50	107.33	103.00	146.67	141.00	39.33	38.00	95.47	86.02
Line 7	96.33	93.67	105.67	101.50	144.00	139.50	38.33	38.00	85.57	85.15
Line 8	97.00	93.83	108.00	102.33	148.33	141.00	40.33	38.67	89.17	84.15
Line 9	97.83	94.33	108.00	101.33	147.67	139.83	39.67	38.50	106.52	103.78
Line 10	100.17	97.67	109.17	106.17	148.67	142.33	39.50	36.17	90.29	91.65
Line 11	96.00	89.67	104.83	98.17	144.67	137.17	39.83	39.00	87.79	89.49
Line 12	100.50	94.50	111.33	102.83	150.33	140.50	39.00	37.67	92.01	90.78
Line 13	99.00	95.83	109.00	103.00	147.83	142.17	38.83	39.17	98.26	86.53
F-Test	**	**	**	**	**	**	**	**	**	**
LSD 0.05	1.08	1.11	1.45	1.54	1.70	1.89	1.36	1.63	6.34	7.87
I x G.	NS	NS	NS	NS	*	NS	**	NS	*	NS

The interaction between studied genotypes and irrigation treatments were significant for days to maturity, grain filling period and grain filling rate in the first season, as shown in Table 6. According to these results, the wheat genotypes were different to water regime for these traits and it is possible to select the most tolerant genotypes among them. Lines 3, 4 and 5 (Early lines) were the earliest matured genotypes under normal and water deficit conditions while the latest wheat genotypes were Misr 2, Giza 171, Shandweel 1 and Line 2. These results agree with the work of Abd El-Rahman and Hammad (2014) and El Hag (2017) where they found significant interaction between wheat genotypes and irrigation treatment. However, the shortest grain filling period were recorded by Lines 1, 6 and 9 under normal irrigation and Lines 1, 3 and 7 under water deficit treatment. The longest grain filling period were obtained by Lines 3, 4 and 5 under normal irrigation while Genotypes; Giza 171, Gemmeiza 11, Shandaweel 1 and Line 2 had the longest period for grain filling under the water shortage treatment. Lines 9 and 1 gave the highest grain filling rate under both normal and water irrigation deficit. The lowest grain filling rate was observed by Line 4 and Gemmeiza 11 under water deficit treatment.

Grain yield and its components

The results in Table 7 displayed significant differences between irrigation treatments and 18 bread wheat genotypes for all yield components. The interaction between treatments of irrigation and bread wheat genotypes were significant for 1000 kernels weight in the second season and kernels number per spike in both growing seasons.

Table 6. Effect of the interaction between irrigation treatments and 18 bread wheat genotypes on days to maturity, grain filling period and grain filling rate in 2015/2016 season.

	Days to maturity (day)		Grain filling period (day)		Grain filling rate kg fed.$^{-1}$ day^{-1}	
Trait Genotype	**Normal irrigation**	**Water deficit**	**Normal irrigation**	**Water deficit**	**Normal irrigation**	**Water deficit**
Misr 1	151.67	145.67	41.67	39.00	89.53	89.03
Misr 2	155.33	149.00	42.00	38.33	85.36	84.62
Giza 171	154.00	149.33	42.33	41.67	82.87	82.14
Gemmeiza 11	150.33	146.33	41.67	41.00	77.74	64.65
Shandaweel 1	153.67	149.67	42.33	41.00	77.23	73.68
Line 1	149.67	146.00	39.33	37.33	110.43	108.41
Line 2	153.67	149.67	43.67	41.33	89.76	85.77
Line 3	145.33	137.00	44.67	37.67	83.01	82.51
Line 4	144.67	137.33	46.00	39.67	75.51	70.95
Line 5	142.67	135.00	45.67	40.00	84.05	79.33
Line 6	148.33	145.00	39.67	39.00	107.70	83.24
Line 7	146.33	141.67	40.00	36.67	89.56	81.58
Line 8	150.00	146.67	41.00	39.67	90.17	88.17
Line 9	148.33	147.00	39.67	39.67	112.40	100.64
Line 10	151.33	146.00	41.33	37.67	90.83	89.76
Line 11	146.67	142.67	41.33	38.33	93.78	81.80
Line 12	152.33	148.33	40.00	38.00	95.75	88.26
Line 13	150.00	145.67	39.67	38.00	99.48	97.04
LSD 0.05	2.41		1.92		8.69	

Concerning irrigations treatments, results exhibited that the average values of these studied characters over all genotypes decreased under the reduced irrigation treatments, except for 1000-kernel weight in both growing seasons. Farhat (2015), Zaman *et al.*, (2016), El Hag (2017) and Noreldin and Mahmoud (2017) showed that number of spikes m^{-2}, number of kernels spike^{-1} and 1000-kernel weight was affected by diverse irrigation treatments. Also, they reported that the above-mentioned characters were higher under normal irrigations than the water deficit conditions. Menshawy and Hagras (2008) reported that mean value of 1000-kernel weight under water stress conditions (two irrigations) was higher than normal irrigation conditions (five irrigations).

Number of spikes m^{-2}, 1000-kernel weight and number of kernels per spike are important characters for wheat crop production. These differences among the wheat genotypes might partially reflect their different genetic backgrounds. Generally, Line1 gave the maximum number of spikes m^{-2} without significant differences among Misr 2, Line 8 and Line 13 in the 1st season and Line 8 in the 2nd second season. While cultivar Gemmeiza 11 recorded the lowest values of these trait in both growing seasons. These results are similar with Abdelkhalek *et.al.,* (2015), Farhat (2015), El- Esmail *et al.,* (2016), El Hag (2017) and Noreldin and Mahmoud (2017).

Regarding the weight of 1000-kernel, it is the second important characteristic of grain yield. The highest values of 1000.kernels weight were obtained by wheat genotypes; Giza 171, Gemmeiza 11 cultivars and Line 6. While, the lowest values for 1000-kernel weight were recorded by cultivars; Misr 2 and Shandaweel 1 in both growing seasons. The results of our study showed the significant variations found among the wheat genotypes referring the influence of the estimate of genotypes performance under the studied environments in order to identify the superior genetic make up for a particular environment.

Table 7. Effect of irrigation treatments, 18 bread wheat genotypes and their interaction on number of spikes m^{-2}, 1000-kernel weight, number of kernels $spike^{-1}$ and spike length in 2014/2015 and 2015/2016 seasons.

Trait	Number of spikes m^{-2}		1000-kernel weight (g)		Number of kernels $spike^{-1}$		Spike length (cm)	
Factor	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal irrigation	396.92	385.33	43.35	42.53	54.67	51.41	12.93	11.79
Water deficit	346.44	330.47	46.85	46.47	49.21	46.87	11.59	10.88
F Test	**	**	**	**	*	**	NS	**
Genotype (G)								
Misr 1	337.67	345.17	45.10	45.20	57.65	49.88	12.47	11.41
Misr 2	408.50	381.83	38.50	37.62	51.16	50.41	11.17	10.41
Giza 171	325.83	322.50	51.76	50.15	52.45	49.05	13.02	11.66
Gemmeiza 11	267.50	302.00	50.36	46.66	51.83	44.05	14.62	12.98
Shandaweel 1	366.17	361.00	37.25	37.72	54.94	52.67	13.60	12.28
Line 1	427.00	424.17	47.17	45.18	52.56	50.53	11.67	11.47
Line 2	381.83	377.50	45.46	43.55	53.61	50.38	12.80	11.95
Line 3	390.00	338.33	45.04	44.83	49.12	48.65	11.18	10.25
Line 4	356.33	323.17	43.45	46.54	48.13	45.97	11.72	10.28
Line 5	344.67	339.33	47.45	43.80	51.99	49.48	10.95	10.81
Line 6	375.00	372.00	48.83	48.00	51.54	43.58	12.62	10.95
Line 7	379.83	342.00	43.63	45.96	49.75	49.42	12.82	11.78
Line 8	416.33	393.00	43.77	41.05	49.28	47.70	12.23	11.82
Line 9	389.17	380.50	44.87	44.64	57.66	53.64	11.77	11.03
Line 10	370.83	352.50	43.34	43.54	53.89	51.62	12.15	11.68
Line 11	382.83	378.33	42.31	45.62	51.20	49.42	12.80	10.59
Line 12	361.50	348.67	48.69	45.10	50.20	50.30	11.97	10.72
Line 13	409.17	360.25	44.86	45.90	47.96	47.77	11.18	11.98
F Test	**	**	**	**	**	**	**	**
$LSD_{0.05}$	35.12	38.59	2.34	2.08	2.74	3.08	1.03	0.90
I X G	NS	NS	NS	**	*	**	NS	NS

With respect to number of kernels $spike^{-1}$, it is among the most important components of grain yield after the number of spikes m^{-2}. The results indicated that genotypes; Line 9 and Shandaweel1 had the highest number of kernels $spike^{-1}$ in the both growing seasons. While, the lowest number of kernels $spike^{-1}$ were obtained by Lines 4 and 13 in the 1st season and Gemmeiza 11, Line 4 and Line 6 in the 2nd season. It is obvious that local wheat cultivars; Gemmeiza 11 and Shandaweel1 were superior in spike length in both seasons, while three earliest matured genotypes being Lines 3, 4 and 5 recorded lower values for spike length under this experiment. Generally, these results are in line with those found by Farhat (2015), Esmail *et al.,* (2016), El Hag (2017), Noreldin and Mahmoud (2017) and Al-Otayk (2019).

Concerning biological and straw yields, harvest index and grain yield data are shown in Table 8 which illustrate the effects of irrigation treatments, 18 bread wheat genotypes and their interaction on these traits in the two growing seasons. Values of these traits were decreased under less water treatment (two irrigations) compared to full irrigation, except the harvest index in the 1st season (without significance). The reduction in the final grain yield of wheat under water deficit treatment was caused by a reduction in many yield components especially the number of spikes m^{-2}, the number of kernels $spike^{-1}$ and the weight of single grain. In this study, reduction in biological and straw yields may be corelated with reduced number of spikes and plant height under deficit irrigation treatment. Abd El-Rahman and Hammad (2014), Farhat (2015) and El Hag (2017) indicated that reduced irrigation decreased all yield characters.

There existed highly significant differences among 18 bread wheat genotypes for all characters (Table 8). To understand the causes of variation in final grain yield, its components must be studied along with the growth of the crop. These differences among genotypes might partially reflect their different genetic backgrounds. Results represented that Lines 1 and 9 produced the highest values for biological and straw yields in the two growing seasons. The lowest values of biological and straw yields were obtained by Gemmeiza 11, as well as the three earliest matured genotypes being Lines 3, 4 and 5 in both growing seasons, indicating that the earliest matured genotypes produce low yields under the current study. The highest values of harvest index, were obtained by Lines 3 and 5 in the first season and Lines 1, 4, 8 and 9 in the 2nd season with insignificant differences among them, while the lowest harvest indices were obtained by local cultivar Giza 171 in both seasons. In grain yield, generally, Lines 1 (27.95 and 26.20 ardab fed^{-1}) and 9 (28.16 and 26.63 ardab fed^{-1}) recorded the maximum grain yield in 1st and 2nd seasons, respectively, which giving the justification to use these genotypes in the advanced yield trials. Gemmeiza 11 and Line 4 produced the lowest grain yield in both seasons. Our results are in parallel line with those reported by Esmail *et al.,* (2016), El Hag (2017), Noreldin and Mahmoud (2017) Gab Alla *et al.,* (2018), Patel *et al.,* (2019) and Al-Otayk (2019).

Table 8. Effect of irrigation treatments, 18 bread wheat genotypes and their interaction on biological yield, straw yield, harvest index and grain yield in 2014/2015 and 2015/2016 seasons.

Irrigation treatment (I)	Biological yield (T fed^{-1})		Straw yield (T fed^{-1})		Harvest index (%)		Grain yield (Ard. fed^{-1})	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal	10.88	9.67	7.11	6.14	34.83	36.63	25.19	23.53
Water deficit	9.31	8.82	5.99	5.69	35.96	35.60	22.14	20.88
F Test	*	**	*	**	NS	**	**	**
Genotype (G)								
Misr1	10.64	10.26	7.04	6.78	33.89	33.91	24.00	23.17
Misr2	10.20	9.17	6.79	5.92	33.76	35.50	22.77	21.68
Giza171	11.20	10.80	7.74	7.46	31.03	30.99	23.11	22.30
Gemmeiza11	8.50	8.12	5.55	5.46	35.24	32.71	19.63	17.72
Shandaweel1	9.74	9.09	6.59	5.90	32.37	35.13	20.97	21.29
Line 1	11.97	10.23	7.78	6.30	35.17	38.64	27.95	26.20
Line 2	10.18	9.58	6.44	6.02	36.85	37.08	24.89	23.68
Line 3	8.86	8.49	5.45	5.36	38.50	36.90	22.73	20.88
Line 4	9.03	7.78	5.89	4.82	35.03	38.22	20.96	19.73
Line 5	8.92	8.80	5.41	5.72	39.45	35.07	23.36	20.53
Line 6	10.19	8.61	6.43	5.34	36.94	37.93	25.03	21.78
Line 7	9.52	8.88	6.23	5.63	34.76	36.49	21.91	21.63
Line 8	9.95	8.49	6.36	5.23	36.28	38.39	23.96	21.68
Line 9	12.67	10.30	8.45	6.31	33.37	38.81	28.16	26.63
Line 10	10.12	9.31	6.55	6.00	35.39	35.62	23.78	22.11
Line 11	9.65	9.80	6.15	6.30	36.24	35.59	23.36	23.31
Line 12	10.17	9.10	6.58	5.68	35.59	37.63	23.94	22.82
Line 13	10.26	9.59	6.44	6.21	37.25	35.53	25.43	22.58
F-Test	**	**	**	**	**	**	**	**
$LSD_{0.05}$	0.90	1.03	0.71	0.76	1.78	1.98	1.63	2.15
I X G	NS	NS	NS	NS	NS	NS	*	NS

Regarding the interaction effects, only the significant effects will be shown and discussed. The interaction between genotypes and treatments of irrigation was significant for 1000.kernels weight (1st season), grain yield (2nd season), and number of kernels $spike^{-1}$ (both seasons) as shown in Tables 7 and 8. The results (Table,9) presented that genotypes; Misr 1 and Line.9 recorded the maximum number of kernels $spike^{-1}$ under both full and reduced irrigation in the 1st season. Meanwhile, the minimum number of kernels $spike^{-1}$ was obtained by Line 8 and Line 4 under normal and less irrigation water, respectively. In the 2nd season, the highest number of kernels $spike^{-1}$ were observed in Lines 2 and 7 under normal irrigation and Shandaweel1, Lines 1, 9 and 10 under less irrigation water conditions. However, the lowest number of kernels $spike^{-1}$ was produced by Gemmeiza11 and Line 6 under adequate irrigation and Lines 6 and 7 under less irrigation water conditions. Grain yield under both normal and limited irrigated conditions of the 1st season, Line 9 produced maximum grain yield with insignificant difference than Line 1. The minimum grain yield was recorded by Gemmeiza11and Shandaweel1 under normal irrigation and Gemmeiza 11, Lines 4 and 11 under less irrigation water. With respect to 1000-kernel weight under both adequate and limited irrigated conditions, genotypes; Giza 171 and Line 6 gave the heaviest weight of 1000-kernel weight, while Misr 2 and Shandaweel 1 had the lightest 1000-kernel weight. Similar conclusion was reported by previous investigators Omar *et.al.,* (2014) and Abdelkhalek *et al.,* (2015).

Table 9. Effect of the interaction between irrigation treatments and 18 bread wheat genotypes on number of kernels $spike^{-1}$, 1000 kernels weight and grain yield in 2014 / 2015 and 2015 / 2016 seasons.

Wheat genotype	2014 / 2015				2015 / 2016			
	Number of kernels $spike^{-1}$		Grain yield (Ardb/fed)		1000-kernel weight (g)		Number of kernels $spike^{-1}$	
	N	S	N	S	N	S	N	S
Misr 1	59.15	56.15	24.87	23.12	44.44	45.96	50.37	49.40
Misr 2	53.28	49.03	23.90	21.63	36.00	39.23	53.42	47.40
Giza 171	53.08	51.82	23.39	22.83	46.22	54.07	50.67	47.43
Gemmeiza 11	53.55	50.10	21.59	17.66	46.60	46.71	45.10	43.00
Shandaweel 1	56.02	53.87	21.79	20.16	36.90	38.54	54.73	50.60
Line 1	56.77	48.35	28.92	26.99	44.42	45.94	50.67	50.40
Line 2	56.68	50.53	26.13	23.64	38.13	48.97	56.60	44.17
Line 3	52.04	46.20	24.73	20.72	43.08	46.57	53.07	44.23
Line 4	53.53	42.72	23.17	18.74	44.54	48.54	48.80	43.13
Line 5	54.73	49.25	25.57	21.15	41.79	45.80	51.27	47.69
Line 6	54.63	48.45	28.42	21.64	46.04	49.96	44.47	42.70
Line 7	54.60	44.90	23.88	19.93	43.20	48.73	57.07	41.77
Line 8	51.37	47.18	24.60	23.31	39.99	42.11	48.33	47.07
Line 9	59.18	56.13	29.70	26.61	43.47	45.80	55.00	52.27
Line 10	55.92	51.87	25.01	22.55	41.16	45.92	52.93	50.30
Line 11	55.25	47.15	25.81	20.90	43.34	47.90	50.70	48.13
Line 12	52.25	48.15	25.54	22.34	41.77	48.42	54.33	46.27
Line 13	52.03	43.88	26.32	24.55	44.47	47.33	47.90	47.63
$LSD_{0.05}$	3.87		2.30		2.30		4.36	

Morpho-physiological measurements

The results in Table 10 showed significant differences between irrigation treatments and 18 bread wheat genotypes in Morpho-physiological measurements i.e. plant height (cm), flag leaf area (cm^2), relative water content and rate of water loss in the two growing seasons. The interaction between treatments of irrigation and bread wheat genotypes were significant for relative water content in the 2nd season.

Variations of plant height due to irrigation treatments were highly significant in the two seasons, (Table,10). Well-watered treatment resulted in taller wheat plants than those received low number of irrigations. Similar results are in agreement with those obtained by Amin and Tork (2015), Farhat (2015) El Hag (2017) and Zeboon *et al.,* (2017) they indicated that plant height was decreased at water shortage conditions. Reduction of plant height in response to water deficiency may be because of the reduction in relative turgidity and dehydration of protoplasm, which is related to the absence of turgor and reduced expansion of cell and cell division (Mahfuz *et al.,* 2014).

Variation among genotypes in plant height were highly significant in both seasons. Line 11 produced the tallest plants (125 and 118.33 cm) in both growing seasons, meanwhile there were insignificant differences with Line 13 in plant height at the studied seasons. While, Line 4 produced the shortest plants (107.50 and 100.83 cm) in 1st and 2nd seasons. Our results were in line with Farhat (2015), El Hag (2017) and Zeboon *et al.,* (2017) they indicated that there were highly significant effects of wheat genotypes on plant height. Blum and Pnuel (1990) concluded that taller wheat cultivars had a greater capacity to support grain filling from stem reserves under drought because of their greater storage.

Flag leaf area is the most important leaf in cereals like wheat, because it provides the maximum photosynthetic assimilates to be stored in the grain. A greater flag leaf area will eventually help to increase the photosynthetic efficiency by increasing the production of photosynthesis, which had then translocated into grains and increasing their weights. Therefore, flag leaf area has a direct relationship with grain yield. Results (Table 10) indicated that, the variation because of irrigation treatments were highly significant in the two growing seasons. The results showed that decreasing water irrigation led to decrease in flag leaf area.

Table 10. Effect of irrigation treatments, 18 bread wheat genotypes and their interaction on plant height, flag leaf area, relative water content, rate of water loss and water use efficiency in 2014 /2015 and 2015/ 2016 seasons.

Irrigation	plant height (cm)		Flag leaf area (cm^2)		Relative water content		Rate of water loss		WUE ($kg\ m^{-3}$)	
treatment (I)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal	120.19	114.54	52.48	47.03	81.18	83.66	70.58	75.23	1.55	1.56
Water deficit	111.20	105.09	42.39	40.92	65.34	69.91	57.60	60.43	2.49	2.72
F Test	**	**	**	*	*	*	*	*	**	**
Wheat genotype (G)										
Misr1	110.00	105.00	47.84	44.84	78.98	79.31	73.76	76.88	2.07	2.26
Misr2	119.17	114.17	42.09	40.01	74.43	76.82	60.86	57.39	1.96	2.10
Giza 171	117.50	112.50	52.45	50.73	77.56	80.20	64.31	75.76	2.01	2.16
Gemmeiza11	115.83	108.33	55.99	53.69	68.69	71.19	56.75	63.53	1.66	1.69
Shandaweel1	115.83	110.00	40.98	41.35	76.87	81.57	60.57	72.69	1.81	2.08
Line 1	115.00	111.67	46.50	39.87	81.97	81.23	74.16	73.35	2.41	2.55
Line 2	115.83	110.83	51.81	48.73	66.78	77.145	66.41	72.42	2.14	2.27
Line 3	109.17	103.33	46.63	43.95	63.47	69.71	57.78	62.34	1.93	1.99
Line 4	107.50	100.83	47.47	43.82	79.20	80.86	69.18	69.75	1.77	1.93
Line 5	109.17	100.83	46.11	43.32	72.21	71.16	64.22	66.57	1.98	1.96
Line 6	115.83	110.00	48.38	43.96	78.47	82.32	69.00	73.23	2.10	2.10
Line 7	117.50	113.33	45.26	44.98	63.52	67.42	56.00	56.09	1.86	2.06
Line 8	117.50	111.67	50.05	46.82	69.75	78.95	58.93	68.84	2.07	2.13
Line 9	116.67	107.50	43.33	36.77	77.64	82.25	71.52	69.56	2.41	2.59
Line 10	115.00	112.50	46.01	44.94	80.00	79.85	70.72	75.68	2.04	2.13
Line 11	125.00	118.33	47.62	38.93	73.79	74.54	60.26	56.42	1.97	2.21
Line 12	115.83	110.00	45.03	44.84	68.68	73.12	61.54	70.23	2.05	2.20
Line 13	124.17	115.83	52.47	51.67	66.73	74.42	57.67	60.02	2.19	2.18
F test	**	**	**	**	**	**	**	**	**	**
$LSD_{0.05}$	3.32	4.1	5.17	3.9	6.32	5.46	5.86	6.96	0.15	0.21
I X G	NS	NS	NS	NS	NS	*	NS	NS	**	NS

These results agreed with those obtained by Esamil *et al.,* (2016), Hafez and Gharib (2016) and Zeboon *et al.,* (2017), they showed that flag leaf area was decreased with water deficit.

Data in Table 10 showed highly significant differences in flag leaf area among the tested wheat genotypes in both seasons. This may be due to the differences in genetic background of the tested genotypes. Gemmeiza 11 cultivar recorded the largest flag leaf area (55.99 and 53.69 cm^2), meanwhile there were insignificant differences with Giza 171 and Line 13 in both seasons. Shandaweel1 and Line 9 had the lowest values (40.98 and 36.77cm^2) in the two growing seasons, respectively. These results are in agreement with Esamil *et al.,* (2016) and Hafez and Gharib (2016). Wery *et al.,* (1994) pointed out that, reduction in leaf area is an important adaptive mechanism for drought stress and it is usually the first strategy a plant adapts when water become limiting.

The results (Table, 10) showed that with the increase in the duration of water stress period there was advanced decrease in the relative water content of flag leaves. Higher relative water content (RWC) values 81.18% and 83.66% were recorded at well-watered treatment in both growing seasons, respectively. Whereas, lower RWC values 65.34% and 69.91% were recorded at water deficit treatment in both seasons, respectively. Saeidi *et al.,* (2015), Hafez and Gharib (2016) and Hafiz Ghulam *et al.,* (2019) showed that relative water content decreased under drought or water stress condition.

Results indicated that 18 bread wheat genotypes were highly significant differed in RWC character. This variation in relative water content between wheat genotypes may be attributed to differences in the ability of genotypes to absorb more water from the soil and or the ability to control water loss through the stomata (Keyvan, 2010). Khakwani *et al.,* (2011) reported that relative water content for all varieties was significantly decreased when subjected to stress conditions as compared to control. Relative water content of the leaves has been proposed as a good indicator to water stress than other growth or biochemical parameters of the plants (Sinclair and Ludlow, 1985). Schonfeld *et al.,* (1988) they observed a decline in the amount of relative water content in wheat due to drought stress and reported the highest relative water content in the tolerant genotype. Relative water content of leaves has been reported as direct indicator of plant water deficit conditions (Lugojan and Ciulca 2011). These results are in agreement with Saeidi *et al.,* (2015) and Zeboon *et al.,* (2017).

Reducing number of irrigations from 5 to 2 significantly influenced rate of water loss character (Table 10) and caused decrease in rate of water loss. Water deficit caused a decline in rate of water loss (RWL) which may indicate some inhibiting mechanisms of water loss under drought stress. This result is consistent with that of Golestani and Asad (1998) who observed decrease in the rate of water loss under stress condition in wheat. These results are in conformity with those obtained by Lonbani and Arzani (2011).

The results (Table 10) indicated that the highest value was recorded by wheat genotypes (Line 1 and Misr 1) in the two seasons, respectively. While, the lowest value for rate of water loss recorded by wheat genotype (Line 7) in rate of water loss in both growing seasons (Table 10). In this study may indicate some inhibiting mechanism of less water under drought stress. These results consistent with Golestani and Asad (1998) who observed decrease in the rate of water loss under stress condition in wheat.

Water use efficiency

Table 10 showed highly significant differences between irrigation treatments and bread wheat genotypes in both seasons and their interaction in the first season only for water use efficiency. Normal irrigation treatment recorded the lowest values (1.55 and 1.56 kg m^{-3}), while reduced irrigation treatment recorded the highest values (2.49 and 2.72 kg m^{-3}) in both growing seasons, respectively. Gab Alla (2007) found the highest values of water use efficiency recorded by one irrigation applied at tillering stage, while the lowest values were obtained from the well-watered (5 irrigations). Similar results were found by Singh *et al.*, (2018).

The differences among the wheat genotypes for water utilization efficiency in both growing seasons were highly significant. The values of water utilization efficiency for different wheat genotypes ranged from 1.66 to 2.41 and 1.69 to 2.59 kg m^{-3}, in the two growing seasons, respectively. The highest values of water use efficiency 2.41 and 2.59 kg m^{-3} were recorded by Line 1 and Line 9, while the lowest values were recorded by Gemmeiza 11 (1.66 and 1.69 kg m^{-3}) in both seasons. Waraich *et al.*, (2010) reported that WUE indicates the performance of a crop growth under any environment. These results coincide with the findings of Allahverdiyev (2015).

Data (Table 11) indicated that water treatments × genotypes interaction was highly significant. These results indicate that wheat genotypes responded differently to water treatments. Regarding water productivity of tested genotypes, data showed that, the highest values of water use efficiency were recorded with Lines 1 and 9. This is may be due to their tolerant to abiotic stress particularly drought and temperature, favoring their productivity compared with other genotypes. Meanwhile, the lowest values were noticed with Lines 4 and 9, indicating their sensitivity to less water reducing yield. The obtained results clearly showed that applying two irrigation, under this area (Kafer El-Sheikh) with the tested genotypes is more effective to save water, which could be, used for other crops or for more wheat cultivated areas.

Drought tolerance indices

Mean values of grain yield (ardab fed^{-1}.) of thirteen wheat genotypes and five checks under water stress and non-stress conditions in both growing seasons 2014/2015 and 2015/2016 are presented in Table 12. Using grain yield across non-stress (Yn) and water stress circumstance (Ys), six quantitative stress tolerant indices and their respective ranks were calculated under the two seasons (Table 12).

The genotypes with high values of these six tolerance indices parameters can be selected as tolerant genotypes to water deficit. Under normal irrigation, the grain yield varied from 20.51 ardab fed^{-1} for Gemmeiza 11 to 28.71 ardab fed^{-1} for Line 9, by average of 24.36 ardab fed^{-1}, while the average grain yield of genotypes across water stress treatment ranged from 16.83 ardab fed^{-1} for Gemmeiza 11 to 26.14 ardab fed^{-1} for Line 1, by average grain yield equal 21.51 ardab fed^{-1}.

Table 11. Effect of the interaction between irrigation treatments and wheat genotypes on water use efficiency (WUE) in 2014/2015 and relative water content (RWC) in 2015/2016 seasons.

Wheat genotype	2014/2015 WUE		2015/2016 RWC	
	N	S	N	S
Misr1	1.53	2.61	87.22	71.40
Misr2	1.47	2.44	80.52	73.13
Giza171	1.44	2.57	86.56	73.84
Gemmeiza11	1.33	1.99	74.94	67.44
Shandaweel1	1.34	2.27	90.35	72.79
Line 1	1.78	3.04	90.01	72.45
Line 2	1.61	2.66	86.82	67.48
Line 3	1.53	2.33	77.37	62.06
Line 4	1.43	2.11	89.29	72.44
Line 5	1.58	2.38	81.04	61.28
Line 6	1.75	2.44	86.81	77.84
Line 7	1.47	2.25	72.17	62.67
Line 8	1.52	2.63	84.20	73.70
Line 9	1.83	3.00	89.12	75.38
Line 10	1.54	2.54	84.94	74.77
Line 11	1.59	2.35	83.94	65.15
Line 12	1.58	2.52	80.03	66.21
Line 13	1.62	2.77	80.50	68.34
$LSD_{0.05}$	0.23		7.72	

Two promising genotypes being Line 9 followed by Line 1 gave the highest grain yield with average across the two treatments 27.40 and 27.08 ardab fed^{-1}, respectively, as well as they gained the lowest reduction % in grain yield (ardab fed^{-1}.), recording 9.16 and 6.71%, respectively. However, the lowest grain yield across the two sites was obtained by check genotype Gemmeiza 11 (18.67 ardab fed^{-1}), while the highest estimate of reduction in grain yield (19.75%) was shown by Line 11 with moderate average grain yield 23.34 (ardab fed^{-1}). The current results were also reported by previous investigators such as, Sharafi *et al.*, (2011).

There were obvious differences among genotypes for grain yield under non-stressed and water stressed treatments which reflect high genetic diversity among them that make possible to screen water shortage tolerant genotypes.

It is noted that the three indices of harmonic mean (HM), geometric mean of productivity (GMP), and stress tolerance index (STI) gave identical ranks for water stress tolerance. The similarity of the three indices in categorizing genotypes for water stress tolerance may be because that these indices are function of each other and they could be interchangeably used as a substitute for each other. The ranks of MP index were very close to the ranks belong to the three aforementioned indices while the two indices of yield index (YI) and modified stress tolerance index (MSTI) gave different tolerance ranks. Overall the six stress tolerance indices, results indicated that Line 9 and Line 1 had the first and second ranks of water stress tolerance with highly significant differences with the other genotypes.

Table 12. Estimates of six stress tolerance indices (STI) and their respective ranks for 18 bread wheat genotypes based on grain yield under normal and water stress sites combined over the two seasons.

Genotypes	Grain yield (ardab/fed)				Stress Tolerance Index (STI)										Water less tolerance degree
	Y_N	Y_S	average	Red. %	MP	Rank	H M	GMP	STI	Rank	YI	Rank	MSTI	Rank	
Misr 1	24.40	22.77	23.59	6.65	23.58	5	23.56	23.57	0.94	5	1.05	4	1.05	5	
Misr 2	23.32	21.12	22.22	9.45	22.22	12	22.17	22.19	0.83	12	0.98	10	0.80	12	Moderate
Giza 171	23.36	22.05	22.71	5.62	22.70	11	22.68	22.69	0.87	11	1.02	7	0.91	8	
Gemmeiza 11	20.51	16.83	18.67	17.93	18.67**	18	18.49**	18.58**	0.58**	18	0.78**	18	0.36**	18	Sensitive
Shandweel 1	21.78	20.48	21.13	5.98	21.13*	16	21.11*	21.12*	0.75*	16	0.95	13	0.68*	14	
Line 1	28.02	26.14	27.08	6.71	27.08**	2	27.05**	27.06**	1.23**	2	1.22**	1	1.82**	2	High
Line 2	25.82	22.75	24.29	11.88	24.28	3	24.19	24.24	0.99	3	1.06	5	1.11	3	Moderate
Line 3	23.81	19.79	21.80	16.89	21.80*	14	21.62*	21.71*	0.79*	14	0.92*	15	0.67*	15	
Line 4	21.58	19.11	20.35	11.46	20.34*	17	20.27*	20.31*	0.69*	17	0.89*	17	0.55*	17	Sensitive
Line 5	24.03	19.87	21.95	17.30	21.95*	13	21.75*	21.85*	0.81*	13	0.92*	14	0.69*	13	
Line 6	25.85	20.96	23.41	18.91	23.40	6	23.15	23.28	0.91	7	0.97	11	0.87	10	Moderate
Line 7	23.80	19.74	21.77	17.07	21.77	15	21.58	21.67	0.79*	15	0.92*	16	0.67*	16	Sensitive
Line 8	23.28	22.36	22.82	3.96	22.82	10	22.81	22.82	0.88	10	1.04	6	0.95	6	Moderate
Line 9	28.71	26.08	27.40	9.16	27.39**	1	27.33**	27.36**	1.26**	1	1.21**	2	1.85**	1	High
Line 10	24.24	21.65	22.95	10.67	22.94	9	22.87	22.91	0.88	9	1.01	9	0.90	9	
Line 11	25.89	20.78	23.34	19.75	23.33	8	23.05	23.19	0.91	8	0.97	12	0.85	11	Moderate
Line 12	24.96	21.80	23.38	12.64	23.38	7	23.27	23.33	0.92	6	1.01	8	0.94	7	
Line 13	25.11	22.90	24.01	8.80	24.01*	4	23.96	23.98*	0.97*	4	1.06*	3	1.10	4	

Yn: Grain yield under non-stress, Ys: Grain yield under water deficit conditions, MP: mean productivity, GMP: geometric mean of productivity, STI: stress tolerance index, YI: yield index, HM: harmonic mean, MSTI: Modified stress tolerance index, * and ** significant and highly significant at 0.05 and 0.01 probability levels, respectively.

Therefore, the above mentioned two Lines 9 and 1 were considered high tolerant to water stress conditions. Fortunately, they also were had the greatest grain yield in normal and shortage irrigations and reflected the lowest reduction % of grain yield between the two sites, as above shown. Accordingly, Line 9 and Line 1 were preferred to be cultivated whether under the normal or water stress conditions.

Significantly, the two check genotypes of Gemmeiza11 and Shandweel1 and four lines namely: Lines 3, 4, 5 and 7 were sensitive to water stress with lower values of the six stress tolerance indices recording the latest tolerance ranks. Consequently, it is not advisable to cultivate these genotypes in water stress environments. The rest genotypes of Misr1, Misr 2, Giza 171, Lines 2, 6, 8, 10, 11, 12 and 13 gave intermediate estimates of grain yield and satisfactory degree of drought tolerance. Mohammadi-joo *et al.,* (2015) indicated that STI, MP and GMP are the suitable indices for screening tolerant genotypes that produce higher yields in both stress and normal conditions. The same trend was reported by Singh *et al.,* (2015), Abdelghany *et al.,* (2016), Gadallah *et al.,* (2017) and Patel *et al.,* (2019).

REFERENCES

Abd El-Rahman, Magda E. and S.M. Hammad (2014). Evaluation of some bread wheat *(Triticum aestivum*) genotypes under normal and reduced irrigation regimes. Minufiya J. Agric. Res. Vol. 39 No 2(2):711-721.

Abdelghany, A. M.; Hanaa M. Abouzied and M.S. Badran (2016). Evaluation of some Egyptian wheat cultivars under water stress conditions in the North Western Coast of Egypt. Agric. &Env. Sci. Dam. Univ., Egypt Vol.15 (1) 63-84.

Abdelkhalek, A.A.; R. Kh. Darwesh and Mona A.M. El-Mansoury (2015). Response of some wheat varieties to irrigation and nitrogen fertilization using ammonia gas in North Nile Delta. Annals of Agricultural Science 60 (2), 245–256.

Acevedo, E. (1991). Improvement of winter cereal crops in Mediterranean environments. Use of yield, morphological and physiological traits. In Acevedo, E. (ed): Physiology-Breeding of Winter Cereals for Stressed Mediterranean Environments. Le Colloque No. 55, pp 273–305, INRA, Paris.

Allahverdiyev, T. (2015). Effect of drought stress on some physiological traits of durum (*Triticum durum* Desf.) and bread (*Triticum aestivum* L.) wheat genotypes. Journal of Stress Physiology & Biochemistry, Vol. 11 No. 1, pp. 29-38.

Al-Otayk, S. M. (2019). Evaluation of agronomic traits and assessment of genetic variability in some popular wheat genotypes cultivated in Saudi Arabia. AJCS 13(06):847-856.

Amin, F. and A. Tork (2015). Changes in yield and yield components of wheat cultivars under water stress condition. International J. Sci., 9 (5): 103-107.

Blum, A. and Y. Pnuel (1990). Physiological attributes associated with drought resistance of wheat cultivars in a Mediterranean environment. Aust. Jour. Agric. Res. 41: 799-810.

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

Ceccarelli, S. and S. Grando (2000). Barley landraces from the fertile crescent: A Lesson for Plant Breeders,' in S. B. Brush (ed.), Genes in the Field: On-Farm Conservation of Crop Diversity, International Development Research Centre, Boca Raton, Florida, pp. 51–76.

Dhanda S.S.; G.S Sethi and R.K Behl (2004). Indices of drought tolerance in wheat genotypes at early stages of plant growth. J. Agron. Crop Sci., 190: 6–12.

Doornbos, J. and W.O. Pruit (1975). Crop Water Requirements. Irrigation and Drainage Paper, No. 24. FAO, Rome.

El Hag-Dalia, A. A. (2017). Effect of irrigation number on yield and yield components of some bread wheat cultivars in North Nile Delta of Egypt. Egypt. J. Agron. Vol. 39, (2):137-146.

Esmail, R.M.; Sara E.I. Eldessouky; Sherin A. Mahfouze and I.S. EL-Demardash (2016). Evaluation of new bread wheat lines (*Triticum aestivum* L) under normal and water stress conditions. International Journal of ChemTech Research, 9 (5), pp 89-99.

Farhat, W. Z. E. (2015). Response of 21 spring bread wheat genotypes to normal and reduced irrigation in North Delta. J. of Plant Production, Mansoura Univ., Vol. 6 (6): 943 – 963.

Farshadfar, E. and J. Sutka (2002). Screening drought tolerance criteria in maize. Acta Agron. Hung., 50(4):411–416.

Fernandez, G.C.J. (1992). Effective selection criteria for assessing stress tolerance. In: Kuo C.G. (Ed.), Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress, Aug. 13-16, Shanhua, Taiwan. pp 257-270.

Gab Alla, M.M.M. (2007). Effect of irrigation numbers on some varieties and strains of wheat. M.Sc. Thesis, Kafr EL-Sheikh Univ., Egypt.

Gab Alla, M.M. M.; Eman M. A. Hussein and W. M. Fares (2018). Evaluation of some bread wheat genotypes using genotypes by trait (GT) biplot analysis. Proceeding of the seventh Field Crops Conference, 18-19 Dec. Giza, Egypt; 59-76.

Gadallah, Maha A.; Sanaa I. Milad; Y. M. Mabrook; Amira, Y. Abo Yossef and M.A. Gouda (2017). Evaluation of some Egyptian bread wheat (*Triticum aestivum* L) cultivars under salinity stress. Alex. Sci. Exchange J.,38 (2): 259-270.

Gavuzzi, P.; F. Rizza; M. Palumbo; R.G. Campaline; G.L. Ricciard and B. Borgh (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Canadian J. Plant Sci., 77, 523-531.

Golestani, A. S. and M. T. Assad (1998). Evaluation of four screening techniques for drought resistance and their relationship to yield reduction ratio in wheat. Euphotic, 103: 293–299.

Gomez, K.A. and A.A. Gomez (1984). Statistical Procedures for Agriculture Research (2nd Ed.). John Wiley and Sons Inc., New York, USA., 72: 203-206.

Hafez E.M. and H.S. Gharib (2016). Effect of exogenous application of ascorbic acid on physiological and biochemical characteristics of wheat under water stress. International Journal of Plant Production10 (4): 579-596.

Hafiz G.; M. Ahmed; M. Sajjad; M. Li; M. A. Azmat; M. Rizwan; Rana H. Maqsood and S. H. Khan (2019). Selection criteria for drought-tolerant bread wheat genotypes at seedling stage. Sustainability, 11, 2584. pp.1-17.

Jafari, A.; F. Paknejad and M. AL-Ahmaidi (2009). Evaluation of selection indices for drought tolerance of corn (*Zea mays* L.) hybrids. Int. J. Plant Prod., 3:33–38.

Keyvan, S. (2010). The effects of drought stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. Journal of Animal & Plant Sciences, Vol. 8, Issue 3: 1051- 1060.

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

Levene, H. (1960). Robust tests for equality of variances. In Ingram Olkin, Harold Hotel ling, Italia, Stanford, Univ. Press, PP. 278- 292.

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

Lugojan C. and Ciulca S. (2011). Evaluation of relative water content in winter wheat. J. Hortic. Fores. Biotechnol., 15: 173–177.

Mahfuz, Md. B.; A. Al-Mahmud and Md. S.A. Khan (2014). Effects of water stress on morpho-phenological changes in wheat genotypes. Global Journal of Science Frontier Research, Vol. 14, 91-100.

Menshawy A.M.M. and A.A.I. Hagras (2008). Evaluation of some bread wheat genotypes under normal and reduced irrigation. The First International Conference on Environment Studies and Research. Minufiya University-Sadat Branch, Egypt, 7-9 April, pp.312-323.

Mohammadi-joo, A.M.; R. Saeidi-aboeshaghi and M. Amiri (2015). Evaluation of bread wheat (*Triticum aestivum* L.) genotypes based on resistance indices under field conditions. Int. J. Bio.sci. Vol. 6, No. 2, p. 331-337.

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

Noreldin, T. and M. SH. M. Mahmoud (2017). Evaluation of some wheat genotypes under water stress conditions in Upper Egypt. J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 8 (6): 257 – 265.

Omar, A. M.; A. A. E. Mohamed; M. S. A. Sharsher and W.A.A. El Hag (2014). Performance of some bread wheat genotypes under water regime and sowing methods. J. Agric. Res. Kafr El-Sheikh Univ., 40 (2):327-341

Patel, J.M.; A.S. Patel; C.R. Patel; H.M. Mamrutha; Sh. Pradeep and Karen P. Pachchigar (2019). Evaluation of selection indices in screening durum wheat genotypes combining drought tolerance and high yield potential. Int. J. Curr. Microbiol. App. Sci., 8(4): 1165-1178.

Pirayvatlou A.S. (2001). Relations among yield potential, drought tolerance and stability of yield in bread wheat cultivars under water deficit conditions. Proceedings of the 10thAustralian Agronomy Conference. Hobart, Jan. 29.

Pireivatlou, A. G. S.; R. T. Aliyev and B. S. Lalehloo (2011). Grain filling rate and duration in bread wheat under irrigated and drought stressed conditions. J. Plant Phys. and Breeding, 1: 69–86.

Rajaram, S. and M. Van Ginkel (2001). Mexico, 50 years of international wheat breeding, In the world wheat book: A history of wheat breeding, Bonjean, A.P. and W.J. Angus (Eds.). Paris, France: Lavoisier Publishing, pp.579-604.

Ritchie, S. W.; H.T. Nguyen and A.S. Holaday (1990). Leaf water content and gas exchange parameters of two wheat genotypes differing in drought resistance. Crop Sci., 30: 105–111.

Rosielle, A.A. and J. Hamblin (1981). Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci., 21 (6): 943-946.

Saeidi, M.; S. Ardalani; S. Jalali-Honarmand; M.E.Ghobadi and M. Abdoli (2015). Evaluation of drought stress at vegetative growth stage on the grain yield formation and some physiological traits as well as fluorescence parameters of different bread wheat cultivars. Acta Biol Szeged, 59 (1):35-44.

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

Sharafi, S.; K.Ghassemi-Golezani; S. Mohammadi; S. Lak and B. Sorkhy (2011). Evaluation of drought tolerance and yield potential in winter barley (*Hordeum vulgare*) genotypes. J. Food, Agric. and Envir. 9 (2): 419-422.

Sinclair, T.R. and M.M. Ludlow. (1985). Who taught plants thermodynamics? The unfulfilled potential of plant water potential. Aust. J. Plant Physiol. 33: 213-217.

Singh, K.; A.S Dhindwal; A.K. Dhaka; M. Sewhag and R.K. Pannu (2015). Water use pattern and productivity in bed planted wheat (*Triticum aestivum* L.) under varying moisture regimes in shallow water table conditions. Indian J. Agri. Sci., 85 (8): 1080–1084.

Singh, V.; R. K. Naresh; V. Kumar; M. Chaudhary; N.C. Mahajan; D.K. Sachan; A. Pandey; A. Yadav and L. Jat (2018). Effect of Irrigation Schedules and crop establishment methods on physiological processes, light interception, water and crop productivity of wheat under a semiarid agro-ecosystem. Int. J. Curr. Microbiol. App. Sci., 7(12): 3427-3451.

Wang, YC.; H. Liu; J.S. Sun; F.T. Guo and C.C. Wang (2012). Effects of regulated deficit irrigation on quality and water consumption of solar greenhouse green eggplant. Journal of Irrigation and Drainage 31, 75–79.

Waraich, E.A.; R. Ahmad; Saifullah, S. Ahmad and A. Ahmad (2010). Impact of water and nutrient management on the nutritional quality of wheat. J. Plant Nutr., 33: 640-653.

Wery, J.; S. N. Silim; E. J. Knights; R. S. Malhotra and R. Cousin (1994). Screening techniques and sources and tolerance to extremes of moisture and air temperature in cool season food legumes. Euphytica, 73-83.

Yang, R. C.; S. Jana and J. M. Clark (1991). Phenotypic diversity and associations of some potentially drought-responsive characters in durum wheat. Crop Sci., 31: 1484–1491.

Zaman, E.; M. Abdul Karim; Md. Nasimul Bari; N. Akter and J. Ahmed (2016). Growth and yield performance of selected wheat varieties under water deficit conditions. Bangl. J. Sci. Res. 29 (2): 163-172.

Zeboon, N.H.; S. A. A. Hassan and H. A. Bager (2017). Response of two wheat varieties to irrigation blocking and ethephon foliar application. Alex. J. Agric. Sci., Vol. 62, No.1, pp. 111-118.

استجابة بعض التركيب الوراثية من قمح الخبز لنقص ماء الري

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أجريت هذه الدراسة بمحطة البحوث الزراعية بسخا – كفرالشيخ – مركز البحوث الزراعية في موسمي 2015/2014 و2016/2015م تحت ظروف الري العادي (خمس ريات) ونقص الري (رية واحدة فقط بعد رية الزراعة). وتم تقييم 18 تركيب وراثي من قمح الخبز في تجربتين منفصلتين من معاملات الري لدراسة الصفات المحصولية والفسيولوجية وكذلك دلائل التحمل لتمييز أفضل التراكيب الوراثية من القمح ذات المحصول المرتفع تحت ظروف نقص الري. تم تقييم التراكيب الوراثية المستخدمة بواسطة تصميم القطاعات الكاملة العشوائية في ثلاث مكررات. أوضحت النتائج أن تقليل عدد الريات من خمس ريات الي ريتين أدى الى نقص جميع القيم للصفات تحت الدراسة ما عدا وزن الالف حبة في كلا الموسمين. اختلفت التراكيب الوراثية فيما بينها لجميع الصفات المدروسة وأشارت النتائج الي انه يمكن استخدام السلالات رقم 3 و4 و5 في برنامج التربية للتبكير. وسجلت السلالتان 1 و9 أعلى القيم لمعظم الصفات تحت الدراسة وخصوصا محصول الحبوب في كلا الموسمين. وأظهرت النتائج أن التراكيب الوراثية الممثلة في السلالات رقم 1 و4 و6 و9 و10 والاصناف مصر 1 وجيزة 171 شندويل 1 كانت لها أعلى القيم للمحتوى النسبي للمياه في الأوراق ومعدل فقد الماء في كلا الموسمين. وسجلت السلالتان 1 و9 اعلي القيم في كفاءة استخدام مياه الري. واستنادا إلى مؤشرات تحمل الجفاف لمتوسط الإنتاجية (MP)، المتوسط الهندسي للإنتاجية (GMP) ودليل تحمل الاجهاد (STI)، دليل المحصول (YI)، الوسط التوافقي (HM) قسمت التراكيب الوراثية الي تراكيب عالية التحمل مثل السلالة رقم 1 و9 وهي أنماط وراثية مناسبة للزراعة سواء مع الري العادي او عند وجو د عجز في ماء الري. بينما كانت بعض الطرز الوراثية لقمح الخبز مثل (مصر 1، مصر 2، جيزة 171، والسلالات 2، 6، 8، 10، 11، 12 و13) متوسطة التحمل بينما باقي التراكيب الوراثية كانت حساسة لنقص ماء الري.