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PERFORMANCE AND STABILITY OF SOME EARLY MATURING BREAD WHEAT GENOTYPES UNDER DIFFERENT ENVIRONMENTS

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ABSTRACT

Four bread wheat promising early maturing lines and two local cultivars were evaluated in two locations, i.e. Sakha and Sids Agricultural Research Stations for the two successive seasons 2014/2015 and 2015/2016 under two sowing dates (recommended and late). The experimental design was randomized complete block design with four replicates in each experiment. The main objective of this study was to select the best genotypes and study the relationships among characters under recommended and late sowing dates. The combined analysis of variance showed significant or highly significant differences among environments and genotypes for all studied characters. The results revealed that the genotypes responded differently to sowing dates for grain yield, indicating the possibility of selecting the best genotypes under a specific environment. Line 2 and Line 1 had the highest grain yield under late sowing conditions (8.166 and 8.038 ton/hectare, respectively). The relationships between grain yield and each of days to heading and days to maturity were significant positive under the recommended sowing date, indicating that the genotypes which have long growth duration had the highest grain yield. On the contrary, these relationships were negative under late sowing date, indicating the advantages of earliness under late conditions. High heritability estimates were obtained for days to maturity indicating selection would be effective to improve this character. Moderate heritability was detected for days to heading, grain filling rate, plant height and grain yield, suggesting that delaying selection to advanced segregating generations is better. Expected genetic advance from selection as a percentage of the mean was high for grain yield and grain filling rate, and low for plant height, days to maturity, kernels per spike and 1000-kernel weight. According to stability analysis and GGE-biplot, Line 2 was the most stable genotype across all environments followed by Line 1 and Shandaweel 1.

Key words: ***Wheat, Sowing dates, Earliness, Stability parameters, GGE-biplot.***

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the staple food for several countries all over the world including Egypt, in which wheat production became one of the crucial elements of food security (Curtis and Halford 2014). In Egypt wheat grains used as a food for human and straw as a fodder for animals. More than 30% of caloric intake is from wheat flour products, especially bread. Although, the yield average per hectare in Egypt is one of the highest yields around the world (6.4 tons ha^{-1}) (https://data.worldbank.org/indicator), the gap between production and consumption still about 6.5 million tons. Limited favorable area is the first constraint to self-sufficiency. Wheat breeders aim to develop new wheat cultivars that consistently have high yield under variety of environments. The adaptability of a cultivar is usually tested by the degree of its interaction with different environments. A cultivar or genotype is considered to be more adapted or stable if it has a high mean yield with a low degree of fluctuation in yielding ability across different climatic conditions. In Egypt, earliness has several advantages, for instance, early- maturing wheat cultivars are highly needed to fit in new crop intensive rotation, such as planting cotton after wheat and planting wheat after harvesting short duration vegetable crops. Also, wheat cultivars that can be harvested early could save more water and provide farmers more time to grow other crops.

Elbasyoni (2018) found a significant variation in yield and its components among wheat genotypes under normal and late planting and reported that delaying sowing date reduced the number of kernels spike^{-1}, 1000-kernel weight and grain yield. Babiker *et al* (2017) reported that late planting affects the growth, yield and quality of wheat grain, while early sowing produces higher yields than late sowing, due to longer duration of grain development. In late planted wheat, low temperature prevailing during germination substantially affects the germination and seedling emergence. Late planting may cause yield losses, especially in medium and late maturing varieties (Tapley *et al* 2013). On the other hand, delayed planting of the early maturing variety had lower effect on seed weight. Moreover, late planted wheat had less time to tiller during the fall. Late planting may also shorten the grain filling period and delay it until the weather gets warmer.

Evaluation of genotype x environment interactions gives an idea about the buffering capacity of the population under study. The low magnitude of genotype environment interactions indicates consistent performance of a population across variable environments. In other words, it shows high buffering ability of the population (Singh and Narayan 2000). Various statistical methods have been proposed to determine the stability of new cultivars; the most commonly used method is the joint regression analysis for yield stability (Finlay and Wilkinson 1963 and Eberhart and Russell 1966). The regression coefficient (b_i) and the average deviation from regression line (S^2_d) are two mathematical indices for the assessment of stability (Eberhart and Russell 1966). A genotype with a high b_i and S^2_d reacts rapidly to change in the environment and possesses considerable variability, whereas, cultivars with a $b_i < 1.0$ and S^2_d near to 0.0 react slowly to changes in growing conditions and are considered to be stable in yield (Shindin and Lokteva 2000). Finlay and Wilkinson (1963) regarded those genotypes with a b_i near 1.0 and high mean yield as being well adapted to all environments. Stability measurements, the additive main effects and multiplicative interaction model (AMMI) and genotype main effect plus genotype x environment interaction (GGE), were useful to determine the ideal genotypes for recommended and late sowing conditions (Elbasyoni 2018). The objective of this investigation was to: (1) evaluate some earliness and agronomic characters for six wheat genotypes under recommended and late sowing dates, (2) estimate phenotypic stability, with respect to grain yield, of six bread wheat genotypes across 8 environments, (3) select lines with high grain yield and yield stability and (4) study the relationships among all characters under recommended and late sowing.

MATERIALS AND METHODS

During 2014/2015 and 2015/2016 wheat growing seasons, two experiments were conducted to screen six selected genotypes of bread wheat (*Triticum aestivum* L.) at two locations (Sakha and Sids Agriculture Research Stations) under two sowing dates (recommended and late sowing dates). Each planting date was considered as a separate experiment. Planting of recommended sowing date was on Nov. 20th and late sowing date on Dec. 20th in both seasons. The plant materials in this study comprised four early maturing bread wheat promising lines selected from the national wheat research program, in addition to two local check cultivars (Sids 4 and Shandaweel 1). Table (1) shows the names, pedigree and selection history of the six genotypes. The plant materials were evaluated in a randomized complete block design experiment, for each sowing date, with four replicates in each environment. Each genotype was sown in a plot of 10.5 m^2 area. The recommended package of the agricultural practices was followed. In each environment the measurements were taken for earliness traits, i.e. number of days to heading (DH), number of days to maturity (DM), grain filling period (GFP, number of days from heading to maturity) and grain filling rate (GFR, grain yield divided by GFP). Some other traits were recorded including plant height (PH), number of spikes per square meter (SM^{-2}), number kernels $spike^{-1}$ (KS), 1000-kernel weight (TKW), grain yield (GY) and straw yield (STY) in ton ha^{-1}.

Analysis of variance was used to evaluate the responses of each studied character according to Gomez and Gomez (1984). All analyses of variance were computed using the "GENSTAT" microcomputer program, VSN International (2011).

Table 1. Name, pedigree, number of days to heading (DH) and to maturity (DM) of the six studied bread wheat genotypes.

Genotype	Pedigree	DH†	DM
Line 1	**ATTILA*2/PBW65/4/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/2*KAUZ** **S. 16233-010S-06S-3S-0S**	**88**	**139**
Line 2	**ATTILA*2/PBW65/4/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/2*KAUZ** **S. 16233-010S-06S-5S-0S**	**88**	**139**
Line 3	**ATTILA*2/PBW65/4/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/2*KAUZ** **S. 16233-010S-08S-0SY-1S-0S**	**86**	**138**
Line 4	**OPATA/RAYON//KAUZ/3/IZAZ-1** **GM8827-1GM-5GM-3GM-3GM-0GM**	**89**	**142**
Sids 4	**MAYA “S” / MON “S” // CMH 74A. 2/3/*2 Giza157 SD 10001-2SD-3SD-2SD-0SD.**	**81**	**135**
Shandaweel 1	**SITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC** **CMSS93B00567S-72Y-010M-010Y-010M-3Y-0M-0HTY-0EG**	**98**	**149**

† Source: average for days to heading and maturity representing of the recommended sowing date from this paper.

The significance of differences among genotype means were calculated by LSD at 5% level of probability. Phenotypic (PCV) and genotypic (GCV) coefficients of variation were calculated according to Singh and Narayanan (2000). Variance components and heritability were calculated for studied characters using multi location trails model according to Singh and Ceccarelli (1996).

Stability analysis of grain yield of the studied genotypes was done for the 8 environmental conditions (two locations two × sowing dates × two years) (E1 = Sakha recommended sowing date in 2014/15, E2 = Sakha late sowing date in 2014/15, E3 = Sids recommended sowing date in 2014/15, E4 = Sids late sowing date in 2014/15, E5 = Sakha recommended sowing date in 2015/16, E6 = Sakha late sowing date in 2015/16, E7 = Sids recommended sowing date in 2015/16, E8 = Sids late sowing date in 2015/16.). Stability was defined as a function of slope and deviation from the regression of cultivar`s yield on an environmental index. Yield stability was analyzed according to Eberhart and Russell (1966). The two statistics depending on genotypes × environment interaction, (1) regression coefficient (b_i) and (2) the deviation from regression (S^2d) were used to estimate stability. The genotype main effect plus G×E interaction (GGE biplot) (Akcura and Kaya 2008) was used to visualize the G×E interaction. The stability and G×E analysis was conducted using R (software) package GEA-R (Version 4.0, 2017, CIMMYT, El Batán, Mexico) (Pacheco *et al* 2018).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance for days to heading, days to maturity, grain filling period, grain filling rate, plant height, spikes per square meter, kernels per spike, 1000-kernel weight, straw yield, and grain yield under the two sowing dates and different environments is presented in Table (2). The combined analysis of variance showed significant or highly significant differences among the four environments (two years and two locations) for all studied characters. Furthermore, significant differences between the two sowing dates were detected for all characters except for spikes per square meter and kernels per spike. More importantly, genotypes and their interactions showed highly significant differences in most cases. These results suggested that the measurement of differences among wheat genotypes was adequate to provide a possibility to characterize the effect of late sowing conditions. Similar results were reported by Babiker *et al* (2017) and Elbasyoni (2018).

Table 2. Mean squares for days to heading (DH), days to maturity (DM), grain filling period (GFP), grain filling rate (GFR), plant height (PH), spikes per square meter (SM^{-2}), kernels per spike (KS^{-1}), 1000-kernel weight (TKW), straw yield (STY), and grain yield (GY) under two sowing dates and different environments.

SOV	df	DH	DM	GFP	GFR	PH	S M^{-2}	K S^{-1}	TKW	STY	GY
(E)	3	307.3**	447.91**	639.13**	13555**	851.17**	410209**	1469.9**	705.38**	579.28**	12.57**
Error	12	8.573	10.257	7.524	619.9	12.196	1699	35.14	3.84	3.412	1.5342
(SD)	1	963.0**	6580.1**	2508.5**	6256.3**	1225.1**	642ns	97.9ns	1716.3**	37.57**	19.64**
E × SD	3	312.8**	58.53**	245.79**	9068.9**	169.23**	33135**	446.7**	198.13**	154.25**	11.33**
Error	12	2.399	4.319	5.649	457.9	11.675	2414	34.89	12.24	2.58	1.2439
(G)	5	867.8**	644.53**	20.38**	20168**	462.94**	55599**	1076.6**	367.53**	144.25**	43.49**
E × G	15	24.19**	5.59**	25.23**	1281.4**	11.484ns	6985**	197.54**	60.38**	14.47**	2.14**
SD × G	5	30.75**	9.65**	32.35**	1368.1**	21.07*	7744**	715.08**	119.33**	3.52ns	5.35**
E × SD × G	15	38.91**	8.67**	28.93**	1671**	23.08**	5472**	120.4**	23.18*	11.23**	4.09**
Error	120	1.49	2.492	3.162	239.2	9.436	1719	38.93	11.14	2.881	0.3808

E= environment, SD= sowing date, G= genotype, ns, *, ** insignificant, significant at 0.05 and 0.01 probability level, respectively.

Mean performance

The data in Table (3) illustrate the main effect of years, locations and sowing dates for all studied traits. The highest mean values recorded for days to heading and maturity, grain filling rate and straw and grain yield in the second year at Sids, while it was recorded for grain filling period, plant height and number of spikes m^{-2} in the first year at Sakha. The late sown date had a significant decrease for all characters, except for grain filling rate and straw yield. The average number of days to heading for all cultivars under recommended and late sown conditions was 88.2 and 83.7 days, respectively. Moreover, the late sowing conditions shortened the number of days to maturity from 140.4 to 128.7 days.

Table 3. Main effects of environments (year × location) and sowing dates (SD) for days to heading (DH), days to maturity (DM), grain filling period (GFP), grain filling rate (GFR), plant height (PH), spikes per square meter (SM-2), kernels per spike (KS-1), 1000 kernel weight (TKW), straw yield (SY) and grain yield (GY) at Sakha (SK) and Sids (SD) stations.

Variable	DH	DM	GFP (day)	GFR (kg/ha/day)	PH (cm)	SM^{-2}	KS^{-1}	TKW (g)	SY (ton/ha)	GY (ton/ha)
Environment										
SK 1st year	**85.4b**	**137.5a**	**52.1a**	**147.3b**	**110.5a**	**483.8a**	**54.0b**	**41.1c**	**17.320b**	**7.632b**
SD 1st year	**87.4a**	**131.0c**	**43.7d**	**177.6a**	**100.8d**	**366.9b**	**47.9c**	**49.5a**	**14.120c**	**7.551b**
SK 2nd year	**82.6c**	**133.1b**	**50.5b**	**148.4b**	**103.9c**	**257.5c**	**59.1a**	**41.6c**	**18.030b**	**7.478b**
SD 2nd year	**88.3a**	**136.8a**	**48.4c**	**176.3a**	**107.4b**	**374.6b**	**47.5c**	**44.2b**	**22.550a**	**8.569a**
Sowing date										
Recom. SD	**88.2**	**140.4**	**52.3**	**156.7**	**108.2**	**372.5**	**52.8**	**47.1**	**17.6**	**8.127**
Late SD	**83.7**	**128.7**	**45.1**	**168.1**	**103.1**	**368.9**	**51.4**	**41.1**	**18.4**	**7.488**
F test	**	**	**	**	**	**ns**	**ns**	**	**	**

In the same manner, the late sowing conditions shortened the grain filling period from 52.3 to 45.1 days. The late sowing conditions had an adverse effect on plant height in which mean plant height across cultivars dropped from 108.2 to 103.1 cm. Furthermore, the late sowing conditions decreased overall 1000-kernel weight (from 47.1 to 41.1g) and grain yield (from 8.127 to 7.488 ton ha^{-1}). On the contrary, the late sowing conditions increased straw yield from 17.6 to 18.4 ton/ha.

The data in Table (4) illustrate the effects of sowing dates and genotype interaction for all studied characters. Comparing to the late sowing date, recommended sowing date increased the number of days to heading and to maturity for all cultivars. Under recommended and late sowing dates, Sids 4 was the earliest genotype in heading and maturity (80.9, 78.8 and 134.6, 124.4 days), while Shandaweel 1 was the latest one (97.5, 93.2 and 149.4, 135.8 days), respectively. Under the recommended sowing date, grain filling period ranged from 53.7 to 51.1 days for Sids 4 and Line 2, respectively.

Table 4. Mean effects for the interaction between genotypes and sowing dates for days to heading (DH), days to maturity (DM), grain filling period (GFP), grain filling rate (GFR), plant height (PH), spikes per square meter (SM^{-2}), kernels per spike (KS^{-1}), 1000-kernel weight (TKW), straw yield (STY) and grain yield (GY).

Trait	Sowing date	Genotype (G)						LSD 5%	
		Line 1	Line 2	Line 3	Line 4	Sids 4	Shand. 1[§]	G[†]	SD×G[‡]
DH	Recom.	88.1	88.0	85.9	88.5	80.9	97.5	3.51	0.87
	Late	81.8	81.1	81.2	86.1	78.8	93.2	2.29	
DM	Recom.	139.4	139.1	138.1	142.1	134.6	149.4	1.49	1.13
	Late	127.9	127.7	126.2	130.6	124.4	135.8	1.81	
GFP	Recom.	51.3	51.1	52.2	53.6	53.7	51.9	3.59	1.28
	Late	46.1	46.6	45.0	44.5	45.6	42.6	3.10	
GFR	Recom.	170.2	175.5	153.5	163.25	97.25	180.38	16.86	11.16
	Late	175.7	177.81	177.31	164.0	129.13	184.69	24.18	
PH	Recom.	105.3	107.2	105	107.2	110.6	113.8	2.62	2.15
	Late	98.1	103.8	98.1	103.4	106.6	108.8	4.61	
SM^{-2}	Recom.	393.3	404.2	394.6	363.3	287.1	392.7	67.9	29.25
	Late	418.8	424.1	371.5	341.7	312.0	345.2	73.14	
KS^{-1}	Recom.	46.89	52.14	46.86	56.55	48.31	66.29	7.71	4.30
	Late	48.19	44.19	44.44	53.99	63.58	54.09	5.49	
TKW	Recom.	45.43	45.66	43.19	48.12	56.93	43.02	3.23	2.32
	Late	40.66	40.08	41.91	41.42	43.99	38.4	4.54	
STY	Recom.	17.83	17.894	18.596	18.067	13.274	19.725	3.51	1.17
	Late	18.73	18.702	18.597	18.408	14.872	21.390	2.17	
GY	Recom.	8.686	8.909	7.994	8.746	5.183	9.247	0.59	0.47
	Late	8.038	8.166	7.934	7.229	5.783	7.775	0.45	

§ = Shandaweel 1, †G = genotype and ‡ SD × G = sowing date × genotype, ‟ Recom. = recommended.

Furthermore, under the late sowing date, Line 2 had the longest grain filling duration (46.6 days) while Shandaweel 1 had the shortest grain filling period (42.6 days). In both sowing dates, Shandaweel 1 and Sids 4 recorded the highest and lowest grain filing rate, respectively. Shandaweel 1 was the tallest genotype (113.8 and 108.8cm), while Line 3 was the shortest (105.0 and 98.1 cm) under the two sowing conditions, respectively. The genotypes had differently responded to sowing dates for spikes per square meter trait. Line 2 recorded the highest values for spikes per square meter (404.2 and 424.1), while the lowest values for Sids 4 (287.1 and 312) were obtained from recommended and late sowing conditions, respectively. Shandaweel 1 had the highest number of kernels per spike (66.3) under the recommended sowing date, while Sids 4 had the highest number of kernels per spike (63.6) under the late sowing date. Sids 4 recorded the highest values for 1000-kernel weight (56.9 and 43.9 g), while Shandaweel 1 had the lowest values (43.0 and 38.4 g) under recommended and late sown conditions, respectively. On the other hand, straw yield measurements were higher under the late sowing comparing to the recommended sowing in all genotypes. Shandaweel 1 and Sids 4 recorded the highest and lowest straw yield, respectively. Significant reduction in grain yield due to the late sowing was also detected. Genotypes responded differently to sowing dates for grain yield and reflected the possibility of selecting the best genotype under a specific sowing date. Shandaweel 1 produced the highest grain yield (9.247 ton/ha) under recommended sowing date without significant difference with Line 2 (8.909 ton/ha). Furthermore, Line 2 and Line 1 had the highest grain yield under the late sowing conditions (8.166 and 8.038 ton/ha, respectively) while Sids 4 and Shandaweel 1 recorded 5.783 and 7.775 ton/ha., respectively. Line 2 was the best genotype for grain yield under both sowing dates.

Interrelationships among the studied traits

The correlation coefficients among all possible pairs of various characters under the recommended sowing date are presented in Table (5, above diagonal). Results in Table (5) indicated that days to heading had a significant and positive correlation with days to maturity, grain filling rate, plant height, spikes per square meter, grain yield and straw yield and a significant and negative correlation with 1000-kernel weight.

Table 5. Correlation coefficients among days to heading (DH), days to maturity (DM), grain filling period (GFP), grain filling rate (GFR), plant height (PH), spikes per square meter (SM^{-2}), kernels per spike (KS^{-1}), 1000-kernel weight (TKW), straw yield (STY) and grain yield (GY) under recommended sowing date (above diagonal-italic), and under late sown date (below diagonal).

Trait	DH	DM	GFP	GFR	PH	SM^{-2}	KS^{-1}	TKW	GY	STY
DH		0.705**	-0.501	0.673**	0.336**	0.220*	0.059	-0.220*	0.528**	0.477**
DM	0.652**		0.261*	0.465**	0.532**	0.556**	0.427**	-0.41**	0.628**	0.441**
GFP	-0.645**	0.160		-0.348**	0.192	0.378**	0.441**	-0.202*	0.047	-0.111
GFR	0.422**	0.016	-0.534**		-0.034	0.214*	0.179**	-0.473	0.914	0.518
PH	0.131	0.452**	0.286	-0.272		0.183	0.347**	0.058	0.048	0.117
SM^{-2}	0.201*	0.078	-0.183	0.369**	0.232*		0.120	-0.299**	0.403**	0.113
KS^{-1}	-0.132	-0.042	0.129	-0.474**	0.140	-0.608**		-0.320**	0.343**	0.074
TKW	0.050	-0.428**	-0.497**	0.441**	-0.517**	-0.006	-0.103		0.099	-0.40**
GY	-0.089	-0.036	-0.051	0.868**	0.0213	0.355**	0.015	0.235*		0.536**
STY	0.196	0.573**	0.322**	0.289	0.372**	0.269	-0.31**	-0.282**	0.566**	

Days to maturity had a significant and positive correlation with all characters, except for 1000-kernel weight. A significant negative correlation was detected between 1000-kernel weight and each of days to heading, days to maturity, grain filling period, spikes per square meter, kernels per spike, and straw yield and a significant positive correlation with grain yield. Grain yield showed a significant positive correlation with days to heading, days to maturity, spikes per square meter, kernels per spike, and straw yield, but it showed insignificant correlation with grain filling period, grain filling rate, plant height, and 1000-kernel weight.

The correlation coefficients among the studied traits under the late sowing date are presented in Table (5, below diagonal). Days to heading had significant positive correlation with days to maturity, grain filling rate, spikes per square meter and a significant negative correlation with grain filling rate. The correlation of days to maturity with days to heading, plant height, and straw yield were significant positive, but it was not significant with grain filling period, grain filling rate, spikes per square meter, number of kernels per spike and grain yield. Grain filling period had a significant positive correlation only with straw yield, but a negative correlation with grain filling rate, and 1000-kernel weight. A significant positive correlation was recorded between spikes per square meter and each of days to heading, grain filling rate and grain yield, but it was significant and negative with kernels per spike. Negative correlations were detected between 1000-kernel weight and all studied characters except, days to heading, grain filling rate and grain yield which showed positive correlation. Grain yield showed a positive correlation with grain filling rate, spikes per square meter, 1000-kernel weight and straw yield. `1The correlations between grain yield and each of days to heading, days to maturity and grain filling period were negative, reflecting the importance of earliness for late sowing.

The results revealed that correlations among some characters were inconsistent between the two-sowing date conditions. The relationships between grain yield and each of days to heading, days to maturity and grain filling period were positive under recommended sowing date indicating that the genotypes which have the long growth duration have the highest grain yield. On the contrary, these relationships under late sowing date with grain yield were negative, indicating the advantages of earliness under late sowing. The same trend was recorded between kernels per spike and each of days to heading and days to maturity. Al-Karaki (2011) reported that grain yield was strongly associated with spikes m^{-2} but not with grains $spike^{-1}$; rapid grain fill rate was positively correlated with GDD to heading but was negatively correlated with GDD to physiological maturity. The length of the grain fill period was positively associated with time to physiological maturity.

Genetic variation

To compare the magnitude of variation among studied characters, phenotypic (PCV) and genotypic (GCV) coefficient of variations, variance components, broad sense heritability (h^2_b) and genetic advance were worked out and presented in Table (6).

Table 6. Phenotypic (PCV) and genotypic (GCV) coefficient of variation, variance components, heritability ($h^2{}_b$) and genetic advance (GA) of days to heading (DH), days to maturity (DM), grain filling period (GFP), grain filling rate (GFR), plant height (PH), spikes per square meter (SM^{-2}), kernels per spike (KS^{-1}), 1000 kernel weight (TKW), straw yield (SY) and grain yield (GY); based on average of the eight studied environments.

Character	PCV	GCV	Variance components			$h^2{}_b$	GA	GA%
			Vp	Vg	Ve			
DH	6.9	5.95	35.11	26.14	1.49	0.74	9.09	10.57
DM	3.61	3.31	23.65	19.91	2.49	0.84	8.43	6.27
GFR	20.69	14.89	1129.2	584.6	239.2	0.52	35.84	22.07
PH	4.77	3.53	25.44	13.91	9.44	0.55	5.68	5.38
Sm^{-2}	17.97	10.57	4436.5	1536.07	1718.97	0.35	47.51	12.82
KS^{-1}	20.57	9.82	115	26.19	38.93	0.23	5.03	9.65
TKW	12.72	7.12	31.41	9.83	11.14	0.31	3.61	8.2
GY	19.83	14.33	2.4	1.25	0.38	0.52	1.67	21.33
SY	16.83	11.31	9.19	4.15	2.88	0.45	2.82	15.65

According to Deshmukh *et al* (1986), PCV can be categorized as low (<10%), moderate (10-20%) and high (>20%). Accordingly, high PCV estimates were recorded for grain filling rate and kernels per spike, while it was low for days to heading, days to maturity and plant height. Medium PCV estimates were recorded for spikes per square meter, 1000-kernel weight, grain yield and straw yield. The PCV were higher than the GCV for studied characters, indicating the presence of environmental influence on the phenotypic expression of the characters. The magnitude of differences between PCV and GCV was remarkably low for days to heading, days to maturity and plant height, revealing that the influence of the environment factors for phenotypic expression was low for these characters and improvement of these characters through selection can be applied based on phenotypic performance. A similar result was reported by Kyosev *et al* (2015), and Wolde *et al* (2016). A moderate difference between PCV and GCV was recorded for grain filling rate, 1000 kernel weight, grain yield and straw yield. This result agreed with results of Khan *et al* (2015). Whereas, Yadawad *et al* (2015) reported a slight difference between PCV and GCV for grain yield and thousand grain weight. The difference between PCV and GCV was relatively high for kernels per spikes and spikes per square meter, indicating a high magnitude of the environmental effect on phenotypic expression of these traits and therefore, improvement of these characters via selection is difficult to achieve based on phenotypic performance. This result agrees with the findings of Demelash *et al* (2013) and Adhiena *et al* (2016).

Successful selection is related to high heritability of a character. Estimates of heritability and genetic advance are critical for predicting genetic improvement for any quantitative character (Khali and Afridi, 2004). According to Singh (2001), heritability of a character is considered as high or very high when the value is ≥ 80%, moderate when the values range from 40% to 80% and low when it is less than 40%. Accordingly, high heritability estimates were obtained for days to maturity, indicating that selection in early segregating generations would be effective for improving this character (Table 6). Adhiena *et al* (2016) reported high heritability estimates for days to maturity (83.1%). Moderate heritability in the broad sense was detected for days to heading, grain filling rate, plant height and grain yield, suggesting that delaying selection to advanced segregating generations would be more effective for improving such characters. On the contrary, Salman *et al* (2014) reported high heritability for number of spikes per square meter, kernels per spike and grain yield; however Mollasadeghi *et al* (2012) reported low heritability for grain yield. Low heritability estimates for spikes per square meter, kernels per spike, 1000-kernel weight and straw yield were detected. In harmony of this study, Demelash *et al* (2013) and Adhina *et al* (2016) reported low heritability for straw yield and kernels per spike. The difference of heritability estimates among different authors may be due to different genotypes under particular environment conditions (Dabholkar 1992).

Expected genetic advance from selection as a percentage of the mean ranged from 5.38% for plant height to 22.07% for grain filling rate. The estimate was high (22.07) for grain filling rate, while it was low for days to maturity, kernels per spike and 1000-kernel weight.

Stability analysis

The analysis of variance across all environments (sowing dates, locations and years) revealed that genotypes (G), environments (E) and the G×E interaction mean squares had significant effect on grain yield of the six bread wheat genotypes (Table 7). Singh and Narayanan (2000) reported that, if G×E interaction is found to be significant, the stability analysis can be carried out.

The joint regression analysis of variance for grain yield showed highly significant differences among genotypes and environments (Table 8). This indicated the presence of genetic and environmental variability among the studied genotypes. The G×E interaction was partitioned into linear and non-linear (pooled deviation) components. Mean squares due to the environmental linear effect were highly significant. This means that a large portion of the interaction between genotypes and environments was obtained by the linear regression on the environmental means. The magnitude of non-linear components was considerably smaller than that of linear one.

Table 7. Mean squares of combined analysis of variance for grain yield.

SOV	df	Mean squares
Environments (E)	**7**	**13.05****
Error	**24**	**1.39**
Genotypes (G)	**5**	**43.49****
E×G	**35**	**3.44****
Error	**120**	**0.38**

**** = Significant at 0.01 levels of probability.**

Eberhart and Russel (1966) defined the desired variety as that of a high mean performance, unit regression coefficient (b_i=1) and deviation from regression as small as possible (S^2d=0). In the present study, the regression coefficients of most genotypes were not significantly different from unity. Therefore, the stability performance of the studied genotypes in this case can be predicted on the basis of the other two parameters, i.e. deviation from regression and average yield across all environments (Amin *et al* 2005).

Table 8. Summary of the joint regression analysis of variance for grain yield.

SOV	df	Mean squares
Genotypes (G)	**5**	**10.87****
Environment (E) + G×E	**42**	**1.26***
Environment (linear)	**1**	**22.84****
G×E (linear)	**5**	**0.78ns**
Pooled deviation	**36**	**0.73**
Pooled Error	**144**	**0.18**

ns,*, ** = Non significant, significant at 0.05 and 0.01 levels of probability, respectively.

The simultaneous consideration of the three stability parameters for the individual genotype revealed that Line 2, Shandaweel 1 and Line 1 gave the highest yield of 8.537, 8.511 and 8.362 ton ha^{-1} over the average, respectively. Line 2 had regression coefficients value not significantly different from 1.0 and mean square deviations from regression not significantly different from zero, therefore it was considered as stable. Fortunately, this Line had a mean yield greater than the average yield of all genotypes.

Table 9. Stability parameters for grain yield of the studied wheat genotypes across eight environments.

Genotype	Mean yield (ton ha^{-1})	Relative yield to average	Regression coefficient (bi)	t-value	(S^2d)
Line 1	**8.362**	**0.55**	**0.74±0.18**	**1.446**	**-0.064**
Line 2	**8.537**	**0.73**	**0.98±0.19**	**0.095**	**-0.043**
Line 3	**7.964**	**0.16**	**0.39±0.34**	**1.816**	**0.252**
Line 4	**7.988**	**0.18**	**1.35±0.31**	**1.135**	**0.173**
Sids 4	**5.483**	**-2.32**	**1.67±0.82**	**0.812**	**2.369**
Shandaweel 1	**8.511**	**0.7**	**0.83±0.45**	**0.279**	**0.576**

GGE biplot analyses for comparison of genotypes were performed to detect the ideal and desirable genotypes (Figure 1). An ideal genotype should have both high mean yield performance and high stability across environments (Kaya *et al* 2006 and Yan and Tinker 2006). The ideal genotypes should be in the center of concentric circles. In this study, Line 2 was the ideal genotype in addition to Line 1 and Shandaweel 1 (desirable genotypes) as they grouped in the centric circle next to ideal one. However, Sids 4 seems to be undesirable. The comparison biplot for the environments is illustrated in Figure 2. The E3 and E7 (recommended sowing date in Sids location in both seasons) were more recommended environments than the others. This result agreed with previous reports indicating that Sids site is one of the most high yielding locations in Egypt (El-Areed *et al* 2014).

The ranking biplot for genotypes and environments (Figure 3 and 4) showed that Sids location under recommended sowing date in the first season (E3) was the best environment. In the ranking of genotypes based on their performance in all environments, a line is drawn that passes through the biplot origin and the environment. This line is called the axis for the environment (Yan and Tinker 2006) and along it is the ranking of genotype. Thus, Figure 4 showed rank of genotypes performance. From the graph, the highest yielder genotype was shandaweel 1 followed by Line 2 but Line 2 showed more stable. In the contrast, Sids 4 was the lowest. One of the most attractive features of GGE biplot is its ability to show the "which-won-where" pattern of a genotype by environment dataset as it graphically addresses important concepts such as cross-over GE, mega-environment differentiation, specific adaptation, etc. (Yan and Tinker 2006).

The polygon view of the GGE biplot (Figure 5) indicates the best genotype(s) in each environment and groups of environments (Yan *et al* 2000 and Yan and Hunt 2001). Line 2 gave high yield at all environments except the late sowing date at Sakha location in both seasons (E2 and E6) where Line 1 was the best in these environments. The other genotypes lying on the vertices did not respond at any of the locations.

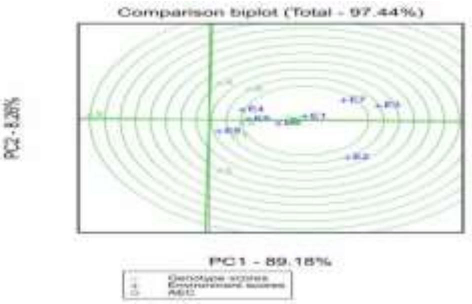

Fig. 1. GGE-biplot focused scaling for comparison of the genotypes. E1 –E8 are the environments; no. 1 – 4 are Line1, 2, 3, 4, Sids 4 and Shandaweel 1.

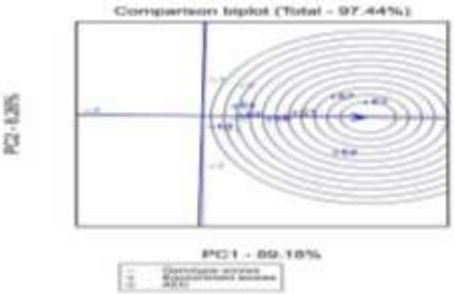

Fig. 2. GGE-biplot for comparison of environments. E1 –E8 are the environments; no. 1 – 4 are Line1, 2, 3, 4, Sids 4 and Shandaweel 1.

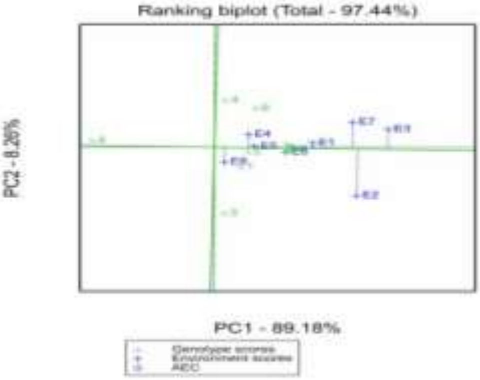

Fig. 3. Ranking biplot for environments. E1 –E8 are the environments; no. 1 – 4 are Line1, 2, 3, 4, Sids 4 and Shandaweel 1.

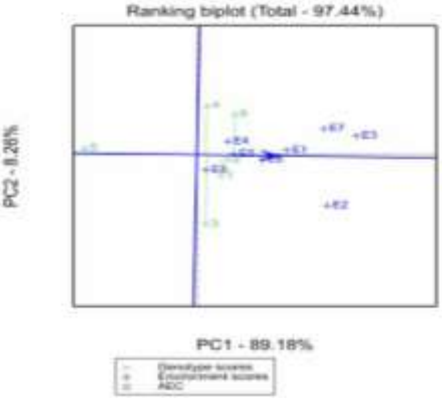

Fig. 4. Identification of winnig genotypes across 8 environments. E1 –E8 are the environments; no. 1 – 4 are Line1, 2, 3, 4, Sids 4 and Shandaweel 1.

The winning genotype and Mega-environment to visualize the "which-won-where" pattern of MET data (Figure 5) is important for studying the possible existence of different mega-environments in a region (Gauch and Zobel 1997 and Yan *et al* 2000 and 2001). The polygon view of a biplot is the best way to visualize the interaction patterns between genotypes and environments and to effectively interpret a biplot (Yan and Kang 2003). The vertex genotypes in this investigation are G2 (Line 2) in mega environments E1, E3, E4, E5, E6 and E7; meantime G1 (Line 1) win in the other mega environments E2 and E8 (Sakha and Sids late sowing in 2014/15 and 2015/16 seasons, respectively).

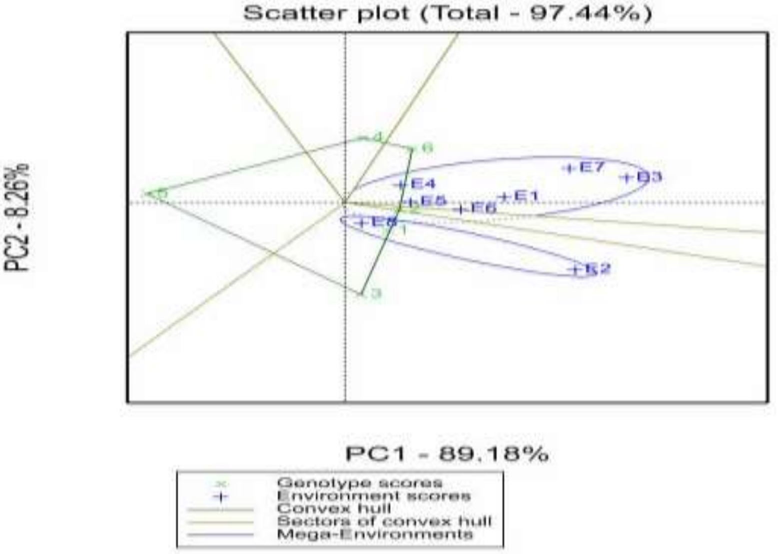

Fig. 5. The which-won-where view of the GGE biplot to show which genotypes performed better in which location for grain yield. No. 1 – 4 are Line 1, 2, 3, 4, Sids 4 and Shandaweel 1 and E1 = Sakha recommended sowing date in 2014/15, E2 = Sakha late sowing date in 2014/15, E3 = Sids recommended sowing date in 2014/15, E4 = Sids late sowing date in 2014/15, E5 = Sakha recommended sowing date in 2015/16, E6 = Sakha late sowing date in 2015/16, E7 = Sids recommended sowing date in 2015/16, E8 = Sids late sowing date in 2015/16.

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أداء وثبات بعض سلالات قمح الخبز مبكرة النضج في بيئات مختلفة

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أجريت تجربة لتقييم أربع سلالات قمح مبشرة مبكرة النضج بالإضافة إلى صنفين قمح تجارية في محطتي البحوث الزراعية بسخا وسدس خلال موسمي الزراعة ٢٠١٤/٢٠١٥م و ٢٠١٥/٢٠١٦م تحت موعدي الزراعة: الأمثل والمتأخر. استخدم تصميم القطاعات كاملة العشوائية في أربعة مكررات. هدفت الدراسة إلى اختيار أفضل التراكيب الوراثية ودراسة العلاقة بين الصفات تحت موعدي الزراعة: الأمثل والمتأخر. أوضح تحليل التباين المجمع وجود اختلافات عالية المعنوية بين البيئات والتراكيب الوراثية لجميع الصفات تحت الدراسة. أوضحت النتائج اختلاف استجابة السلالات لموعدي الزراعة مما يدل على إمكانية انتخاب سلالات مناسبة لكل بيئة. سجلت السلالتان ٢ و ١ أعلى محصول حبوب تحت موعد الزراعة المتأخر (٨,١٦٦ و ٨,٠٣٨ طن/هكتار على التوالي). أوضحت دراسة الارتباط بين الصفات تحت موعد الزراعة الأمثل وجود ارتباط إيجابي بين محصول الحبوب وكل من عدد الأيام حتى طرد السنابل وحتى النضج الفسيولوجي ، مما يدل على أن السلالات ذات فترة النمو الأطول تنتج محصول حبوب أعلى ، وعلى العكس من ذلك فقد سجلت علاقة سالبة بين محصول الحبوب ونفس الصفتين تحت موعد الزراعة المتأخر مما يدل على تميز السلالات المبكرة تحت ظروف تأخير موعد الزراعة. سجلت تقديرات كفاءة التوريث قيما عالية لصفة عدد الأيام حتى النضج الفسيولوجي , مما يدل على إمكانية تحسين هذه الصفة ، بينما كانت التقديرات متوسطة القيمة لصفات عدد الأيام حتى طرد السنابل , ومعدل امتلاء الحبوب وارتفاع النبات ومحصول الحبوب ، مما يدل على أن الانتخاب لتحسين هذه الصفات يجب أن يكون في الأجيال الانعزالية المتقدمة. سجلت تقديرات التحسين الوراثي المتوقع بالانتخاب قيما مرتفعة لصفات محصول الحبوب وارتفاع النبات وعدد الأيام حتى النضج الفسيولوجي وعدد حبوب السنبلة ووزن الألف حبة. أوضح تحليل الثبات أن السلالة رقم ٢ هي السلالة الأفضل ثباتا في جميع البيئات يليها السلالة رقم ١ ثم الصنف شندويل ١ .

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