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PERFORMANCE AND ADAPTABILITY OF SOME BREAD WHEAT GENOTYPES FOR WATER STRESS UNDER HIGH TEMPERATURE AT UPPER EGYPT REGION

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ABSTRACT

Water and heat stress are the major constraints facing wheat improvement in Upper Egypt. High yielding genotypes under stress and non-stress conditions is the key factors for the improvement of wheat production. Thus, two field experiments were carried out in two seasons 2017/2018 and 2018/ 2019. Each experiment evaluates eight genotypes of bread wheat under two irrigation regimes (stress, and Normal). A Split–plot design in randomized complete block with three replications was used. The irrigation regimes were arranged in the main plots, while the eight genotypes were randomly arranged in the subplots. Results revealed that increasing irrigation water had significantly increased yield, and yield components. This increase estimated by 19.28% for grain yield, by 24.54% for number of spikes per square meter, by 14.04% for number of kernels per spike, and by 6.76% for kernels weight as a result of increasing in irrigation water from low to normal. Data showed reduction in grain yield for all genotypes under stress as compared to non-stress condition. Th**is** reduction ranged from 16.46% for Shandaweel 1 to 26.72% for line 5. The correlation matrix between grain yield under stress and non-stress conditions and stress tolerance indices revealed that stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), and harmonic mean (HM) could be detected as the most suitable indices for identifying high yielding genotypes in both conditions. Therefore, these indices could be used successfully as selection tools for screening genotypes. Screening water stress tolerant genotypes by using mean rank, standard deviation of ranks and rank sum (RS) distinguished genotypes, Results revealed that ranking of wheat genotypes for indices of class 2 (STI, MP, and GMP) indicated the superiority of Line 3, Line 2, and Line 4. Meanwhile, genotypes varied moderately between indices in class 1. Furthermore, the rank of stress susceptibility index (SSI), yield stability index (YSI), and reduction ratio (YR) obtained the superiority of Shandaweel 1 and Line 2.Cluster analysis showed the genotypes, based on indices tended to group into three groups: tolerant, semi-tolerant and sensitive genotypes. Tolerant group included two genotypes; Line 2 and Line 3 which had the highest values of tolerance indices under stress conditions. Principal component analysis (PCA), indicated that the first and second components justified 99.908% of variations among water stess tolerance indices. Biplot analysis showed significant positive correlation between grain yield in the stress condition (Ys) with indicators GMP, HM, YI, YSI and DI, Thus, they are separating water stress tolerant genotypes. According to all different statistical procedures: Among all genotypes, Giza 171, Shandaweel 1, Line 1, and Misr 2 were identified as the genotype with high and stable yield in stress and non-stress conditions. Thus, they can be considered as a moderate water stress-tolerant genotypes. Meanwhile, Line 3, Line 2, and Line 4 were identified as the most tolerant to water and heat stress. Hence, results indicated the possibility of released and expanding planting of these new advanced lines especially under heat and water stress conditions in Upper Egypt region.

INTRODUCTION

Wheat (Triticum aestivum L.) is considered as the main food and the most strategic cereal crop in Egypt. The total wheat production is not enough for local consumption where the annual wheat grains consumption is about 18.6 million tons. (**FAO 2020**) Wheat demand is increasing day by day due to continuously increasing population. Thus, increasing wheat production is

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the main challenge facing wheat breeder. Shortage in irrigation water has been a serious problem facing the world by the year 2025 around 65% of the world's population will be facing water shortage and live under water–stress environments (**Reynolds et al., 2012**). Mild water shortage causes 20–30% yield reduction whereas severe drought stress can cause more than 70% yield reduction (**Behera and Sharma 2014**).

High temperature is one of the most abiotic stress factors limiting the growth and production of wheat cultivars. This yield reduction varies according to the development stage and the adaptability of genotypes and varieties to high temperatures, all vegetative and reproductive stages are influenced by heat stress to some level (**Wahid et al. 2007**). Water and Heat Stress has direct and indirect impacts on productively. It has negatively affected wheat yields in many regions, as well as globally. (**FAO 2020**). Although bread wheat is a thermo-sensitive crop, but it has become adapted to nearly all the climates as a results to its genetic diversity. Wheat is cultivated in winter season but it exposed to high temperature (> 35ºC) especially in Upper Egypt. High temperature at the grain filling period which is known as terminal heat stress has strong effect on yield reduction (**Fahad et al 2017**). High temperature had negative affect on phenological, morphological, physiological and biochemical traits, which produced reduction on plant growth and finally in grain yield (**Kurck et al., 2007; Dupont et al. 2006**).

Selection of tolerant cultivars with high yield under water stress conditions has been considered as economic and efficient method (**Moustafa et al, 1996; Blum, 2005; Ashraf, 2010**). Although, it is very important to select high yielding genotypes under stress condition, they must be relatively stable yielding under non-stress environments. Select a stable and high yielding genotypes has been considered as efficient methods. A number of stress screening indices described by different mathematicians have been used to identify the tolerant cultivars. Selection of different yield genotypes under stress conditions in comparison to yield under normal conditions is a good method for determine water stress tolerant genotypes (**Mitra, 2001; Rosielle and Hamblin 1981**). These physiological characters may be useful to identify the drought tolerance of wheat genotypes. These indices were grouped into two classes, the first class represents the susceptibility indices (SSI and TOL). The second class represents the tolerance indices (Mp, GMP, and STI) which are used to screen genotypes that performs well under stress and non-stress conditions. (**Rosiellle and Hamblin, 1981; and Sareen et al, 2012**). According to **Fernandez (1992**) theory, genotypes classified into four groups based on their performance in stress and non-stress conditions, i.e. (1) genotypes producing high yield under both water stress and non-stress conditions (group A), (2) genotypes with high yield under non-stress (group B), (3) genotypes with high yield under stress conditions (group C) and (4) genotypes with poor performance under both stress and non-stress conditions (group D).

The objectives of the present study were to evaluate five new released promising lines and three Egyptian wheat cultivars through field evaluation under terminal heat stress in Upper Egypt by using water stress to identify the best performing and adapted genotypes under stress, and non-stress conditions using several water stress tolerance indices and different statistical procedures

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MATERIALS AND METHODS

The present experiments were conducted at the experimental farm of Al- Mataana Agricultural Research Station - Luxor governorate located at 25°25'18"N 32°32'06"E. Monthly maximum and minimum temperature for the two growing seasons are summarized in Table (1).

Breeding Materials

The seed of five advanced lines of bread wheat obtained from Low input program at El-Gemmiza Agricultural Research Station and the seed of three commercial bread wheat cultivars were used in this study. The name and pedigree of these new bread wheat lines and the three commercial bread wheat cultivars (Table 2).

Experimental design and treatments

Two field experiments were carried out in two seasons 2017/2018 and 2018 / 2019. Each experiment evaluates eight genotypes of bread wheat under two irrigation regimes (stress, and Normal). Stress irrigation (L), wheat plants were irrigated 3 times at Germination, tillering and at booting stages with 1275 m^3 water, and normal irrigation (N) (recommended irrigation) 6 times of irrigation at germination, tillering, elongation, booting, heading, grain filling and physiological development stages with 2550 m^3 regime. The amount and time of irrigation depends on weather conditions and plant needs i.e. The quantity of water applied was measured in the studied area by using a rectangular sharp crested weir. The discharge was calculated using the following formula according to (**masoud 1967**) :

Q = CLH3/2

Where Q: The discharge in cubic meters per second .

L: The length of the crest in meters. H: The head in meters .

C: An empirical coefficient that must be determined from discharge measurements.

Experimental factors

Split–plot arrangement in randomized complete block design with three replications was applied. The irrigation regimes were arranged in the main plots, while genotypes were randomly arranged in the subplots. The sub plot area was 5.5 m^2 with 10 rows, 2.75 m long and 20 cm apart. All recommended cultural practices were applied. The effect of different irrigation regimes on yield parameters such as the number of spikes per square meter, number of kernels per spike, 1000 kernel weight (g), grain yield (ard./fad), were determined.

Data for the two years was tested for homogeneity using (**Bartlett's 1937**) test of homogeneity and it was found to be homogeneous so the data were combined for analysis. The combined ANOVA was carried out according to (**Steel et al., 1997**) to estimate the main effects of the different sources of variation and their interactions.

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Table 1: Maximum and minimum air temperature (C) for Al-Matana Agricultural Research Station during the two seasons.

Months	2017/2018		2018/2019	
	Max	Min	Max	Min
November	27.85	13.91	28.30	14.91
December	25.84	11.83	21.87	9.46
January	22.20	7.72	20.78	7.24
February	27.88	11.98	24.12	10.30
March	33.75	16.90	27.25	12.63
April	34.87	19.20	32.63	17.52
May	40.02	25.50	40.09	24.18

Table 2: List of pedigree for eight bread wheat genotypes used in this study.

Genotypes	name	Pedigree
G1	**Line 1**	KIRITATI/2*WBLL1 CGSS02B00118T-099B-099Y-099M-099Y-099M-18WGY-OB-OGM
G2	**Line 2**	WBLL1*2/VIVITTSI//AKURI/3/WBLL1*2/BRAMBLING CMSS07Y01066T-099TOPM-099Y-099M-099Y-7M-OWGY-OGM
G3	**Line 3**	PFAU/SERI.IB//AMAD/3/WAXWING*2/4/TECUE#1 CMSS07B00614T-099TOPY-099M-099Y-099M-49WGY-OB-OGM
G4	**Line 4**	WHEAR/VIVITIS//WHEAR. CGSS03-B00069T-099Y-099M-34WGY
G5	**Line 5**	SIDS#1/ATTILA/3/KAUZ//BOW/NKT S16494-032S-031S-14S-0S
G6	**Giza 171**	SAKHA 93 / GEMMEIZA 9 Gz 2003-101-1Gz-4Gz-1Gz-2Gz-0Gz
G7	**Shandawee 11**	Site/Mo/4/Nac/Th.Ac//3*Pvn/3/Mirlo/Buc CMSS93 B00S 67S-72Y-010M-010Y-010M-3Y-0M-0THY-0SH
G8	**Misr 2**	SKAUZ/BAV92 CMSS96M03611S-1M-0105Y-010M-010SY-8M-OY-OS

Calculation of water stress Tolerance Indices

Ten stress tolerance indices were calculated based on grain yield under water stress and normal irrigated conditions. The tolerance indices including stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM), tolerance index (TOL), stress susceptibility index (SSI), yield stability index (YSI), yield reduction ratio (YR), drought resistance index (DI) and yield index (YI) were calculated based on grain yield under water stress (Ys) and irrigated (Yp) conditions. Where, Ys and Yp are the mean yield of genotypes under stress and non-stress conditions, respectively. Water stress tolerance indices were calculated by using the equations cited in (Table 3).

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Table 3: Water stress indices were calculated using the following equations:

Index name	Outcome	Formula	Reference
Stress Tolerance Index (STI)	The genotypes with high STI values will be tolerant to drought stress	$STI = \frac{(Yp * Ys)}{(G\hat{Y}p)^2}$	**Fernandez 1992 Kristin et al.1997**
Mean Productivity (MP)	The genotypes with high value of this index will be more desirable	$MP = \frac{GYs + GYp}{2}$	**Rosielle and Hamblin, 1981**
Geometric Mean Productivity (GMP)	The genotypes with high value of this index will be more desirable	$GMP = \sqrt{(GYp \times GYs}$	**Fernandez, 1992; Kristin et al., 1997**
Harmonic Mean (HM)	The genotypes with high value of this index will be more desirable	$HM = \frac{2(GYp * GYs)}{(GYp + GYs)}$	**Jafari et al., 2009**
Tolerance index (TOL)	The genotypes with low values are more stable	$TOL = Yp - Ys$	**Rosielle and Hamblin (1981)**
Stress Susceptibility Index (SSI)	The genotypes with SSI<1 are more resistant to drought stress conditions	$SSI = \frac{1 - (GYs/GYp)}{1 - (G\hat{Y}s/G\hat{Y}p)}$	**Fisher and Maurer, 1978**
Yield Stability Index (YSI)	**The** genotypes with high YSI values can be regarded as stable genotypes under stress and non-stress conditions.	$YSI = \frac{Ys}{YP}$	**Bouslama and Schapaugh, 1984**
Yield reduction ratio (YR)	The genotypes with low value of this index will be suitable for drought stress condition	$YSI = 1 - \left(\frac{Ys}{YP}\right)$	**Golestani–Araghi and Assad 1998**
Drought Resistance Index (DI)	The genotypes with high value of this index will be suitable for drought stress condition	$DI = \frac{Ys(Ys/Yp)}{\hat{Y}p}$	**Lan, 1988**
Yield Index (YI)	The genotypes with high value of this index will be suitable for drought stress condition	$YI = \frac{Ys}{\hat{Y}s}$	**Gavuzzi et al., 1997**

Correlation, cluster and principal component analysis

Correlation among indices and grain yield in two conditions was performed by SPSS Ver. 20. A principal component analysis was performed using statistical and graphical approaches with Eigen-values greater than or equal to 1.0 were selected, (**Jeffers, 1967**). A biplot display of the first two components was used for grouping genotypes under different stress conditions and illustrating the relationship between the genotypes and stress tolerance indices. To identify the most desirable water stress tolerance criteria, correlation coefficients between Ys (grain yield under stress conditions), Yp (grain yield under non-stress conditions) and other water stress tolerance indices were determined (**Yan and Rajcan, 2002**). In addition, cluster analysis was also calculated to assess the level of dissimilarity among the genotypes. A dendrogram was created based on squared Euclidean distance

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Results and Discussions

Combined analysis of variance was performed after proving the homogeneity of separate error variances for wheat grain yield and related-traits across the growing seasons. Table 4 presented combined analysis of variance for grain yield, number of spikes m^{-2}, number of kernels $spike^{-1}$ and 1000-kernel weight (g) as most important yield-traits of bread wheat genotypes. Results revealed that season and irrigation regimes had significant effect on grain yield, number of spikes per square meter 1000-kerenel weight and number of kernel per spikes. Among wheat genotypes (G) yield and its components were highly significant ($P < 0.01$) that clear the differences among genotypes. Moreover, the interaction between Irrigation regimes and genotypes was significance ($P < 0.05$) which indicated the existence of differential responses of wheat genotypes under different irrigation regime. Therefore, it indicates the genetic variation and possibility of selection for favorable genotypes. A similar trend of results was found significant variation in yield and yield components among wheat genotypes under stress and non-stress conditions (**Tawfelis 2006; Hamam and Khaled, 2009; Mohammadi et al., 2011; and Yasir et al., 2013**)

Table 4: Pooled analysis of variance for grain yield and yield component under two irrigation regimes.

Source	d.f.	No. Kernels $spike^{-1}$	No. spikes m^{-2}	1000-kernel weight (g)	Grain yield (tons hec^{-1})
Season (S.)	1	392.04**	90132.5**	518.89**	424.66**
Error	4	414.18	426.32	39.74	25.08
Irrigation(Ir.)	1	2053.50**	3623.58**	195.54**	519.08**
S * Ir.	1	126.04	15296.0**	26.09	2.58
Error	4	39.12	1095.8	13.76	1.2
Genotyes(G)	7	106.07**	1647.36**	63.69*	2.18*
S * G	7	51.30*	907.33**	24.87	1.05
Ir. * G	7	49.57	1117.4*	37.20	0.49
S * Ir. * G	7	48.07	1083.9*	42.56	1.30
Error	56	24.15	226	26.73	4.32

* And ** significant at 0.05 and 0.01 probability levels, respectively.

Performance for Yield, and Yield components

Data in table 5 revealed increasing irrigation regime had significant increased on yield, and yield components. This increasing estimated by 19.28% for grain yield, 24.54% for number of spikes per square meter, 14.04% for number of kernels per spike, and 6.76% for kernels weight as a result to increase in irrigation regimes from low to normal.

Among genotypes the data indicate the superiority of line3 in grain. Yield. Meanwhile, Line5 had the lowest grain yield. Results in table (5) recorded the superiority of Shandaweel1 in number of spikes per square meter without significant different from Misr2, Line5, and Line3.

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Furthermore, data indicate Shandaweel1 had the highest number of kernels per spike without significant different from Misr2, Giza171, Line1 and Line 3. The lightest kernels was obtained by line1.

Table 5: Mean Performance of Yield and Yield components.

S O V	Grain Yield (ton.hac^{-1}.)	No spik m^{-2}	No of Ker. Sp^{-1}	1000 Ker. Weight. (g)
Season 1	8.53	354	59.23	43.06
Season 2	7.03	311	63.27	38.41
L.S.D	0.42	8	ns	ns
Irr-1(stress)	6.95	286	56.63	39.31
Irr-2 (normal)	8.61	379	65.88	42.16
L.S.D	0.43	8	ns	2.49
G1	7.58	324	61.83	36.60
G2	8.17	325	60.17	43.78
G3	8.26	338	61.42	41.53
G4	7.97	328	58.75	42.36
G5	7.42	340	56.08	38.81
Giza 171	7.74	319	62.75	42.48
Shandawil1	7.68	343	65.92	39.97
Misr 2	7.45	341	63.08	40.37
L.S.D	0.86	16	5.68	5.98

Wheat breeders prefer selection for the best genotypes with the highest yield performance, because select for high yielding genotypes had the observed expression gain of the important yield-traits values (**Karaman, 2017**). The grain yield is the ultimate expression of many physiological processes especially under stress treatments. Then, the interaction between irrigation regimes and genotypes and the percentage of yield reduction are presented in Table 6. Data showed reduction in grain yield for all genotypes under stress irrigation as a compared to non-stress condition. The average of this reduction was 19.28%. It ranged from 16.46% for Shandaweel 1 to 26.72% for line 5. This reduction was attributed to the adverse of combination effect of water deficiency and high temperature. (The variances among genotypes under stress conditions was reported from several researches (**Tawfelis, 2006; Mohammadi et al., 2011; Yasir et al., 2013; Abd El-Mohsen and Abd El-Shafi, 2014, and Ashraf et al 2015**).

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Table 6: Mean Grain Yield (tons/hec.) of Genotypes under Normal Irrigation and Water Stress Conditions

Genotypes	Stress	Normal Ir.	Mean	Reduction %
G1	6.65	8.50	7.58	21.71
G2	7.43	8.90	8.16	16.49
G3	7.50	9.01	8.26	16.79
G4	7.12	8.81	7.97	19.24
G5	6.28	8.56	7.42	26.72
G171	6.90	8.58	7.74	19.53
Sh.1	6.99	8.37	7.68	16.47
Misr 2	6.75	8.16	7.45	17.32
Mean	6.95	8.61	7.78	19.28
L.S.D 0.05 For Irrig.	0.43			
Genotypes	0.86			
Irig x Genotypes	----			

Correlation analysis

The correlation matrix between grain yield under stress and non-stress conditions and water stress tolerance indices were calculated to determine the most desirable water stress tolerance criteria, it can be applied as a standard tool to select better genotypes and indices (Table 7).

The suitable index can be described by having a significant correlation with grain yield under both conditions. Yield in normal condition shows positive and meaningful correlation with stress tolerance index (STI = 0.853) mean productivity (MP 0.88) and geometric mean Productivity (GMP 0.855) in probability level 1%, and with harmonic mean (HM 0.831) in probability level 5%. These results were in harmony with (**Abd El-Mohsen et al 2015**), (**Mohammadi et al 2006**), and (**Mollasadeghi et al 2011**). Yield under stress conditions show significant correlations with all indices. These correlations were positive with STI (0.96), MP (0.943), and GMP (0.959) HM (0.971), DI (0.962), and YI (0.999) in probability level 1% and with HM (0.971), and TOL (0.713) in probability level 5%. Meanwhile, data showed adversely correlation between yield under stress condition and SSI (0.813), YSI (0.804), and YR (0.804) in probability level 5%. **Rosielle and Hamblin (1981)** showed that in a majority of comparative experiments, the correlation of yield between MP and Yi, and MP and GYs were positive. According to their reports, selection on the basis of MP generally caused to increasing yield in both normal and stressed conditions. .According to (**Farshadfar et al. 2001**) the best appropriate index to identify stress tolerance genotypes, is the index that has a relatively high correlation with grain yield under stressed and non-stressed conditions. Therefore, STI, MP, GMP, and HM could be it can be detected the most suitable introduced as major indices.

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Table 7: Correlation Coefficients between Yield Potential (Y_P), Yield stress (Y_S) and Drought Tolerance Indices

Genotype	Yp	Ys	STI	MP	GMP	H M	TOL	SSI	YSI	YR	DI	YI
Yp	1.00	0.67	.853**	.880**	.855**	.831*	0.04	-0.12	0.11	-0.11	0.45	0.66
Ys		1.00	.960**	.943**	.959**	.971**	-.713*	-.813*	.804*	-.804*	.962**	.999**
STI			1.00	.998**	1.000**	.999**	-0.49	-0.62	0.61	-0.61	.849**	.952**
MP				1.00	.999**	.995**	-0.44	-0.57	0.56	-0.56	.820*	.935**
GMP					1.00	.999**	-0.49	-0.62	0.60	-0.60	.848**	.952**
H M						1.00	-0.52	-0.65	0.64	-0.64	.870**	.965**
TOL							1.00	.988**	-.987**	.987**	-.874**	-.727-*
SSI								1.00	-.997**	.997**	-.938**	-.824*
YSI									1.00	-1.00**	.935**	.815*
YR										1.00	-.935**	-.815-*
DI											1.00	.966**
YI												1.00

Screening water stress tolerant genotypes and indices

Yield potential (Yp), and (Y_S) yield under stress condition and ten quantitative indices of water stress tolerance were calculated (Table 8). Results cleared that genotypes Shandaweel1, Line 2, and Line 3 had high yield production under stress and non-stress. Meanwhile, genotype line 5 had the highest reduction in grain yield under stress condition. This reduction of yield under water stress is an important index to evaluate the changes of grain yield cultivars under stress conditions. Results showed wheat genotypes with high values of STI, MP, and GMP indices can be selected as tolerant genotypes to water stress similar finding reported by (**Mollasadeghi et al, 2011; Muhe, 2011, and Ashraf et. al, 2015**) using of selection indices is more efficient than direct selection of grain yield. The genotypes with high values of stress tolerance index (STI), geometric mean productivity (GMP) and mean productivity (MP) can be selected as tolerant genotypes to water stress. According to STI, MP, GMP values and mean genotypes Line3, Line2 and Line4 can be selected as tolerant genotypes to water stress. While, Genotypes Line1, Line5 and Miser2 were identified as susceptible genotypes, because of their low values for STI, MP and GMP. Moreover, genotypes with high values of HM and low values of TOL would be more stable under stress and non-stress condition. Data showed that genotypes (Shandaweel1, Line2, and Line3) were the most stable genotypes. Regarding to stress susceptibility index (SSI) which its value less than one indicated high tolerance to stress. Meanwhile, the genotypes which had indices values of SSI less than 1 identify as water stress resistance (**Clarke et al, 1992**). According to SSI genotypes Shandawel1, Line2, and Line3 were identify as resistance to water stress. On the other hand, genotypes 5 and 1 were identify as sensitivity to water stress. However, Shandawel1 had the highest value yield stability index

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(YSI), and the lowest value of drought resistance index (DI) these results revealed the ability of shandaweel1 to adapt under this stress condition. According to yield index (YI) Line 3 recorded the highest value followed by Line 2

Table 8: Mean grain yield (ard /feddan^{-1}) under normal and water stress conditions

Genotypes	Yp	Ys	STI	MP	GMP	H M	TOL	SSI	YSI	YR	DI	YI
G1	8.50	6.65	0.76	21.22	21.06	20.91	5.17	1.08	0.78	0.22	0.60	0.97
G2	8.90	7.43	0.89	22.87	22.78	22.69	4.11	0.82	0.84	0.16	0.72	1.08
G3	9.01	7.50	0.91	23.13	23.03	22.93	4.25	0.84	0.83	0.17	0.72	1.09
G4	8.81	7.12	0.85	22.32	22.19	22.06	4.75	0.96	0.81	0.19	0.67	1.03
G5	8.56	6.28	0.72	20.78	20.53	20.29	6.41	1.33	0.73	0.27	0.53	0.91
G171	8.58	6.90	0.80	21.67	21.55	21.42	4.70	0.97	0.80	0.20	0.64	1.00
Sh.1	8.37	6.99	0.79	21.51	21.42	21.34	3.86	0.82	0.84	0.16	0.68	1.02
Misr 2	8.16	6.75	0.74	20.88	20.79	20.69	3.96	0.86	0.83	0.17	0.65	0.98

Rank and indices scores

Genotypes have different responses to water stress indices. Hence, Identify the water stress-tolerant genotypes based on a single index is unacceptable. Thus, to determine the most appropriate genotype to water stress condition, the rank of previous physiological indices and the mean of ranks and standard deviation of ranks of all indices were calculated (Table 9). The standard deviation of ranks and man rank (RS) of all water stress tolerance indices were calculated. Based on the mean rank, the most water stress tolerant genotypes were detected. Results revealed that ranking of wheat genotypes for indices of class 2 (STI, MP, and GMP) indicated the superiority of Line 3, Line 2, and Line 4. Meanwhile, genotypes varied moderately between indices in class 1. According to the rank of STI, MP, GMP, HM, DI, YI data indicated the superiority of Line 3 and 2. Meanwhile, the rank of SSI, YSI, and YR obtained the superiority of Shandaweel 1 and Line 2. Moreover, the lowest mean rankings and mean rank and standard division was recorded from Line 2 and Line 3, Line 5 and Shandaweel 1.

Table 9: Rank (R), mean of ranks (R), standard deviation of ranks (STDRs), and Rank Sum (RS) of water stress tolerance indices

Genotypes	STI	MP	GMP	H M	TOL	SSI	YSI	YR	DI	YI	R-	STD	RS
G1	6	6	6	7	7	7	7	7	7	7	6.70	0.46	7.16
G2	2	2	2	3	2	2	1	2	2	2	2.00	0.45	2.45
G3	1	1	1	4	3	3	3	1	1	2	2.00	1.10	3.10
G4	3	3	3	6	5	5	5	4	3	4	4.10	1.04	5.14
G5	8	8	8	8	8	8	8	8	8	8	8.00	0.00	8.00
G171	4	4	4	5	6	6	6	6	5	5	5.10	0.83	5.93
Sh.1	5	5	5	1	1	1	1	3	4	3	2.90	1.70	4.60
Misr 2	7	7	7	2	4	4	4	5	6	5	5.10	1.58	6.68

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Cluster analysis

Cluster analysis was done to estimate the variation among different genotypes based on tolerance indices and grain yield under stress and non-stress conditions. The cluster analysis was applied to place the similar genotypes in one group. The genotypes were classified into three groups (Figure 1). The first group included two genotypes; Line 2 and Line 3 which had the highest values of tolerance indices, These two genotypes had the highest rank of STI, MP, GMP, YI and YSI values, thus they considered to be the most desirable genotypes for both growth conditions (class 2 tolerant group). Meanwhile, the second group included five genotypes Line4, Giza171, Shandaweel1, Misr2 and Line1 which had intermediate values, therefore, they could be considered as moderate water sress-tolerant genotypes. Hence, these results cleared the superiority of Line 2 and Line 3 under both conditions as a compared to the new released varieties Giza171, Shandaweel1 and Misr2. Thus, it indicated the possibility of released and expanding planting these new lines especially under water stress conditions. Finally, the third group contained Line 5 which had low values, which could be considered sensitive genotype. These results were in a harmony with many studies which reported the cluster analysis has been generally descripted of variation between genotypes and grouping based on water stress tolerance indices (**Khodadadi et al., 2011; Najaphy and Geravandi, 2011; Abd El-Mohsen et. al, 2015; Moustafa, 2021**).

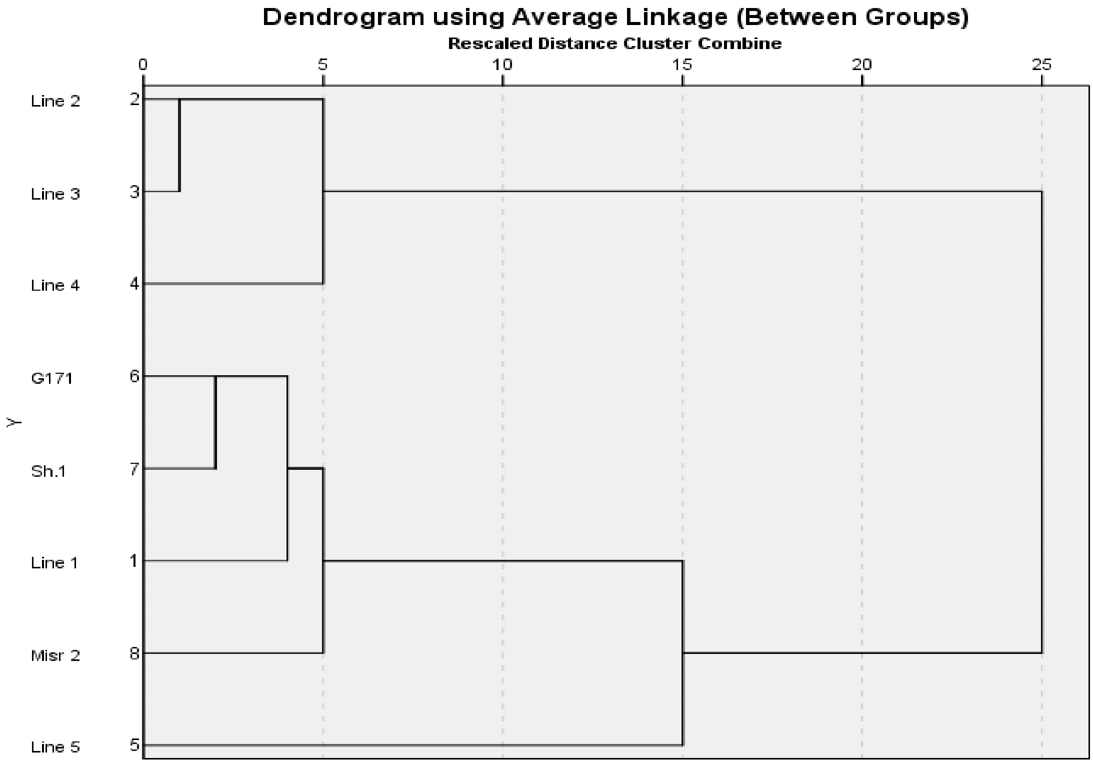

Fig. 1: Dendrogram between groups showing classification of genotypes based on resistance/tolerance indices.

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Principal component biplot analysis

Plant breeders are employing PCA as a "pattern finding method" to complement cluster analysis. **Khodadadi et al., (2011)** and **Sajjad et al, (2011)**. According to the method, twelve indices were reduced to two independent components. These two components had eigen values greater than or equal to 1.0 These two components explained 99.91% of total variation. (Table 10). In each component, a high correlation between the component and an index indicating that the index is associated with the direction of the maximum amount of variability. The first component (PC1) mostly was affected by, Yp, Y_S, STI, TOL, MP, and GMP. It explained 79.749 of the total variation. Thus, the first component can be named as the yield potential and water stress tolerance. Considering the high and positive value of genotypes which have high values of these indices. The second PCA explained 20.16% of the total variation and correlated positively with GMP, Y_P, YSI, STI, and SSI. Therefore, the second component can be named as a stress-tolerant dimension and separates the stress-tolerant genotypes from stress susceptibility genotypes. The genotypes which have high value of PC1 are expected to have high yield under both stress and non-stress conditions. Similar results were revealed the most effective indices in the second component (PC2) were Yp, SSI and GMP (**Golabadi et al., 2006; Ashraf et al., 2015**).

Table 10: Principal components analysis for water stress tolerance indices of eight wheat genotypes under normal irrigation and water stress conditions.

Drought Tolerance Indices	Component	
	1	2
Y_P	0.30	0.54
Y_S	0.53	0.23
SSI	0.03	0.01
STI	0.42	0.16
TOL	0.43	0.11
MP	0.45	0.07
GMP	0.23	0.77
SSI	-0.06	0.14
YSI	0.01	-0.03
YR	-0.01	0.03
DI	0.03	-0.03
YI	0.03	-0.01
Eigen value	9.570	2.419
Percent of variance	79.749	20.159
Cumulative Percentage	79.749	99.908

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

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Principal component analysis biplot of Ys, Yp and water stress indices (Figure 2) the angle between Ys, Yp, MP, STI, GMP, HM, YI, YSI and DI is acute angle, therefore they have positive correlation. On the other hand, results cleared the obtuse angle between Yp, SSI, and YR. and between Ys and TOL, SSI and YR indicated the negative correlation. Meanwhile, a right angle between Yp and TOL Indicated near zero correlation these results were confirmed by correlation analysis (Table 7).

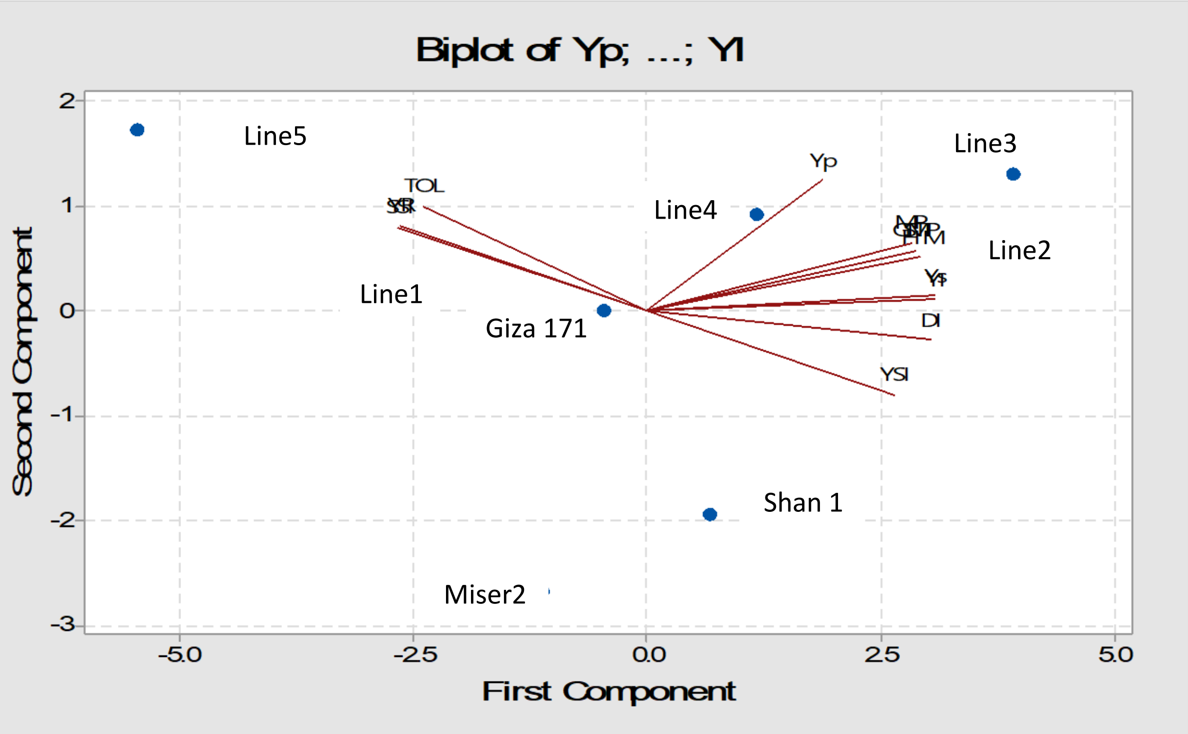

Fig. 2: The biplot diagram of principle components analysis of 8 wheat genotypes of bread wheat according to mean measured of water stress tolerance indices together with mean grain yield under stress (Ys) and irrigation (Yp) conditions.

CONCLUSION

Selection based on a combination of indices is the most suitable tool to improve water stress tolerance for wheat genotypes. This study revealed the tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), and harmonic mean (HM) were effective in judging tolerance to water stress. Cluster analysis showed the genotypes, based on indices tended to group into three groups: tolerant, semi-tolerant and sensitive genotypes. Tolerant Group included two genotypes; Line 2 and Line 3 which had the highest values of tolerance indices under stress and non-stress conditions. Principal component analysis (PCA), indicated that first and second components justified 99.908% of variations among water stress tolerance indices. According to all different Line 3, Line 2, and Line 4 were identified as the

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most water stress tolerant to water stress. Among all genotypes, Giza 171, Shandaweel 1, Line 1, and Misr 2 were identified as the genotype with high and stable yield in stress and non-stress conditions. Thus, they can be considered as a moderate water stress-tolerant genotypes. Meanwhile, Line 3, Line 2, and Line 4 were identified as the most tolerant to water and heat stress. Hence, results indicated the possibility of released and expanding planting these new advanced lines especially under heat and water stress conditions

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REFERENCES

Abd El-Mohsen AA, and Abd El-Shafi MA. (2014). Regression and path analysis in Egyptian bread wheat. J. Agri-Food and Appl. Sci., 2(5): 139-148.

Abd El-Mohsen, A.A.; M. A. Abd El-Shafi, E. M. S. Gheith, and H. S. Suleiman (2015). Using Different Statistical Procedures for Evaluating Drought Tolerance Indices of Bread Wheat Genotypes. Adv. Agric. Biol. 4 (1) 19-30.

Ashraf, A.; A. El-Mohsen; M.A Abd El-Shafi, E.M.S Gheith, and H.S. Suleiman, (2015). Using different statistical procedures for evaluating drought tolerance indices of bread wheat genotypes.Advance in Agriculture and Biology, 4: 19-30.

Ashraf, M. (2010). Inducing drought tolerance in plants: recent advances. Biotechnology Advances 28(1), 169-183. Doi: 10.1016/ j.biotechadv.2009.11.005.

Bartlett M.S. (1937). Some examples of statistical methods of research in agriculture and applied biology. J. Roy. Stat. Soc. Suppl., 4: 137- 185.

Behera UK, and AR Sharma (2014). Productivity and water use efficiency of wheat (Triticum aestivum) under different resource conversation techniques and irrigation regimes. Cereal Res Commun 42(3):439–449

Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential—are they compatible, dissonant, or mutually exclusive? Australian Jour. of Agric. Res. 56: 1159–1168.

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

Clarke JM, De Pauw RM, and TM.Townley-Smith (1992). Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci., 32: 728-732.

Dupont, F. M., Hurkman, W. J. Vensel, W. H., Tanaka, C. K., Kothari, K. M., Chung, O. K. and Al tenbach, S. B. (2006). Protein accumulation and composition in wheat grains: effects of mineral nutrients and high temperature. Europian J. Agronomy, 25, 96-107.

Fahad,S; Bajwa ,AA; Nazir ,U; Anjum, S.A; Farooq ,A.; Zohaib, A; Sadia S; Nasim W, Adkins,s.; Saud S, Ihsan MZ, Alharby HF, Wu CY, Wang D, and Huang J (2017). Crop Production under Drought and Heat Stress: Plant Responses and Magement Options. Front Plant Sci.8:1147 Published online. doi:10.3389/fpls.2017.01147.

FAO STAT (2020). Food and Agriculture Organization of the United Nations. Statistics Division. Accessed on 05/03/ 2020, http://faostat3.fao.org

Farshadfar, A.; A. Zamani; M. Matlabi, and A. Imam Jome (2001). Tolerance in Pea Lines. Iranian Jour.of Agric. Sci. 32, 65-77.

DOI 10.5281/zenodo.6966801

Fernandez, G.C.J. (1992). Effective selection criteria for assessing plant stress tolerance. In kuo, CG (Eds.). Proc. Sympos. Asaptation of vegetative and other food crops to temperature and water stress. Shanhua Taiwan. 13-18 Aug, pp. 257-70.

Fischer, R.A., and R. Maurer, (1978). Drought resistance in spring wheat cultivars. 1. Grain yield response. Australian. Journal of Agricultural Research 29, 897–912.

Gavuzzi P, F. Rizza,M. Palumbo, R.G. Campaline,GLicciardi ,and B. Borghi (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can. J. Plant. Sci., 77: 523-531.

Golabadi M, A. Arzani,and M. Maibody (2006). Assessment of drought tolerance in segregating populations in durum wheat. African J. of Agric. Res., 1(5) 162-171.

Golestani -Araghi S, and M.T. Assad (1998). Evaluation of four screening techniques for drought resistance and their relationship to yield reduction ration in wheat. Euphytica, 103: 293-299.

Hamam, K.A and A.G.A. Khaled (2009). Stability of Wheat Genotypes under Different Environments and Their Evaluation under Sowing Dates and Nitrogen Fertilizer Levels. Aust. J. Basic and Applied Sci., 3: 206-217.

Jafari AA, Paknejad F, Jamial-Ahmadi M. (2009). Evaluation of selection indices for drought tolerance of corn (Zea mays L.) hybrids. Int. J. Plant. Prot., 3 33-38.

Jeffers JNR. (1967). Two case studies in the application of principal component analysis. Appl. Stat., 16:225-236.

Karaman, M. (2017). Determination of physiological and morphological parameters associated with grain yield and quality traits in durum wheat. – Ph.D. Thesis, Dicle University.

Khodadadi M, M.H. Motokian, and M. Miransari (2011). Genetic diversity of wheat (Triticum aestivum L.) genotypes based on cluster and principal component analyses for breeding strategies. Aust J Crop Sci., 5(1): 17-24.

Kristin, A.S., Senra, R.R.,Perez,F.I.,Enriquez, B.C., Gallegos, J.A.A., Vallego, P.R., N. Wassimi, ,and J.D. Kelley (1997). Improving common bean performance under drought stress. Crop Science 37, 43–50.

Kurck, I., Chang, T. K., Bertain, S. M., Madrigal, A., Liu, L., M. W.Lassner, and G. Zhou, (2007). Enhanced thermostability of Arabidopsis Rubiso activase improves photosynthesis and growth rates under moderate heat stress. Plant Cell, 19, 3230-3241.

Lan J. (1988). Comparison of evaluating methods for agronomic drought resistance in crops. Acta Agric. Boreali-occidentalis Sinica, 7: 85–87.

Masoud F.I. (1967). Water, Soil and plant relationship. New publication House, Alexandria. (In Arabic).

Mitra, J., (2001). Genetics and genetic improvement of drought tolerance in crop plants. Current Science 80, 758-762.

Mohammadi M, R .Karimizadeh, and M. Abdipour (2011). Evaluation of drought tolerance in bread wheat genotypes under dryland and supplemental irrigation conditions. Austr. j. of Crop Sci., 5(4): 487-493.

Mohammadi, R., R. Haghparast, M. Aghaei Sarbarzeh and A. Abdollahi (2006). Evaluation of drought tolerance rate of advanced genotypes of Durum wheat on the basis of physiologic standards and other related indices. Iranian Agric. Sci., 37(1): 561-567.

Mollasadeghi,V.; V. Mostafa; R. Shahryari and A.A. Imani (2011). Evaluation of End Drought Tolerance of 12 Wheat Genotypes by Stress Indices World Applied Sciences Journal 13 (3): 545-551, 201 ISSN 1818-4952 © IDOSI Publications, 201

Moustafa, E. S.A. (2021). Evaluation of Bread Wheat Advanced Lines under Salinity Conditions using Tolerance Indices Egyptian J. Desert Res., 71: (1) 23-52

ISSN 1533-9211

DOI 10.5281/zenodo.6966801

Moustafa, M.A., L. Boersma, and W.E. Kronstad (1996). Response of spring wheat cultivars to drought stress.Crop.Sci. 36: 982-986.

Muhe,K.(2011). Selection index in durum wheat Triticum turgidum var durum) variety development. Acad J. Plant Sci. 4, 77-83.

Najaphy A, and M. Geravandi (2011). Assessment of indices to identify wheat genotypes adapted to irrigated and rain-fed environments. Adv. in Environ. Biology, 5(10): 3212-3218.

Reynolds, M.P., A.J.D. Pask and D.M. Mullan (2012). Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation. Mixico D.F.: CIMMYT.

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

Sajjad M, S.H. Khan, Abdus Salamand and A. Khan (2011). Exploitation of Germplasm for Grain Yield Improvement in Spring Wheat (Triticum aestivum L.). Int Agric Biol., 13:695-700.

Sareen, S.B.S. Tyagi and I.Sharma, (2012). Response estimation of wheat synthetic lines to terminal heat stress using stress indices. Jor. Of Agric. Sci. 4 doi:http//dx.doi.org/10.5539/jas.v4n10p 97-104.

Steel RGD, GH Torrie, and DA. Dickey (1997). Principles and Procedures of Statistics: A Biometrical Approach. 3rd ed. McGraw-Hill, New York, USA, 450 p.

Tawfelis, M.B. (2006). Stability parameters of some bread wheat genotypes (Triticum aestivum L.) in new and old lands under Upper Egypt. Egypt J. Plant Breed. 10: 223-246.

Wahid, A., Gelani, S., M. Ashraf, and M. Foolad (2007). Heat tolerance in plants: An overview. Environ. Exp. Bot. 61, 199.223.

Yan W, and I. Rajcan (2002). Biplot analysis of test sites and trait relations of soybean in Ontario. Crop Sci., 42: 11-20.

Yasir TA, X Chen, L Tian, AG Condon, and HU Yin-Gang. (2013). Screening of Chinese bread wheat genotypes under two water regimes by various drought tolerance indices. Austr. J. of Crop Sci., 7(13):2005-2013.