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EFFECT OF REDUCED IRRIGATION ON PRODUCTIVITY AND BEHAVIOR OF TWENTY BREAD WHEAT GENOTYPES UNDER UPPER EGYPT CONDITIONS

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ABSTRACT

Water deficiency is a very serious problem in Egypt recently. Thus, a two-year study was conducted at Al Gharirah, Esna, Luxor Governorate, Egypt during the two successive season of 2019/2020 and 2020/2021 to study response of twenty bread wheat genotypes to recommended irrigation (12 times, normal at experiment site conditions) and a reduced number of irrigation (6 irrigations, as stressed treatment). The 20 genotypes that included two high yielding cultivars and eighteen promising lines selected form 22^nd^ High Rainfall Wheat Yield Trial (At CIMMYT breeding program). The design used for the experiment randomized complete block design with three replications. The results showed that reduced number of irrigations caused noticeable reduction in days to heading and maturity and reduction in yield and yield components in both growing seasons. Two lines 16 and 18 were the earliest ones and could be used in breeding programs for earliness. Besides, two lines (1 and 2) and two cultivars (Misr 2 and Sids 14) recorded the maximum values for most studied characters, especially, grain yield under stress condition. The interaction between irrigation and bread wheat genotypes was significant for days to heading, maturity and grain yield in the second growing season. Based on the drought tolerance indices of mean productivity (MP), geometric mean of productivity (GMP), stress tolerance index (STI), yield index (YI), harmonic mean (HM) and modified stress tolerance index (MSTI), Misr 2, Sids 14, Lines 1, 2, 4 and 6 were identified as suitable genotypes under well-watered and water deficit conditions. 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 for genotypes tolerant to water deficit. The first cluster aggregated the genotypes that had the highest grain yield and its component.

Keywords: ***Wheat, Triticumaestivum L, Water stress, Drought tolerance indices***

INTRODUCTION

Wheat (*Triticumaestivum* L.) is the most important cereal crop worldwide and provides more than a quarter of the total world cereals production. In Egypt, wheat is the oldest and most important cereal crop and considered the first food grain for all societies and the main source of straw yield as feed for animals. Water scarcity is an alarming situation recently and has become a risk to wheat production in developing countries (Rogers and Lydon 1994). Egypt faces major challenges due to its fixed share of the limited Nile waters. The River Nile is the backbone of agricultural and industrial sector and also the primary source of drinking water for the population. Crop interactions with irrigation water depend on water application schedules. Farmers have already realized this and have been able to build up enough experience for the required irrigation Land (Pereira *et al* 2009) based on irrigation scheduling as crucial decision. The sustainability of wheat yield is highly dependent on the availability of water.To cope with the case of water shortage, based on agronomic approach, wheat should be grown with lower water requirements or apply in less amount of water. Water reduction is the most important environmental stress in agriculture, and obtaining a high yield under water-reducing conditions is a major goal of plant producers (Cattivelli *et al* 2008). The yield of water-deficient crops can be increased through the application of modern breeding techniques and knowledge of the stress-related characteristics of plants (Li *et al* 2013). Therefore, evaluation and selection of wheat genotype under reducing of water are the main breeding objectives (Albokari *et al* 2016).

A large number of studies have used drought indices to select stable germplasm according to their performance under normal and water-deficient conditions (Mursalova *et al* 2015, Abdelghany *et al* (2016), Mohammed and Abdul-Hamid 2017, Gab Alla *et al* 2019and Biljon 2021)

This research was designed to study the effect of reduced number of irrigations on yield and using some drought tolerance/resistance indices obtained from the grain yield and yield characters data and identifies the high yielding and drought tolerant genotypes to be introduced for cultivation in Upper Egypt. Selection the best genotypes that are tolerant to water stress and provide them to researchers and wheat breeders for more intense evaluation and screening in wheat breeding programs.

MATERIALS AND METHODS

Field experiments were conducted in the new reclaimed sandy soil at Al Gharirah, Esna, Luxor Governorate (lat. 25.482485, long. 32.448397) for two successive winter growing seasons, 2019–2020 and 2020–2021 to study the response of 20 bread wheat genotypes to different irrigation treatments. Under normal irrigation, the first irrigation treatment represented the normal irrigation after planting plus eleven irrigations. The second regime was the water reduced treatment. At the second regime, the experiment was irrigated five times after planting irrigation. A wide border (15 m) was used to minimize the underground water permeability surrounded each experiment. Twenty bread wheat genotypes (Table 1) were tested including two high yielding cultivars i.e.

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

No.	Genotype	Cross Name and Selection History
1	Misr 2	SKAUZ / BAV92 CMSS96M03611S-1M-10SY-10M-10SY-8M-0Y-0S
2	Sids 14	SW8488*2/KUKUNA. CGSS01Y00081T-99M-99Y-99M-99B-9Y-0B-0SD
3	Line#1	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI CMSS08B00254S-99M-99NJ-99NJ-7RGY-0B
4	Line#2	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI CMSS08B00254S-99M-99NJ-99NJ-14RGY-0B
5	Line#3	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/WAXWING*2/KRONSTAD F2004 CMSS08B00256S-99M-99NJ-99NJ-26RGY-0B
6	Line#4	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/WHEAR/SOKOLL CMSS08B00259S-99M-99NJ-17RGY-0B
7	Line#5	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/WHEAR/SOKOLL CMSS08B00259S-99M-99NJ-30RGY-0B
8	Line#6	PFAU/WEAVER*2//TRANSFER#12,P88.272.2/5/BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ CMSS08B00269S-99M-99Y-12M-0RGY
9	Line#7	VEE#8//JUP/BJY/3/F3.71/TRM/4/BCN/5/KAUZ/6/MILAN/KAUZ/7/SKAUZ/PARUS//PARUS/8/BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ CMSS08B00381S-99M-99Y-1M-0RGY
10	Line#8	BECARD//ND643/2*WBLL1 CMSS08B00422S-99M-99NJ-5RGY-0B
11	Line#9	KRL 19/5/BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ CMSS08B00575S-99M-99Y-20M-0RGY
12	Line#10	BJY/COC//PRL/BOW/3/FRTL/5/BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ CMSS08B00594S-99M-99Y-4M-0RGY
13	Line#11	TACUPETO F2001*2/BRAMBLING//ND643/2*WBLL1/3/TACUPETO F2001*2/BRAMBLING CMSS08B00703T-99TOPY-99M-99Y-16M-0RGY
14	Line#12	KACHU*2/3/ND643//2*PRL/2*PASTOR CMSS08B 712T-99TOPY-99M-99NJ-99NJ-14RGY-0B
15	Line#13	KACHU*2/3/ND643//2*PRL/2*PASTOR CMSS08B712T-99TOPY-99M-99NJ-99NJ-15RGY-0B
16	Line#14	KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ/5/ND643//2*PRL/2*PASTOR/6/SUP152 CMSS08B00756T-99TOPY-99M-99NJ-99NJ-6RGY-0B
17	Line#15	ND643/2*WBLL1/4/CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/5/BECARD CMSS08B00776T-99TOPY-99M-99NJ-99NJ-21RGY-0B
18	Line#16	ND643/2*WBLL1/3/KIRITATI//2*PRL/2*PASTOR/4/BECARD CMSS08B00777T-99TOPY-99M-99NJ-99NJ-12RGY-0B
19	Line#17	SUP152*2//ND643/2*WBLL1 CMSS08B00798T-99TOPY-99M-99NJ-11RGY-0B
20	Line#18	TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/5/KAUZ/6/FRET2/7/2*VORB CMSA08Y00065T-99B-50Y-50ZTM-50Y-14BMX-10Y-0B

Misr 2 and Sids 14 and eighteen promising lines selected form 22nd High Rainfall Wheat Yield Trial from CIMMYT. In each treatment, the aimed entries were laid out in a randomized complete block design (RCBD) with three replications.The experimental plot area was 4.2 m^2. Each plot consisted of 6 rows, 3.5 m-long and 20 cm apart. The harvested area was 3.2 m^2 included the four guarded rows. Sowing dates were 15 and 20 November in the two seasons, respectively. Soil physical and chemical analyses for the two growing seasons (Table 2).

Table 2.The physical and chemical properties of the experimental soils in the two growing seasons.

Property	2019-2020	2020-2021
Sand	**85.02**	**87.70**
Silt	**6.78**	**6.90**
Clay	**8.20**	**5.40**
Texture grade	**Sandy**	**Sandy**
pH	**7.9**	**8.1**
EC (dS m^{-1} at 25°C)	**0.35**	**0.34**
$CaCo_3$ (%)	**8.45**	**8.57**
Saturation percent (%)	**22.55**	**23.10**
Organic matter (%)	**0.25**	**0.21**

All other cultural practices were applied as recommended for wheat cultivation in Luxor region. This location is part of the development and cultivation of one and a half million feddan project that is being reclaimed by the state. The monthly maximum and minimum, temperature from sowing date to harvest during the 2019-2020 and 2020-2021 seasons at Al Gharirah, Esna, Luxor Governorate are summarized in (Table 3).

Agronomical characters

Recorded data included, earliness characters, i.e. days to heading (DTH, day), days to maturity (DTM, day) and grain filling period (GFP, day), equal to the number of days from heading 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: plant height (PH, cm), number of spikes m^{-2} (NSm^{-2}), 1000-kernel weight (1000 KW, g), number of kernels spike^{-1} (NKS^{-1}) and grain yield (GY, ardab/ feddan, Ardab =150 kg).

Table 3.The Monthly mean temperatures degree (maximum and minimum) through the growing periods in the two seasons.

Months	2019/2020		2020/2021	
	Max	Min	Max	Min
November	30.56	16.84	28.30	14.91
December	23.83	9.65	21.87	9.46
January	20.65	7.67	20.78	7.24
February	23.61	9.72	22.12	9.30
March	28.90	14.73	27.25	12.63
April	32.73	18.83	32.63	17.52
May	38.32	23.60	38.09	23.18

Drought tolerance indices

Six tolerance indices were calculated based on average grain yield under normal irrigation (Y_n) and reduced irrigation (Y_s) treatments across the two seasons. The names, equations and references of the tolerance indices are shown in Table 4. 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).

Table 4.The names and equations of drought tolerance indices that were used.

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 e*t 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 respectively, $\bar{Y}_n$ and $\bar{Y}_s$ indicate average grain yield overall genotypes under normal and stress conditions respectively.

Statistical analysis

Levene test (1960) test was applied to determine homogeneity of separate error variances for all studied characters that permits to apply combined analysis. Data were subjected to individual and combined analysis of variance with three replications of randomized complete block design (RCBD) across the two cultivated trials (normal irrigation and water shortage) for each season (Gomez and Gomez, 1984). Least significant difference (LSD) test was used to detect the significant differences among the items at probability level (0.05). In order to assort genotypes according to their agronomic characters across normal and reduced irrigation, agglomerate hierarchical cluster analysis using " Euclidean distance" was employed describe by Rao, 1952. Data processing was performed using SPSS computer software (1995).

RESULTS AND DISCUSSION

Earliness characters and plant height

The results (Table 5) indicated that reducing number of irrigations from 12 to 6 recorded lower values for all earliness characters, i.e. days to heading, days to maturity, grain filling period, grain filling rate and plant height in both growing seasons.Farhat (2015) and Gab Alla *et al* (2019) indicated that reduced number of irrigation from 5 to 2 irrigations decreased all earlinesscharacters and plant height. This may be due to applying the lower water input at the end of elongation stage in addition to a relatively high temperature until early flowering which speed up maturation. On the other hand, the reason of normal heading and maturity due to applying full irrigation at all stages leading to excessive uptake of nutrients and absence of abiotic stresses (Sarwar *et al* 2010). Similar results were reported by El Hag (2017), Noreldin and Mahmoud (2017), Al-Otayk (2019), Gab Alla *et al* (2019) and Ali *et al* (2021).

In addition, data indicated highly significant differences among the 20 bread wheat genotypes under study in both growing seasons for earlinesscharacters and plant height. These differences among the bread wheat genotypes might partially reflect their diverse genetic backgrounds. Days to the timing of heading and maturity are among the major characters that were related to adaptation of wheat genotypes under field conditions, Al-Karaki (2012). Generally, Line 16 was the earliest bread wheat genotype for days to heading and maturity in both growing seasons (Table 5).

Table 5. Effect of reduced irrigation, wheat genotype and their interaction on days to heading (DTH), maturity (DTM), grain filling period (GFP), grain filling rate (GFR) and plant height (cm) during the two seasons.

Treatment	DTH (day)		DTM (day)		GFP (day)		GFR(kg/fed/day)		Plant height (cm)	
Irrigation	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Normal	80.92	82.37	127.25	132.95	46.33	50.58	54.48	57.74	106.58	113.59
Reduced	73.53	74.55	118.23	123.55	44.70	49.00	33.87	38.69	96.58	102.41
F Test	**	**	**	**	**	**	**	**	**	**
Genotype										
Misr 2	75.33	77.67	118.50	125.33	43.17	47.66	58.58	59.69	104.17	107.50
Sids 14	76.50	79.67	124.50	132.33	48.00	52.66	52.22	53.65	105.00	109.17
Line 1	88.17	90.83	131.50	136.00	43.33	45.17	59.34	60.87	100.00	103.33
Line 2	84.83	83.17	126.83	131.17	42.00	48.00	57.93	56.59	108.33	117.50
Line 3	74.83	78.00	121.17	127.00	46.33	49.00	46.07	54.52	91.67	99.17
Line 4	81.33	80.00	126.33	134.33	45.00	54.33	53.53	49.39	98.33	105.00
Line 5	74.83	77.67	118.50	123.00	43.67	45.33	54.75	56.39	106.67	115.00
Line 6	79.00	77.00	123.83	130.67	44.83	53.67	53.64	50.06	102.50	107.50
Line 7	76.00	77.00	123.00	127.67	47.00	50.67	44.11	50.21	100.83	106.67
Line 8	77.17	79.33	125.17	131.17	48.00	51.84	38.22	44.54	104.17	107.50
Line 9	76.17	76.17	119.00	123.50	42.83	47.33	42.97	48.36	101.67	109.17
Line 10	76.67	77.33	123.00	127.83	46.33	50.50	38.07	45.53	104.17	113.33
Line 11	79.00	78.50	124.50	129.67	45.50	51.17	37.68	44.88	103.33	109.17
Line 12	74.17	76.83	119.67	125.33	45.50	48.50	38.04	46.95	96.67	105.83
Line 13	76.33	77.83	125.67	131.67	49.33	53.84	33.97	39.46	101.67	107.50
Line 14	75.17	78.67	124.00	130.50	48.83	51.83	32.22	42.54	102.50	109.17
Line 15	75.17	77.50	124.50	130.33	49.33	52.83	34.88	38.30	103.33	108.33
Line 16	73.33	73.00	116.00	120.50	42.67	47.50	38.28	44.40	95.83	104.17
Line 17	76.33	75.83	122.00	125.50	45.67	49.67	33.37	43.76	95.83	103.33
Line 18	74.17	77.17	117.17	121.50	43.00	44.33	38.79	45.71	105.00	111.67
F-Test	**	**	**	**	**	**	**	**	**	**
LSD $_{0.05}$	1.16	1.19	1.11	1.15	1.37	1.24	3.62	3.56	3.30	3.15
I x G	NS	**	NS	*	NS	NS	NS	NS	NS	NS

NS, * and ** indicate non-significant, significant at 0.05 and 0.01 probability levels, respectively.

In contrast, Line 1 was the latest one for days to heading, maturity and have shorter grain filling period. Al-Otayk (2019) and Gab Alla *et al* (2019) revealed that the earliest wheat genotypes for days to heading might be usually the earliest for days to maturity. For grain filling period, the results indicated that, lines 13, 14, 15 and 1 and Lines 4, 6 and 13 in recorded the longest grain filling period in both season. While, Line 1, 2 and 18 recorded the lowest values for grain filling period in the first season and Line 1, 5 and 18 in the second growing seasons. For grain filling rate, Line 14 recorded the lowest values for grain filling rate in the first season and Line 15 in the second season. While, Line 1 and Misr 2 recorded the highest value for grain filling rate in both growing seasons, respectively. Pireivatlou *et al* (2011) reported that, the short grain filling period along with high grain filling rate are major factors for producing higher grain yield.

These results indicate the possibility of superiority of these genotypes under some abiotic stresses especially heat stress conditions (Gab Alla *et al* 2018). Wheat breeders prefer to select wheat plants that are characterized by short grain filling periodalong with high grain filling rate. Similar results were reported by Noreldin and Mahmoud (2017), Al-Otayk (2019) and Gab Alla *et al* (2019).

Concerning plant height, variances due to irrigation treatments were highly significant in both growing seasons (Table 5). Full watered treatment produced taller wheat plants than those received low number of irrigations. These results are in agreement with those reported by Farhat (2015), El Hag (2017), Zeboon *et al* (2017), Al-Otayk (2019), Gab Alla *et al* (2019) and Ali *et al* (2021) who indicated that plant height was decreased under water stress conditions. Reduction in plant height in response to water deficiency may be due to the decrease in relative turgidity and dehydration of protoplasm, which is associated with loss of turgor and reduced cell expansion and cell division (Mahfuz *et al* 2014).

Variability among bread wheat genotypes in plant height was highly significant in both growing seasons. Line 2 was the tallest one in both growing seasons. By contrast, Line 3 produced the shortest genotypes in both seasons. These differences among wheat genotypes might partially reflect their diverse genetic backgrounds. Our results are in agreement with Farhat (2015), El Hag (2017),Zeboon *et al* (2017), Al-Otayk (2019), Gab Alla *et al* (2019), Ali *et al* (2021) and Aissaoui and Fenni (2021), who indicated that there were highly significant effects of wheat genotypes on plant height.

Grain yield and its components

Number of spikes m^{-2}, number of kernels per spike and 1000-kernel weight (g) are important characters for wheat crop production. Data in Table (6) showed the effects of irrigation treatments on grain yield and its components and they were significant or highly significant in both seasons. The results illustrate that reducing number of irrigations had significantly reduced number of spikes per m^{2}, kernels per spike, 1000 kernel weight and grain yield.The decrease in the final grain yield of wheat under reduced irrigation treatment caused by a reduction in many yield components especially number of spikes m^{-2}, number of kernels spike^{-1} and the weight of 1000 kernels. Farhat (2015), Zaman *et al* (2016), El Hag (2017), Noreldin and Mahmoud (2017), Al-Otayk (2019) and Gab Alla *et al* (2019), reported 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 values of the above-mentioned characters were increased with increasing number of irrigations and decreased under water deficit conditions. These differences among the wheat genotypes might partially reflect their different genetic backgrounds. Generally, Line 2 gave the maximum number of spikes m^{-2} in the 2nd second season, while Line 10 and 16 recorded the lowest values of these characters in both growing seasons, respectively.

Regarding the 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 1, 2, 3 and 12 recorded the highest number of kernels spike^{-1} in both growing seasons, while, the lowest number of kernels spike^{-1} was obtained by lines 11 and 7 in the 1st season and lines 7, 11 and 18 in the 2nd season. 1000-kernel weight is the third important characteristic of grain yield.

Table 6.Effect of irrigation regime, genotype and their interaction on grain yield (GY) and its components in the two seasons.

Treatment	NSm^{-2}		NKS^{-1}		1000-KW (g)		GY (ard/fed)	
Irrigation	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Normal	372.50	405.50	43.07	50.42	43.22	51.26	16.72	19.44
Reduced	251.10	275.40	28.67	34.55	28.90	34.94	10.03	12.84
F Test	**	**	**	**	*	**	**	**
Genotype								
Misr 2	339.50	334.50	45.17	52.50	39.86	51.52	16.87	18.98
Sids 14	334.00	327.50	40.33	47.83	47.52	45.02	16.71	18.84
Line 1	323.00	335.50	45.00	47.33	46.37	46.82	17.14	18.34
Line 2	341.00	377.50	31.17	38.17	39.19	47.01	16.22	18.11
Line 3	330.00	361.00	33.67	44.00	33.00	42.19	14.23	17.82
Line 4	324.50	317.50	40.00	44.83	35.66	42.91	16.06	17.89
Line 5	299.00	325.50	29.50	36.83	36.34	41.92	15.94	17.04
Line 6	325.50	348.50	34.83	39.33	31.92	38.45	16.03	17.91
Line 7	295.00	331.00	40.50	43.83	33.83	41.49	13.82	16.97
Line 8	308.00	321.50	35.00	40.50	34.62	42.89	12.23	15.39
Line 9	291.00	332.50	29.33	37.50	36.83	44.09	12.27	15.27
Line 10	281.00	314.50	43.00	51.83	37.03	43.18	11.76	15.34
Line 11	323.00	355.50	38.33	45.83	33.48	41.39	11.43	15.31
Line 12	283.50	321.00	33.67	39.33	37.81	39.24	11.54	15.18
Line 13	339.00	377.00	33.33	42.83	37.75	45.30	11.17	14.17
Line 14	288.00	371.00	32.00	42.50	33.87	42.85	10.49	14.70
Line 15	302.50	341.00	33.50	39.83	33.09	38.69	11.47	13.49
Line 16	317.00	306.00	30.33	36.83	29.85	46.92	10.89	14.07
Line 17	310.00	372.00	37.17	39.83	26.71	35.40	10.16	14.49
Line 18	281.50	338.50	31.50	38.17	36.50	44.74	11.12	13.51
F-Test	**	**	**	**	**	**	**	**
LSD $_{0.05}$	51.37	42.03	5.31	7.16	3.82	4.77	1.04	1.11
I x G	NS	NS	NS	NS	NS	NS	**	**

NSm^{-2}: number of spikes per meter square, NKS^{-1}, number of kernels spikes^{-1}: 1000-kw, kernel thousand weight, GY: grain yield

The highest values of 1000- kernel weight were obtained by wheat genotypes, Sids 14 and Line 1 in the first season and Sids 14 and Line 1, 2 and 16 in the second season. However, the lowest values for 1000-kernel weight were recorded by line 7 in both growing seasons. The results of our study showed that significant variations were found among the wheat genotypes suggesting the importance of the assessment of genotypes performance under different environments in order to identify the best genetic make up for a particular environment. These results are similar with those of Abdelkhalek *et al* (2015), Farhat (2015), Esmail *et al* (2016), El Hag (2017), Noreldin and Mahmoud (2017) and Al-Otayk (2019).

Concerning grain yield, there were highly significant differences among the 20 bread wheat genotypes for grain yield character (Table 6). To understand the causes of variation in final grain yield, its components must be studied along with the growth of the crop. Results showed that lines 1, Misr 2, Sids 14 and line 2 produced the highest values for grain yield in the two growing seasons, in addition to line 6 and 8 in the second season. In the second season, lines 15, 18, 16, 13 and 17 had non-significant differences among them in grain yield. These 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), Al-Otayk (2019), Ali *et al* (2021), Aissaoui and Fenni (2021) and Ouda *et al* (2021).

The interaction between bread wheat genotypes and irrigation treatments had significant effects for days to heading, maturity in the second season and grain yield in both seasons, as shown in Table (7). The results revealed that, the wheat genotypes responded differently to water regime for these characters and reflected the possibility of selecting the most tolerant genotypes among them. Line 16 was the earliest heading genotype under normal and water deficit conditions while the latest wheat genotypes for heading, maturity and grain filling rate was recorded by the cultivar Misr 2. These results agree with the work of Abd El-Rahman and Hammad (2014) and El Hag (2017) they found significant interaction between wheat genotypes and irrigation treatments. However, the earliest maturity and the shortest grain filling period were recorded by lines 18 and 15 under reduced irrigation, respectively. The interactions between treatments of irrigation and bread wheat genotypes were significant for grain yield in both growing seasons. With reference to irrigation treatments, results showed that the average values of these studied characters across all genotypes decreased under the reduced irrigation treatments. The data in Table (7) are demonstrating that there are significant effects for the interaction between genotypes and irrigation treatments for grain yield in the two growing seasons. Besides, the genotypes, line 2 and 1 produced the maximum grain yield under normal irrigation.

Table 7.Effect of interaction between genotypes and irrigation treatments on days to heading (DH), days to maturity (DM) in the second season (2020-2021) and grain yield in both growing seasons.

Wheat genotype	2nd Season				Grain yield (ard/fed)			
	DH (day)		DM (day)		1st season		2nd season	
	Normal irrigation	Reduced irrigation	Normal irrigation	Reduced irrigation	Normal	Reduced	Normal	Reduced
Misr 2	**80.67**	**74.67**	**129.67**	**121.00**	**19.66**	**14.07**	**21.90**	**16.05**
Sids 14	**84.67**	**74.67**	**137.67**	**127.00**	**19.62**	**13.79**	**21.65**	**16.02**
Line 1	**96.33**	**85.33**	**142.00**	**130.00**	**21.39**	**12.89**	**21.84**	**14.83**
Line 2	**86.00**	**80.33**	**135.33**	**127.00**	**21.68**	**10.76**	**21.80**	**14.41**
Line 3	**81.33**	**74.67**	**131.00**	**123.00**	**17.47**	**10.98**	**22.42**	**13.21**
Line 4	**83.67**	**76.33**	**139.00**	**129.67**	**19.86**	**12.26**	**20.61**	**15.17**
Line 5	**81.33**	**74.00**	**127.67**	**118.33**	**19.15**	**12.73**	**20.94**	**13.14**
Line 6	**81.33**	**72.67**	**135.33**	**126.00**	**19.72**	**12.34**	**21.44**	**14.38**
Line 7	**81.33**	**72.67**	**133.00**	**122.33**	**18.79**	**8.85**	**21.60**	**12.33**
Line 8	**84.33**	**74.33**	**136.33**	**126.00**	**16.66**	**7.79**	**19.72**	**11.06**
Line 9	**79.33**	**73.00**	**127.67**	**119.33**	**15.59**	**8.94**	**18.83**	**11.70**
Line 10	**80.33**	**74.33**	**132.00**	**123.67**	**14.49**	**9.03**	**19.02**	**11.65**
Line 11	**82.67**	**74.33**	**134.33**	**125.00**	**14.53**	**8.32**	**18.25**	**12.37**
Line 12	**81.00**	**72.67**	**130.00**	**120.67**	**13.93**	**9.14**	**18.13**	**12.22**
Line 13	**81.67**	**74.00**	**136.33**	**127.00**	**13.84**	**8.51**	**16.69**	**11.64**
Line 14	**82.67**	**74.67**	**135.67**	**125.33**	**12.54**	**8.44**	**17.10**	**12.30**
Line 15	**81.33**	**73.67**	**134.67**	**126.00**	**14.39**	**8.54**	**16.29**	**10.69**
Line 16	**76.33**	**69.67**	**124.33**	**116.67**	**14.10**	**7.68**	**17.53**	**10.60**
Line 17	**79.33**	**72.33**	**130.00**	**121.00**	**12.22**	**8.11**	**16.66**	**12.32**
Line 18	**81.67**	**72.67**	**127.00**	**116.00**	**14.76**	**7.48**	**16.38**	**10.63**
LSD $_{0.05}$	**1.69**		**1.63**		**1.47**		**1.57**	

The minimum grain yield was recorded by lines 17 and 14 under normal irrigation and lines 1 and 2 under reduced irrigation. A similar conclusion was reported by previous investigators, i.e., Omar *et al* (2014) and Abdelkhalek *et al* (2015).

Drought tolerance indices

Mean values of grain yield (ardab fed^{-1}.) of 18 wheat genotypes and 2 check cultivars under normal irrigation and low number of irrigations in both growing seasons are presented in Table (8). Using grain yield across non-stressed (Yn) and water stress circumstance (Ys), six quantitative stress tolerant indices and their respective ranks were calculated under the two seasons (Table 8).The genotypes with high values of these six tolerance indices can be selected as tolerant genotypes to water deficit. Under normal irrigation, the grain yield varied from 14.44 ardab fed^{-1} for line 17 to 21.74 ardab fed^{-1} for line 2 while the average grain yield of genotypes across water stress treatment ranged from 9.06 ardab fed^{-1} for line 18 to 15.06 ardab fed^{-1} for Misr 2.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.

Generally, all drought indices under this study indicated that all wheat genotypes were different. It is noted that two indices (harmonic mean (HM) and geometric mean of productivity (GMP)) gave identical ranks for water stress tolerance. The similarity of the four indices in categorizing genotypes for water stress tolerance may be because these indices are functions 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 (YI) and (MSTI) gave different tolerance ranks. Overall the six stress tolerance indices indicated that wheat genotypes, Misr 2, Sids 14, lines 1, 2, 4 and 6 have the highest values for drought tolerance indices. Therefore, they were considered highly tolerant to water stress conditions. Fortunately, they also had the greatest grain yield under normal and reduced irrigation and reflected the lowest reduction % of grain yield, as shown above. Accordingly, Misr 2, Sids 14 and line 1 were preferred to be cultivated either under the normal or under water stress conditions.

Table 8. Estimates of six stress tolerance indices and their respective ranks for 20 bread wheat genotypes based on grain yield (GY) under normal and water stress sites combined across the two seasons.

Genotype	Grain yield (Normal)	Grain yield (Stress)	STI	Rank	MP	Rank	GMP	Rank	HM	Rank	YI	Rank	MSTI	Rank
Misr 2	20.78	15.06	0.96**	1	17.92**	1	17.69**	1	17.46**	1	1.32**	1	1.66**	1
Sids 14	20.64	14.90	0.94**	2	17.77**	2	17.54**	2	17.31**	2	1.30**	2	1.60**	2
1	21.62	13.86	0.92**	3	17.74**	3	17.31**	3	16.89**	3	1.21**	3	1.35**	3
2	21.74	12.59	0.84**	5	17.17**	4	16.54**	6	15.95**	6	1.10*	7	1.02*	6
3	19.95	12.09	0.74*	8	16.02*	8	15.53*	8	15.06*	8	1.06	8	0.82	8
4	20.24	13.71	0.85**	4	16.98**	5	16.66**	4	16.35**	4	1.20**	4	1.22**	4
5	20.04	12.94	0.79**	7	16.49**	7	16.10**	7	15.73**	7	1.13**	6	1.02*	6
6	20.58	13.36	0.84**	5	16.97**	6	16.58**	5	16.20**	5	1.17**	5	1.15**	5
7	20.19	10.59	0.65	9	15.39	9	14.62	9	13.89	9	0.93	9	0.56	9
8	18.19	9.43	0.52	12	13.81	10	13.10	12	12.42	14	0.82	18	0.36	15
9	17.21	10.32	0.54	10	13.77	11	13.33	10	12.90	10	0.90	13	0.44	11
10	16.75	10.34	0.53	11	13.55	12	13.16	11	12.79	12	0.90	13	0.43	12
11	16.39	10.35	0.52	12	13.37	13	13.02	14	12.69	13	0.91	11	0.43	12
12	16.03	10.68	0.52	12	13.36	14	13.08	13	12.82	11	0.93	9	0.46	10
13	15.26	10.07	0.47	15	12.67	15	12.40	15	12.13	16	0.88	16	0.36	15
14	14.82	10.37	0.47	15	12.60	16	12.40	15	12.20	15	0.91	11	0.39	14
15	15.34	9.62	0.45	17	12.48	17	12.15	17	11.82	18	0.84	17	0.32	18
16	15.82	9.14	0.44	19	12.48	17	12.02	19	11.59	19	0.80	19	0.28	19
17	14.44	10.21	0.45	17	12.33	19	12.14	18	11.96	17	0.89	15	0.36	15
18	15.57	9.06	0.43	20	12.32	20	11.88	20	11.45	20	0.79	20	0.27	20

STI: Stress tolerance index, MP: Mean productivity, GMP: Geometric mean productivity, HM: Harmonic mean, YI: Yield index, MSTI: Modified stress tolerance index, * and ** significant and highly significant at 0.05 and 0.01 probability levels, respectively.

Lines 17 and 18 were sensitive to water stress and showed lower values of the six stress tolerance indices. Thus, they recorded the latest tolerance ranks. Consequently, it is not advisable to cultivate these genotypes under water stress environments. Mohammadi-joo *et al* (2015) indicated that STI, MP and GMP are the most suitable indices for screening tolerant genotypes that produce higher yields in both stress and normal conditions. The same conclusion was reported by Singh *et al* (2015), Abdelghany *et al* (2016), Gadallah *et al* (2017) and Patel *et al* (2019).

Cluster analysis

Twenty wheat genotypes were estimated based on grain yield and its related characters using the cluster analysis as an efficient procedure to emerge the structural relationships among tested genotypes and provides a hierarchical classification of them. The twenty wheat genotypes were split into four main clusters (Fig. 1), each cluster contained the genotypes that had similar phenotypic performance. The clustering pattern of these genotypes is tabulated in Table (9) and diagrammatically displayed as dendrogram graph in Figure (1).

Table 9. Summary of cluster analysis showing the included genotypes, similarity level and cluster means of the 20 wheat genotypes using the studied yield characters.

Cluster no.	Genotypes	DH	DM	GFP	GFR	PH	NSm^2	NKS^{-1}	1000 KW	K/s	GY
1	Misr 2, Sids 14, Line 1, 2	82.02	128.27	46.25	57.17	106.88	339.06	43.44	45.41	32.16	18.56
2	3, 4, 6, 7	77.90	126.75	48.85	50.06	101.46	329.13	40.12	37.43	28.15	17.64
3	8, 10, 11, 13, 14, 15, 17	77.20	126.82	49.62	38.99	105.24	328.86	39.68	37.59	26.32	14.70
4	5, 9, 12, 16, 18	75.35	120.42	45.07	45.30	105.17	309.55	34.30	39.42	27.87	15.01

- Abbreviations: DH: days to heading, DM: days to maturity, PH: plant height, NK/S: no. kernels/spike, NS/m^2: no. spikes/m^2, 1000 KW: 1000 kernels weight, GY: Grain yield.

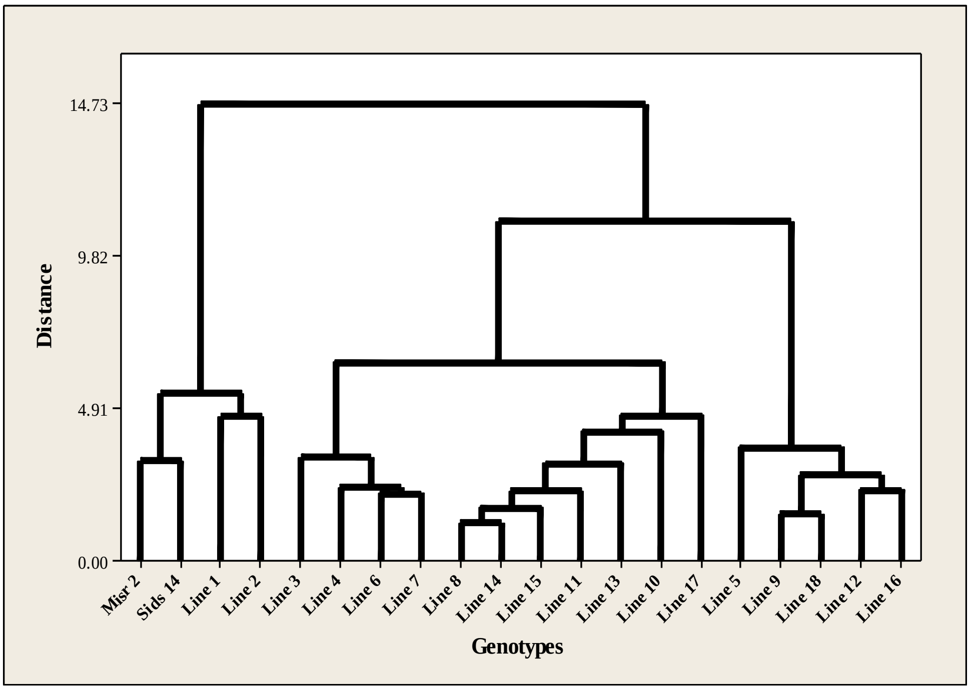

Fig. 1. Linkage dendrogram showing the similarity among the 20 wheat genotypes based on grain yield and its related characters.

The main clusters were divided into sub clusters. The first cluster aggregated the genotypes that had the highest number of kernels per spike, 1000 kernels weight, number of spikes m^{-1}, plant height, grain filling rate and grain yield (Table 9) also, the latest heading and maturating date, while the fourth cluster contained the genotypes that had the earliest heading and maturity date. The second cluster consisted of the genotypes that had the shortest plants. We conclude from the previous results the presence of a large genetic diversity was present among the genotypes under test. It gave a good opportunity to achieve enough scope for improvement of wheat genotypes through the hybridization among genotypes taken from divergent clusters (Savii and Nedelea 2012, Verma *et al* 2014, Sheykhi *et al* 2014, Yonas *et al* 2018 and Eid and Sabry 2019).

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تأثير نقص الري على إنتاجية و سلوك عشرين تركيب وراثي من قمح الخبز تحت ظروف مصر العليا

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قسم بحوث القمح- معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية

أجريت هذه الدراسة في منطقة الظهير الصحراوي الغربي بمحافظةالأقصر، مصر، خلال موسمي الزراعة ٢٠١٩/٢٠٢٠ و ٢٠٢٠/٢٠٢١ لدراسة تأثير نقص عدد الريات للنصف (من اثني عشرة ريه (المعدل الموصي به) الي ستة ريات) علي سلوك وانتاجية بعض التراكيب الوراثية من قمح الخبز. تم استخدم عشرون تركيب وراثيً من قمح الخبز محتوية علي صنفيين تجاريين (مصر٢ – سدس١٤) وثمانية عشر سلالة واعدة تم اختيارها من تجربة المستوردات

(22HRWYT), الواردة من السميت في تجربتين منفصلتين. تم تقييم التراكيب الوراثية المستخدمة بواسطة تصميم القطاعات الكاملة العشوائية في ثلاث مكررات. تم دراسة صفات التبكير(صفة طرد السنابل, النضج الفسيولوجي) وتم حساب كلا من فترة امتلاء الحبوب و معدل امتلاء الحبوب بالإضافة الي ارتفاع النبات ,الصفات المحصولية (عدد السنابل/م٢, عدد حبوب السنبلة, وزن االلف حبه, محصول الحبوب) وقد تم تقدير بعض دلائل التحمل لتمييز افضل التراكيب الوراثية تحملا و ذات المحصول العالي تحت ظروف نقص مياه الري. أظهرت النتائج وجود فروق عالية المعنوية بين معاملات الري حيث ادي نقص عدد الريات الي نقص قيم جميع الصفات تحت الدراسة، كذلك اختلفت التراكيب الوراثية من قمح الخبز فيما بينها لجميع الصفات تحت الدراسة. سجلت السلالتين ١٦ و١٨ اقل القيم لصفتي طرد السنابل والنضج الفسيولوجي وبذلك يمكن ادخالهما في برامج التربية. كما سجلت السلالتين ١و٢ بالإضافة الي الصنفيين مصر ٢ و سدس ١٤ اعلي القيم لصفة المحصول. كما كان التفاعل بين معاملات الري والتراكيب الوراثية معنوياً لصفتي طرد السنابل والنضج الفسيولوجي في الموسم الثاني ومحصول الحبوب في كلا الموسمين. وفقا لمؤشرات تحمل الجفاف (متوسط اإلنتاجية (MP)، المتوسط الهندسي للإنتاجية (GMP) ودليل تحمل االجهاد (STI)، دليل المحصول (YI)، الوسط التوافقي (HM) و مؤشر تحمل االجهاد المعدل(MSTI)). يمكن اختيار التراكيب الوراثية ذات القيم العالية لمؤشرات التحمل الستة المستخدمة. وعليه تم تحديد السالالت رقم ٦،٤،٢،١ والصنفيين مصر٢ و سدس١٤ كمؤشر لقدرتها علي تحملها لنقص مياه الري. كما حدد التحليل العنقودي التراكيب الوراثية الي اربع مجاميع مختلفة. شملت المجموعة الأولى على افضل التراكيب الوراثية وخاصة لمحصول الحبوب ومكوناته.

المجلة المصرية لتربية النبات ٢٥(٢): ٢٧٧-٢٩٧ (٢٠٢١)