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(Original Article)

Yield Potential and Stability of Some Early Promising Bread Wheat Genotypes Under Different Heat Stress Conditions

Ahmed H. A. Hussein* **and Mahmoud S. Mohamed**

Wheat Research Department, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt.

*Corresponding author e-mail: ahmed_heseen2003@yahoo.com.eg
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Abstract

This study was conducted during the 2022/2023 and 2023/2024 growing seasons at Mallawy Agric. Res. Station, Egypt, to evaluate the effect of three sowing dates on the yield and earliness of five bread wheat genotypes and to identify the most stable genotypes under these conditions. Statistical analysis revealed highly significant differences due to seasons, sowing dates, genotypes, and their interactions for most of the studied traits in both seasons and across the combined analysis. Among the tested sowing dates, 15th November produced the highest values for all traits. Lines 1, 2, and 3 were the earliest in heading and maturity, showing the lowest mean values for grain filling rate and growing degree days, but the longest grain filling period. Line 1 outperformed all other genotypes in yield and its components across different sowing dates. Genotype Sids 14 was also early in heading and maturity and exhibited a high grain filling rate. When sown on 15th January, Lines 1 and 2 recorded the smallest reduction in grain yield and maintained significant superiority in earliness traits. These genotypes demonstrated broad adaptability across sowing dates (from 15th November to 15th January). Moreover, their early maturity and ability to maintain performance under late sowing conditions suggest they can be classified as heat-tolerant. This study recommends using these genotypes i.e. (Lines 1 and 2) to improve in breeding programs for early mature and heat tolerant.

Keywords: *GGE-biplot, Heat susceptibility index, Planting dates, Stability parameter, Triticum aestivum.*

Introduction

Wheat (*Triticum aestivum* L.) is the very important cereal crop. It meets one-fifth of the world's food needs and is grown on more than 220 million hectares worldwide (FAO 2022). In the 2023–2024 growth season, its area of around 1.35 million hectares (3.25 million faddan) yielded 9.4 million tons, with an average of 6.94 tons hectare^{-1}, which was equal to 19.33 ardab feddan^{-1} (Economic Affairs Annual Report, 2024). High-yielding cultivars, ideal weather, resource efficiency, and government support for price controls have all contributed to Egypt's steady expansion in wheat production. Nonetheless, imports continue to rise annually in order to provide wheat flour to the growing population. Therefore, there is a gap between the national need and the local wheat production, The United States Foreign Agricultural Service (FAS) in Cairo

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predicts Egyptian wheat imports in 2023/2024 at 12.85 million tons (USDA 2023). Therefore, in order to reduce the gap between production and consumption in Egypt, major efforts must be made to increase the nation's production.

The agriculture industry is especially vulnerable to climate change. The potential yield of every variety is determined by a combination of environmental and genotypic variables. Nowadays, due to global warming, climatic conditions are changing, and temperatures begin to rise in late February and March, accompanied by hot dry winds at post-anthesis stages, during grain development, particularly when grain growth is terminated prematurely, significantly reducing yield (Quan *et al*., 2019). To enhance the production and productivity in wheat cultivation, particularly in warmer areas, a new set of varieties having heat tolerance is required (Xie *et al.,* 2018).

Cultivars with environmental-adapted physical development have a higher potential for grain production. (Singh *et al*., 2024 and Bhandari *et al*. 2025). To succeed in this purpose, assessing breeding lines over time and in different locales has become an essential component of every plant breeding effort. National agricultural production policy relies heavily on the adaptability and stability of varieties across different settings. Thus, a grain producer's primary aims are to choose heat-tolerant wheat genotypes for a specific location and to nurture a cultivar with high yield and stability (Sharma *et al*., 2016). Genetic and environmental differences, as well as genetic-environmental interaction (GEI), can all contribute to variance (Vedi *et al*., 2024 and Bhandari *et al*. 2025). GEI happens when genotypes react differently in various settings. It is regarded to be one of the primary factors impeding breeding programs and, as a result, agricultural production (Cuevas *et al*., 2017).

Sowing date is one of the most significant agronomic elements to consider in order getting excellent crop yields. The optimal planting dates increase wheat grain productivity while improving physiology, phenology, and environmental conditions (Bhandari *et al*., 2024). Furthermore, it regulates the quantity of water, temperature, and sunlight available to the crop. In addition, earlier planting of wheat resulted in an increase in some vegetative characteristics, yield attributes, and grain yields as well as an improvement in biological and economic yield; later planting after the recommended time resulted in a decrease in yield (Abdelkhalik *et al*., 2021, Hussein 2021, Tamiru *et al*., 2023 and Nagar 2024).

Thus, there are a number of benefits to being early in Egypt. For example, early-maturing wheat cultivars are required for crop-intensive rotation, which consists of sowing wheat after harvesting short-duration vegetable crops and cotton after wheat. Early-harvesting wheat varieties may also conserve more water, as well as give farmers more time to plant other crops. The main objectives of the study were to: (1) respond to the productivity of three sowing dates on the performance of three promising early maturing bread wheat genotypes and, (2) to select the most suitable and adapted wheat genotypes for planting under different climates and it can be used in breeding efforts to generate wheat cultivars with high grain yield and early maturity.

Materials and Methods

1. Experimental site

The experiment was conducted at Mallawy Agric. Res. Station, El-Minia Governorate, Egypt, in the wheat-growing seasons of 2022/2023 and 2023/2024. The location's coordinates are 27° 43' 76" N latitude and 30° 83' 71" E longitude, in Middle Egypt. The weather data for the investigational site, shown in Figure (1), were collected at 15-day intervals from November 2022 to June 2024 from the Mallawy Agric. Res. Station, Agricultural Climate Meteorological Station, and Agricultural Research Center during the two seasons of 2022/2023 and 2023/2024.

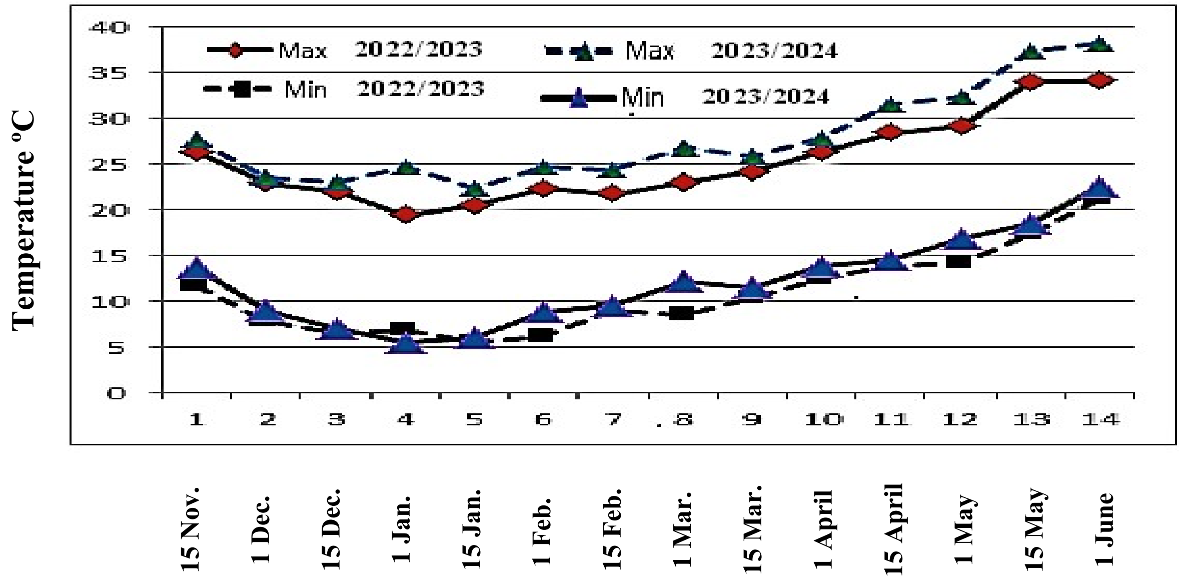

Fig 1. Average of 15 days for maximum (Max) and minimum (Min) temperature from November to June in 2022/2023 and 2023/2024 seasons at Mallawy Agric. Res. Station.

2. Experimental design and treatments

There are five different bread wheat genotypes (*Triticum aestivum* L.), including three early promising genotypes, were selected from F_6 lines in the Mallawy breeding program, and two commercial cultivars were used as checks, and their performance under terminal heat stress was evaluated. Names, pedigree, selection history and origin of those genotypes are shown in Table 1. These genotypes were examined on three different sowing dates, namely, 15th November (recommended), 15th of December (late sowing date), and 15th of January (very late sowing date). Each plot was 3 m^2 and had six rows that were 2.5 m long and 20 cm apart. Planting was done at a seeding rate of 350 seeds m^{-2}, which was equivalent to 120 kg h^{-1} (50 kg feddan). The experiment was three replicated for each planting date, using a Randomized Complete Block Design. The Middle Egypt Region's other wheat recommendation packages were all used.

Table 1. Names, pedigree, selection history, and origin were used to identify the five bread wheat genotypes that were examined

Name	Pedigree	selection history	Origin
Line 1	WHEAR/S0K0LL//Sids 4.	CMal2016-63-2Mal-2Mal-1Mal-0Mal-0Mal.	Egypt
Line 2	Sids 4/Giza 168.	CMal2016-90-1Mal-2Mal-2Mal-1Mal-0Mal.	Egypt
Line 3	WHEAR/S0K0LL/ Sids 4.	CMal2016-91-Mal-2Mal-3Mal-0Mal-0Mal.	Egypt
Giza 171	Sakha 93 / Gemmiza 9.	Gz2003-101-1GZ-4GZ-1GZ-2GZ-0GZ	Egypt
Sids 14	Bow"S"/Vee"S"//Bow"S"/TSI/3/Bani Sewef 1.	SD293-1SD-2SD- 4SD – OSD.	Egypt

3. Characters were studied, and data was collected.

The parameters under investigation included the following earliness components: The number of days to heading (DH) and maturity (DM), the grain filling period (GFP), and the grain filling rate (GFR), which is calculated by dividing grain yield by GFP. Agronomic variables measured were number of spikes per m^{-2} ($NSPM^{-2}$), number of kernels per $spike^{-1}$ (NKS^{-1}), 1000-kernel weight (1000-TKW) and grain yield (GY) ton ha^{-1}. Additionally, the number of days to heading was given in terms of growing degree days (GDD). The GDD was estimated using the formulas from Gomez and Richards 1997.

$$\textbf{The Growing degree days GDD (°C)} = \sum [(T.\ max + T.\ min)/2 - Tb]$$

Where: T. max and T. min are the maximum and minimum daily air temperatures, respectively, and Tb is the base temperature (5°C) below which no growth happens (Przulj and Mladenove, 1999).

In order to minimize the yield loss brought on by unfavorable vs favorable conditions, the heat susceptibility index (HSI) was employed as a gauge of heat tolerance. In comparison to regular sowing, HSI was computed for late and very late sowing dates. HSI was computed for each genotype using Fisher and Maurer's (1978) formulas: [HSI = (1–yh/yp)/H]. Where: yh = mean yield under heat stress (very late planting date), yp = mean yield under optimal conditions (high yield), and H = heat stress intensity = 1-(yh of all genotypes / yp of all genotypes). The GGE-biplot (Akcura and Kaya 2008) was used to depict the G×E interaction. The GGE-biplot of grain yield for the analyzed wheat cultivars was performed for six different environmental circumstances (three planting dates × two seasons).

4. Statistical analysis

Using the "GEN STAT" microcomputer program, (VSN International 2018), the data collected for each factor was statistically evaluated via analysis of variance applying randomized complete block design, combined across seasons, as well as planting dates. Yield stability was examined using Eberhart and Russell's (1966) methodology. The two statistics depending on genotypes × environment interaction, (1) regression coefficient (b_i) and (2) the deviation from regression (S^2d_i) were used to estimate stability**.** The differences among the treatment means were compared using the least significant differences (L.S.D.) at a 0.05 probability level (Gomez and Gomez, 1984).

Results

1. Mean performance for growth characteristics

No. of days to heading (DH)

Data analysis in Table 2 found that seasons, planting dates, genotype, and all interactions between them in the two growing seasons, as well as the combined effect over cross seasons, all had a significant effect on days to heading. It is evident from the mean values of the data that the planting date of 15th November indicated the maximum days to heading 86.2, 82.8, and 84.5 days. whereas those sown on 15th January showed the minimum days to heading 74.7, 79.5, and 77.1 days in the first, second seasons, and the combined over two seasons, respectively. Genotype Line 1 had the earliest one; it indicated the least number of DH, while Sids 14 was the latest one in both seasons and crossed over the two seasons. On the other hand, Sids 14 recorded the latest for days to heading (103.7, 96.3, and 100 days) when sown on 15th Nov. while Line 1 recorded the earliest one (67.6, 75.0, and 71.3 days) when sown on 15th Jan. in the first, second, as well as average of two seasons, respectively.

Table 2. Mean values for the number of days to heading and number of days to maturity of the five bread wheat genotypes cultivated under three sowing dates during the two growing seasons of 2022/2023 and 2023/2024, as well as the combined value for the two seasons.

Season (S)	Sowing Date (SD)	Days to heading (DH)						Days to maturity (DM)					
		Genotype (G)					Mean	Genotype (G)					Mean
		G1	G2	G3	G4	G5	(SD)	G1	G2	G3	G4	G5	(SD)
2022/ 2023	15th Nov. (SD1)	69.7	80.1	75.1	102.3	103.7	86.2	131.4	133.0	134.6	149.0	151.0	139.8
	15th Dec. (SD2)	70.3	75.0	72.7	99.3	100.9	83.6	128.6	133.0	133.6	146.4	145.0	137.3
	15th Jan. (SD3)	67.6	70.6	71.0	81.0	83.3	74.7	113.0	113.6	113.4	120.0	122.6	116.1
	Mean (G)	69.2	75.2	72.9	94.2	96.0	81.5	124.3	125.9	127.2	138.5	139.5	131.1
	LSD 0.05												
	SD						1.39						0.52
	G						1.56						1.31
	SD × G						2.61						2.11
2023/ 2024	15th Nov. (SD1)	74.7	73.3	73.3	96.3	96.3	82.8	132.0	132.0	133.0	150.0	151.0	139.6
	15th Dec. (SD2)	80.3	79.0	78.7	95.7	94.7	85.7	129.0	128.0	129.0	141.0	140.0	133.4
	15th Jan. (SD3)	75.0	75.0	75.0	86.0	86.7	79.5	115.0	118.0	115.0	124.0	125.0	119.4
	Mean (G)	76.7	75.8	75.7	92.7	92.6	82.7	125.3	126.0	125.7	138.3	138.7	130.8
	LSD 0.05												
	SD						0.78						0.43
	G						0.65						0.51
	SD × G						1.28						0.92
Combined over the two seasons	15th Nov. (SD1)	72.2	76.7	74.2	99.3	100.0	84.5	131.7	132.5	133.8	149.5	151.0	139.7
	15th Dec. (SD2)	75.3	77.0	75.7	97.5	97.8	84.7	128.8	130.5	131.3	143.7	142.5	135.4
	15th Jan. (SD3)	71.3	72.8	73.0	83.5	85.0	77.1	114.0	114.8	114.2	122.0	123.8	117.8
	Mean (G)	72.9	75.5	74.3	93.4	94.3	82.1	124.8	125.9	126.4	138.4	139.1	130.9
	LSD 0.05												
	(S)						1.07						NS
	(SD)						1.00						0.74
	S × SD						1.81						1.72
	(G)						0.68						1.01
	S × G						1.30						1.09
	SD × G						1.36						1.63
	S × SD × G						2.48						NS

G1= Line 1, G2= Line 2, G3= Line 3, G4= Giza 171, G5= Sids 14 and NS= insignificant.

No. of days to maturity (DM)

Table 2 revealed that different planting dates, genotypes, and all interactions had a highly significant influence on days to maturity, except season (S) and the season (S) × sowing date (SD) × genotype (G) interaction in the combination across two seasons, which was insignificant. The first planting date had the greatest values for DM when compared to the second and third planting dates. Lines 1, 2 and 3 were the earliest genotypes for DM in the two seasons and when data were combined. Line 1 had the earliest genotype, having the lowest number of DM (124.3, 125.3, and 124.8 days) in the first, second, and combined analyses during the two seasons, respectively. Furthermore, among the interactions between them, Line 1 had the earliest one when planted on three sowing dates (15^{th} November, 15^{th} December, and 15^{th} January.) without significance with Lines 2 and 3 in the two seasons and in the combined data.

2. **Yield and yield components**

No. of spikes m^{-2} (NSPM^{-2})

The number of spikes m^{-2} results as one of the major yield components, is indicated in Table 3. The impact of sowing date findings revealed extremely significant variations throughout both growing seasons and their combined analysis, except (SD × G) in the first season, which was insignificant. The recommended sowing date (15^{th} November) recorded the greatest No. of spikes m^{-2} without a significant difference from the second sowing date (15^{th} December) for the first, second, and combined seasons, compared to the third planting date. On the optimum planting date, the genotype Line1 gave a maximum No of spikes m^{-2} (449.6, 437.0 and 443.3 spikes) more than the other genotypes in both seasons, as well as combined.

No. of kernels spike^{-1} (NKS^{-1})

The averages of NKS^{-1} revealed that different seasons, planting dates, genotypes, and their interactions, except (SD × G) in the first season and (S × SD × G) in the combination across the two seasons, showed insignificant differences (Table 3). In the case of the effect of sowing dates on the number of kernels spike^{-1}, the 15^{th} of November produced the greatest number when compared to the other planting dates in the two growing seasons. Regarding genotype variations' effect on NKS^{-1}, Line 1 surpassed the other genotypes. It was indicated as the greatest one (60.8, 63.0, and 61.9 kernels), followed by Line 2 in both the growing seasons and in the combined. The highest value for KS^{-1} was recorded by line 1 when sown on 15^{th} Nov., 15^{th} Dec., and 15^{th} Jan. in both seasons and in the combined analyses during the two seasons.

Table 3. Mean values for the number of spikes m^{-2} and number of kernel spike^{-1} of the five bread wheat genotypes cultivated under three sowing dates during the two growing seasons of 2022/2023 and 2023/2024, as well as the combined value for the two seasons.

Season (S)	Sowing Date (SD)	No. of spikes m^{-2} (SPM^{-2})						No. of kernel spike^{-1} (KS^{-1})					
		Genotype (G)					Mean	Genotype (G)					Mean
		G1	*G2*	*G3*	*G4*	*G5*	(SD)	*G1*	*G2*	*G3*	*G4*	*G5*	(SD)
2022/ 2023	15th Nov. (SD1)	449.6	430.4	410.4	409.6	430.0	426.0	68.4	63.8	52.6	62.0	59.6	61.3
	15th Dec. (SD2)	433.0	400.4	383.4	423.6	423.0	412.7	56.8	51.8	46.0	54.2	50.4	51.8
	15th Jan. (SD3)	343.6	273.0	293.4	313.4	306.6	306.0	57.2	54.2	45.0	56.6	52.8	53.2
	Mean (G)	408.7	367.9	362.4	382.2	386.5	381.6	60.8	56.6	47.9	57.6	54.3	55.4
	LSD 0.05												
	SD						22.80						2.11
	G						17.71						3.90
	SD × G						NS						NS
2023/ 2024	15th Nov. (SD1)	437.0	423.0	413.0	397.0	410.0	416.0	64.0	63.0	48.0	57.0	64.0	59.2
	15th Dec. (SD2)	427.0	413.0	400.0	373.0	407.0	404.0	62.0	64.0	52.0	61.0	54.0	58.6
	15th Jan. (SD3)	323.0	227.0	220.0	220.0	310.0	260.0	63.0	61.0	57.0	60.0	53.0	58.8
	Mean (G)	395.7	354.3	344.3	330.0	375.7	360.0	63.0	62.7	52.3	59.3	57.0	58.9
	LSD 0.05												
	SD						18.01						1.01
	G						20.11						3.11
	SD × G						33.62						4.92
Combined over the two seasons	15th Nov. (SD1)	443.3	426.7	411.7	403.3	420.0	421.0	66.2	63.4	50.3	59.5	61.8	60.2
	15th Dec. (SD2)	430.0	406.7	391.7	398.3	415.0	408.3	59.4	57.9	49.0	57.6	52.2	55.2
	15th Jan. (SD3)	333.3	250.0	256.7	266.7	308.3	283.0	60.1	57.6	51.0	58.3	52.9	56.0
	Mean (G)	402.2	361.1	353.4	356.1	381.1	370.8	61.9	59.6	50.1	58.5	55.6	57.1
	LSD 0.05												
	(S)						7.21						2.40
	(SD)						12.13						1.01
	S × SD						14.62						2.31
	(G)						13.01						2.42
	S × G						17.32						NS
	SD × G						22.71						3.91
	S × SD × G						31.30						NS

G1= Line 1, G2= Line 2, G3= Line 3, G4= Giza 171, G5= Sids 14 and NS= insignificant.

1000-kernel weight (1000-TKW) (g)

The results revealed that different planting dates and genotypes had a significant ($P < 0.05$) influence on 1000- kernel weight in both seasons and the combined across the two seasons, whereas the interactions of SD × G in both seasons, (S), (S × G), (SD × G) and (S × SD × G) in the combined over the two seasons had insignificant effect (Table 4). The planting on the optimum date (15th November) gave the highest grain weights (52.91, 51.10, and 52.0 g) compared to the second and third sowing dates. The five genotypes showed significant differences in their TKW in each of the two growing seasons and in the combined. Line 3 had the heaviest 1000-kernel weight being (51.60, 52.60 and 52.10 g), and Sids 14 had the lowest kernel weight being (43.91, 45.40 and 44.60 g) in the first, second, and combined seasons, respectively.

Table 4. Mean values for 1000-kernel weight and the grain yield of the five bread wheat genotypes cultivated under three sowing dates during the two growing seasons of 2022/2023 and 2023/2024, as well as the combined value for the two seasons.

Season (S)	Sowing Date (SD)	1000-kernel weight (TKW) (g)						Grain yield (GY) (ton ha^{-1})					
		G5					Mean	Genotype (G)					Mean
		G5	G5	G5	G5	G5	(SD)	G1	G2	G3	G4	G5	(SD)
2022/ 2023	15th Nov. (SD1)	50.59	54.25	58.50	52.58	48.63	52.91	9.166	7.944	8.888	9.222	8.611	8.766
	15th Dec. (SD2)	45.20	48.61	51.04	50.37	43.09	47.66	7.889	7.277	7.221	6.778	6.944	7.222
	15th Jan. (SD3)	43.52	44.32	45.26	40.65	40.01	42.75	6.279	3.889	4.499	4.944	4.945	4.911
	Mean (G)	46.44	49.06	51.60	47.87	43.91	47.77	7.778	6.370	6.869	6.981	6.833	6.966
	LSD 0.05												
	SD						1.046						0.552
	G						2.350						0.469
	SD × G						NS						0.830
2023/ 2024	15th Nov. (SD1)	49.77	54.11	55.54	50.28	45.67	51.10	9.222	7.444	8.278	9.000	8.111	8.411
	15th Dec. (SD2)	47.04	52.29	53.36	48.35	49.21	50.10	7.389	6.611	7.167	6.444	6.444	6.811
	15th Jan. (SD3)	43.04	46.34	49.04	45.47	41.25	45.00	4.833	3.889	3.889	3.944	4.611	4.233
	Mean (G)	46.60	50.90	52.60	48.00	45.40	48.70	7.148	5.981	6.445	6.463	6.389	6.485
	LSD 0.05												
	SD						2.38						0.552
	G						2.33						0.405
	SD × G						NS						0.750
Combined over the two seasons	15th Nov. (SD1)	50.18	54.18	57.02	51.43	47.15	52.00	9.194	7.694	8.583	9.111	8.361	8.589
	15th Dec. (SD2)	46.12	50.45	52.20	49.36	46.15	48.90	7.639	6.944	7.194	6.611	6.694	7.016
	15th Jan. (SD3)	43.28	45.33	47.15	43.06	40.63	43.90	5.556	3.889	4.194	4.444	4.778	4.572
	Mean (G)	46.50	50.00	52.10	48.00	44.60	48.20	7.463	6.176	6.657	6.722	6.611	6.726
	LSD 0.05												
	(S)						NS						0.133
	(SD)						1.08						0.141
	S × SD						1.87						NS
	(G)						1.61						0.150
	S × G						NS						NS
	SD × G						NS						0.272
	S × SD × G						NS						NS

G1= Line 1, G2= Line 2, G3= Line 3, G4= Giza 171, G5= Sids 14 and NS= insignificant.

Grain yield (GY) (ton ha^{-1})

The main target of this investigation was to evaluate the five bread wheat genotypes for their yield potential and crop stability on different planting dates. Grain yield was significantly ($P < 0.05$) affected by seasons, planting dates, and genotypes, as well as their interactions in the 2022/2023 and 2023/2024 growing seasons, except (S × SD), (S × G), and (S × SD × G) over the two seasons that were not significantly impacted (Table 4). The planting date of 15th Nov. is suitable for all tested genotypes and recorded the highest grain yield compared to the other planting dates. It recorded the greatest mean values of GY (8.766, 8.411, and 8.589 ton ha^{-1}) in both seasons and combined over the two seasons. More importantly, Line 1 had superior overall genotypes; it achieved the greatest grain yield (7.778, 7.148, and 7.463 ton ha^{-1}), and the best choice genotype if the farmer has to plant on 15th November, followed by Giza 171. Furthermore, when planted on 15th December, Line 1 achieved the highest grain yield, followed by line 3, as well as the third planting date on 15th January; Line 1 had the highest grain yield in both seasons and combined.

3. Mean performance for Phenological characters

Grain filling period (GFP) (day)

The period between heading to physiological maturity (GFP) revealed highly significant differences between seasons, planting dates, genotypes, and their interactions in both growing seasons, and over the two seasons, except (SD × G) in the second season and (S) over the two seasons (Table 5). Planting on 15th Nov. and 15th Dec. recorded the longest mean values for GFP, while the third planting on 15th Jan. recorded the lowest mean value in both seasons and in the combined. Line 1 recorded the highest GFP followed by Line 3 (55.1 and 54.3 days) in the first season, and Lines 2 and 3 without significant difference from Line 1 in the second season. Also, Lines 1 and 2 gave maximum GFP at the level of the average of the two seasons. In addition, Sids 14 had the lowest GFP in both seasons, as well as combined over the two seasons. In both seasons in the combined analysis, Giza 171 had the shortest GFP under the third sowing date, while Line 3 had the longest GFP under the first sowing date with no evident variation from Line 1.

Grain filling rate (GFR) (kg $ha^{-1}day^{-1}$)

The results in Table 5 revealed that different seasons, planting dates, genotypes, and all the interactions between them had a significant ($P \leq 0.05$) effect on GFR in 2022/2023, 2023/2024 growing season and over the two seasons, except (S) and (S × SD × G) in the combined cross the two seasons. The planting date on 15th Nov. had recorded the highest mean values for GFR (165.6, 148.6, and 157.1 kg $ha^{-1}day^{-1}$) without significance with 15th Dec. in the second season only, while the planting on 15th Jan. had achieved the lowest mean values. The highest GFR was produced for Giza 171 without significance with Sids 14 and Line 1 in both seasons and the average of the two seasons. Giza 171 had achieved the highest GFR (197.8, 167.8, and 182.8 kg $ha^{-1}day^{-1}$) when sown on 15th Nov., while line 2 recorded the lowest one (89.6, 90.9, and 90.3 kg $ha^{-1}day^{-1}$) when sown on 15th Jan. in 2022/2023 and 2023/2024 growing seasons, as well as cross the two seasons, respectively.

Growing Degree Days (GDD) (°C)

GDD was significantly affected by seasons, planting dates, genotypes, and all the interactions between them in both growing seasons and over the two seasons, except (S) and (S × SD × G) in the combined over the two seasons, which were insignificant (Table 5). The first planting date gave the greatest mean values for GDD compared to the second and third planting dates in both seasons and the mean values of the two growing seasons. The lowest values of GDD were recorded by Line 1 (1158, 1168, and 1179 °C) in 2022/2023, 2023/2024, and cross the two seasons, respectively. While, Sids 14 had the greatest values for GDD (1302, 1292, and 1297 °**C**) in the first, second seasons and the average of the two seasons, respectively. Interaction effects presented in Table 5 revealed that Line 2 gave the lowest mean values for GDD (1070 °C) under the third planting date without a significant difference from Line 1 in the first season. In the second season, Line 3 recorded the lowest one (1100 °**C**) without a significant difference from Line 2. Furthermore, Line 1 had minimum values for GDD (1093 °C), followed by Lines 3 and 2 when sown on 15th Jan. over the two seasons. In general, the genotypes Lines 1, 2, and 3 gave the greatest mean values for GDD under three sowing dates (15th Nov. 15th Dec. and 15th Jan.).

Table 5. Mean values for the grain filling period, grain filling rate and growing degree days of the five bread wheat genotypes grown under three planting dates during the two growing seasons of 2022/2023 and 2023/2024, as well as the combined over the two seasons.

Season (S)	Sowing Date (SD)	Grain filling period GFP (day)						Grain filling rate (GFR) (kg ha^{-1}day^{-1})						Growing degree days (GDD) (°C)					
		Genotype (G)					Mean (SD)	Genotype (G)					Mean (SD)	Genotype (G)					Mean (SD)
		G1	G2	G3	G4	G5		G1	G2	G3	G4	G5		G1	G2	G3	G4	G5	
2022/ 2023	15th Nov. (SD1)	61.7	52.9	59.5	46.7	47.3	53.6	164.9	135.3	149.1	197.8	180.8	165.6	1226	1243	1259	1394	1415	1307
	15th Dec. (SD2)	58.3	58.0	60.9	47.1	44.1	53.7	134.7	125.6	117.8	144.3	156.6	135.8	1164	1208	1214	1325	1317	1246
	15th Jan. (SD3)	45.4	41.0	42.4	39.0	39.3	41.4	145.4	89.6	105.4	125.7	127.4	118.9	1083	1070	1090	1154	1174	1114
	Mean (G)	55.1	50.7	54.3	44.3	43.5	49.6	148.3	117.2	124.1	155.9	154.9	140.1	1158	1174	1188	1291	1302	1222
	LSD 0.05																		
	SD						1.40						11.03						4.52
	G						1.84						11.33						12.49
	SD × G						3.01						19.23						19.59
2023/ 2024	15th Nov. (SD1)	57.3	58.7	59.7	53.7	54.7	56.8	160.9	126.5	138.5	167.8	149.4	148.6	1234	1237	1244	1403	1409	1305
	15th Dec. (SD2)	48.7	49.0	50.3	45.3	45.3	47.7	152.9	135.0	143.6	142.1	143.4	143.4	1166	1160	1166	1277	1265	1207
	15th Jan. (SD3)	40.0	43.0	40.0	38.0	38.3	39.9	121.2	90.9	98.4	104.7	119.4	106.9	1103	1132	1100	1186	1202	1144
	Mean (G)	48.6	50.2	50.0	45.6	46.1	48.1	145.0	117.4	126.8	138.2	137.4	133.0	1168	1176	1170	1289	1292	1219
	LSD 0.05																		
	SD						2.91						17.25						15.79
	G						1.63						8.11						13.68
	SD × G						NS						18.74						24.12
Combined over the two seasons	15th Nov. (SD1)	59.5	55.8	59.6	50.2	51.0	55.2	162.9	130.9	143.8	182.8	165.1	157.1	1230	1240	1251	1398	1412	1306
	15th Dec. (SD2)	53.5	53.5	55.6	46.2	44.7	50.7	143.8	130.3	130.7	143.2	150.0	139.6	1165	1184	1190	1301	1291	1226
	15th Jan. (SD3)	42.7	42.0	41.2	38.5	38.8	40.7	133.3	90.3	101.9	115.2	123.4	112.9	1093	1101	1095	1170	1188	1129
	Mean (G)	51.9	50.4	52.1	45.0	44.8	48.8	146.7	117.3	125.5	147.1	146.2	136.5	1163	1175	1179	1290	1297	1221
	LSD 0.05																		
	(S)						NS						NS						NS
	(SD)						1.34						8.50						6.82
	S × SD						2.40						11.52						16.31
	(G)						1.22						6.78						9.02
	S × G						2.23						10.90						15.13
	SD × G						2.41						12.90						17.63
	S × SD × G						3.40						NS						NS

G1= Line 1, G2= Line 2, G3= Line 3, G4= Giza 171, G5= Sids 14 and NS= insignificant.

4. Heat susceptibility index (HSI)

The data in Table 6 show ranged among genotypes from 0.90 for Line 1 to 1.15 for Line 3 and Giza 171. Line 1 and Sids 14 achieved low HSI. One important prerequisite for conventional breeding is the heat susceptibility index (HIS), which is a measure for assessing heat stress. Higher stress tolerance is equivalent to a low-stress susceptibility index estimate (HSI < 1) (Fisher and Mourer 1978).

Table 6. The mean grain yield, relative grain yield to average, and heat susceptibility index (HSI) for the five bread wheat genotypes under investigation.

Genotype	Mean grain yield (ton ha^{-1})	Relative grain yield to average (%)	Heat susceptibility index (HSI)
Line 1	7.463	7.37	0.90
Line 2	6.176	-5.50	1.11
Line 3	6.657	-0.69	1.15
Giza 171	6.722	-0.04	1.15
Sids 14	6.611	-1.15	0.96

5. Stability analysis

The analysis of variance also exhibited highly significant mean squares due to across all environments (three planting dates and two seasons) revealing that genotypes (G), environments (E) and the G×E interaction mean squares significantly influenced the grain yield of the five bread wheat genotypes (Table 7). According to Singh and Narayanan (2000), if the G×E interaction is significant, a stability test can be conducted.

Table 7. The mean squares from a combined analysis of variance for grain yield based on two seasons under three planting dates.

Source of variance	D.f	Mean squares
Environments (E)	**5**	**50.294 ****
Error	**12**	**0.331**
Genotypes (G)	**4**	**3.886 ****
E×G	**20**	**0.502 ****
Error	**48**	**0.202**

** = Significant at 0.01 level of probability.

Table 8 shows a pooled analysis of the variance in grain production across all six environments. The results showed that there were significant differences in grain production among the investigated genotypes, indicating that the genotypes differed significantly in yield performance. The genotypes and the settings in which the trials were conducted varied greatly, as evidenced by the joint regression analysis of variance, which revealed that the mean squares resulting from genotypes (G), environments (E), and GEI was highly significant for grain yield. The significant estimates of GEI revealed that grain yield was unstable and might vary greatly with environmental changes.

Table 8. Stability analysis for grain yield of wheat genotypes grown in six environments.

Source of variance	D.f	Mean squares	Significant.
Genotypes (G)	4	3.89	**
Environment+(G × E)	20	10.46	**
Environment (linear)	1	251.40	**
G × E (linear)	4	0.65	*
Pooled Deviation	20	0.37	*
Line 1 (G1)	4	0.33	NS
Line 2 (G2)	4	0.74	*
Line 3 (G3)	4	0.19	NS
Giza 171 (G4)	4	0.48	NS
Sids 14 (G5)	4	0.11	NS
Average Error	48	0.202	

*, **, NS= Significant at 0.05 and 0.01 probability levels and insignificant, respectively.

Table 9. Estimates of stability and adaptability parameters of grain yield (ton ha^{-1}) for five bread wheat genotypes across six environments

Genotype	Mean grain yield (ton ha^{-1})	Regression coefficient (b_i)	Deviation from regression (S^2d_i)
Line 1	7.463	0.9158	0.044
Line 2	6.176	0.9652	0.178 *
Line 3	6.657	1.099 *	-0.0038
Giza 171	6.722	1.139	0.0942
Sids 14	6.611	0.881	-0.0291

* =Significant at the 0.05 probability level.

Stability parameters for grain yield were calculated according to Eberhart and Russell (1966). Line 1 is classed as extremely stable across settings since its regression coefficients are not significantly different from 1.0. Furthermore, the S^2d_i value was not significantly different from zero, indicating high adaptation and a stable line. Fortunately, this genotype had a mean yield greater than the mean yield of all genotypes under different sowing dates (Table 9).

6. GGE-biplot analysis

To identify the optimum and desirable genotypes, a GGE biplot analysis was used (Figure 2). An ideal genotype should have a high mean yield and be stable across conditions (Kaya *et al*., 2006; Yan and Tinker, 2006). Line 1 (G1) was the selected genotype as it was divided in the central circle. A line that crosses the biplot origin and the environment is used to score the genotypes depending on how well they perform in each environment. This line has been identified as the environment axis (Yan and Tinker 2006), and the genotype ranking follows it. Consequently, the performance ranking of the genotypes is shown in Figure 3. According to the graph, the greatest yielder genotype was Line 1 (G1), which revealed higher stability. In contrast, Line 2 (G2) had the lowest value. Identifying stable, high-yielding genotypes is very important for breeding programs and food security. The superiority and stability of Line 1 under the tested planting dates were validated by GGE biplot analysis and genotype ranking (Figures 2 and 3).

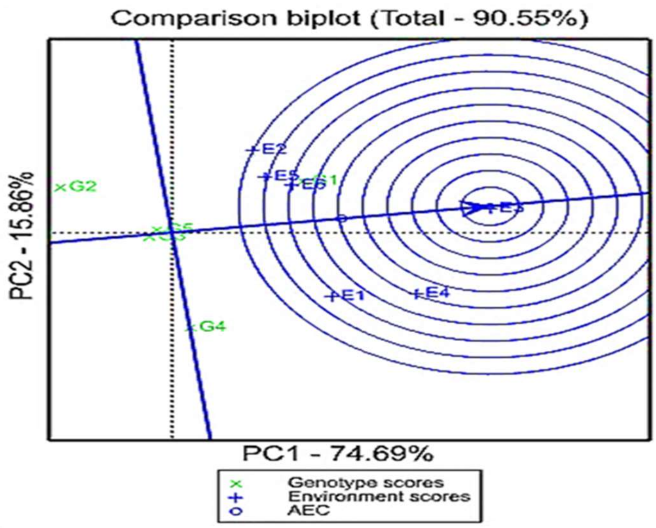

Fig 2. GGE-biplot focused scaling for genotype comparisons. E1-E6 are the environments, whereas G1-G5 are the genotypes.

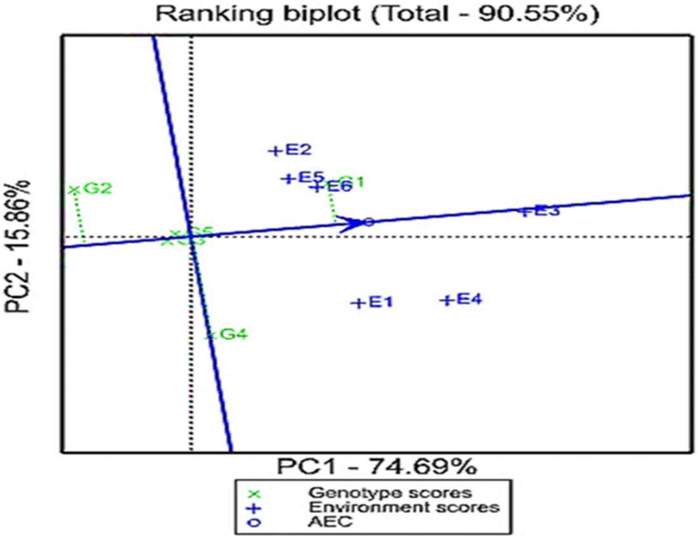

Fig. 3. Identifying winning genotypes across six contexts. E1-E6 are the environments, whereas G1-G5 are the genotypes.

One of the most appealing features of the GGE-biplot is its ability to highlight the "which-won-where" pattern of a genotype by environment dataset, as it graphically addresses crucial subjects such as cross-over GE, mega-environment differentiation, particular adaptation, and so on (Yan and Tinker, 2006). The ideal genotypes for every combination of environment and habitat are displayed in the polygon form of the GGE biplot (Figure 4). Line 1 (G1) achieved the greatest grain yield when planting on three sowing dates (15th Nov., 15th Dec. and 15th Jan.) in season 2021 (E1, E2 and E3), and 15th Nov., 15th Dec. and 15th Jan. in the second season 2023 (E4, E5 and E6). The other genotypes did not record any responses for all the environments.

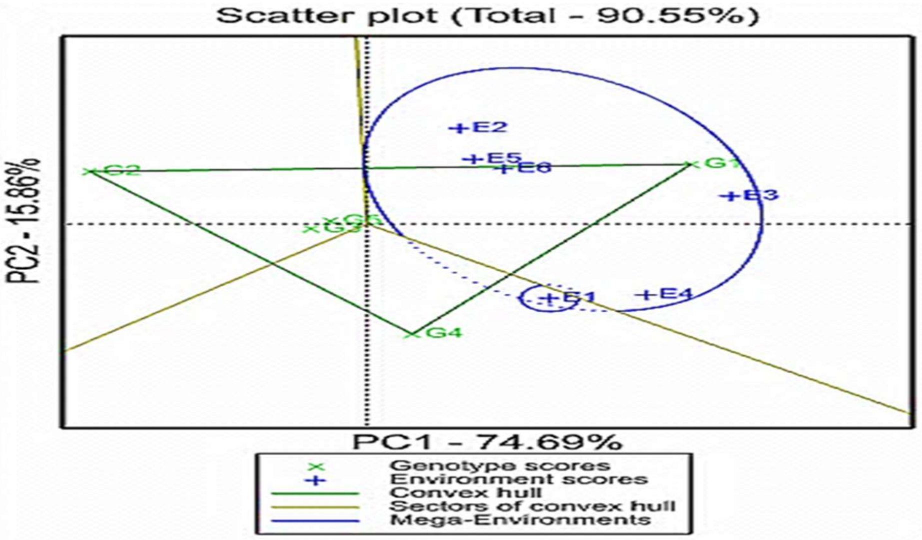

Fig. 4. The GGE biplot's which-won-where a different light reveals which genotypes outperformed which environments in terms of grain yield. The genotypes are G1–G5, and the environments are E1–E6.

Discussions

1. Mean performance for growth characteristics

It is evident from the mean values of the data that the planting date of 15th Nov. showed the greatest number of days to heading, while those planted on 15th Jan. showed a short amount of time to heading. Genotype Line 1 was the earliest one, while Sids 14 was the latest one in both seasons, as well as over the two seasons. These results could be explained by the fact that genotypes remarkably differed in their genetic constitutions. The findings are in agreement with Abdelkhalik *et al.* (2021). In addition, the mean values of the data obtained show that the highest No. of days to heading were produced by Sids 14 when sown on 15th Nov., while Line 1 recorded the earliest one when sown on 15th January. These findings might be attributed to the heat units and accumulated metabolites necessary for wheat heading being decreased in late planting as the air temperature rises (Fig. 1). Mondal *et al*. (2016) found that delaying the sowing date reduced the number of days from sowing to flowering in wheat plants. These results are comparable to those published by Hagras 2019, Al-Otayk *et al*. 2019, Abdelkhalik *et al*. 2021, and Singh *et al*. 2024. Planting on 15th Nov. gave the greatest mean values for No. of days to maturity in comparison to planting on 15th Dec. and 15th Jan. This study indicated that delaying the planting date over the 15th of December decreased this characteristic. Ray and Ahmed (2019) revealed that early crop planting resulted in a longer period of maturity. Line 1 had the earliest genotypes when sown on 15th Nov., 15th Dec. and 15th Jan. without significance with lines 2 and 3 in the two seasons and in the combined data. Mondal *et al*. (2016) found that early maturing genotypes produced better crops for areas experiencing terminal and continuous heat stress, are in line with these results. The crop sowed on the 15th of January matured faster than the other dates due to higher temperatures, which may have been reflected in the growth cycle reducing the wheat plant's photosynthetic capacity and vegetative growth stage, which in turn reduced the amount of grain produced. The identical results were achieved by Hussein 2021, Al-Otayk 2019 and Singh *et al*. 2024.

2. Yield and yield components

Planting on 15th November produced the greatest number of spikes m^{-2} without a significant difference from planting on 15th December in the first, second, and combined seasons as compared to planting on15th January. This suggested that extending the planting date after 15th December resulted in a reduction in the number of spikes m^{-2}. This might be because the climatological conditions at the indicated planting date supported the production of fertile tillers over the later planting date. These results are in harmony with those reported by Abdelkhalik *et al.* (2021) and Hussein (2021). The greatest mean values for $NSPM^{-2}$ were achieved by Line 1 when sown on 15th Dec. and 15th Jan. in the two seasons and a crossover two seasons. The results support that the variation of No of spikes m^{-2} is largely due to the genetic makeup of genotypes and the differences among genotypes in producing fertile tillers. The results noted agree with those published by Xie *et al.* (2018), Ray and Ahmed (2019), Tamiru *et. al*. (2023), Vedi *et al*. (2024) and Bhandari *et al*. (2025).

Concerning the effect of planting dates on (NKS^{-1}), the sowing date of 15th Nov. found a greater number than the other planting dates for the two growth seasons. Line 1 was the better genotype for all the others. It is indicated as the highest value for NKS^{-1} when sown on 15th Nov., 15th Dec., and 15th Jan. in 2022/2023 and 2023/2024 seasons, as well as in the combined over two seasons. Variation among genotypes for NKS^{-1} can be attributed to their genetic constitutions and their interaction with present environmental conditions. These findings are in line with those reported by Abdelkhalik *et al.*, 2021, Hussein 2021, Bhandari *et. al*., 2024 and Nagar 2024.

The optimum planting date (15th Nov.) recorded the heaviest grains than the second and third sowing dates. Thousand-kernel weights decreased accordingly when sowing was delayed. Meanwhile, at the recommended sowing date, the plants experienced favorable and increased environmental conditions for vegetative growth, resulting in active photosynthesis, maximum assimilate transfer to the grains, and therefore the heaviest grains. The results noted agree with those reported by Abdelkhalik *et al.,* 2021, Hussein 2021 and Tamiru *et. al*., 2023 and Bhandari *et al*., 2025.

The recommended planting date on 15th November, It was appropriate for all of the genotypes tested and delivered the greatest grain yield when compared to the other sowing dates. This study found that decreasing the sowing date after the 15th of December resulted in a drop in grain production. These findings reflect the wide variations in the weather that occur during the growing seasons (Fig. 1). The positive influence of wheat grain production on the optimum planting date, results in greater adaptation to phonology, physiology, and ecological conditions (Ray and Ahmed 2019; Hussein 2021 and Nagar 2024). Line 1 was the overall superior genotype and the ideal choice for farmers planting on 15th November. Additionally, the analyzed wheat genotypes may be classified into three groups: Group 1; Line 1 and Giza 171 performed well when sown on 15th November. Group 2; includes Lines 1 and 2, where they performed well when sown on 15th December. Group 3; features the early-maturing genotype Line 1, which yielded the lowest grain yield when sown on 15th January. Furthermore, the wheat genotypes being evaluated exhibited varying responses across different thermo-natural habitats. This highlights the necessity of testing genotypes in diverse environments to identify the most suitable genotype for specific conditions. Similar findings have been reported by Hagras (2019), Abdelkhalik *et al*. (2021), and Bhandari *et al*. (2024).

3. Mean performance for Phenological characters

The planting on 15th Nov. and 15th Dec. dates gave the greatest mean values for GFP, while planted on 15th Jan. date recorded the lowest mean value in both seasons and in the combined. Line 1 achieved the highest GFP in both seasons, as well as over the two seasons. The genotypes of relatively low GFP are relatively early in heading and maturity and as a result, they are highly suited to their regional habitats. Wheat genotypes that can fill their grain fast may have an advantage in situations when crop plants are stresses by high temperatures during grain filling (Moustafa and Hussein 2020 and Sing *et al*., 2024). Cultivar Giza 171 recorded the shortest GFP at sown on 15th Jan. date in all seasons and the combined analysis. Thus, the early genotypes had the shortest No. of days to heading and maturity, which positively affected yield components and thus grain yield, particularly during GFP. Similar results were produced by Hagras (2019) and Moustafa and Hussein (2020).

The planting date on 15th Nov. gave the greatest mean values for GFR without significance with 15th Dec. in the second season only, while the third sowing on 15th Jan. had recorded the lowest mean values. This study found that delaying the planting date over the 15th of December resulted in a decrease in GFR. According to the genotype means, late-heading genotypes had short GFP but high GFR, whereas early ones had opposite results. Giza 171 had the greatest GFR when seeded on 15th November. These findings agree with those of Menshawy (2007), who found that genotypes with extended GFP had reduced GFR in general. Similar findings were achieved by Hagras (2019), Abdelkhalik *et al*. (2021), and Sing *et al*. (2024). It was interesting to observe that GDD estimations didn't change considerably between the two seasons. In this regard, for the majority of the growing season, the first season's minimum and maximum temperatures were lower, while the second season's temperatures were higher (Fig.1). The planted on 15th Nov. date achieved the greatest mean values for GDD compared to the second and third planting dates in the both seasons and the average of the two seasons. This study found that extending the planting date after 15th December resulted in a decrease in growing degree days. The lowest mean values of GDD were recorded by line 1 in 2022/2023, 2023/2024, and across the two seasons, respectively. These results may be due to Line 1 having obtained the least number of days to heading and maturity, which means to produces the lowest thermal units GDD compared to the other genotypes. This is supported by results obtained by Moustafa and Hussein (2020)**,** who found that wheat adapted to environments characterized by high temperature has been reported to mature relatively early and helps prevent heat stress during the crucial grain transferring stages.

Line 1 and Sids 14 showed low HSI (HSI < 1). While, the genotypes line 2, line 3, and Giza 171 showed high HSI values (HSI < 1). Heat-tolerant wheat genotypes were found by comparing yield characteristics in non-stressed (optimal sowing) and heat-stressed (late sowing) environments (Sharma *et al*., 2016). Heat-tolerant genotypes include Sids 14 and lines 1, while heat-sensitive genotypes are Giza 171 and lines 2, 3. According to research by Hagras (2019), Abdelkhalik *et al*. (2021), Vedi *et al*. (2024) and Bhandari *et al*. (2025), late genotypes in flowering dates are more suitable for early sowing.

According to the significant GEI estimates, the production of grain was unstable and could differ significantly depending on environmental variables. With significant mean squares (P < 0.05), the GEI was separated into linear and non-linear components. This indicates the differential reaction to stability in grain production comprised of both predictable and unanticipated components. Shazia *et al*. (2015), and Abd El-Rady and Koubisy (2017) have all found similar findings.

Line 1 is classed as extremely stable across settings since its regression coefficients are insignificantly different from 1.0. Furthermore, the S^2d_i value was insignificantly different from zero, indicating high adaptation and a stable line. Fortunately, this genotype had a mean yield greater than the average yield of all genotypes under different sowing dates (Table 9).

The superiority and stability of line 1 under the tested planting dates were validated by a GGE biplot analysis and genotype ranking (Figures 2 and 3). The consistency of the number of spikes m-2, kernels spike-1, and grain and straw yield in line 1 may be the cause of the final result. The ability of the GGE-biplot to show the "which-won-where" pattern of a genotype by environment dataset is one of its most appealing characteristics. The best genotypes in each environment and combination of habitats are shown in the polygon view of the GGE biplot (Figure 4) (Yan and Hunt, 2001 and Yan *et al*., 2002). Line 1 (G1) produced a high grain yield on planting three dates (15th November, 15th December, and 15th January,) in the first season 2021 (E1, E2 and E3), as well as in the second season 2023 (E4, E5 and E6). While the other genotypes found on the vertices showed no response to any of the environments.

Conclusion

Overall, the early-maturing genotype Line 1, which yielded the lowest grain yield reduction when sown on 15th January. In addition, it is great for sowing in a wide range of sowing dates (15th November to 15th January). Furthermore, it early matures and is suitable for late planting (15th January), which achieves the greatest grain yield when planted on 15th January.

References

Abd El-Rady, A. and Koubisy, Y. S. I. (2017). Performance and stability of some durum wheat genotypes under different sowing dates and nitrogen fertilizer levels. Alexandria Journal of Agricultural Sciences, 62(3): 259-271.

Abdelkhalik, S. A. M. and Hagras, A. A. E. A. (2021). Behavior of some Egyptian bread wheat genotypes under different natural photo-thermal environments. Egyptian Journal of Agricultural Research, 99(2): 142-157. DOI: 10.21608/ejar.2021.62280.1081.

Akcura, M. and Kaya, Y. (2008). Nonparametric stability methods for interpreting genotype by environment interaction of bread wheat genotypes (Triticum aestivum L.). Genetics and Molecular Biology, 31(4): 906-913. DOI: 10.1590/S1415-47572008005000004.

Al-Otayk, S. M. (2019). Evaluation of agronomic traits and assessment of genetic variability in some popular wheat genotypes cultivated in Saudi Arabia. Australian Journal of Crop Science, 13(6): 847-856. DOI: 10.21475/ajcs.19.13.06.p1329.

Bhandari, R. K.; Paudel, H. and Poudel, M. R. (2025). Performance and stability of elite wheat genotypes under irrigated, heat stress and heat drought environment. Current Applied Science and Technology, 25: (1) 1-16. DOI: https://doi.org/10.55003/cast.2024.259959

Bhandari, R.; Paudel, H.; Nyaupane, S. and Poudel, M. R. (2024). Climate resilient breeding for high yields and stable wheat (*Triticum aestivum* L.) lines under irrigated and abiotic stress environments. Plant Stress, 11: 1-14.

Cuevas, J.; Crossa, J.; Montesinos-López, O. A.; Burgueño, J.; Pérez-Rodríguez, P. and de Los Campos, G. (2017). Bayesian genomic prediction with genotype× environment interaction kernel models. G3: Genes, Genomes, Genetics, 7(1): 41-53. DOI:10.1534/g3.116.035584.

Eberhart, S. T. and Russell, W. A. (1966). Stability parameters for comparing varieties1. Crop science, 6(1): 36-40. DOI:10.2135/cropsci1966.0011183X000600010011x.

Economic Affairs Sector, Ministry of Agricultural and land reclamation, Egypt. Annual report 2024.

FAO. (2022). FAOSTAT http:// www. fao.org / faostat /en/#data/QC/visualize.

Fisher, R. A. and Maurer, R. (1978). Drought resistance in spring wheat cultivars. I. Grain yield responses. Australian Journal of Agricultural Research, 29(5): 897-912. DOI: 10.1071/AR9780897.

Gomez M., H. and Richards, R.A. (1997). Effect of early sowing on development in wheat isolines differing in vernalisation and photoperiod requirements. Field Crops Research, 54(1): 91–107. DOI: 10.1016/S0378-4290(97)00057-9.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for agricultural research. John wiley & sons. Toronto, Ontario, Canada.

Hagras, A. A. I. (2019). Response of some early maturing bread wheat genotypes to late sowing date. Egyptian Journal of Plant Breeding, 23(6): 1195-1213. DOI: 10.21608/jpp.2019.71521.

Hussein, A. H. A. (2021). Influence of sowing dates on yield and its components in some early maturing bread wheat genotypes. Egyptian Journal of Agricultural Research, 99(3): 296-313. DOI: 10.21608/EJAR.2021.89865.1131.

Kaya, Y., Akcura, M. and Taner, S. (2006). GGE-biplot analysis of multi-environment yield trials in bread wheat. Turkish Journal of Agriculture, (30): 325-337. https://journals.tubitak.gov.tr/agriculture/issues/tar-06-30-5/tar-30-5-3-0604-6.pdf.

Menshawy, A. M. M. (2007). Evaluation of some early bread wheat genotypes under different sowing dates: 2. Agronomic characters. Fifth Plant Breeding Conference (May 6). Egyptian Journal of Plant Breeding, 11 (1): 41-55 Special Issue.

Mondal, S.; Singh, R. P.; Mason, E. R.; Huerta-Espino, J.; Autrique, E. and Joshi, A. K. (2016). Grain yield, adaptation and progress in breeding for early-maturing and heat-tolerant wheat lines in South Asia. Field crops research, 192, 78-85. (192), 78–85. DOI: 10.1016/j.fcr.2016.04.017.

Moustafa, A. and Hussein, A. H. A. (2020). Performance of some bread wheat cultivars under new land conditions at Middle Egypt. Egyptian Journal of Plant Breeding, 24(4), 721-742. DOI: 10.12816/ejpb.2020.170584

Nagar, J. (2024). Evaluation of the extent of genetic variability and associated traits of bread wheat (*Triticum aestivum* L.) genotypes under heat and drought stress environment conditions. *international* Journal of Advanced Biochemistry Research, 8(10): 1377-1386.

Przulj, N. and Mladenov, N. (1999). Inheritance of grain filling duration in spring wheat. Plant breeding, 118(6): 517-521. https://doi.org/10.1046/j.1439-0523.1999.00436.x

Quan, S.; Li, Y.; Song, J.; Zhang, T. and Wang, M. (2019). Adaptation to climate change and its impacts on wheat yield: perspective of farmers in Henan of China. Sustainability, 11(7): 1928. DOI: 10.3390/su11071928.

Ray, J. and Ahmed, J.U. (2019). Grain growth and yield potential of wheat genotypes under late sown heat stressed condition. Fundamental and Applied Agriculture, 4(1): 671–679. DOI: 10.5455/faa.1122.

Sharma, D.; Singh, R.; Rane, J.; Gupta, V. K.; Mamrutha, H. M. and Tiwari, R. (2016). Mapping quantitative trait loci associated with grain filling duration and grain number under terminal heat stress in bread wheat (*Triticum aestivum* L.). Plant Breeding, 135(5): 538-545. DOI:10.1111/pbr.12405.

Shazia, G.; Bhatt, M. A.; Nida, Y. and Khan, M. A. (2015). Stability analysis for yield, yield component and quality traits in wheat (*Triticum aestivum* L.) under temperate conditions in Kashmir Valley. Plant Archives, 15(1): 433-440.

Singh, C.; Yadav, S.; Khare, V.; Gupta, V.; Kamble, U. R.; Gupta, O. P. and Tiwari, R. (2024). Unraveling the Secrets of Early-Maturity and Short-Duration Bread Wheat in Unpredictable Environments. Plants, 13(20): 2855.

Singh, P. and S. S. Narayanan (2000). Biometrical Techniques in Plant Breeding. Kalyani Publishers, New Delhi, India.

Tamiru, T.; Gemedi, G.; Debelu, B. and Tesfaye, H. (2023). Phenology and yield response of wheat varieties as influenced by sowing dates at gonde and ardayita seed production farm, Ethiopia. Research in Agriculture Livestock and Fisheries, 10(2): 133-145.

USDA (2023). (United States Department of Agriculture), Foreign Agriculture Service. Grain and Feed Annual: Egyptian Wheat Imports Hold Steady Despite Increased Local Production, March 15, 2023.

Vedi, A.; Raghuvanshi, D.; Tripathi, A. and Pandey, G. C. (2024). Characterization of traits associated with grain yield under terminal heat stress in bread wheat (*Triticum aestivum* L.) on the basis of heat susceptibility index. National Academy Science Letters, 47(2): 173-175.

VSN International (2018). Gen Stat for Windows 18th Edition. VSN International, Hemel Hempstead, UK. Available online www.genstat.co.uk.

Xie, W.; Xiong, W.; Pan, J.; Ali, T.; Cui, Q.; Guan, D.; Meng, J.; Mueller, N. D.; Lin, E. and Davis, S.J. (2018). Decreases in global beer supply due to extreme drought and heat. Nature Plants, 4(1): 964–973. http//doi.org: 10.1038/s41477-018-0263-1.

Yan, W. and Hunt, L. A. (2001). Interpretation of genotype× environment interaction for winter wheat yield in Ontario. Crop Science, 41(1): 19-25. http//doi.org:10.2135/cropsci2001.41119x.

Yan, W. and Tinker, N. A. (2006). Biplot analysis of multi-environment trial data: Principles and applications. Canadian journal of plant science, 86(3): 623-645. http//doi.org:10.4141/P05-169.

Yan, W.; Hunt, L. A.; Sheng, Q. and Szlavnics, Z. (2002). Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop science, 40(3): 597-605. https://doi.org:10.2135/cropsci2000.403597x

القدرة المحصولية وثبات بعض التراكيب الوراثية المبشرة المبكرة من قمح الخبز تحت ظروف مختلفة من الإجهاد الحرارى

أحمد حسين أحمد حسين* ومحمود شمروخ محمد

قسم بحوث القمح، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، الجيزة، مصر.

الملخص

أجرى هذا البحث في محطة البحوث الزراعية بملوى بمحافظة المنيا - مصر - خلال موسمي الزراعة 2023/2022م و2024/2023م لدراسة تأثير ثلاثة مواعيد للزراعة على صفات التبكير والمحصول ومكوناته لعدد خمسة تراكيب وراثية من قمح الخبز وتحديد أفضل هذه التراكيب ثباتاً. أظهر التحليل التجميعي فروق عالية المعنوية لكل من المواسم ومواعيد الزراعة والتراكيب الوراثية وتفاعلاتها لمعظم الصفات المدروسة. تفوق ميعاد الزراعة 15 نوفمبر مقارنة بباقي مواعيد الزراعة حيث سجل أعلى القيم لجميع الصفات المدروسة. بينما تأثرت جميع الصفات محل الدراسة تأثراً معنوياً باختلاف التراكيب الوراثية حيث تفوقت السلالات 1، 2، 3 وكانت أبكر النباتات في صفتي طرد السنابل والنضج وأقل قيم لمعدل امتلاء الحبة ودرجات الحرارة التجميعية وسجلت أعلى القيم لفترة امتلاء الحبوب. تفوقت السلالة 1 عن باقي التراكيب الوراثية حيث سجلت أعلى القيم لصفات المحصول ومكوناته. أدى التفاعل بين مواعيد الزراعة والتراكيب الوراثية المختلفة الى وجود اختلافات معنوية في معظم الصفات محل الدراسة حيث سجلت السلالة 1 أعلى محصول حبوب تحت مواعيد الزراعة المختلفة مقارنة بباقي التراكيب الوراثية. وكان الصنف سدس 14 متأخر في ميعاد طرد السنابل والنضج وأقل فترة امتلاء الحبة وأعلى معدل امتلاء الحبة. وتفوقت السلالتان 1،2 بشكل ملحوظ في صفات التبكير وسجلت أقل انخفاض في محصول الحبوب عند الزراعة في الميعاد المتأخر 15 يناير. بالإضافة إلى ذلك فهما أكثر السلالات ملائمة للزراعة في نطاق واسع من 15 نوفمبر إلى 15 يناير. علاوة على ذلك أن إنتاجيتهما عالية في الزراعات المتأخرة لذلك يعتبرا من التراكيب الوراثية المتحملة للإجهاد الحراري. ويمكن التوصية من هذه الدراسة بأن السلالتين 1، 2 أكثر ملائمة للزراعات المتأخرة لذلك ينصح باستخدامهما في برامج التربية للتبكير والإجهاد الحراري.

الكلمات المفتاحية: *التفاعل الجيني والبيئي، الثبات، القمح، دليل الحساسية للحرارة، مواعيد الزراعة.*