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Yield Productivity of Sixteen Egyptian Bread Wheat Varieties Grown under Middle Egypt and West West El-Minya Conditions

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ABSTRACT

The present investigation was carried out at the experimental farm of Sids and West west El-Minya Research Stations to evaluate the yield productivity of 16 bread wheat varieties during the two growing seasons of 2018/2019 and 2019/2020. The experimental design used was a randomized complete block design (RCBD) with three replicates. Four stress tolerance indices were calculated using the grain yield under Sids location as favorable environment and West west El-Minya location as a stress environment. The genotype by trait GxT biplot graph was automated to compare wheat varieties in terms of their multiple traits for each location separately. Results showed significant differences among wheat varieties, growing regions and their interaction for most studied traits across the two seasons. The grain yields produced under West west El-Minya region were slightly lower compared to that produced under Sids region indicating that the West west El-Minya is promising region for future wheat cultivation despite its stress conditions. It is revealed that Gemmeiza 9, Gemmeiza 10, Giza 171 and Shandaweel 1 had the maximum grain yields across the two growing regions. In addition, they recorded the highest values of the four tolerance indices. It is obvious that Sids 1, Giza 171, Misr 2 and Shandaweel 1 reflected the best performance in terms of most studied traits under West west El-Minya region while Sids 14, Shandaweel 1, Sakha 95 and Giza 171 were the best varieties under Sids conditions. It is obvious that GxT biplot graph is considered an easy and effective visual to interpret results.

***Keywords**: wheat, grain yield, tolerance indices, biplot graph.*

INTRODUCTION

There is no doubt that grain crops especially wheat is one of the most important pillars of food and national security. This fact became evident after the Corona crisis and the Russian-Ukrainian war that followed by excessive and exaggerated increase in grain prices. Egypt, as the world's largest wheat importer, has been severely affected economically by these international dilemmas. Increasing wheat production by expanding land reclamation, especially in the Western Desert is an inevitable strategic objective in Egypt to narrow the gap between wheat consumption and production. In the view of food security, selection of suitable and efficient plant type for coping with climatic changes is important aspect where there is always a great need to produce high yielding wheat varieties that would display both high intrinsic yield stability under abiotic stress and the capacity to adapt to future climatic changes (Ram *et al*., 2020).

Beside the soil reclamation is very expensive, the problems of water shortage, soil and water salinity and high temperature are actual constraints founded in the recently reclaimed land in the western desert of Egypt which obstructed the process of expanding agricultural production. When one or more of these abiotic stresses is present, it may cause negative effects on most plant traits, which ultimately leads to the loss of a considerable part of the grain yield. Wheat varieties are relatively differed in their tolerance ability toward the previous abiotic stresses. Accordingly, selecting high yielding and abiotic/biotic tolerant wheat varieties is one of the main foundations of wheat breeding program in Egypt. In this respect, the Egyptian government has established giant agricultural projects to cultivate vast areas in the Western Desert. To achieve this goal, wheat researchers made an exceptional effort to carry out a large number of field experiments for evaluating wheat genotypes under environments suffering from abiotic stresses (El Ameen, 2012; Darwish *et al*., 2017; Gadallah *et al*., 2017; Noreldin and Mahmoud, 2017; Gab Alla *et al*., 2019; Hagras and Moustafa, 2019; Mohiy *et al*., 2021; Darwish *et al*., 2022; Ibrahim and Said, 2020; Sayed *et al*., 2022 and Elfanah *et al*., 2023). These researches have resulted in the development of wheat varieties that can be grown in unfavorable environments as well as in the new reclaimed lands.

Stress tolerance indices are employed as simplified statistical equations that compare among some genotypes by using their grain yields under favorable and stressed environments to detect the tolerant/sensitive ones. In this context, there are many stress tolerance indices were developed such as mean productivity, (Rosielle and Hamblin, 1981), geometric mean productivity, stress tolerance index (Fernandez, 1992), and harmonic mean (Jafari *et al*., 2009) that were used in the current investigation. Singh *et al.* (2015, a and b), Ali and El-Sadek (2016), Darwish *et al.* (2017) and Gab Alla *et al.* (2019) on bread wheat, and Mohammadi (2016) on durum wheat, reported highly significant associations among some stress tolerance indices indicating that these indices are similar for ranking stress tolerant genotypes which allows to use only one of them.

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Genotype x trait (GT) biplot summarized the interrelationships among some genotypes in term of their measured traits that facilitates the identification of elite genotypes for grain yield and its related traits (Yan and Rajcan, 2002; Yan and Tinker, 2005 and Yan, 2014). Gab Alla *et al.* (2018) reported that the results obtained by GT biplot graphs were coincided with those obtained by correlation matrix and cluster analysis indicating that GT biplot graph may be simplified and effective technique instead of these analyses. Ram et al. (2020) and Elfanah *et al.* (2023) mentioned that genotype by traits (GT) and genotype by yield*trait (GYT) biplot graphs are useful for genotypes screening and selection based on grain yield and other associated traits as well as genotypes by stress tolerance indices.

The main objective of this research is to identify the stress tolerant wheat varieties to maximize the obtained yield under West west El-Minya region using four tolerance indices.

MATERIALS AND METHODS

The current investigation was carried out to assess the yield potential of sixteen local bread wheat varieties at two regions representing favorable and newly reclaimed lands during the two growing seasons of 2018/2019 and 2019/2020.

The first location was Sids Agricultural Station, Beni Swef Governorate (latitudes 29° 3' North, longitudes 31° 6' East) representing favorable environment while the second location was the experimental farm of West west El-Minya, El-Minya Governorate which lies between latitudes of 28° 7′ & 28° 25′ N and longitudes of 29° 35′ & 30° 1′ E representing stress environment due to the partly saline irrigation water and the unfavorable environmental conditions.

The location of West west El-Minya is considered the most desert area targeted to soil reclamation in the past decade years depending mainly on the groundwater extraction though drilled wells. Name and pedigree of the studied varieties are listed in Table (1). For the two locations, the meteorological data for the two seasons are measured and shown in Table 2 and Figure 1.

Table 1. Name, cross name and selection history of the sixteen studied bread wheat varieties.

No.	Variety name	Cross name	Selection history
1	Gemmeiza 10	MAYA 74 "S"/ON//1160-147/3/BB/GLL/4 /CHAT"S" /5/CROW "S"	CGM5820-3GM-1GM-2GM-0GM.
2	Gemmeiza 11	BOW"S"/KVZ"S"//7C/SER182/3 /Giza168/Sakha 61	GM7892-2GM-1GM-2GM-1GM-0GM
3	Gemmeiza 9	Ald “S” / Huac // Cmh 74A. 630 / Sx	GM 4583-5GM-1GM-0GM
4	Giza 168	MRL/BUC //SERI	CM93046-8M-0Y-0M-2Y-0B-0SH
5	Giza 171	SAKHA 93/GEMMEIZA 9	GZ.2003-101-1GZ-4GZ-1GZ-2GZ-0GZ
6	Misr 1	OASIS / SKAUZ // 4*BCN /3/ 2*PASTOR	CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S
7	Misr 2	SKAUZ / BAV92	CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S
8	Misr 3	ATTILA*2/PBW65*2/KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B-0EGY
9	Sakha 1001	SIDS1/ ATTILA // GOUMRIA-17	S. 16498-042S-013S-21S -0S
10	Sakha 93	Sakha92/TR810328	S.8871-1S-2S-1S-0S
11	Sakha 94	OPATA/RAYON//KAUZ	CMBW90Y3180-0TOPM-3Y-010M-010M-010Y-10M-015Y-0Y-0AP-0S.
12	Sakha 95	PASTOR // SITE / MO /3/ CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /4/ WBLL1.	CMA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.
13	Shandaweel 1	SITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC	CMSS93B00567S-72Y-010M-010Y-010M-3Y-0M-0HTY-0SH
14	Sids 1	HD 2172 / Pavon “S” // 1158.57/ Maya 74 “S”	S 46-4Sd-2Sd-1Sd-0Sd
15	Sids12	BUC//7C/ALD/5/MAYA74/ ON//1160.147/3/BB/GLL /4/ CHAT"S" /6/MAYA/VUL//CMH74A.630/4*SX	SD7096-4SD-1SD-1SD-0SD
16	Sids 14	BOW "S" / VEE"S" // BOW"S" / TSI/3/ BANI SEWEF 1	SD293-1SD-2SD-4SD-0SD

Table 2. Monthly meteorological data at Sids and West west El-Minya during 2018/2019 and 2019/2020 seasons.

Meteorological parameters	Month	2018/2019		2019/2020	
		Sids	West west El-Minya	Sids	West west El-Minya
Air temperature	November	18.87	18.47	20.49	19.89
	December	13.43	13.09	13.55	13.39
	January	11.06	10.48	10.92	10.65
	February	13.18	12.64	13.13	12.73
	March	16.01	15.59	17.26	16.06
	April	20.79	20.48	21.09	19.88
	May	27.97	27.55	26.83	25.73
	Mean	17.33	16.90	17.61	16.91
Relative humidity	November	50.15	53.38	44.36	48.70
	December	60.50	63.24	62.66	64.69
	January	45.52	49.75	62.87	65.15
	February	46.79	49.69	58.84	63.58
	March	40.66	44.69	43.95	54.31
	April	33.21	36.60	35.73	45.68
	May	21.64	24.62	27.27	35.46
	Mean	42.64	46.00	47.96	53.94
Wind speed	November	2.06	2.35	2.14	2.44
	December	2.32	2.66	2.52	2.89
	January	2.31	2.62	2.50	2.99
	February	2.30	2.56	2.22	2.53
	March	2.96	3.29	2.78	3.06
	April	3.12	3.35	3.06	3.12
	May	3.25	3.38	3.56	3.83
	Mean	2.62	2.89	2.68	2.98

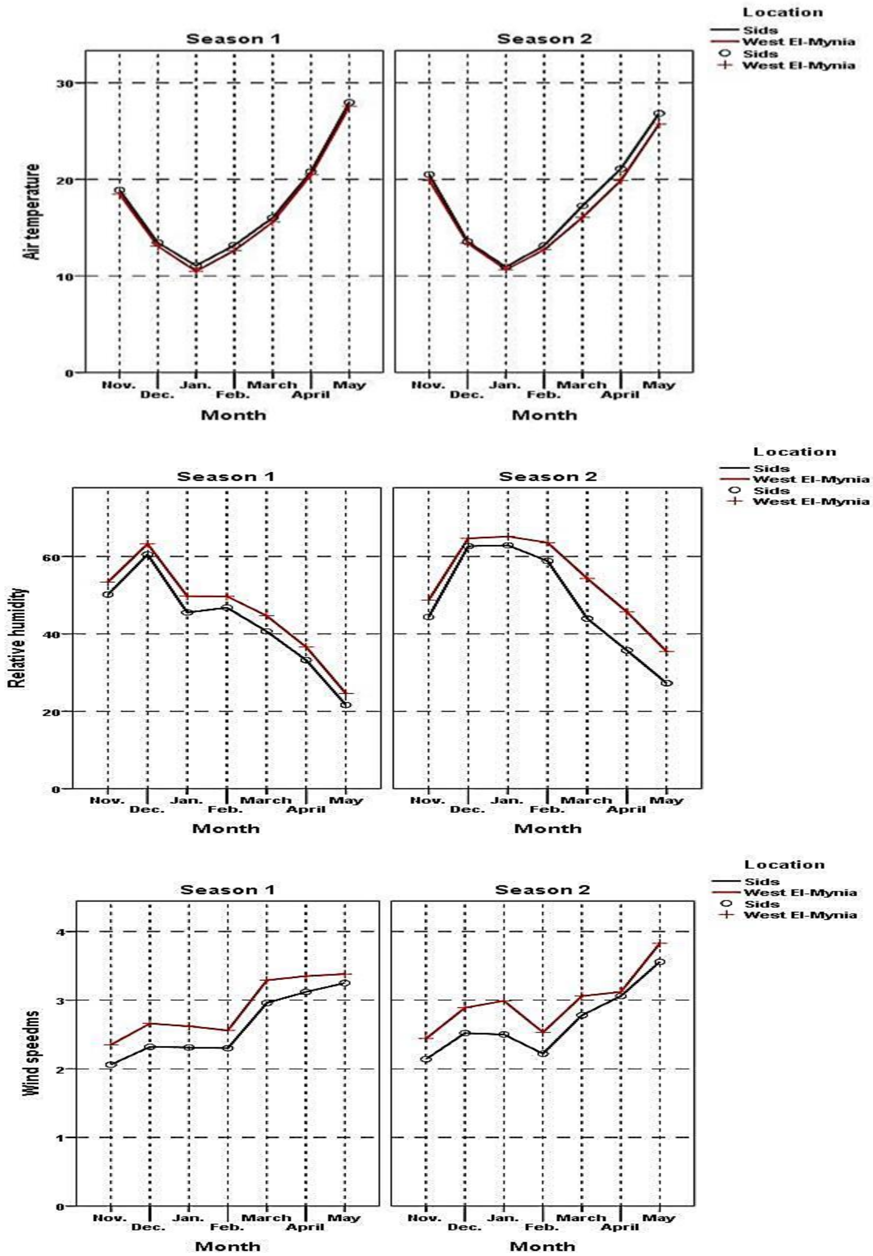

Fig. 1. Monthly meteorological data at Sids and West west El-Minya during 2018/2019 and 2019/2020 seasons.

Also, the physical and chemical properties of the soil are measured and shown in Tables (3), while the physical and chemical analyses of irrigation water are shown in Table (4).

It is clear from the meteorological data (Table 2) that there were no sharp differences between the two regions in terms of air temperature. The relative humidity and wind speed were higher at West west El-Minya region than its corresponding values at Sids region throughout the entire growing season. Surface irrigation was used at Sids location while drip irrigation was applied at West west El-Minya. The recommended agricultural practices package for wheat was applied at the proper time for the two locations.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The plot area was 3.6 m^2 consisting of 6 rows 3 m long and 0.2 m apart. All the agricultural practices were applied as recommended. At the proper time, the data were collected on the following agronomic, physiological and yield: number of days to heading (DH) and maturity (DM), grain filling period (GFP, day) grain filling rate (GFR, g m^{-2} day^{-1}), plant height (PH, cm), normalized difference vegetation index (NDVI), total chlorophyll content (TCC), number of spikes m^{-2} (SM), grain yield (GY, ardab fed^{-1}), harvest index (HI, %), number of kernels per spike (KS) and 1000-kernel weight (KW, g). Regarding Normalized Difference Vegetation Index (NDVI), it was measured by a field portable NDVI sensor (Green Seeker® Handheld Crop Sensor, Trimble Navigation Limited, Westminster, CO, USA) between 11:30 a.m. and 2:00 p.m. With respect to the Total Chlorophyll Content (TCC), it was determined by the chlorophyll content meter (OPTI-SCIENCES, INC., CCM 200 plus) of the blade flag leaf (three readings per plot) at a completed flowering stage between the time of 11 A.M. to 2 P.M. on a sunny day.

The collected data were subjected to the combined analysis of variance of randomized complete block design across the locations and seasons as outlined by Gomez and Gomez (1984). As a necessary statistical step, Levene test

(1960) was run prior to the combined analysis to confirm the homogeneity of individual error terms. Least significant of difference (LSD) test was used to detect the significant differences among means at 0.05 probability level. The statistical analyses were automated using GENSTAT program, VSN International (2014). The factors of wheat variety and location were considered fixed while the growing season was judged to be random that attributed to the environmental effects.

Across the two seasons, four stress tolerance indices were calculated based on average grain yield under Sids location as a normal environment (Yn) and West west El-Minya location as an abiotic stress environment (Ys). The names, equations and references of the four stress tolerance indices are shown in Table (5). The genotypes which recorded high values of mean productivity (MP), harmonic mean (HM), geometric mean productivity (GMP), stress tolerance index (STI), yield index (YI), are considered to be more tolerant to stress conditions.

The analysis of variance (ANOVA) is used to compare wheat varieties regarding each trait separately. To discriminate the tested varieties in terms of all traits, Yan and Rajcan (2002) used a genotype by trait (GxT) biplot, which is a modified pattern of the GGE biplot graph. Because the traits were measured in different units, the (GxT) biplot graph was depicted using standardized values.

Table 3. Physical and chemical analyses of the experimental soil for the two regions (West west El-Minya and Sids).

Soil properties	Growing region: West west El-Minya	Growing region: Sids
Physical properties		
Clay (%)	2.7	52.31
Silt (%)	3.1	30.45
Fine sand (%)	92.2	16.13
Coarse sand (%)	2	1.11
Texture grade	Sandy	Clay
Chemical properties		
pH	7.97	7.93
EC (dS m^{-1})	2.13	1.13
Organic matter (%)	0.68	1.33
CaCO3 (%)	-	1.51
Soluble cations		
Ca^{+2}	6.93	3.83
Mg^{+2}	2.65	3.69
Na^{+}	0.86	2.08
K^{+}	0.22	1.61
Soluble anions		
Cl^{-}	1.05	4.93
SO_4^{-2}	8.80	4.71
HCO_3^{-}	0.80	1.57

Table 4. Chemical composition of used irrigation water for the two locations (West west El-Minya and Sids).

Location	used water	pH	EC (dS m^{-1})	Soluble cations: Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Soluble anions: Cl^{-}	SO_4^{-2}	HCO_3^{-}
West west	Irrigation water	7.5	3.15	7.8	4.7	1.03	0.12	27.7	0.15	3.3
El-Minya	Draining water	7.88	3.38	7	7.9	8.51	0.39	26.15	4.55	3.1
Sids	Irrigation water	7.3	0.56	3.48	0.99	1.21	0.23	1.14	2.27	2.5

Table 5. The equations and references of four tolerance indices used in this study.

No.	Index name	Formula	Reference
1	Mean Productivity (MP)	(Ys+Ym)/2	Rosielle and Hamblin, 1981
2	Harmonic Mean (HM)	(2*Ys*Ym)/(Ys+Ym)	Jafari *et al.*, 2009
3	Geometric Mean Productivity (GMP)	$(Ys*Ym)^{0.5}$	Fernandez, 1992
4	Stress Tolerance Index (STI)	$(Ys \times Ym)/(\overline{Y}s)^2$	Fernandez, 1992

- Y_s and Y_m indicate to average grain yield of each genotype under Sids and West west El-Minya locations.

- $\overline{Y}$ s indicates to average grain yield of Sids location.

RESULTS AND DISCUSSION

Mean performance

The homogeneity of individual error variances for all studied traits was satisfied which allows for running a combined analysis over seasons and locations. The two factors of wheat variety and location were adapted as fixed effect while the season term was considered random (unexpected environmental effects). The genotype x season interaction effect was no significant for most studied traits. In accordance, the averages of locations, varieties and their interaction were tabulated across the two seasons as summarized in Tables (6, 7 and 8).

1- Effect of growing location

The mean values of all studied traits under the two growing regions (West west El-Minya and Sids) as combined across the two seasons are given in Table (6). Results revealed the presence of significant differences between the two locations in terms of all traits except grain filling ratio, normalized difference vegetation index (NDVI), total chlorophyll content, number of spikes m^{-2} and harvest index. This result confirms the existence of substantial differences between the two regions with regard to climate, irrigation method, soil and irrigation water properties which affected the characteristics and productivity of wheat plant.

Also, Table (6) showed the reduction percentage of all studied traits when recorded at West west El-Minya region (stress environment) compared to those cultivated under Sids conditions (favorable environment). It is clear that the reduction % ranged from -4.35 % for normalized difference vegetation index (NDVI) to 16.67 % for grain filling period. The results showed that the wheat plants grown at the West west El-Minya region were earlier in heading and maturity than those cultivated under Sids conditions by about two and three weeks, respectively. As a type of adaptation, wheat plants tend to be early matured under stress conditions. However, the wheat plants cultivated at West west El-Minya region had a longer grain filling period than those cultivated in Sids region and vice versa for the grain filling ration. The plant height was 10% shorter at West west El-Minya than those cultivated at Sids region.

With respect to yield productivity and its attributes, it is shown that the grain yields produced from West west El-Minya region were decreased by 13.92 % compared to those produced from Sids region where the reduction rate of number of kernels spike^{-1} and 1000 kernels weight were about 10.42 % and 8.71 %, respectively. The current results confirmed that the West west El-Minya region is promising for future wheat cultivation due to its good yield productivity despite its stress conditions. Al-Naggar *et al.* (2020) mentioned that the stress tolerant genotypes are characterized by early maturity, short grain filling period, short plant height and high grain yield. The current results are in accordance with the findings obtained by Ibrahim and Said (2020), Abdelkhalik *et al.* (2021) and Sayed *et al.* (2022) who confirmed that wheat plants are strongly affected by the surrounding environmental conditions.

Table 6. Mean values for earliness and physiological traits, yield and its attributes as affected by the growing locations as combined across the two seasons.

Location	DH	DM	GFP	GFR	PH	NDVI	TCC	SM	GY	HI	KS	1000 KW
West west El-Minya	87.39	131.98	44.59	59.09	95.52	0.72	47.19	379.26	19.08	30.99	61.31	49.27
Sids	102.54	156.24	53.70	56.67	109.22	0.69	48.25	375.83	22.17	31.83	68.44	53.97
Reduction %	15.53	15.38	16.67	-4.27	11.93	-4.35	2.20	-1.06	13.92	2.63	10.42	8.71
Sig.	**	**	**	NS	*	NS	NS	NS	*	NS	*	*

Abbreviations: DH: days to heading, DM: days to maturity, GFP: grain filling period, GFR: grain filling ratio, PH: plant height, NDVI: normalized difference vegetation index, TCC: total chlorophyll content, SM: no. spikes m^{-2}, GY: grain yield, HI: harvest index, NS: no. kernels spike^{-1}, 1000 KW: 1000 kernels weight.

2- Effect of wheat variety

The mean performance of wheat varieties regarding earliness and physiological traits, yield and its attributes as combined across locations and seasons are summarized in Table (7). The results exhibited significant differences among the wheat varieties for all studied characters except for normalized difference vegetation index (NDVI). This conclusion gave evidence for the possibility to design a sufficient selection program for wheat development on the basis of these characters.

Concerning the two earliness characters, it is clear that the two varieties Sakha 1001 and Sids 12 were among the earliest in heading and maturity in both growing locations. However, Gemmeiza 10, Misr 2, Sids 1 and Sids 14 were lately headed and matured across the two cultivated sites. The varieties; Gemmeiza 11, Misr 2, Sakha 94 and Sakha 95 recorded the shortest grains filling periods accompanied by the highest grain filling ratios. Abdelkhalik *et al.* (2021) reported that the wheat genotypes which had long grain filling periods showed low grains filling rate.

Across the two locations, the tallest plants were recorded for Sids 1 and Giza 171 while Sakha 93 and Gemmeiza 10 recorded the shortest ones. The maximum values of total chlorophyll content (TCC) were recorded for Sakha 93, Sakha 94 and Sids 14 whilst the minimum values were recorded for Sakha 1001 and Sids 1.

Results in Table (7) elucidate that Sids 1 followed by Gemmeiza 9, Gemmeiza 10 and Giza 171 significantly surpassed all other varieties with regard to number of spikes m^{-2} as combined across the two locations while the lowest spikes number were produced by Sids 12 and Sids 14. However, Gemmeiza 9, Gemmeiza 10, Giza 171 and Shandaweel 1 gave the profuse grain yields across the two growing regions while the lowest productivity was obtained by Sakha 1001 and Sids 12. In accordance, it is not recommended to grow that Sakha 1001 and Sids 12 varieties under reclaimed lands in the western region of Minya government.

Table 7. Mean values for earliness and physiological traits, yield and its attributes as affected by the wheat varieties as combined across locations and seasons.

Genotype	DH	DM	GFP	GFR	PH	NDVI	TCC	SM	GY	HI	KS	1000 KW
Gemmeiza 10	98.83	148.25	49.42	60.07	91.67	0.67	48.73	395.83	21.78	31.69	61.80	52.46
Gemmeiza 11	93.75	140.58	46.83	61.47	102.08	0.68	46.33	376.75	20.99	29.99	73.74	52.27
Gemmeiza 9	95.92	145.25	49.33	61.95	102.92	0.74	47.47	402.50	22.09	30.20	67.43	50.81
Giza 168	93.17	144.92	51.75	54.28	104.58	0.71	46.31	387.42	20.53	32.69	60.69	50.44
Giza 171	96.42	147.08	50.67	60.00	109.17	0.72	47.55	395.42	21.82	35.54	61.85	55.38
Misr 1	94.08	142.50	48.42	61.54	102.92	0.72	46.30	372.33	21.20	30.90	59.00	52.91
Misr 2	99.50	146.00	46.50	61.86	107.50	0.66	47.07	375.17	20.78	33.15	67.82	50.75
Misr 3	97.25	147.25	50.00	57.11	100.83	0.73	47.93	378.92	20.79	30.25	61.45	51.03
Sakha 1001	81.25	131.75	50.50	48.50	100.00	0.67	45.37	365.00	17.99	31.39	58.20	50.26
Sakha 93	94.33	142.58	48.25	54.50	87.08	0.71	51.16	374.58	19.30	31.05	58.93	51.86
Sakha 94	98.08	142.92	44.83	62.73	104.17	0.71	50.01	371.83	20.28	32.94	63.95	50.27
Sakha 95	97.67	145.08	47.42	56.70	105.42	0.73	47.37	364.83	19.57	30.79	61.06	51.39
Shandweel 1	94.42	149.58	55.17	56.27	104.17	0.72	48.92	377.33	22.50	30.08	73.68	50.02
Sids 1	99.25	148.58	49.33	58.22	111.25	0.70	44.48	404.58	20.83	30.75	69.17	51.75
Sids 12	86.92	136.17	49.25	51.49	100.00	0.68	47.75	342.92	18.54	31.98	68.88	51.24
Sids 14	98.58	147.25	48.67	59.37	104.17	0.72	50.76	355.33	21.01	29.16	70.37	53.15
$LSD_{0.05}$	1.31	1.43	1.96	4.61	3.19	NS	2.85	18.25	1.49	1.83	4.43	2.64

Abbreviations: DH: days to heading, DM: days to maturity, GFP: grain filling period, GFR: grain filling ratio, PH: plant height, NDVI: normalized difference vegetation index, TCC: total chlorophyll content, SM: no. spikes m^{-2}, GY: grain yield, HI: harvest index, NS: no. kernels spike^{-1}, 1000 KW: 1000 kernels weight.

Concerning harvest index, this expression is used in wheat crop to quantify the grain yield versus the total amount of biomass that has been produced. The current investigation showed that Giza 168, Giza 171, Misr 2 and Sakha 94 had the highest harvest index but the lowest values were recorded by Gemmeiza 11 and Sid 14. When taking the number of kernels spike^{-1} into account, it is clear that Gemmeiza 11 and Shandaweel 1 ranked as the first ones while Misr 1, Sakha 1001 and Sakha 93 were the least varieties. The heaviest weight of 1000 kernels was obtained by Giza 171 and Sids 14.

The previous outcomes indicated that there was no variety superior in both grain yield and its components at the same time. Darwish *et al*. (2017) and Gab alla *et al*. (2018) explained that this result may be attributed to the phenomenon of compensatory interrelationships among yield components which means that an increase in one trait may be accompanied by a decrease in another trait. The current results are similar to the findings obtained by Mohiy *et al*. (2021), Darwish *et al*. (2022), Ibrahim and Said (2022), Sayed *et al*. (2022) and Elfanah *et al*. (2023) who found significant differences among the tested genotypes for most studied characters.

3- Effect of interaction (location x wheat variety)

The interaction effect of wheat variety x location on the studied traits across the two seasons are presented in Table (8) and graphically illustrated in Fig. (2-4)**.** Results in Table (8) revealed significant genotype x location interaction effect for all studied characters across the two seasons except for normalized difference vegetation index (NDVI) indicating the different responses of wheat varieties under the two locations (West west El-Minya and Sids). The scatter diagram depicted the mean values of wheat varieties grown at Sids location versus their corresponding values at West west El-Minya, as shown in Fig. (2). The figure is divided into four rectangles, the vertical dotted line representing the grand mean of Sids location while the horizontal dotted line representing the grand mean at West west El-Minya location. The upper right rectangle shows the best wheat varieties over the two locations while the lower left rectangle shows the bad ones at the two locations. The interaction effect of wheat varieties x growing location expressed in the upper left and the lower right rectangles. The varieties located in the lower right rectangle had good performance at Sids location and weak performance at West west El-Minya location and vice versa. Varieties located far from the grand mean reflected a strong interaction effect and vice versa. Meanwhile, varieties located around the origin point shows no interaction effect. We will focus on the varieties that gave high productivity in one area, while their productivity was lower in the other area.

Sakha 1001 and Sids 12 varieties were the earliest in heading and maturity in the two locations while Sids 1 and Gemmeiza 10 were the latest ones in West west El-Minya and Sids respectively, Fig. (2). The longest grain filling was recorded for Sakha 1001, Giza 171, Gemmeiza 10 and Sids 12 at West west El-Minya location only while it is recorded for Sids 14, Misr 1 and Misr 3 at Sids location. It was noticed that the varieties recording the longest grains filling periods reflected the lowest grains filling ratios.

Concerning plant height, it is exhibited from (Fig. 3) that Misr 2 had the tallest plants at West west El-Minya location while Misr 1 and Giza 168 were the tallest ones at Sids. On the other hand, the shortest plants were obtained by Sids 12 at West west El-Minya location and Gemmeiza 11 at Sids. Regarding normalized difference vegetation index (NDVI), there was interaction effect between varieties and location but it did not reach the level of significance. High NDVI estimates recorded for Misr 1, Sids1 and Giza 168 at West west El-Minya location and for Sakha 94 at Sids. The best total chlorophyll content under West west El-Minya conditions was obtained for Gemmeiza 9, Gemmeiza 10, Misr 2 and Sakha 94 while the equivalent varieties at Sids location were Misr 3, Shandaweel 1 and Sakha 95 as outlined by Fig. (3).

With respect to grain yield and its attributes, information obtained from Table (8) and Fig. (4) indicated that Gemmeiza 11 and Shandaweel 1 surpassed the other varieties in terms of number of spikes m^{-2} at West west El-Minya location while Giza 168, Misr 3 and Sakha 93 recorded the highest spike number at Sids location. It is obvious that Giza 168, Misr 1, Misr 2 and Sids 1 gave the profuse grain yield under West west El-Minya conditions while Misr 3, Sakha 95 and Sids 14 gave the highest productivity of grain yield under Sids conditions. Across the two locations, the lowest grain yield was scored for Sakha 1001 and Sids 12 indicating that these two varieties were the worst in terms of yield productivity during this investigation.

Results showed that Giza 171 and Gemmeiza 10 overpassed the other varieties regarding harvest index whereas Gemmeiza 9 and Sakha 94 were the best ones in terms of number of kernels $spike^{-1}$ under West west El-Minya conditions and Sids, respectively. Meanwhile, the heaviest weight of 1000 kernels were produced by Gemmeiza 10, Gemmeiza 11, Misr 1 and Sids 1 at West west El-Minya location but the seed index of Gemmeiza 9, Sakha 95, Sakha 93, Misr 3 and Sids 12 were the heaviest at Sids location. From the previous results, it is clear differentiated response of wheat varieties under the two locations, which necessitates determining the appropriate varieties for each region separately. The biplot graph will be used to perform this task, as shown in the last part of the results and discussion.

Tolerance indices

Grain yield of the evaluated varieties under West west El-Minya location (stress environment) and Sids locations (favorable environment) as well as their tolerance indices and respective ranks are presented in Table (9). The grain yield average overall varieties under West west El-Minya was 19.08 ardab fed^{-1} while it was 22.17 ardab fed^{-1} under Sids location. Accordingly, the grain yield productivity under Sids location increased by 16.16 % than its respective grain yield under West west El-Minya location. There were distinctive differences among studied varieties regarding grain yield under the two locations which reflected genetic diversity among them that helps to study the tolerance ability. The equations of four tolerance indices used in this investigation depend on the average grain yield across the two environments under study. Therefore, varieties scored high values of the four tolerance indices were considered as stress tolerant varieties and vice versa. Results cleared that there was a slight difference among the four tolerance indices when ranking wheat varieties for tolerance ability. Accordingly, it is sufficient to use only one of them as a measure of tolerance in future studies.

It is concluded from Table (9) that the four varieties being Shandaweel 1, Gemmeiza 9, Giza 171 and Gemmeiza 10 were considered as stress tolerant items because they recorded the highest values of the four tolerance indices. Therefore, the abovementioned varieties were preferred to be cultivated in both locations under study (West west El-Minya and Sids). On the contrary, varieties Sakha 1001, Sids 12, Sakha 93, Sakha 94 and Sakha 95 were identified as susceptible ones as shown from their low tolerance index values which means that these varieties may be unprofitable when cultivated at West west El-Minya region. Similar pattern of results were concluded by Al-Naggar *et al*. (2015 a,b), Mohammadi (2016), Darwish *et al*. (2017).

Table 8. Mean values of earliness, physiological traits, yield and its attributes as affected by the variety x location interaction as combined across the two seasons.

Varieties	DH		DM		GFP		GFR		PH		NDVI	
	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids
Gemmeiza 10	87.8	109.8	134.7	161.8	46.8	52.0	60.4	59.8	90.0	93.3	0.66	0.67
Gemmeiza 11	86.0	101.5	127.5	153.7	41.5	52.2	62.5	60.4	97.5	106.7	0.68	0.68
Gemmeiza 9	88.2	103.7	131.5	159.0	43.3	55.3	65.5	58.4	96.7	109.2	0.76	0.71
Giza 168	84.0	102.3	133.8	156.0	49.8	53.7	53.6	54.9	95.0	114.2	0.74	0.69
Giza 171	85.8	107.0	134.8	159.3	49.0	52.3	60.6	59.5	101.7	116.7	0.74	0.69
Misr 1	88.2	100.0	128.2	156.8	40.0	56.8	70.9	52.2	91.7	114.2	0.76	0.69
Misr 2	93.8	105.2	136.2	155.8	42.3	50.7	68.8	54.9	105.0	110.0	0.65	0.67
Misr 3	91.0	103.5	134.2	160.3	43.2	56.8	57.0	57.3	94.2	107.5	0.74	0.71
Sakha 1001	74.0	88.5	122.7	140.8	48.7	52.3	45.3	51.8	91.7	108.3	0.66	0.68
Sakha 93	87.5	101.2	132.7	152.5	45.2	51.3	50.8	58.2	81.7	92.5	0.72	0.70
Sakha 94	91.3	104.8	129.8	156.0	38.5	51.2	66.8	58.7	96.7	111.7	0.72	0.70
Sakha 95	90.2	105.2	131.3	158.8	41.2	53.7	52.9	60.5	98.3	112.5	0.74	0.71
Shandweel 1	87.3	101.5	136.3	162.8	49.0	61.3	60.9	51.7	95.8	112.5	0.74	0.71
Sids 1	94.5	104.0	139.3	157.8	44.8	53.8	62.9	53.6	106.7	115.8	0.73	0.68
Sids 12	77.2	96.7	125.7	146.7	48.5	50.0	45.8	57.2	90.0	110.0	0.68	0.68
Sids 14	91.3	105.8	133.0	161.5	41.7	55.7	61.0	57.8	95.8	112.5	0.73	0.71
LSD 0.05	2.01		2.16		2.87		7.75		4.63		NS	

Varieties	TCC		SM		GY		HI		KS		1000KW	
	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids	West west El-Minya	Sids
Gemmeiza 10	49.4	48.1	400.8	390.8	20.8	22.8	27.2	36.2	57.7	65.9	52.1	52.8
Gemmeiza 11	46.0	46.7	390.8	362.7	19.1	22.9	28.0	31.9	76.5	71.0	52.6	51.9
Gemmeiza 9	50.8	44.1	416.7	388.3	20.5	23.7	26.9	33.5	67.5	67.4	46.1	55.6
Giza 168	45.7	46.9	377.5	397.3	19.6	21.5	35.2	30.2	52.4	69.0	49.5	51.4
Giza 171	46.8	48.3	412.5	378.3	21.2	22.4	39.1	31.1	56.5	67.2	52.9	57.9
Misr 1	46.0	46.6	367.5	377.2	20.7	21.7	30.7	31.1	55.2	62.8	52.0	53.9
Misr 2	48.6	45.6	375.8	374.5	21.1	20.5	35.7	30.6	66.1	69.6	47.3	54.2
Misr 3	46.2	49.6	371.7	386.2	18.0	23.6	28.9	31.6	59.5	63.4	47.2	54.9
Sakha 1001	45.0	45.7	365.0	365.0	16.1	19.9	32.0	30.8	53.9	62.5	47.5	53.0
Sakha 93	53.1	49.3	368.3	380.8	16.6	22.0	29.0	33.1	55.7	62.2	48.7	55.1
Sakha 94	52.0	48.1	375.8	367.8	18.8	21.8	34.8	31.1	53.0	74.9	49.2	51.3
Sakha 95	43.0	51.8	363.3	366.3	15.6	23.5	29.1	32.5	58.6	63.6	47.2	55.6
Shandweel 1	46.1	51.7	383.3	371.3	21.8	23.2	28.0	32.1	70.7	76.7	47.8	52.2
Sids 1	41.2	47.8	414.0	395.2	20.7	21.0	32.2	29.3	67.0	71.3	50.5	53.0
Sids 12	47.1	48.4	326.7	359.2	16.2	20.9	31.6	32.4	63.6	74.2	47.8	54.7
Sids 14	48.1	53.5	358.3	352.3	18.6	23.4	26.5	31.9	67.1	73.6	50.2	56.1
LSD 0.05	4.11		25.3		2.38		2.97		6.37		3.84	

Abbreviations: DH: days to heading, DM: days to maturity, GFP: grain filling period, GFR: grain filling ratio, PH: plant height, NDVI: normalized difference vegetation index, TCC: total chlorophyll content, SM: no. spikes m^{-2}, GY: grain yield, HI: harvest index, NS: no. kernels spike^{-1}, 1000 KW: 1000 kernels weight.

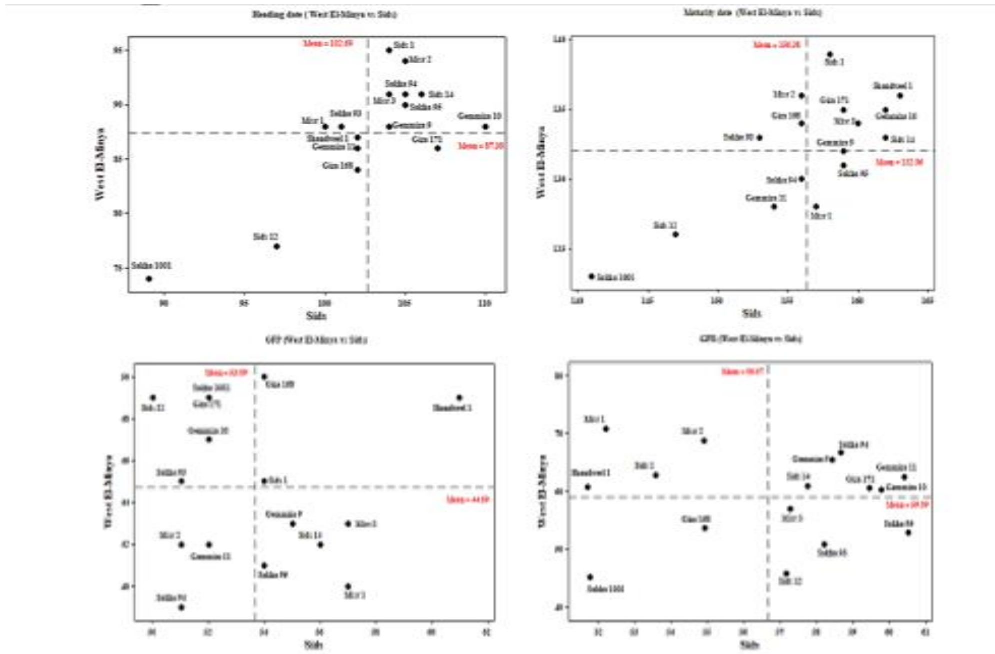

Fig. 2. The interaction effect of wheat variety x location regarding days to heading and maturity, grain filling period and grain filling rate as combined across the two growing seasons.

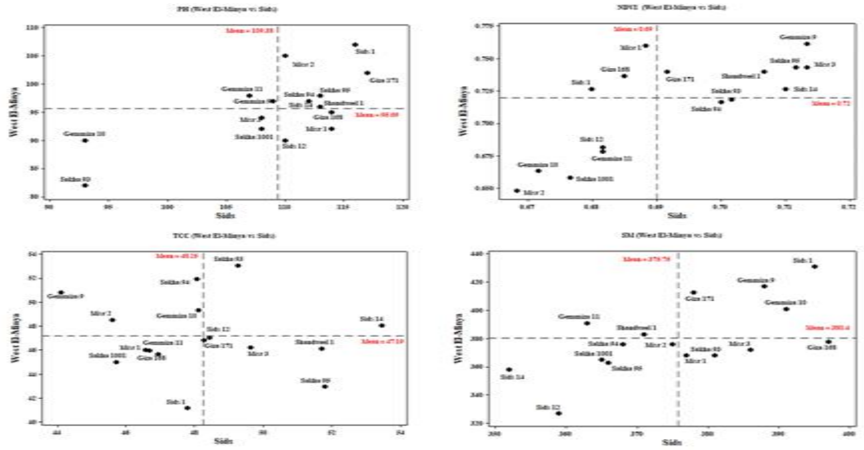

Fig. 3. The interaction effect of wheat variety x location regarding plant height, normalized difference vegetation index (NDVI), total chlorophyll content and number of spike m^{-2} as combined across the two growing seasons.

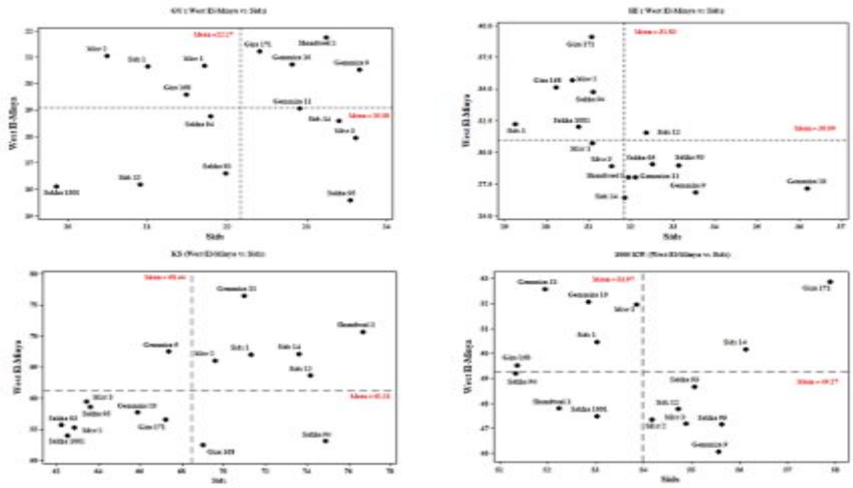

Fig. 4. The interaction effect of wheat variety x location regarding grain yield, harvest index, number of kernel spike^{-2} and 1000 kernel weight as combined across the two growing seasons.

Table 9. Estimates of four tolerance indices and their respective ranks for 16 bread wheat varieties based on grain yield at West west El-Minya and Sids locations as combined across the two seasons.

No.	Wheat variety	Grain yield (ardab fed^{-1})		Tolerance indices			
		West west El Minya	Sids	MP	H M	GMP	STI
1	Gemmeiza 10	20.75	22.81	21.78	21.73	21.76	1.30
2	Gemmeiza 11	19.07	22.91	20.99	20.81	20.90	1.20
3	Gemmeiza 9	20.53	23.66	22.10	21.98	22.04	1.33
4	Giza 168	19.59	21.48	20.54	20.49	20.51	1.16
5	Giza 171	21.24	22.40	21.82	21.80	21.81	1.31
6	Misr 1	20.68	21.71	21.20	21.18	21.19	1.23
7	Misr 2	21.07	20.49	20.78	20.78	20.78	1.19
8	Misr 3	17.96	23.61	20.79	20.40	20.59	1.17
9	Sakha 1001	16.13	19.85	17.99	17.80	17.89	0.88
10	Sakha 93	16.62	21.98	19.30	18.93	19.11	1.00
11	Sakha 94	18.78	21.79	20.29	20.17	20.23	1.12
12	Sakha 95	15.59	23.54	19.57	18.76	19.16	1.01
13	Shandweel 1	21.76	23.24	22.50	22.48	22.49	1.39
14	Sids 1	20.66	21.00	20.83	20.83	20.83	1.19
15	Sids 12	16.19	20.90	18.55	18.25	18.39	0.93
16	Sids 14	18.61	23.40	21.01	20.73	20.87	1.20
		Corresponding ranks					
1	Gemmeiza 10	4	7	4	4	4	4
2	Gemmeiza 11	9	6	7	7	6	6
3	Gemmeiza 9	7	1	2	2	2	2
4	Giza 168	8	12	11	10	11	11
5	Giza 171	2	8	3	3	3	3
6	Misr 1	5	11	5	5	5	5
7	Misr 2	3	15	10	8	9	9
8	Misr 3	12	2	9	11	10	10
9	Sakha 1001	15	16	16	16	16	16
10	Sakha 93	13	9	14	13	14	14
11	Sakha 94	10	10	12	12	12	12
12	Sakha 95	16	3	13	14	13	13
13	Shandweel 1	1	5	1	1	1	1
14	Sids 1	6	13	8	6	8	8
15	Sids 12	14	14	15	15	15	15
16	Sids 14	11	4	6	9	7	7

Abbreviations: MP: mean productivity, HM: harmonic mean, GMP: geometric mean productivity and STI: stress tolerance index.

GxT biplot graph (Which-won-where or polygon)

Biplot graphs have been basically used to describe the stability concept of such crop cultivated in multi-environments (GGE biplot graph). Because, the method is very flexible, it has been modified to be automated for genotype comparison using multiple traits (GxT biplot graph), as reported by Yan and Rajcan (2002) and Yan and Tinker (2005). In this graph, the genotypes that are located far away from the origin point (namely vertex varieties) are connected by lines forming a polygon shape where the other genotypes are laid out inside this polygon. Also, the perpendicular lines from the original point to the polygon sides divided the figure into some sectors that facilitate the comparison among neighbor's vertex varieties. In accordance, genotypes that exist together in one section with one or some traits reflected the best behavior regard these traits. While, the genotypes are close to the origin point of the graph had moderate mean values for most traits. In this study, the genotype x trait (GxT) biplot graph was adopted to detect the elite varieties for certain traits that can be selected for cultivation in the western desert of Egypt. While the analysis of variance (ANOVA) compares among the genotypes on the basis of each individual trait, Biplot graph is considered a simplified procedure to evaluate the genotypes based on all their corresponding traits at the same time. In the current investigation, it should be mentioned that biplot graph did not include the traits calculated by mathematical equations (grain filling period, grain filling ratio and harvest index) in order to avoid multicollinearity.

1- West west El-Minya Location

The polygon of genotypes x traits (GxT) biplot graph (Fig. 3) showed the superior bread wheat varieties with respect to agronomical, physiological and yield characteristics across the two seasons at West west El-Minya location. GxT biplot graph explained 54.19 % of the total variation of the standardized data that expressed the linear relationships among the bread wheat varieties in terms of their measured traits where the 1st and 2nd principal components (PC_1 and PC_2) explained 38.90 % and 15.28 %, respectively. This relatively moderate variability proportion explained by the GxT biplot graph (54.19 %) may be attributed to the complexity of the relationships (nonlinear relation) among the varieties with regard to the measured traits and to the measurement errors.

Examining the graph (Fig. 3), it is obvious that Sids 1 reflected the best performance in terms of all measured traits under West west El-Minya conditions except for normalized difference vegetation index (NDVI) and total chlorophyll content (TCC). Also, Giza 171, Misr 2 and Shandaweel 1 are located in the same sector reflecting similar performance for the traits per se. It is clear that the angles among the points of these varieties and traits were acute indicating positive associations among them. However, Sakha 93 and Sakha 94 gave the best results in terms of normalized difference vegetation index (NDVI) and total chlorophyll content (TCC). On the other hand, the varieties located around the original point are not considered distinctive for any of the studied traits. As for the two varieties of Sakha 1001 and Sids 14, they fall in the left side far away from the rest varieties indicating their poor performance towards most studied traits. Abdelkhalik *et al.* (2021) and Sayed *et al.* (2022) confirmed that the GGE biplot graph is considered an appropriate approach for identifying high yielding and stable wheat genotypes under different environmental conditions and it may help the breeders to classify wheat genotypes according to the suitable environment. Abd El-Rady (2022) used GxT biplot graph to evaluate some bread wheat genotypes for heat tolerance under terminal heat stress conditions. He found that Shandaweel 2 and Giza 171 had the best traits profile and recommended the release of Shandaweel 2 as new heat tolerant wheat variety.

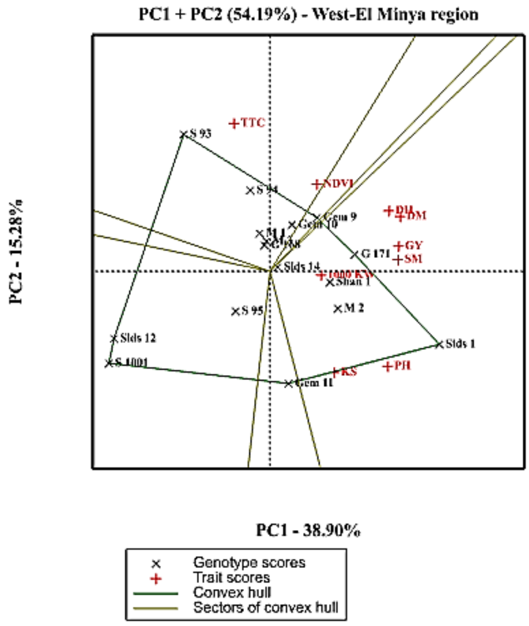

Fig. 3. Which-won-where or polygon of genotype by trait (GxT) biplot graph displaying which elite genotype regard studied traits at West west El-Minya location as combined across the two seasons.

2- Sids location

Considering Sids location, the GxT biplot graph (Fig. 4) accounted for 56.98 % of the standardized data variability for the two-way table of bread wheat varieties and their measured traits. It is cleared that the first and second principal components (PC_1 and PC_2) explained 37.02 % and 19.96 %, respectively. Information obtained from the graph (Fig. 4) elucidated that Sids 14, Shandaweel 1, Sakha 95 and Giza 171 were the best varieties with respect to all measured traits except heading and maturity dates, and number of spikes per square meter. However, Gemmeiza 10 followed by Gemmeiza 9 and Sakha 93 gave the best results in terms of number of spikes m^{-2}. Although they are early in heading and maturity, the two varieties of Sids 12 and Sakha 1001 were placed far from all studied traits indicating their poor productivity under Sids location. Based on GxT biplot analysis, Youldash *et al.* (2020) concluded that genotypes; Misr 1, Misr 2 and 'Shandaweel 1 revealed good performance under different thermal environments. Therefore, they recommended including these varieties among the future breeding program to develop heat tolerant varieties for the Mediterranean region. Mohiy *et al.* (2021) used GxE biplot graph to study the genetic behavior of twelve varieties of bread wheat under heat stress in the new land at Middle and Upper Egypt. They found that varieties; Sids 12, Sids 14, Misr 1, Misr 2, Shandaweel 1 and Giza 171 are characterized by high and stable yield productivity. They recommended using these wheat varieties in the breeding programs to develop tolerant genotypes of wheat to heat stress.

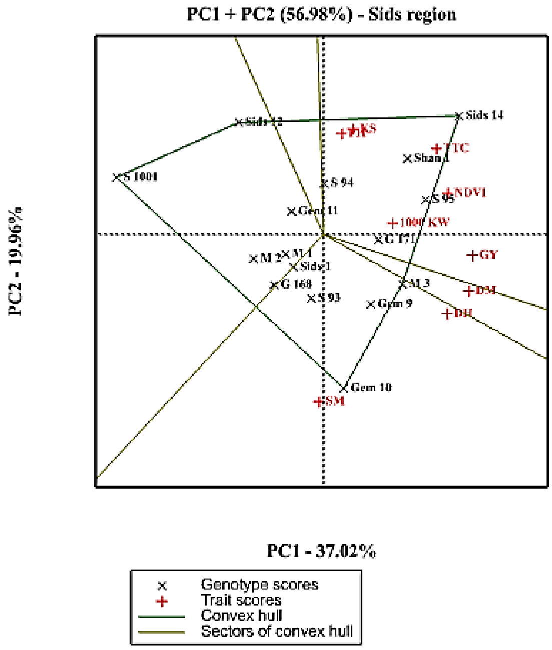

Fig. 4. Which-won-where or polygon of genotype by trait (GxT) biplot graph displaying which elite genotype regard studied traits at Sids location as combined across the two seasons.

CONCLUSION

Despite the unfavorable environmental conditions, the present study indicates that West west El-Minya location is considered a promising region for horizontal agricultural expansion. Results revealed that the grain yields produced under West west El-Minya region were slightly decreased compared to those produced under Sids region. It is cleared that Gemmeiza 9, Gemmeiza 10, Giza 171 and Shandaweel 1 were the higher grain yielding varieties across the two growing regions (West west El-Minya and Sids) where they recorded the highest values of the four tolerance indices. Using GxT biplot graph, it is shown that Sids 1, Giza 171, Misr 2 and Shandaweel 1 were the superior varieties in terms of most studied traits under West west El-Minya region while Sids 14, Shandaweel 1, Sakha 95 and Giza 171 were the best ones under Sids conditions.

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الإنتاجية المحصولية لستة عشر صنفا من قمح الخبز المنزرعة تحت ظروف منطقتى مصر الوسطى وغرب غرب المنيا

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الملخص

تم إجراء هذا البحث بالمزرعة التجريبية لكل من محطتي سدس وغرب غرب المنيا للبحوث الزراعية لتقييم الإنتاجية المحصولية لستة عشر صنفا من قمح الخبز خلال موسمي الزراعة ٢٠١٩/٢٠١٨ و ٢٠٢٠/٢٠١٩م. وقد تم تنفيذ التجربة باستخدام تصميم القطاعات الكاملة العشوائية فى ثلاث مكررات. تم حساب أربعة مؤشرات لتحمل الإجهاد باستخدام محصول الحبوب لكل صنف تحت ظروف موقع سدس (بيئة ملائمة) وموقع غرب المنيا (بيئة اجهاد). كما تم عمل الاشكال البيانية لطريقة المحاور الثنائية Biplot graph وذلك لمقارنة أصناف القمح من حيث صفاتها المتعددة فى كل موقع على حدة. أظهرت النتائج وجود فروق معنوية بين منطقتى الزراعة وبين أصناف القمح وكذلك التفاعل بينهما لمعظم الصفات المدروسة كمتوسط للموسمين. اتضح من النتائج ان محصول الحبوب في موقع غرب غرب المنيا قد انخفض بشكل طفيف مقارنة بمحصول الحبوب في موقع سدس مما يشير إلى أن غرب المنيا منطقة واعدة لزراعة القمح في المستقبل على الرغم من ظروف الإجهاد. سجل كل من الصنف جميزة ٩ ، جميزة ١٠ ، جيزة ١٧١ وشندويل ١ أعلى إنتاجية من محصول الحبوب في موقعى الزراعة، بالإضافة إلى أنها سجلت أعلى قيم لمؤشرات التحمل الأربعة. بالنسبة لكل موقع على حدة فقد تبين أن الأصناف سدس ١، جيزة ١٧١ ، مصر ٢ وشندويل ١ أعطت أفضل النتائج من حيث معظم الصفات المدروسة في موقع غرب غرب المنيا بينما الأصناف سدس ١٤، شندويل ١، سخا ٩٥ وجيزة ١٧١ سجلت أفضل النتائج تحت ظروف موقع سدس. كان من الواضح ان الرسم البياني لطريقة المحاور الثنائية GxT biplot وسيلة سهلة وفعالة لتفسير النتائج.