Tolerance Indices and Cluster Analysis to Evaluate Some Bread Wheat Genotypes under Water Deficit Conditions

Thanaa, H. A. Abd El-Kreem, E.A.M. Abdelhamid and M. N. A. Elhawary
Wheat Research Dep., Field Crops Research Institute, ARC, Egypt

ABSTRACT

The present study was carried-out at the Experimental Farm of Sakha Agricultural Research Station, during 2017/2018 and 2018/2019 seasons to evaluate eighteen bread wheat genotypes including fourteen promising lines and four cultivars namely; Sakha 93, Sakha 95, Giza 171 and Shandaweel 1 under normal irrigation and deficit conditions. Additionally, six selection indices were used to identify the best genotypes that might be grown under water deficit condition using different drought indices namely; Mean Productivity (MP), Harmonic Mean (HM), Geometric Mean Productivity (GMP), Stress Tolerance Index (STI), Yield Index (YI), and Modified Stress Tolerance Index (MSTI). The results indicated that, the effect of the irrigation treatments, genotypes and their interactions were significantly different in most studied characteristics. The means of all genotypes significantly decreased in all characters except for, proline content that was increased in the two growing seasons under water deficit conditions compared with to normal condition. Genotype 5 recorded the highest number of spikes /m², while the heaviest 1000-kernel weight was produced from Giza 171 under normal and water deficit condations. Sakha 95 gave the highest values for grain yield under both conditions. Based on drought indices HM, GMP, STI, YSI and MSTI, genotype 3 followed by Sakha 95, Shandweel 1, genotype 5 and Giza 171 were identified as suitable genotypes for water deficit conditions. The cluster analysis classified the tested genotypes into five main different groups, each group contained similar genotypes similar based on grain yield and stress tolerance indices. The fifes cluster consisted of one genotype (Sakha 95) that recorded high grain yield and stress tolerance degree followed by the third cluster which consisted of genotypes 3, 5, Giza 171 and Shandaweel 1 which had a moderate grain yield and tolerance to water deficit genotypes. So these genotypes might be used as parents in breeding programes to produce new genotypes with desirable characters related to drought tolerance.

Keywords: Wheat genotypes, Water deficit, Drought indices, Cluster analysis.

INTRODUCTION

Wheat is among the most important cereal crop all over the world and the main food crop in Egypt as in many other parts of the world. The climate is changing all over the world, particularly in semi-arid and arid regions. This changing climate is might strongly affect wheat production worldwide. Since, the world population continues growing, water resources for crop production decline and temperature raises, the development of heat and drought tolerant cultivars is an issue of global concern (El Ameen *et. al,* (2013).

Water is the main abiotic limiting factor in many wheat production areas around the world. Water stress limits plants growth more than any other environmental factor and this occurs when water loss from plants by evaporation and transpiration processes exceeds absorption by root (Huang (2000)).

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 Abdelghany *et. al*, (2016). Esmail *et. al,* (2016) evaluated 25 bread wheat genotypes under deficit water conditions. They found highly significant differences among the genotypes for all characters, indicating the presence of considerable variability. Numerous studies showed that days to heading, days to maturity, plant height, number of spikes/m², grain yield, straw yield, harvest index, number of grains/spike, and 1000-grain weight were affected by different irrigation number (Zafarnaderi and Mohammadi (2013), Noreldin and Mohmoud (2017). Physiological traits of wheat genotypes are strongly influenced under soil water deficit. Wheat genotypes survive under water scarcity by adaptive changes in morphological traits and in the course of physiological, biochemical processes. Grain formation stage is very sensitive to water scarcity. Traits, such as optimal heading time, high relative water content (RWC), photosynthesis rate, and chlorophyll content can be used as a good selection criteria for breeding of wheat genotypes under rain-fed condition. Water stress not only affects the morphology but also severely affects the metabolism of the plant. Chlorophyll content is one of the major factors affecting photosynthesis. Reduction in chlorophyll content under drought stress has been observed in durum and bread wheat (Allahverdiyev 2015). Chlorophyll content of leaves is an indicator of photosynthetic capability; light reflection from leaf was increased with increasing drought stress and chlorophyll content of leaf significantly decreased (Fotovat. *et. al,* 2007). 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. The present study aimed to identify the high yielding and drought tolerant wheat genotypes under normal irrigation and water deficiency.

MATERIALS AND METHODS

This study was conducted at the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during 2017/2018 and 2018/2019 seasons. Eighteen bread wheat (*Triticum aestivum* L.) genotypes were used sowing dates were mid-November in the two seasons. The tested wheat genotypes contained 14 lines promising lines from the local breeding program in addition to four cultivars (checks) being Giza 171, Shandweel 1, Sakha 93 and Sakha 95. The name and pedigree of the studied genotypes were listed in Table 1.

Table 1: Name and pedigree of the studied wheat genotypes

Genotype	Pedigree and selection history
G1	SAKHA 94/6/ GIZA 158 /5/ CFN /CNO "S" // RON /3/ BB / NOR 67 /4/ TL /3/ FN / TH // NAR 59*2 S. 16209 -08S-05S-1S -0S
G 2	CAZO / KAUZ // KAUZ /3/ MILAN / KAUZ // CHIL / CHUM18 S. 16222 -017S-05S-1S -0S
G 3	CHEN / AEGILOPS SQUARROSA (TAUS) // BCN/3/2*KAUZ /4/ PJN / BOW // OPATA*2 /3/ CROC-1 / AE.SQUARROSA (224) // OPATA S. 16279 -026S-07S-1S -0S
G 4	GEN*2 // BUC / FLK /3/ BUCHIN /7/ BUC // 7C / ALD /5/ MAYA74 / ON // 1160.147 /3/ BB / GLL /4/ CHAH"S" /6/ MAYA / VUL // CMH74A.630 / 4*SX S. 16297 -028S-011S-1S -0S
G 5	WEAVER/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC /5/ SAKHA 93 S. 16307 -062S-08S-4S -0S
G 6	BUC // 7C / ALD /5/ MAYA74 / ON // 1160.147 /3 BB / GLL /4/CHAH"S" /6/ MAYA / VUL // CMH74A.630 /4*SX /7/ SW 89.3064 *2 / BORL 95 S. 16353 -027S-07S-5S -0S
G 7	CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /3/ 2*KAUZ /4/ HAAMA-11 S. 16276-02S-07S-3S -0S
G 8	PJN / BOW // OPATA*2 /3/ CROC-1 / AE.SQUARROSA (224) // OPATA /4/ SKAUZ *2 / SRMA S. 16331-04S-04S-1S -0S
G 9	CHIBIA//PRLII/CM65531 /7/ BUC // 7C / ALD /5/ MAYA74 / ON // 1160.147 /3 BB / GLL /4/CHAH"S" /6/ MAYA / VUL // CMH74A.630 /4*SX S. 16342-011S-09S-1S -0S
G 10	CHIBIA // PRLII /CM65531/3/ SKAUZ *2 / SRMA S. 16338-03S-1S-2S -0S
G 11	GIZA 158 /5/ CFN /CNO "S" // RON /3/ BB / NOR 67 /4/ TL /3/ FN / TH // NAR 59*2 S10232-3S-2S-4S-0S
G 12	GIZA164 / SAKHA 61 S.9242-IBR-2BR-5BR-2BR-0BR
G 13	ATTILA*2/PBW65 /4/ CHEN/AEGILOPS SQUARROSA (TAUS) // BCN /3/ 2*KAUZ S. 16233-01S-06S-5S-0S
G14	VOROBEY CMSS96Y02555S-040Y-020M-050SY-020SY-6M-0Y
Sakha 93 (G15)	SAKHA92/TR810328 S.8871-1S-2S-1S-0S
Giza 171 (G16)	SAKHA 93 / GEMMEIZA 9 S.6-1GZ-4GZ-1GZ-2GZ-0S
Shandweel1 (G 17)	SITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC CMSS93B00567S-72Y-010M-010Y-010M-3Y-0M-0HTY-0SH
Sakha 95 (G18)	PASTOR/SITE/MO/3/CHEN/AEGILOPS SQUARROSA(TAUS)//BCN/4/WBLL1 CMA01Y00158S-040POY-040M-030ZTM-040SY26M-0Y-0SY-0S.

In each season, the entries were evaluated in two experiments representing two different irrigation conditions. The first was to irrigate four times after planting irrigation (normal irrigation treatment N) while the second was to give one surface-irrigation after planting irrigation (water deficit treatment D). The experimental design was randomized complete block design with three replicates for each experiment. Details of soil properties of the research site in each season were summarized in Table 2. The meteorological data were recorded for the two winter growing seasons from Sakha meteorological station as shown in Table 3.

A wide border (25 m) surrounded each experiment to minimize the underground water permeability. The wheat grains were planted in six rows / plot (3.5 m long and 20 cm apart). Thus, the plot area was 4.2 m^2. All other cultural practices were applied as recommended for wheat cultivation. The studied characters were: flag leaf area (FLA), chlorophyll a content (µg/ml, chl a), chlorophyll b content (µg/ml, chl b) according to Wettstein (1957), proline content (mg/g fw^{-1}) according to Bates et. al, (1973), plant height (PH, cm), number of spikes/m^2 (S/m^2), number of kernels / spike (K/S), 1000-kernel weight (1000 KW in g), straw yield (SY in Kg $plot^{-1}$) and grain yield (GY, Kg $plot^{-1}$).

Stress Tolerance Indices:

For each genotype, six stress tolerance indicies were calculated based on average grain yield under normal irrigation (Yn) and reduced irrigation (Ys) over the two seasons. The names, equations and references of the stress tolerance indices are shown in Table (4).The genotypes which possess high values of Mean Productivity (MP), Harmonic Mean (HM), Geometric Mean Productivity (GMP), Stress Tolerance Index (STI), Yield Index (YI), and Modified Stress Tolerance Index (MSTI) are considered to be more tolerant to reduced irrigation.

Statistical analysis

The data were subjected to individual and combined analysis of variance of randomized complete block design over the two experiments (normal and deficit irrigation) for each season (Steel *et. al,* 1997). As a routine statistical step, Levene test was run prior to the combined analysis to confirm the homogeneity of individual error terms, (Levene, 1960).

Table 2: Mechanical and chemical soil analyses during the two growing seasons

Season	Sample depth	Soil structure	PH	EC dsm-1	Anions my/l				Cations mg/l			
					CO3--	HCO3--	CL^-	$SO4^{--}$	Ca^{++}	Mg^{++}	Na^+	K^+
2017/2018	0 -30	Clayey	8.61	2.33	-	2.5	10	43.32	10.6	6.1	12.38	0.29
	30 - 60	Clayey	8.7	2.1	-	2.25	12.5	48.69	6.6	4.9	8	0.33
2018/2019	0 - 30	Clayey	8.06	2.01	_	3	8.11	9.11	5.6	3.91	10.34	0.31
	30 - 60	Clayey	7.90	1.5	_	2.5	4.8	7.16	3.23	2.33	8.42	0.29

Table 3: Monthly mean of air temperature (AT ^{O}C), relative humidity (RH %) and rainfall (mm/month) in winter seasons 2017/2018 and 2018/2019 at Sakha location.

Month	AT ^{O}C 2017/18		AT ^{O}C 2018/19		RH%		Rainfall (mm)	
	Max.	Min.	Max.	Min.	2017/18	2018/19	2017/18	2018/19
December	21.50	15.40	20.22	14.31	65.12	75.63	32.94	21.70
January	18.85	14.03	19.63	12.69	60.00	67.68	9.60	14.90
February	21.53	14.50	19.58	14.95	62.21	70.69	25.20	15.30
March	25.51	16.59	22.05	18.21	67.50	72.21	0.00	17.30
April	27.80	19.94	25.80	20.64	66.32	68.78	10.60	3.90
May	37.00	28.00	33.00	26.29	55.25	57.09	0.00	0.00

* Max = maximum temperature, ** Min = minimum temperature.

Table 4: The name, equation and reference of some stress tolerance indices

No.	Index name	Formula	Reference
	% Reduction	$(Y_n-Y_s)*100/Y_n$	
	The high values of these indices indicated to stress 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 average grain yield of each genotype under normal and stress conditions.
- $\bar{Y}_n$ and $\bar{Y}_s$ indicate average grain yield overall genotypes under normal and stress conditions

Least significant difference (LSD) test was used to detect the significant differences among the proper items at probability level of 0.05 according to Waller and Duncan (1969). In order to assort genotypes according to their grain yield and water deficit tolerance, agglomerate hierarchical cluster analysis was worked out using the average grain yield and the six tolerance indices. A dendrogram was constructed based on "Euclidean distance" procedure. Genotypes were clustered using un-weighted pair group method using arithmetic average as outlined by Kovach (1995).

RESULTS AND DISCUSSIONS

The results of Levene test proved homogeneity of separate error variances for all studied characters that permited the application of combined analysis.

Effect of water deficit

Data in Table 5,6,7 and 8 showed that water conditions (normal or deficit) had significantly affected all studied characters in the two seasons of the study, except for 1000-kernel weight, kernels spike^{-1} and harvest index. These results indicated that water deficiency caused significant decreases in all studied characters, except for, proline content which had increased in most cases. These results were in agreement with those reported by Abdul jeleel *et. al,* (2008), Abd El Kreem and El Saidy (2011) and El-Hosery *et. al,* (2019).

Genotypes performance

Regarding the studied genotypes performance, results in Table 5 showed that, the studied genotypes significantly differed in all studied characters. All genotypes under water deficit condition gave lower values of FLA. Akram (2011) reported that leaf area is a reflection of transpiration and assimilation. It was evident that G 6 and Giza 171 had the highest FLA under normal and water deficit conditions during the first season with insignificant difference. In addition, G 13 and Sakha 95 gave the highest values of Chl content in the first season. G 6 and G 7 had the highest values of Chl content in the second season. On the other side, G 7 exhibited higher values of proline content in the second season. These results were in harmony with those reported by Shan *et. al,* (2012). All genotypes under water deficit irrigation had mean values of Chl content lower than normal conditions. The decrease in Chl content under water deficit condition may be the result of pigment photo-oxidation and degradation under drought stress that lead to more reduction of Chl a and b, (Allahverdiyev, 2015).

Results in Table (6) showed that, G 14 had the tallest plants, while G 12 showed the shorter plants in both seasons. G 5 obtained the highest number of spikes/m^2 over the two seasons. Regarding the 1000-kernel weight, the results indicated that the heaviest weight of kernels were produced by Giza 171 in both seasons. Results in Table 7 showed that, G 8, Giza 171 and Shandaweel 1 had the maximum recorded number of kernels/spike in both seasons with insignificant differences. Most genotypes under water deficiency gave the least values of grain yield (kg/plot). Substantial losses in grain yield are caused by water deficiency depending on the developmental stage at which water stress occured (Ozturk and Aydin, 2004). Water stress at various stages before anthesis can reduce plant height as reported by El-Banna *et. al,* (2002). Moreover, plant characters recorded to main tiller might play an important role in determining grain yield under water stress conditions (Okuyama *et. al,* 2005). Also, G 3, G 9, Giza 171, Shandaweel1 and Sakha 95 gave similarly the highest grain yield (Kg/plot) in the first season, whereas, the maximum grain yield was produced by Sakha 95 in the second season. Moreover, the highest straw yield (kg/plot) was obtained from G 14 in the two seasons; similarly, highest values of harvest index % was expressed G 8 in the first season while G 5 and Sakha 95 had the highest value in the second season in the Table (8). These results were in agreement with those reported by Esmail *et. al,* (2016) and Noreldin and Mahmoud (2017).

Interaction effect

Results in Table (5) indicated that, the interaction between irrigation treatment and wheat genotype significantly differed in FLA, Chl and proline content during the two seasons. G 4, G 6, G 11 and Giza 171 gave the highest value in FLA under normal irrigation. While, G 6 and Giza 171 gave the highest value under water deficiency in the first season. However G 4 gave the highest value under normal irrigation but Sakha 93 gave the highest value under water deficiency in the second season.

Concerning Chl content, the results indicated that G 13 and Sakha 95 contained the highest values under normal irrigation. However, G 5 and Line 9 had the highest values under water deficit in the first season. While, G 3 and G 7 had the highest value under normal irrigation versus G 7 that had the highest value from Chl content under water deficiency in the second season.

The highest proline content produced from G 10 and Sakha 95 under water deficiency. However, G 8, G 11 and Sakha 93 had the lowest value under normal irrigation in the first season. On the other side, G 5 and G 7 gave the highest value under water deficiency. While, G 10 and G 14 gave the least values under normal irrigation in the second season.

he results in Table (6) indicated that, the interaction between irrigation treatments and wheat genotypes significantly affected plant height and 1000-kernels weight in the first season and

Table 5: Mean values of flag leaf area (FLA), total chlorophyll (Total chl.) and Proline content for 18 wheat genotypes evaluated under normal and water deficit treatments in the two wheat growing seasons 2017 / 2018 and 2018 /2019.

Character	FLA						Total chl.						Proline					
Season	2017 / 2018			2018 / 2019			2017 / 2018			2018 / 2019			2017 / 2018			2018 / 2019		
Treatment / Genotype	N	D	Mean.	N	D	Mean.	N	D	Mean.	N	D	Mean.	N	D	Mean.	N	D	Mean.
G1	63.4	34.16	48.78	63.9	37.2	50.55	4.329	4.222	4.275	5.126	4.599	4.862	1.34	1.55	1.45	1.42	1.98	1.70
G 2	44.0	31.56	37.83	55.66	40.2	47.92	4.431	4.386	4.408	5.003	4.819	4.911	1.40	1.50	1.45	1.39	2.17	1.78
G 3	41.4	36.22	38.82	49.35	38.18	43.76	5.027	4.339	4.683	5.33	4.702	5.016	1.36	1.53	1.45	1.66	2.05	1.85
G 4	60.2	33.81	47.01	69.16	37.27	53.21	5.271	4.694	4.982	5.123	4.828	4.975	1.29	1.64	1.46	1.45	2.23	1.84
G 5	54.3	40.99	47.69	61.5	38.21	49.85	4.923	4.763	4.843	5.122	4.877	4.999	1.36	1.47	1.42	1.45	2.29	1.87
G 6	65.1	52.77	58.96	58.68	45.14	51.91	4.795	4.684	4.739	5.162	4.868	5.015	1.25	1.50	1.38	1.49	2.24	1.86
G 7	54.8	43.19	49.02	63.00	38.59	50.79	4.520	4.505	4.512	5.34	4.931	5.135	1.35	1.56	1.45	1.60	2.31	1.96
G 8	51.3	30.50	40.93	59.97	34.99	47.47	5.009	4.613	4.811	4.975	4.542	4.758	1.21	1.62	1.42	1.38	1.94	1.66
G 9	51.2	42.63	46.96	54.19	39.34	46.76	4.778	4.746	4.762	5.152	4.598	4.875	1.36	1.39	1.37	1.49	1.43	1.46
G 10	51.7	32.43	42.1	61.27	40.12	50.7	4.132	3.962	4.047	4.978	4.572	4.775	1.26	1.83	1.54	1.31	1.39	1.35
G 11	62.8	42.38	52.63	54.37	40.44	47.41	4.761	4.663	4.712	5.214	4.721	4.967	1.18	1.57	1.37	1.49	1.49	1.49
G 12	51.7	33.82	42.81	53.21	41.10	47.16	4.733	4.338	4.535	5.133	4.715	4.924	1.28	1.53	1.41	1.62	1.49	1.56
G 13	55.1	31.26	43.21	60.08	39.15	49.61	5.993	4.415	5.204	5.014	4.752	4.883	1.30	1.55	1.43	1.43	1.52	1.47
G14	59.7	42.91	51.34	58.99	39.11	49.05	4.567	4.297	4.432	4.760	4.691	4.726	1.37	1.57	1.47	1.26	1.54	1.40
Sakha 93 (G15)	52.6	45.78	49.24	54.97	47.20	51.09	5.437	4.308	4.872	5.017	4.646	4.831	1.22	1.56	1.39	1.40	1.41	1.40
Giza 171 (G16)	66.2	50.34	58.24	54.85	41.85	48.35	5.252	4.645	4.948	5.204	4.605	4.904	1.29	1.39	1.34	1.46	1.99	1.72
Shandweel1 (G 17)	47.9	33.09	40.52	55.51	38.36	46.94	4.949	4.610	4.779	5.112	4.644	4.878	1.25	1.63	1.44	1.45	1.43	1.44
Sakha 95 (G18)	43.5	37.317	40.45	53.10	44.55	48.82	5.603	4.426	5.014	5.003	4.711	4.857	1.24	1.78	1.51	1.39	1.48	1.43
Irrigation	63.4	34.15	48.78	63.90	37.2	50.55	4.917	4.780	4.848	5.098	4.712	4.905	1.30	1.56	1.43	1.45	1.80	1.63
LSD $_{0.05}$ I		2.44			3.27			0.134			0.093			0.03			0.08	
LSD $_{0.05}$ G		5.03			5.04			0.209			0.124			0.09			0.10	
LSD $_{0.05}$ IxG		7.12			7.14			0.295			0.176			0.22			0.14	

I; irrigation treatment G; genotype

Table 6: Mean values of plant height, number of spikes/ m² (S/m²) and1000-kernel weight (1000 KW) for 18 wheat genotypes evaluated under normal and water deficit treatments in the two wheat growing seasons 2017 / 2018 and 2018 /2019.

Character	Plant Height						S/m²						1000 KW					
Season	2017/2018			2018/2019			2017/2018			2018/2019			2017/2018			2018/2019		
Treatment / Genotype	N	D	Mean	N	D	Mean	N	D	Mean	N	D	Mean	N	D	Mean	N	D	Mean
G1	120.0	113.3	116.7	125.0	115.0	120.0	337	255	296	345	271	308	40.9	45.1	43.0	35.7	40.9	38.3
G 2	111.7	105.0	108.3	110.0	98.3	104.2	409	343	376	433	344	388	38.0	41.8	39.9	38.4	38.1	38.3
G 3	115.0	103.3	109.2	111.7	105.0	108.3	456	377	417	391	316	354	43.1	44.3	43.7	42.8	42.0	42.4
G 4	115.0	106.7	110.8	118.3	108.3	113.3	335	271	303	364	320	342	46.3	50.0	48.1	47.3	45.9	46.6
G 5	108.3	96.7	102.5	113.3	98.3	105.8	465	420	443	451	425	438	40.3	40.6	40.4	39.4	36.9	38.1
G 6	105.0	96.7	100.8	105.0	96.7	100.8	277	252	265	342	312	327	46.3	48.5	47.4	49.3	42.3	45.8
G 7	118.3	115.0	116.7	113.3	106.7	110.0	366	316	341	389	343	366	43.2	44.4	43.8	43.9	41.0	42.4
G 8	118.3	111.7	115.0	115.0	103.3	109.2	355	304	329	363	293	328	46.9	47.9	47.4	46.0	44.1	45.1
G 9	105.0	100.0	102.5	105.0	95.0	100.0	401	380	391	371	340	356	41.7	46.1	43.9	41.7	37.8	39.7
G 10	113.3	105.0	109.2	116.7	105.0	110.8	349	309	329	374	309	341	43.5	42.8	43.1	45.7	44.8	45.3
G 11	121.7	120.0	120.8	126.7	120.0	123.3	305	243	274	313	249	281	41.4	49.7	45.6	42.7	43.6	43.1
G 12	100.0	95.0	97.5	103.3	95.0	99.2	468	396	432	401	367	384	45.5	51.3	48.4	45.2	42.2	43.7
G 13	111.7	98.3	105.0	110.0	98.3	104.2	424	357	390	419	331	375	41.9	44.8	43.4	40.8	45.3	43.1
G14	131.7	126.7	129.2	128.3	121.7	125.0	340	305	323	375	298	336	42.2	45.1	43.7	40.0	40.6	40.3
Sakha 93 (G15)	106.7	95.0	100.8	105.0	95.0	100.0	385	321	353	408	349	378	39.1	41.8	40.4	40.2	39.2	39.7
Giza 171 (G16)	125.0	111.7	118.3	123.3	115.0	119.2	354	288	321	301	275	288	48.6	52.5	50.5	46.6	47.9	47.2
Shandweel1 (G 17)	120.0	110.0	115.0	120.0	110.0	115.0	376	335	355	343	306	325	39.5	42.3	40.9	39.2	36.4	37.8
Sakha 95 (G18)	118.3	115.0	116.7	123.3	115.0	119.2	419	341	380	360	322	341	46.9	50.1	48.5	47.0	46.9	47.0
Irrigation	114.7	106.9	110.8	115.2	105.6	110.4	379	323	351	375	320	348	43.1	46.1	44.6	42.9	42.0	42.4
LSD $_{0.05}$ I		1.9			1.8			47			46			n. s.			n. s.	
LSD $_{0.05}$ G		3.6			3.1			48			52			1.8			3.5	
LSD $_{0.05}$ IXG		5.1			n. s.			n. s.			73			2.5			n. s.	

I; irrigation treatment G; genotype n. s.; not significantly different.

Table 7: Mean values of number of kernels/spike (K/S), grain yield Kg/Plot and straw yield Kg/Plot for 18 wheat genotypes evaluated under normal and water deficit treatments in the two wheat growing seasons 2017 / 2018 and 2018 /2019.

Character	K/S						Grain yield Kg/Plot						Straw yield Kg/Plot					
Season	2017/2018			2018/2019			2017/2018			2018/2019			2017/2018			2018/2019		
Treatment / Genotype	N	D	Mean	N	D	Mean	N	D	Mean	N	D	Mean	N	D	Mean	N	D	Mean
G1	66.0	60.4	63.2	64.3	58.4	61.3	3.7	3.0	3.3	4.3	3.0	3.7	6.0	4.6	5.3	6.6	5.2	5.9
G 2	65.8	60.5	63.2	52.4	42.6	47.5	4.3	3.6	3.9	4.0	3.3	3.6	6.5	4.5	5.5	5.9	4.6	5.3
G 3	69.3	65.6	67.4	55.6	54.1	54.8	4.8	3.8	4.3	4.4	3.7	4.1	6.6	5.0	5.8	6.1	4.7	5.4
G 4	62.0	56.7	59.4	53.7	51.0	52.3	4.2	3.6	3.9	4.7	3.4	4.1	6.3	4.8	5.5	6.2	4.7	5.5
G 5	72.5	60.8	66.7	56.6	51.7	54.1	4.4	3.6	4.0	4.8	3.8	4.3	6.6	4.8	5.7	6.7	4.6	5.7
G 6	64.1	61.1	62.6	55.1	52.7	53.9	3.9	3.1	3.5	4.2	3.5	3.9	5.8	5.0	5.4	5.8	4.4	5.1
G 7	64.6	56.6	60.6	58.5	55.9	57.2	4.1	3.3	3.7	4.2	3.6	3.9	6.3	5.0	5.6	6.9	5.4	6.1
G 8	72.1	64.7	68.4	68.2	63.0	65.6	4.5	3.6	4.0	4.4	3.3	3.9	5.7	4.3	5.0	6.0	4.6	5.3
G 9	69.8	62.2	66.0	62.0	53.0	57.5	4.6	3.7	4.1	4.2	3.5	3.9	5.7	4.8	5.2	5.8	4.8	5.3
G 10	73.4	63.5	68.4	57.6	55.7	56.6	4.3	3.4	3.9	4.2	3.4	3.8	5.8	5.0	5.4	6.0	4.8	5.4
G 11	63.6	53.8	58.7	61.8	53.1	57.5	3.8	3.0	3.4	3.9	3.2	3.5	6.6	4.9	5.8	6.7	5.0	5.8
G 12	48.5	46.2	47.4	46.4	43.2	44.8	4.0	2.7	3.3	3.6	2.6	3.1	5.5	4.8	5.2	5.4	4.4	4.9
G 13	42.0	30.9	36.5	52.5	47.1	49.8	4.4	3.6	4.0	4.4	3.6	4.0	5.9	4.8	5.4	6.2	5.1	5.6
G14	62.9	59.5	61.2	65.5	56.3	60.9	4.2	3.5	3.9	4.2	3.5	3.8	7.4	5.5	6.4	7.5	5.7	6.6
Sakha 93 (G15)	60.4	54.6	57.5	46.9	43.3	45.1	3.5	2.7	3.1	3.9	2.7	3.3	6.3	5.0	5.7	6.1	4.9	5.5
Giza 171 (G16)	75.4	64.8	70.1	63.0	60.1	61.6	4.5	3.7	4.1	4.6	3.8	4.2	6.8	4.7	5.7	6.5	4.8	5.6
Shandweel1 (G 17)	68.5	64.0	66.3	66.7	58.0	62.3	4.7	3.5	4.1	4.7	3.7	4.2	7.5	5.3	6.4	7.1	5.2	6.1
Sakha 95 (G18)	60.2	55.0	57.6	54.3	50.0	52.1	4.9	3.9	4.4	5.2	4.1	4.7	6.4	5.0	5.7	6.6	5.2	5.9
Irrigation	64.5	57.8	61.2	57.8	52.7	55.3	4.3	3.4	3.8	4.3	3.4	3.9	6.3	4.9	5.6	6.3	4.9	5.6
LSD $_{0.05}$ I		n.s.			n.s.			0.6			0.4			0.9			0.6	
LSD $_{0.05}$ G		6.7			7.9			0.3			0.3			0.6			0.5	
LSD $_{0.05}$ IXG		n.s.			n.s.			n.s.			n.s.			n.s.			n.s.	

I; irrigation treatment G; genotype n.s.; not significantly different.

Table 8: Mean values of harvest index % for 18 wheat genotypes evaluated under normal and water deficit treatments in the two wheat growing seasons 2017 / 2018 and 2018 /2019.

Character	Harvest index %					
Season	2017/2018			2018/2019		
Treatment / Genotype	N	D	Mean	N	D	Mean
G1	38.1	39.3	38.7	39.6	36.9	38.3
G 2	40.0	45.1	42.5	40.1	41.9	41.0
G 3	42.0	43.6	42.8	42.2	44.3	43.3
G 4	40.0	43.0	41.5	42.8	41.8	42.3
G 5	39.5	42.8	41.2	41.6	45.4	43.5
G 6	40.6	38.4	39.5	41.7	44.6	43.2
G 7	39.2	40.0	39.6	38.1	39.6	38.9
G 8	44.1	45.2	44.6	42.8	41.9	42.4
G 9	44.5	43.5	44.0	42.3	42.1	42.2
G 10	42.6	41.4	42.0	41.5	41.8	41.7
G 11	37.0	38.2	37.6	36.9	38.7	37.8
G 12	42.0	36.0	39.0	40.2	37.0	38.6
G 13	42.8	42.9	42.8	41.6	41.3	41.5
G14	36.5	38.7	37.6	35.5	38.2	36.9
Sakha 93 (G15)	35.6	35.3	35.5	38.9	35.6	37.2
Giza 171 (G16)	40.0	44.1	42.0	41.5	44.3	42.9
Shandweel1 (G 17)	38.4	39.7	39.0	40.0	41.9	40.9
Sakha 95 (G18)	43.2	43.5	43.4	44.2	44.0	44.1
Irrigation	40.3	41.1	40.7	40.6	41.2	40.9
$LSD_{0.05}$ I		n.s.			n.s.	
$LSD_{0.05}$ G		2.8			2.9	
$LSD_{0.05}$ IXG		n.s.			n.s.	

number of spike /m² in the second season. The tallest plants were produced from G 14 under normal and water deficit treatments, while, the shortest plants were produced by G 12 and Sakha 95 in the first season. G 5 recorded the highest number of spike/m^2 under any of the studied irrigation conditions. While, the least number of spikes/m² obtained from G11 under water deficit treatment in the second season. The heaviest kernels were obtained from Giza 171 under irrigation and water deficit treatment in the first season. These, results agree with the results of Shan *et. al,* (2012).

Drought indices.

Results, in Table 9, showed that, the highest grain yielding genotypes under normal irrigation were Sakha 95 (5.03 Kg/plot) and shandaweel 1 (4.68 Kg/plot), whereas Sakha 93 had the least value (3.6 kg/plot). However under water deficiency, Sakha 95 (3.99 kg/plot) and G 3 (3.78 kg/plot) had the highest grain yield. Meanwhile, G 12 and Sakha 93 gave the least values (2.65 and 2.72 kg/plot), respectively. According to the MP index the highest value of MP recorded by Sakha 95 under both normal and water deficit conditions. Whereas, the least values was expressed by Sakha 93.

Genotypes that enjoyed high grain yield under normal and stressed irrigation condation, had high values of MP index. The MP index was more favorable as reported by Farshadfar and Sutka (2002). While, Shirazi *et. al,* (2009) stated that high yield under non-stress condition led to MP index to increase and could not be considered as a valid indicator to identify the tolerant genotypes. Sakha 95 and Line 3 recorded the highest HM, GMP, STI. YSI and MSTI as compared with other genotypes suggesting more stress tolerance mechanism. Genotypes had high values of STI showed high MP and GMP. STI was more useful index in order to select favorable cultivars under stress and non-stress conditions (Moghaddam and Hadi-Zadeh 2002) Therefore, selection based on STI might lead to high-yielding tolerant genotypes (Abdelghany *et. al,* 2016).

Cluster analysis

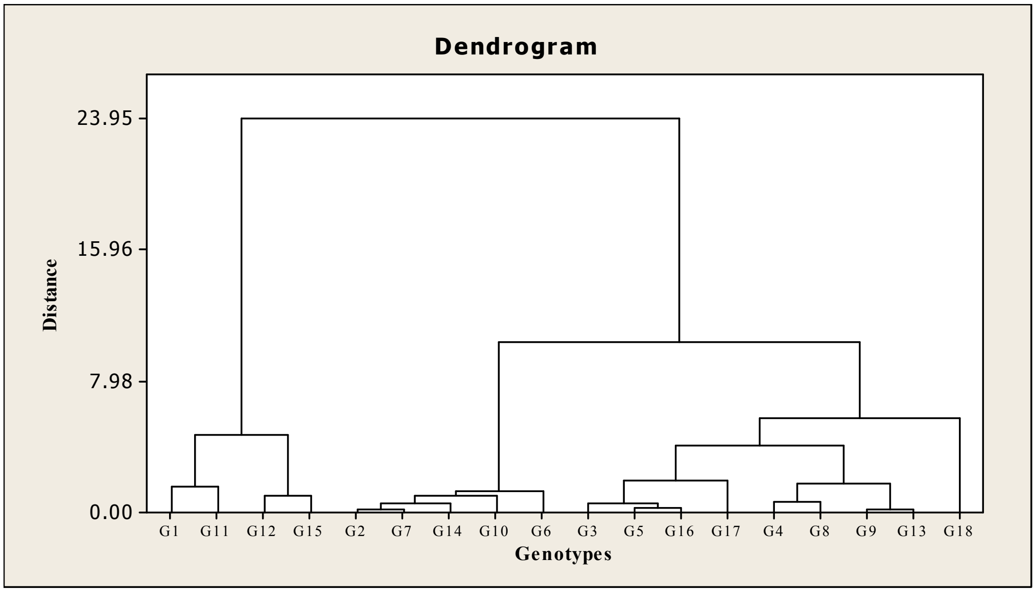
The cluster analysis was used as an efficient procedure to emerge the structural relationships among tested genotypes and provides a hierarchical classification of them. In the present work the similarity levels of 18 wheat genotypes were estimated based on grain yield and stress tolerance indices.

Table 9: Estimates of stress tolerance indices (STI's) of 18 bread wheat genotypes based on grain yield under normal and stress conditions across the two seasons.

Genotypes	Grain yield		Stress tolerance indices (STI)					
	Y_n	Y_s	MP	H M	GMP	STI	YSI	MSTI
			Calculated values					
G1	3.99	3.00	3.50	3.43	3.46	0.65	0.88	0.50
G 2	4.16	3.42	3.79	3.76	3.78	0.77	1.00	0.78
G 3	4.60	3.78	4.19	4.15	4.17	0.94	1.11	1.15
G 4	4.44	3.52	3.98	3.92	3.95	0.85	1.03	0.89
G 5	4.59	3.70	4.14	4.10	4.12	0.92	1.08	1.08
G 6	4.06	3.33	3.69	3.66	3.68	0.73	0.97	0.70
G 7	4.15	3.43	3.79	3.75	3.77	0.77	1.00	0.77
G 8	4.46	3.44	3.95	3.89	3.92	0.83	1.01	0.84
G 9	4.40	3.58	3.99	3.95	3.97	0.85	1.05	0.93
G 10	4.28	3.44	3.86	3.81	3.83	0.80	1.01	0.80
G 11	3.86	3.10	3.48	3.44	3.46	0.65	0.91	0.53
G 12	3.78	2.65	3.22	3.12	3.17	0.54	0.78	0.33
G 13	4.42	3.60	4.01	3.97	3.99	0.86	1.05	0.95
G14	4.20	3.48	3.84	3.81	3.83	0.79	1.02	0.82
Sakha 93 (G15)	3.69	2.72	3.21	3.13	3.17	0.54	0.80	0.34
Giza 171 (G16)	4.56	3.73	4.14	4.10	4.12	0.92	1.09	1.10
Shandweel1 (G 17)	4.68	3.61	4.14	4.08	4.11	0.92	1.06	1.02
Sakha 95 (G18)	5.03	3.99	4.51	4.45	4.48	1.09	1.17	1.48

Table 10: Summary of hierarchical cluster analysis represents the classification of tested wheat genotypes based on grain yield and stress tolerance indices.

Cluster No.	Gain yield			Average grain yield	Stress tolerance rank	Grain yield category	Stress tolerance degree
	Genotypes	Normal	Stress				
1	G 1	3.99	3.00	3.35	16	Low	Sensitive
	G 11	3.86	3.10		15		
	G 12	3.78	2.65		18		
	G 15	3.69	2.72		17		
	Mean	3.83	2.87				
2	G 2	4.16	3.42	3.79	12	Low	Moderate
	G 6	4.06	3.33		14		
	G 7	4.15	3.43		13		
	G 10	4.28	3.44		11		
	G 14	4.20	3.48		9		
	Mean	4.17	3.42				
3	G 3	4.60	3.78	4.16	1	Moderate	Tolerant
	G 5	4.59	3.70		4		
	G 16	4.56	3.73		3		
	G 17	4.68	3.61		5		
	Mean	4.61	3.70				
4	G 4	4.44	3.52	3.98	8	Moderate	Moderate
	G 8	4.46	3.44		10		
	G 9	4.40	3.58		7		
	G 13	4.42	3.60		5		
	Mean	4.43	3.53				
5	G 18	5.03	3.99	4.51	2	High	Tolerant



These genotypes were classified into five main groups. The clustering pattern of these genotypes is tabulated in Table 10 and Figure 1.

The first cluster aggregated G 1, G 11, G 12 and Sakha 93 that had the low grain yield (3.35 Kg/plot) and sensitive to drought, while the second cluster contained G 2, G 6, G 7, G 10 and G 14 that had the low grain yield (3.79 kg/plot) and moderate to tolerance drought. The third cluster consisted of G 3, G 5, Giza 171 and Shandaweel 1 had the moderate grain yield (4.16 kg/plot) and tolerant drought, however, the fourth cluster contained G 4, 8, 9 and 13 had the moderate grain yield (3.98 Kg/plot) and moderate stress tolerance degree. The fifes cluster consisted of one genotype Sakha 95 that recorded high grain yield and tolerant stress tolerance degree. These results in agreement with El-Hosary *et. al,* (2019).

Finally, in the present work results indicated that cultivar Sakha 95 exhibited the highest grain yield and the most tolerant genotype to water stress. G 3, G 5, Giza 171 and Shandaweel 1 that had moderate grain yield and were tolerant to water deficit. So, these genotypes might be used as parents in breeding programs to produce new genotypes with desirable characters related to drought to tolerance.

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الملخص العربى

مؤشرات الجفاف والتحليل العنقودى لتقيم بعض التراكيب الوراثية من قمح الخبز تحت ظروف الاجهاد المائى

ثناء حمد عبد السلام عبد الكريم، السيد على محمد عبد الحميد، محمد نبيل عوض الهواري
قسم بحوث القمح – معهد بحوث المحاصيل الحقلية– مركز البحوث الزراعية– مصر

أجريت هذه الدراسة بمزرعة محطة البحوث الزراعية بسخا لتقييم ثمانية عشر تراكيب وراثيه لقمح الخبز تضمنت اربعة عشر سلاله جديدة وأربعة أصناف منزرعة وهى جيزة ١٧١، شندويل ١، سخا ٩٣ و سخا ٩٥ تحت ظروف الرى العادى ونقص المياه خلال موسمي ٢٠١٧/٢٠١٨ و٢٠١٨/٢٠١٩. بالاضافة الى تقييم مؤشرات الجفاف المختلفة تحت معاملات الرى المختلفة، أظهرت النتائج ان معظم الصفات تأثرت معنويا بالتركيب الوراثي و معاملات الرى والتفاعل بينهما فى الموسمين حيث تأثرت كل الصفات المدروسة سلبيا تحت نقص مياه الرى ما عدا صفة البرولين حيث زاد محتوى البرولين فى كلا الموسمين، سجل التركيب الوراثى رقم ٥ أعلى عدد سنابل /م٢ بينما أعلى وزن ل١٠٠٠ حبة تم الحصول عليه من الصنف جيزة ١٧١ وتفوق الصنف سخا ٩٥ فى محصول الحبوب تحت ظروف الرى العادى ونقص المياه فى كلا الموسمين: وفقا لمؤشرات الجفاف متوسط الانتاجيه (MP)، المتوسط الهندسى للانتاجيه (GMP) ومؤشر تحمل الاجهاد (STI) تم تحديد السلاله ٣ يليها الصنف سخا ٩٥. شندويل ١. التركيب الوراثى رقم ٥ وجيزة ١٧١ متحملين للاجهاد المائى. كما أتضح من نتائج التحليل العنقودي أن التراكيب الوراثية المختبرة أمكن تقسيمها إلي خمسة مجموعات متباينة فيما بينهما وذلك تبعا لمؤشرات تحمل الجفاف ومحصول الحبوب كما أظهرت النتائج أن المجموعة الخامسة احتوت على الصنف سخا ٩٥ أعلي التراكيب الوراثية لصفة محصول الحبوب والتحمل للاجهاد المائى، تليها المجموعة الثالثة حيث ضمت التراكيب الوراثية متوسطة المحصول ولكنها متحملة للاجهاد المائى واشتملت على التركيب الوراثى رقم ٣ و٥ وصنفين هما جيزة ١٧١ وشندويل ١ والتى يمكن استخدامهم كاباء فى برامج التربية لتحمل الجفاف.