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Behavior of some Egyptian bread wheat genotypes under different natural photo-thermal environments

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ABSTRACT
This investigation was conducted during the 2018/2019 and 2019/2020 seasons at Sakha Agricultural Research Station, Egypt to study the influence of four planting dates on earliness and yield of fourteen wheat genotypes. The combined analyses showed highly significant differences due to years, sowing dates, genotypes and their interactions for most studied traits. December 5th was the best sowing date for wheat production. The wheat new genotypes lines 1 and 2 had the lowest days to booting, heading, anthesis and maturity on the other side they had the highest values for grain filling period (GFP) and 1000-kernel weight. Based on the genotype means, the late heading genotype (Giza 163) had short GFP (29.5 days) and possessed a high grain filling rate (233 kg ha^{-1} $days^{-1}$). The cultivar Misr 3 was superior overall genotypes for grain yield (10.529 t $ha.^{-1}$), spikes per square meter (552 spikes), and straw yield (20.164 t $ha.^{-1}$); and it ranked first under early sowing date (Nov. 5th) with 9% higher grain yield overstudied genotypes. According to stability analyses, Misr 3, Sakha 95 and Giza 171 recorded the highest yield, with the regression coefficient values >1. This study recommended release of new wheat genotypes (Lines 1 and 2) as new cultivars and use them to develop early maturing and heat-tolerant bread wheat genotypes in breeding programs.
Keywords: Wheat, Sowing dates, Stability, Heat susceptibility index

INTRODUCTION
Cereal food crops are the main human food source in the world. Wheat is the most important one, it is planted on about 220 million hectares worldwide, and provides one-fifth of the needs of the world's population (FAO 2019). It is one of the central pillars of food security, providing 20% of total calories and a similar portion of the total protein to the global population (Nazim Ud-Dowla *et al.,* 2018). The total wheat production has been steadily increased in Egypt due to high yielding cultivars, favorable weather conditions, efficient use of resources, better storage facilities and governmental support for price policies. However, imports are still increasing every year to supply our growing population with wheat flour. A recent report by the U.S' Foreign Agricultural Service (FAS) in Cairo forecasts Egypt's wheat production in marketing year (MY) 2020/2021 to reach 8.9 million metric tons (MMT). As for imports, FAS Cairo forecasts Egyptian wheat imports in MY 2020/2021 at 12.85 MMT (USDA Economics, Statistics and Market Information System, March 15, 2020)

The agricultural sector is the most susceptible to climate fluctuations. Climate changes have a detrimental effect on agricultural production (Quan *et al*., 2019). It is expected to severely affect cropping systems and food production in many parts of the world unless local adaptation can recover these impacts (Rodríguez *et al*., 2019). The average yield of wheat decreases from 3% to 17% worldwide due to the severity of climate change conditions (Xie *et al.,* 2018). To confront these changes, wheat breeders must increase efforts to improve and develop new cultivars that are higher-yielding, pest and disease resistant, more nutritious and climate-smart (Hickey *et al.,* 2019). The genotypic response of wheat to planting dates varies for yield contributing characters due to different genetic potential (Menshawy *et al*., 2015, Wahid *et al.,* 2017 and Ray & Ahmed 2019). The grain yield is a complex character, as it significantly depending on the number of spikes per unit area, number of kernels per spike and kernel weight, so it is one of the most challenging objectives in wheat breeding (Flohr *et al.,* 2017 and Li *et al.,* 2019). Brdar *et al*. (2008) reported that grain weight, a component of yield in wheat, results from the grain filling process which is defined by two parameters: grain filling duration and grain filling rate.

Grain yield potential increases when cultivars have physical development adapted to the environment (Angus, 2006 and Harris, 2015). Identifying stable, high yielding varieties is crucial for food security (Zhongfu *et al.,* 2018). The relative performance of yield components under heat-stressed and non-stressed environments has been commonly used as an indicator to select heat-tolerant wheat genotypes (Sharma *et al.,* 2016). The variation can be divided into genetic and environmental variance in addition to the genetic × environmental interaction (GEI) (Warzechat *et al.,* 2011). GEI occurs when the genotypes respond differently through environments. It is considered one of the main causes limiting progress in breeding programs and, hence, in agricultural production (Esuma *et al.,* 2016 and Cuevas *et al.,* 2017).

Using suitable sowing dates and promising cultivars is vital to increase wheat productivity (Wahid *et al.,* 2017). An optimum sowing date positively impacts the grain yield of wheat, causing better adjustment to the physiology, phenology and environmental conditions (Ribeiro *et al.,* 2009). In addition, the optimum sowing date also affects water, temperature and solar radiation available for the crop (Silva *et al.,* 2014). Numerous authors (Anderson & Smith 1990, Connor *et al.,* 1992, Owiss *et al.,* 1999, Bassu *et al.,* 2009 and Bannayan *et al.,* 2013) have notified an increased yield with early sowing and a reduction in yield when sowing is delayed after the optimum time and it may be due to avoid frost risk at anthesis or in regions or seasons with low frost risk, aiming at high above-ground biomass at flowering to maximize radiation interception.

The delay in sowing date not only affects yield, but it affects the yield components (Inamullah *et al.,* 2007 and Menshawy *et al.,* 2015) and other aspects of the growth and development of wheat. It is generally related to a reduced kernel weight (Radmehr *et al.,* 2003), a number of spikes per plant and per unit area (Stapper & Fischer 1990), harvest index and number of grains per spike (Ansary *et al.,* 1989). Accurate knowledge of the sowing window of any particular variety at a particular location is critical to achieving a high grain yield (Ortiz-Monasterio *et al.,* 1994). The present study aimed to recognize the influence of planting dates on the performance of fourteen Egyptian bread wheat genotypes, to select the best wheat genotypes for planting under different climates.

MATERIALS AND METHODS

Experimental site:

The experiments of this study were conducted at Sakha Agricultural Research Station, Kafrelsheikh, Egypt during 2018/19 and 2019/20 wheat growing seasons. The geographical location is 31° 5' N latitude, 30° 56' E longitude and 7 m above sea level, in North Delta. The weather data for the investigational site is presented in **Figure (1)** during the two growing seasons**.**

Experimental design and treatments:

The plant material comprised twelve commercial bread wheat cultivars and two national promising lines. Name and pedigree of all genotypes are shown in **Table 1.** These genotypes were evaluated in four **sowing dates** i.e., 5th of November (early sowing), 5th of December (close to normal sowing), 5th of January (late sowing) and 5th of February (very late sowing). Each sowing date in each year was considered as a separate experiment. The area of each plot was 2 m^2 and consisted of 5 rows, 2 m long and 20 cm apart. **Planting was done** using sowing rate of 350 seeds m^{-2}. The experiment was laid out in a Randomized Complete Block Design with three replications in each sowing date. All the wheat recommendation packages in North Delta Region were applied.

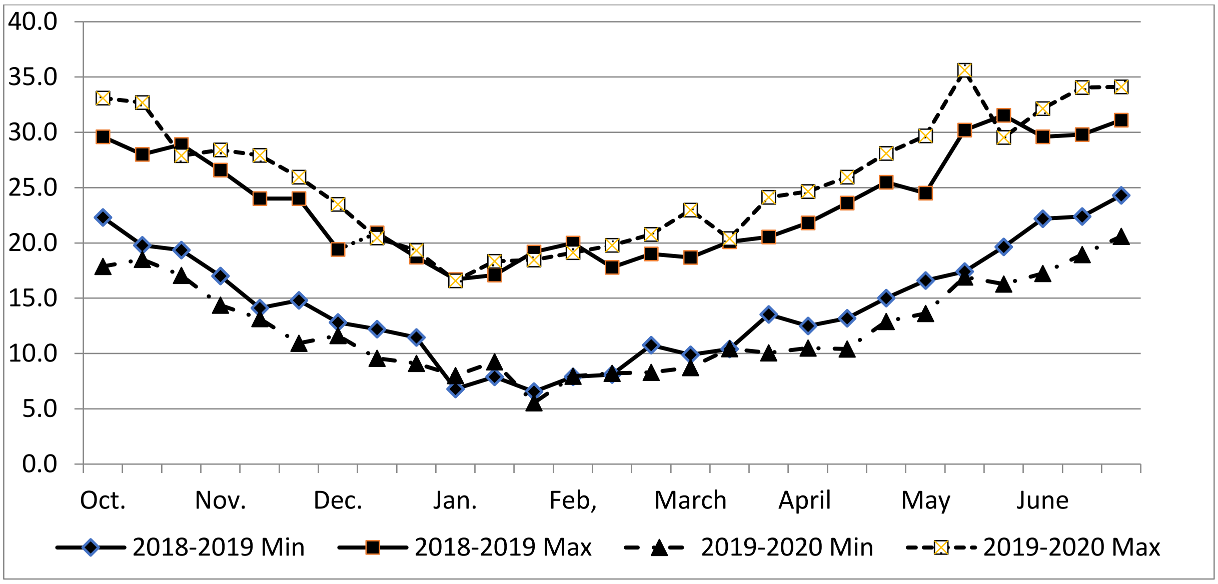

Figure 1. Average 10 days minimum (Min) and maximum (Max) temperature from October to June 2018/2019 and 2019/2020 at Sakha Agricultural Research Station.

Studied characters and data collection:

The studied characteristics consisted of earliness and agronomic components. The earliness components were: the number of days to booting (DB), to heading (DH), to anthesis (DA), and maturity (DM), grain filling period (GFP, equal to the number of days from anthesis to maturity) and grain filling rate (GFR, equal to grain yield divided by GFP). The agronomic characteristics were taken on plant height, number of spikes per square meter (Sm^{-2}), number of kernels per spike (KS^{-1}), 1000-kernel weight (TKW), grain yield, straw yield and harvest index. Grain and straw yields were measured and converted into ton per hectare. In addition, the number of days to heading also was expressed as growing degree days (GDD). The GDD were calculated according to Gomez & Richards 1997, in which GDD $=\sum[(T_{max i} + T_{min i})/2 - T_b]$ where $T_{max\,i}$ and $T_{min\,i}$ are the maximum and minimum daily air temperature on the *i*th day and T_b is the base temperature below which the rate of development is assumed to be zero. Weather data were collected from the Central Laboratory for Agricultural Climate Meteorological Station, Agricultural Research Center, Ministry of Agriculture and Land Reclamation.

The heat susceptibility index (HSI) was used as a measure of heat tolerance in terms of minimization of the reduction in yield caused by unfavorable versus favorable environments. HSI was calculated in late sowing as heat stress (very late sowing versus normal sowing). For each genotype, HSI was calculated according to the formulae of Fisher &Maurer (1978): HSI = $(1-y_h/y_p)/H$. Where: y_h = mean yield in heat environment (very late sowing date), y_p= mean yield in normal condition (potential yield), H = heat stress intensity = 1-(y_h of all genotypes/y_p of all genotypes).

The genotype main effect plus G x E interaction (GGE biplot) (Akcura and Kaya 2008) was used to visualize the G x E interaction. The G xE analysis was conducted using R (software) package GEA-R (Version 4, 2017, CIMMYT, El Batan, Mexico) (Pacheco *et al.* 2018). The GGE biplot of grain yield for the studied wheat genotypes was done for the eight environmental conditions (four sowing dates x two years)

Statistical analysis:
The collected data for all variables were statistically analyzed using MSTATC statistical package microcomputer program (MSTATC, 1990) via analysis of variance using randomized complete block, one factor mode1, combined across years and sowing dates. The means of sowing dates and genotypes were obtained and differences were assessed with LSD at 5% level of probability.

Table 1. Name, pedigree, and selection history of the fourteen tested bread wheat genotypes.

Name	Pedigree	Selection history
Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR	CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S
Misr 2	SKAUZ/BAV92	CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S
Misr 3	ATTILA*2/PBW65*2/KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B-0EGY
Sakha 94	OPATA/RAYON//KAUZ	CMBW90Y3180-0TOPM-3Y-010M-010M-010Y-l0M-0I5Y-0Y-0AP-0S.
Sakha 95	PASTOR//SITE/MO/3/CHEN/ AEGILOPS SQUARROSA(TAUS)//BCN/4/WBLL1	CMSA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.
Line1	SIDS1/ATTILA//GOUMRIA-17	S. 16498-042S-013S-21S -0S
Line 2	MINO/6/SAKHA 12/5/KVZ//CNO 67/PJ 62/3/YD "S"/BLO "S"/4/K134 (60)/VEE	S. 16869-010S -07S-1S-2S -0S
Giza 163	T. AESTIVUM/BON//CNO/ 7C	CM33009-F-15M-4Y-2M-lM-1M-1Y-0M
Giza 171	SAKHA 93/GEMMEIZA 9	S.6-lGZ-4GZ-lGZ-2GZ-0S
Gemmiza 9	ALD “S”/HUAC//CMH 74A. 630/ SX	GM 4583-5GM-1GM-0GM
Gemmiza 12	OTUS/3/SARA/THB//VEE	CMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM
Sids12	BUC//7C/ALD/5/MAYA74/ ON//1160.147/3/BB/GLL/4/CHAT"S" /6/MAYA/VUL//CMH74A.630/4*SX	SD7096-4SD-1SD-1SD-0SD
Sids 14	BOW "S"/VEE"S"//BOW"S"/TSI/3/BANI SEWEF 1	SD293-1SD-2SD-4SD-0SD
Shandaweel 1	SITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC	CMSS93B00567S-72Y-0l0M-010Y-010M-3Y-0M-0HTY-0SH

RESULTS

Analysis of variance:
The combined analyses showed highly significant differences (P ≤ 0.01) due to years, sowing dates and genotypes for all the studied traits. The differences due to the interactions between genotypes and each of years and sowing dates and interactions among genotype, sowing date and year were significant for all the studied characteristics except for GFR, SY and harvest index (supplementary **Tables 1 & 2**).

The largest proportions of mean squares for most studied characteristics were due to sowing dates. Meanwhile, the proportion of mean squares due to years was higher only in three characteristics i.e., harvest index, SM^{-2} and KS^{-1}. The magnitude of mean squares due to genotypes was noticed for GDD, DH, DA and TKW.

Year and sowing date effect:
The characteristics DB, DH, DA and DM, plant height, SM^{-2} and straw yield recorded significantly higher values in the first season comparing to the second, while the remaining studied characters recorded significantly higher values in the second season (Tables 2 & 3 and supplementary Table S3). It was interesting to notice that growing degree days' estimates did not differ significantly between the two seasons. In this respect, the first season recorded higher degrees of minimum and lower degrees of maximum temperature during most of the growing season while the second season was vice versa (Fig.1).
In general, the first and second sowing dates (5th November and 5th December) recorded the highest mean values for most studied characteristics. The first sowing date recorded the highest mean values for DM, GDD and GFP. Meanwhile, the highest mean values for DB, DH, DA, GFR, plant height, grain yield, KS^{-1}, TKW and straw yield recorded in the second sowing date.

Genotype effect:
Genotype effects were highly significant on all studied traits when the data were combined across years and planting dates. Therefore; the comparisons among genotypic means are valid. The least values of DB, DH, DA and DM recorded by Lines 1 and 2. Also, they recorded the highest values for GFP and TKW where the differences were significant with most of the remaining genotypes.

Line 2 was the earliest genotypes, it's recorded the least number of DB, DH, DA and DM and lowest GDD. Both Lines 2 and 1 reached heading after accumulation of the lowest thermal units (1023 and 1056 units, respectively). The shortest GFP (29.5 days) was recorded for Giza 163 followed by Gemmiza 9, Sakha 95 and Misr 2. Based on the genotype means, the late heading genotypes had short GFP and possessed high GFR, while the reverse was found for early ones. The highest GFR was recorded for Sakha 95 (279 kg day^{-1} ha^{-1}) followed by Sakha 94 and Misr 3. These results are in accordance with the findings of Menshawy (2007) who reported that the genotypes which had long GFP showed low GFR in general.

Table 2. Mean values of earliness characters for fourteen bread wheat genotypes grown under four sowing dates during the two growing 2018/2019 and 2019/2020 seasons.

Variable	DH†	DM	GFP (day)	GFR (kg/ha/day)	GDD (°C)
Year					
2018/2019	88.3	137.9	39.6	230.6	1242.8
2019/2020	83.3	132.7	40.3	248.7	1244.4
F test	**	**	**	**	Ns
Sowing date					
Nov. 5th	88.3	154.6	51.9	210.8	1369.8
Dec. 5th	96.8	146.4	39.4	275.6	1325.8
Jan. 5th	86.2	130.6	37.5	259.0	1183.2
Feb. 5th	71.9	109.5	31.0	213.3	1095.5
LSD 0.05	0.4	0.4	0.5	8.8	6.9
Genotype					
Misr 1	86.8	134.6	40.0	245.8	1252.6
Misr 2	90.0	137.8	37.8	246.0	1298.8
Misr 3	85.5	136.6	41.4	255.7	1233.1
Sakha 94	88.7	134.9	38.0	256.0	1282.6
Sakha 95	87.5	134.8	37.7	279.0	1260.9
Line 1	72.5	128.2	46.0	223.9	1056.2
Line 2	70.3	127.8	46.8	218.9	1023.2
Giza 163	105.7	143.3	29.5	233.5	1553.0
Giza 171	85.7	137.0	42.3	248.6	1240.4
Gemmiza 9	90.5	138.2	37.6	235.2	1315.5
Gemmiza 12	85.0	134.2	41.1	217.6	1228.1
Sids12	79.8	133.1	42.8	208.3	1152.2
Sids 14	88.6	136.1	38.0	258.7	1284.2
Shandaweel 1	84.9	137.4	40.5	228.2	1229.3
LSD 0.05	0.79	0.76	0.93	16.41	12.95

DH; number of days to heading, DM: number of days to maturity, GFP: grain filling period, GFR: grain filling rate, GDD: growing degree days.

Table 3. Mean effects of yield characters and harvest index for fourteen bread wheat genotypes grown under four sowing dates during the two growing seasons 2018/2019 and 2019/2020.

Variable	Grain yield (t ha^{-1})	SM^{-2}†	KS^{-1}	TKW (g)	Harvest index (%)
Year					
2018/2019	9.013	545	53.0	41.3	32.4
2019/2020	9.913	424	63.4	43.0	37.9
F test	**	**	**	**	**
Sowing date					
Nov. 5th	10.717	472	60.4	45.2	34.9
Dec. 5th	10.783	508	60.6	45.6	34.8
Jan. 5th	9.685	518	58.5	42.4	37.6
Feb. 5th	6.667	441	53.2	35.5	33.3
LSD 0.05	0.321	23.64	2.04	1.34	1.07
Genotype					
Misr 1	9.838	547	55.8	41.8	35.7
Misr 2	9.331	542	62.5	37.8	32.1
Misr 3	10.529	552	52.3	43.7	34.5
Sakha 94	9.685	489	57.5	41.1	38.9
Sakha 95	10.517	515	56.0	44.2	37.9
Line 1	10.025	497	52.9	44.5	39.0
Line 2	9.878	469	51.6	49.4	40.3
Giza 163	7.022	440	52.9	37.7	27.0
Giza 171	10.347	425	62.6	46.8	35.9
Gemmiza 9	8.87	444	59.9	40.6	31.8
Gemmiza 12	8.867	463	59.6	41.5	34.8
Sids12	8.626	376	69.2	40.2	38.0
Sids 14	9.898	495	60.0	43.8	33.5
Shandaweel 1	9.045	531	61.8	37.2	32.7
LSD 0.05	0.60	44.23	3.82	2.52	2.00

† SM^{-2}: number of spikes per square meter, KS^{-1}: number of kernels per spike, TKW: one thousand kernel weight.

Interaction effects:

All factors except genotypes and sowing dates were considered random. Therefore, only the most interesting interactions, genotypes × sowing dates, will be discussed. Interaction effects presented in Tables 4 and 5 and supplementary Table S5 showed that Line 2 and Line 1 recorded the lowest values for DB, DH, under the first sowing date and for DA, DM and GDD under the fourth sowing date. Meanwhile, Giza 163 recorded the highest values for DB, DH, DA, DM and GDD under the first sowing date. The shortest GFP was recorded for Giza 163 under the fourth sowing date while the longest one was recorded for Line 2 under the first sowing date. The highest GFR was recorded for both Misr 2 and Giza 163 under the second sowing date, while the lowest one was recorded by Giza 163 under the fourth sowing dates.

The results of this study indicated that there are some genotypes performed well under specific sowing date and did not differ significantly in their grain yield (Figure 3). Under the first sowing date (5th Nov.), the highest grain yield was produced by Misr 3, Sids 14, Sakha 95 and Giza 171. The highest grain yield under the second sowing date (5th Dec.) was produced by Sakha 95, Misr 2, Misr 1, Giza 171, Misr 3, Sids 14 and Line 1. Under the third sowing date (5th Jan.), the highest grain yield was produced by Misr 3, Sakha 95, Sids 14, Giza 171, Line 2, Sakha 94 and Misr 2. The highest grain yield under the fourth sowing date (5^{th} Feb.) was produced by Line 1, Line 2, Sids 12, Giza 171 and Sakha 95.

The highest values for SM^{-2} were recorded by Shandaweel 1 on 5^{th} Nov., Line 1 on 5^{th} Dec., Sids 14 on 5^{th} Jan. and Misr 3 on 5^{th} Feb. sowing date. It was interesting to notice that the three cultivars Misr 1, Misr 2 and Misr 3 were among the highest genotypes in SM^{-2} in all the tested sowing dates. Out of the tested 14 genotypes, 5 to 9 genotypes did not differ significantly in their SM^{-2} with the highest ones, where the highest number of such genotypes was on 5^{th} Jan. followed by 5^{th} Feb. then 5^{th} Dec. and 5^{th} Nov.

The highest KS^{-1} was recorded by the cultivar Sids 12 in the first, second and fourth sowing dates while it was recorded by Misr 2 in the third sowing date with an insignificant difference from that of Sids 12. At least three cultivars did not differ significantly in their KS^{-1} from the highest cultivar in each of the four sowing dates. From these cultivars Giza 171 in the second, third and fourth sowing dates and Shandaweel 1 in the first, third and fourth sowing dates.

The highest values for TKW was recorded by Line 2 in the first, third and fourth sowing dates. Meanwhile, the highest value was recorded by Giza 171 in the second sowing date and did not differ significantly from that of Line 2 in the other three sowing dates. The following genotypes recorded high values for TKW and their values did not differ significantly from that of the highest genotype; Line 1 in the first, third and fourth sowing dates; Misr 3 in the first and third sowing dates; Sakha 95 in the second and third sowing dates; Sids 14 in the third and fourth sowing dates.

The tallest plants were recorded by Sids 14 in 5^{th} Dec. sowing date and its value did not differ significantly from that of the tallest plants in the first and third sowing date. Both cultivars Misr2 and Giza 163 recorded the tallest plants in the first, third and fourth sowing dates, respectively. The following three cultivars recorded high values for plant height and their values did not differ significantly from that of the tallest ones; Sakha 95 on 5^{th} Nov., Giza 171 on 5^{th} Dec., Gemmiza 9 on 5^{th} Jan. sowing dates.

The highest SY was recorded for Sids 14 on 5^{th} Dec. followed by Gemmiza 9 on 5^{th} Nov. then Sids 14 on 5^{th} Jan. and Giza 163 on 5^{th} Feb. sowing date. Misr 3 recorded high values for SY yield in the four sowing dates and its values did differ significantly from that of the highest cultivars. In addition, both Misr 2 and Shandaweel 1 cultivars recorded high values under the first and third sowing dates. The following cultivars recorded their high values under specific sowing date; Sakha 95 on 5^{th} Nov., Gemmiza 9, Giza 171 and Gemmiza 12 on 5^{th} Jan sowing date.

The highest harvest index value was recorded for Sids 12 on 5^{th} Feb. sowing date followed by Line 2 on both 5^{th} Jan. and 5^{th} Nov. sowing dates, and then Sakha 94 on 5^{th} Dec. sowing date. Line 1 recorded high values for harvest index under the four sowing dates and its value did not differ significantly from that of the highest genotypes. Sakha 95 was among recorded the highest harvest index genotypes under both 5^{th} Dec. and 5^{th} Jan. The differences were insignificant between values of the following genotypes and that of best genotypes in the harvest index; Giza 171 on 5^{th} Nov., both Misr 1 and Misr 2 on 5^{th}Dec., and Sakha 94 on 5^{th} Jan sowing date.

Stability analysis:

Combined analysis of variance revealed that genotypes (G), environments (E) and their interaction (GEI) mean squares had a highly significant effect on grain yield of the studied wheat genotypes across 8 environments, i.e. 4 sowing dates in 2-years (supplementary Table 4). Singh and Narayanan (2000) reported that, if GEI interaction is found to be significant, the stability analysis can be carried out. Environments effects accounted for the largest proportion of sums of squares (57.21%) followed by genotypic effects (14.57%) then GEI effects captured (14.13%), all terms being highly significant. Environmental variation was conquered by the sowing date effect.

GGE biplot analyses for comparison of genotypes were performed to detect the ideal and desirable genotypes (**Figure 2**). An ideal genotype should have both high mean yield performance and high stability across environments (Kaya *et al*. 2006 and Yan and Tinker 2006). Giza 171, Sakha 95 and Misr 3 (G9, G5 and G4, respectively) were the desirable genotypes as they grouped in the centric circle. However, Giza 163 (G8) seems to be undesirable.

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 3** showed rank of genotypes performance. From the graph, the highest yielder genotype was Giza 171 (G9) followed by Sakha 95 (G5) and Misr 3 (G3) but Giza 171 showed more stability. In the contrast, Giza 163 (G8) was the lowest.

Table 4. Mean values over two years (2018/19 and 2019/20) for days to heading, days to maturity, grain filling period, grain filling rate and growing degree days of fourteen bread wheat genotypes grown under four sowing dates.

Genotype	Days to heading				Days to maturity				Grain filling period (day)				Grain filling rate (kg ha^{-1} day^{-1})				Growing degree days (^{o}C)			
	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.
Misr 1	94	97	85	71	155	145	129	109	49.3	40.7	38.3	31.5	228.7	292.2	246.4	216.0	1436	1326	1165	1084
Misr 2	99	99	88	73	161	148	132	110	45.7	37.0	37.5	30.8	213.5	322.1	266.2	182.3	1509	1362	1207	1118
Misr 3	88	97	87	71	157	148	133	109	55.2	41.3	38.3	30.8	228.6	277.7	293.4	223.1	1354	1321	1188	1070
Sakha 94	95	99	88	73	155	147	130	108	47.5	38.3	36.7	29.5	229.4	278.5	275.9	240.1	1456	1362	1205	1107
Sakha 95	96	97	86	72	156	146	128	110	45.3	39.0	35.3	31.0	255.3	309.8	313.3	237.8	1469	1318	1168	1089
Line 1	63	85	77	66	141	140	126	107	62.7	44.7	40.3	36.5	170.3	255.2	236.3	233.8	1056	1149	1033	987
Line 2	60	81	75	64	142	138	126	106	66.2	44.5	40.5	36.0	159.8	243.3	255.4	217.0	1020	1099	1011	963
Giza 163	127	112	96	87	170	152	134	117	34.7	28.2	29.8	25.2	261.7	315.4	259.7	97.1	1895	1562	1361	1393
Giza 171	84	98	89	72	154	150	133	111	56.7	41.7	39.5	31.5	203.3	282.1	269.5	239.6	1304	1342	1217	1099
Gemmiza 9	95	101	90	76	159	150	133	111	49.0	38.3	35.0	28.2	222.3	265.1	245.7	207.8	1456	1394	1253	1160
Gemmiza 12	86	97	86	71	153	145	131	108	53.2	40.8	39.3	31.2	190.4	247.0	219.9	213.0	1330	1324	1177	1081
Sids12	76	94	83	67	150	145	130	108	57.0	41.8	39.7	32.5	160.2	215.6	217.6	239.7	1208	1278	1124	999
Sids 14	91	101	90	73	156	148	132	109	48.5	37.5	37.2	28.7	241.5	302.7	287.1	203.6	1401	1384	1240	1112
Shandaweel 1	82	98	89	71	157	149	134	110	55.3	38.0	37.8	30.7	185.9	252.2	239.2	235.6	1285	1339	1218	1076
LSD $_{0.05}$	1.6				1.5				1.9				32.8				25.9			

Table 5. Mean values over two years (2018/19 and 2019/20) for grain yield, spikes per square meter , kernels per spike, 1000-kernel weight , and harvest index of fourteen bread wheat genotypes grown under four sowing dates

Genotype	Grain yield (ton ha.$^{-1}$)				Spikes per square meter				Kernels per spike				1000-kernel weight (g)				Harvest index (%)			
	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.
Misr 1	11.30	11.83	9.44	6.79	585	572	535	497	60.9	57.4	52.1	52.9	44.9	47.4	42.3	32.8	34.8	35.9	39.4	32.7
Misr 2	9.75	11.97	10.00	5.61	546	610	512	501	62.8	62.9	66.8	57.5	42.5	39.6	39.2	29.8	29.6	36.4	35.3	26.8
Misr 3	12.58	11.49	11.19	6.86	540	607	546	517	54.1	47.7	57.7	49.7	49.2	46.0	43.4	36.1	36.1	32.9	38.8	30.1
Sakha 94	10.90	10.65	10.11	7.09	488	494	519	454	64.3	57.5	57.0	51.3	41.9	43.4	41.9	37.3	36.6	39.4	41.2	38.5
Sakha 95	11.58	12.07	11.05	7.37	545	511	567	436	57.7	58.3	53.6	54.3	47.0	52.1	43.2	34.5	33.8	37.6	41.4	38.7
Line 1	10.65	11.39	9.53	8.53	396	612	512	470	48.9	54.3	57.5	51.0	51.3	45.8	43.5	37.4	37.9	36.8	40.1	41.2
Line 2	10.55	10.83	10.35	7.79	346	525	567	439	47.9	56.3	54.1	48.2	54.6	52.6	48.1	42.4	41.5	36.4	43.4	40.0
Giza 163	9.09	8.88	7.69	2.43	425	416	504	417	55.1	65.1	56.6	34.8	35.9	42.1	40.6	32.3	30.9	32.8	32.6	11.8
Giza 171	11.50	11.69	10.66	7.55	404	405	549	341	60.6	68.1	61.5	60.3	51.5	53.2	44.0	38.4	37.4	33.7	37.4	35.1
Gemmiza 9	10.92	10.16	8.54	5.86	443	433	505	395	69.3	57.1	57.5	55.7	43.7	44.8	41.2	32.5	31.6	33.2	33.0	29.5
Gemmiza 12	10.13	10.04	8.65	6.65	441	496	469	446	60.5	64.6	58.3	54.9	44.2	43.6	42.3	35.8	36.3	33.9	33.5	35.4
Sids12	9.08	9.01	8.64	7.77	374	377	438	315	74.1	72.2	65.9	64.5	41.4	43.2	39.9	36.3	34.7	33.8	39.9	43.6
Sids 14	11.68	11.42	10.66	5.83	462	524	568	427	65.9	64.6	56.4	53.2	48.4	45.8	43.4	37.8	35.8	31.6	36.9	29.6
Shandaweel 1	10.33	9.55	9.08	7.23	609	537	460	516	64.0	62.4	63.9	57.1	36.0	38.4	40.4	33.9	32.1	32.2	33.2	33.4
$LSD_{0.05}$	1.2				88				7.6				5.0				4.0			

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 4**) indicates the best genotype(s) in each environment and groups of environments (Yan *et al.,* 2000 and Yan and Hunt 2001). Sakha 95 (G5) and Misr 3 (G3) gave high yield at Nov. 5th , 2019, Jan. 5th , 2020 and Jan. 5th , 2019 sowing dates (E5, E7 and E3), Giza 171 (G9) gave high yield at Nov.5th , 2018, Dec. 5th , 2018 and Jan. 5th , 2019 sowing dates (E1, E2 and E3), Line 1 (G6) gave high yield at Feb. 5th , 2019 and Feb. 5th , 2020 sowing dates (E4 and E8) and Sids 14 (G13) gave high yield on Dec. 5th , 2019 sowing dates (E6). The other genotypes lying on the vertices did not respond at any of the environments.

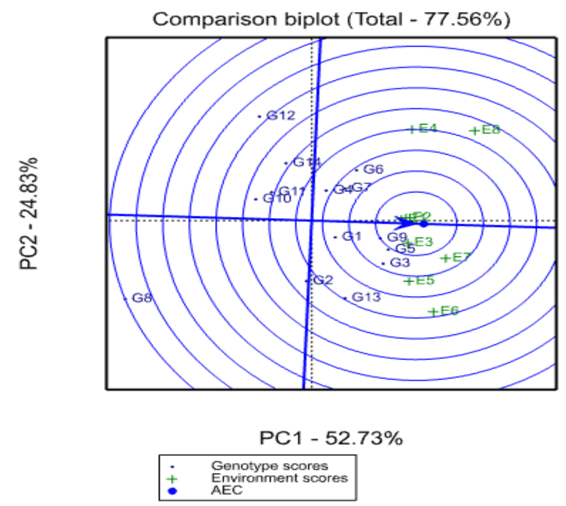

Figure 2. GGE-biplot focused scaling for comparison of the genotypes. E1 –E8 are the environments; G1-G14 *are* the genotypes.

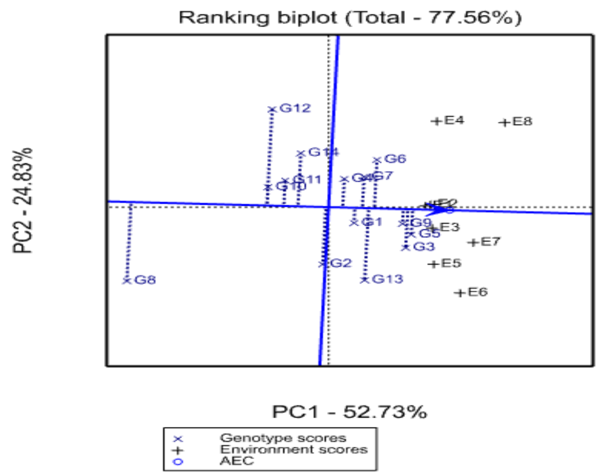

Figure 3. Identification of winnig genotypes across 8 environments. E1 –E8 are the environments; G1-G14 are the genotypes.

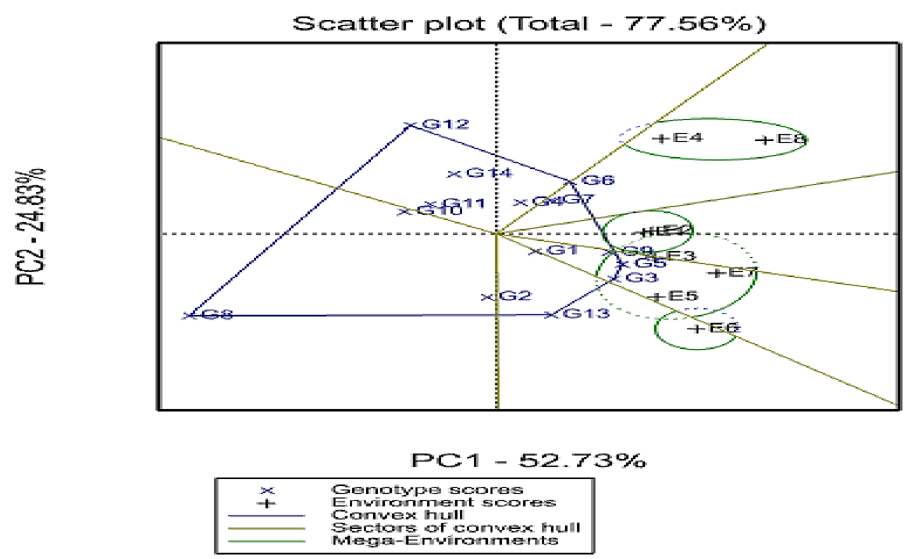

Figure 4. The which-won-where view of the GGE biplot to show which genotypes performed better in which environment for grain yield. G1-G14 are the genotypes; E1 –E8 are the environments.

Heat susceptibility index (HSI):

The HSI estimates ranged among genotypes from 0.36 for Sids 12 to 1.39 for Misr 2 (**Table 6**). The genotypes Sids 12, Shandaweel 1, Line 1, Gemmiza 12 and Sakha 94 recorded low HSI (HSI<1). Meanwhile, the genotypes Misr 2, Sids 14, Misr 1 and Gemmiza 9 had high HSI values (HSI >1).

Table 6. Mean grain yield, relative grain yield to average and heat susceptibility (SI) index for grain yield of the studied wheat genotypes

Genotype	Mean grain yield (ton ha^{-1})	Relative grain yield to average (%)	Susceptibility index
Misr 1	9.84	3.97	1.12
Misr 2	9.33	-1.39	1.39
Misr 3	10.53	11.27	1.06
Sakha 94	9.69	2.35	0.88
Sakha 95	10.52	11.14	1.02
Line 1	10.03	5.94	0.66
Line 2	9.88	4.39	0.74
Giza 163	7.02	-25.79	1.90
Giza 171	10.35	9.35	0.93
Gemmiza 9	8.87	-6.26	1.11
Gemmiza 12	8.87	-6.30	0.88
Sids12	8.63	-8.84	0.36
Sids 14	9.90	4.60	1.28
Shandaweel 1	9.05	-4.42	0.64

DISCUSSION

The analysis of variance showed significant differences due to years reflected the differences in climate conditions during the two growing seasons (**Fig. 1).** The significance of differences among genotypes and their interactions with sowing date and year indicated that genotypes ranked differently via sowing dates. These results coincide with the findings of Talukder *et al.* (2014), Menshawy *et al*. (2015), Al-Otayk *et al*. (2019) and Hagras (2019).

Year and sowing date effect:

This study indicated that delaying sowing date after 5th Dec. recorded a reduction in most studied characteristics. The mean values for grain yield, KS^{-1}, plant height and SY did not differ significantly under both the first and second sowing date. These results may be due to the appropriate temperature at different developmental stages. The third sowing date (5th January) recorded the highest mean values for SM^{-2} and harvest index. Although the third sowing date recorded the highest means for SM^{-2} and KS^{-1} but this did not reflect in higher grain yield. On the other hand, the fourth sowing date (5th February) recorded the least mean values for all studied characters except for GFR. Thus the late-sowing recorded the least number of days for earliness characters and growing degree days which negatively affected yield components and hence the grain yield. The positively impacts the wheat grain yield in an optimum sowing date, causing better adjustment to the phonology, physiology and ecological conditions (Menshawy *et al.,* 2015, Wahid *et al.,* 2017, Hagras 2019 and Ray & Ahmed, 2019). Different reasons were reported for grain yield reductions under late sowing (heat stress), especially during GFP. The reduction in grain yield in different sowing dates was reported to be due to many reasons; Zhao *et al*. (2008) to the reduction in activities of vital enzymes involved in starch accumulation; Hedhly *et al*. (2009) to the effect on pollen composition, morphology, quantity, metabolism and pollen tube growth rate; Riaz- Ud-Din *et al*. (2010) to be due to the reduction in SM^{-2} and grain yield and shortened DH, DM and GFP and Cossani & Reynolds (2012) to abnormal anther formation in a high percentage of florets.

Genotype performance:

Giza 163 cultivar recorded the tallest plants with an insignificant difference with both Misr 2 and Sids 14. The cultivar Misr 3 was superior overall genotypes for grain yield, SM^{-2}, and SY; 10.529 ton, 552 spikes and 20.164 ton, respectively. The following cultivars recorded the highest values for specific characters with insignificant differences among them; Misr 3, Sakha 95, Giza 171 and Line 1 in grain yield; Misr 1, Misr 2, Misr 3, Shandaweel 1 and Sakha 95 in SM^{-2}; Giza 171, Misr 2, Shandaweel 1, Sids 14, Gemmiza 9 and Gemmiza 12 in KS^{-1}; Line 1, Sakha 95, Sids 14 and Misr 3 in TKW; Misr 3, Sids 14, Misr 2 and Gemmiza 9 in SY; Line 2, Line 1 and Sakha 94 in harvest index. It was interesting to notice that, Line 1 was early by 15 days in heading, 13 days in both booting and anthesis and 8 days in maturity and did not differ significantly in grain yield with Misr 3 (10.025 and 10.529 ton, respectively). These results coincide with the findings of Mondal *et al.* (2016) who reported that early maturing genotypes are an excellent crop adaptation approach in regions suffering from terminal and continual high-temperature stress. Many researchers reported significant differences among genotypes for earliness and agronomic characters (Talukder *et al.,* 2014, Menshawy *et al.,* 2015, Wahid *et al.,* 2017, Hagras 2019 and Al-Otayk *et al.,* 2019).

Interaction effects:

5th Dec. sowing date is suitable for all tested genotypes except Misr 1 as their grain yield did not record a significant reduction comparing to 5th Nov. sowing date. This is an advantage of saving one month time and irrigation water. On the other hand, Misr 3 is the best choice if farmer has to plant on 5th Nov. as he can get about 9% higher grain yield. Generally, the tested wheat genotypes can be divided into three groups: Group 1; include the two cultivars Sakha 95 and Giza 171 where they generally performed well when planted starting from 5th Nov. to 5th Feb. Group 2; include the two cultivars Misr 3, Sids 14, where they performed well when planted starting from 5th Nov. to 5th Jan. Group 3; include the early maturing genotypes, Line 1 and Line 2 where they recorded the lowest grain yield reduction when planted staring from 5th Jan. to 5th Feb. Also, the studied wheat genotypes were different responses for different thermo-natural environments, indicating the importance of evaluating genotypes in different environments in order to determine the best genotype for a given environment. Similar results were obtained by Talukder *et al*. (2014) Al-Menshawy *et al*. (2015) Wahid *et al*. (2017) Al-Otayk *et al*. (2019) and Hagras (2019).

Stability analysis:

Identifying stable, high-yielding genotypes is a very important task for breeding program and food security. The yield potentiality of a genotype is controlled by three factors, i.e., genotypic main effects (G), environmental main effects (E) and their interaction. Genotype × environment interaction (GEI) is considered as the variation that cannot be explained directly by genotypic or environmental components (Warzecha *et al.,* 2011). Both GGE biplot analyses and ranking of genotypes (**Figures 2 &3**) confirmed the superiority and stability of the three cultivars Sakha 95, Misr 3 and Giza 171 under the tested sowing dates. This finding might be due to stability in number of spikes and TKW in both Misr 3 and Sakha 95 and for number of kernels per spike in Giza 171. 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 4) indicates the best genotype(s) in each environment and groups of environments (Yan *et al*., 2000 and Yan and Hunt 2001). Sakha 95, Misr 3 and Giza 171 cultivars suitable for planted in a wide range of planting date (from 5th Nov. to 5th Jan.) while, early maturing Line 1 can be recommended for late sowing (5th Dec.). On the other hand, the remaining genotypes shows their high yield potentiality if planted on 5th Dec.

Heat susceptibility index:

The relative performance of yield traits under heat-stressed (late sowing) and non-stressed environments (optimum sowing) has been widely used as an indicator to identify heat-tolerant wheat genotypes (Sharma *et al*., 2016). Heat susceptibility index (HIS), an index for evaluating heat stress, is a major requirement for traditional breeding. Low stress susceptibility index estimate (HSI < 1) is synonymous with higher stress tolerance (Fisher & Mourer 1978). The genotypes Sids 12, Shandaweel 1, Line 1, Gemmiza 12 and Sakha 94 can be labeled as heat-tolerant genotypes while, Misr 2, Sids 14, Misr 1 and Gemmiza 9 can be considered as heat-sensitive one. The early maturing genotypes, Line 1 and Gemmiza 12 recorded low HIS values (0.66 and 0.74 respectively) confirming the previous finding as these two genotypes seemed to be fit for unfavorable conditions (late sowing). Misr 2, which is the latest genotype in heading recorded the highest HSI value (1.39), indicating that this cultivar is very sensitive to late sowing dates. These results are consistent with the findings of Menshawy (2007), Talukder *et al*. (2014) and Hagras (2019) where they reported that early maturing genotypes might be more suitable for late planting. On the other hand, Menshawy (2008) and Hagras (2019) reported that late genotypes in heading date are more suitable for early planting.

CONCLUSION

Generally, the tested genotypes were divided into three groups: Group 1; include the two cultivars Sakha 95 and Giza 171 where they generally performed well when planted starting from 5th Nov. to 5th Feb. Group 2; include the four cultivars Misr 3, Sids 14, where they performed well when planted starting from 5th Nov. to 5th Jan. Group 3; include the early maturing genotypes, Line 1 and Line 2 where they recorded the lowest grain yield reduction when planted staring from 5th Jan. to 5th Feb. According to stability analyses, Misr 3, Sakha 95 and Giza 171 recorded the highest yield, 10.53, 10.52 and 10.35-ton ha-1, over the grand mean yield with the regression coefficient values more than 1 so were good for a favorable environment (optimum sowing date). The genotypes Line 1 and Line 2 had a regression coefficient value lower than 1 and were above the average of yield that seemed to be fit for the unfavorable condition. The new wheat lines Line 1 and Line 2 had remarkable superiority for all earliest characters with an insignificant difference in grain yield with Misr 3 for Line 1.

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سلوك بعض أصناف قمح الخبز المصري في بيئات حرارية وضوئية طبيعية مختلفة

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أجرى هذا البحث في محطة البحوث الزراعية بسخا - محافظة كفر الشيخ - مصر- خلال الموسمين 2019/2018و2020/2019, بهدف دراسة تأثير مواعيد الزراعة على صفات التبكير والمحصول ومكوناته لعدد أربعة عشر تركيب وراثي من قمح الخبز. تم التقييم تحت أربعة مواعيد زراعة بفاصل زمني شهر حيث تم زراعة الموعد الأول من التجربة في الخامس من شهر نوفمبر. أظهر التحليل التجميعي فروق عالية المعنوية لكل من السنوات ومواعيد الزراعة والتراكيب الوراثية وتفاعلاتها لمعظم الصفات المدروسة. على الرغم من أن صفات التبكير سجلت قيمًا أعلى في الموسم الأول مقارنة بالموسم الثاني، إلا أن تقديرات درجات الحرارة المجمعة لم تختلف بين الموسمين. سجل ميعاد الزراعة الثاني أعلى قيم لعدد الأيام الي الحبلان وطرد السنابل والتزهير ومعدل امتلاء الحبوب وارتفاع النبات ومحصول الحبوب وعدد حبوب السنبلة ووزن 1000 جبة ومحصول القش. سجلت كلا من السلالة 1 والسلالة 2 أقل قيم لعدد الأيام الي الحبلان وطرد السنابل والتزهير والنضج بينما سجلت أعلى قيم لفترة امتلاء الحبوب ووزن الألف حبة مقارنة مع معظم التراكيب الوراثية. بناءً على متوسط التراكيب الوراثية فإن التراكيب الوراثية المتأخرة مثل جيزة 163 كان لها فترة امتلاء الحبوب قصيرة (29.5 يومًا) وتمتلك اعلي معدل امتلاء الحبوب (233 كجم / هكتار / يوم) بعكس التراكيب الوراثية المبكرة. تفوق الصنف مصر 3على جميع التراكيب الوراثية في محصول الحبوب (10.529 طن/هكتار) وعدد السنابل في المتر المربع (552 سنبلة) ووزن القش (20.164 طن/هكتار) وبناء عليه يعتبر هو الخيار الأفضل إذا كان على المزارع أن يزرع في الخامس من نوفمبر حيث يمكنه الحصول على محصول حبوب أعلى بنسبة 9٪. كان من المثير للاهتمام ملاحظة أن السلالة 1 كانت مبكرة بمقدار 15 يومًا في طرد السنابل و13 يومًا في والتزهير و8 أيام في النضج ولم تختلف بشكل كبير في محصول الحبوب مع مصر 3 (10.025 و10.529 طن على التوالي). وفقا لتحليلات الثبات، سجلت الأصناف مصر 3 وسخا 95 وجيزة 171 أعلى محصول حبوب (10.53، 10.52 و10.35 طن للهكتار، على التوالي) مع قيم معامل الانحدار أكثر من 1 لذلك كانت جيدة لميعاد الزراعة الموصى به. سجلت كلا من السلالة 1 والسلالة 2 قيمة معامل انحدار أقل من 1 وكانت أعلى من متوسط المحصول لذلك فإنها مناسبة للزراعة في المواعيد المتأخرة ويمكن تصنيفها على أنها تراكيب وراثية تتحمل الحرارة. وفي الوقت نفسه فإن الأصناف مصر2 وسدس 14 ومصر 1 وجميزة 9 تعتبر حساسة للحرارة حيث سجلت تقديرات عالية لدليل الحساسية للحرارة ، كما اكدت النتائج أن التراكيب الوراثية المبكرة النضج قد تكون أكثر ملائمة للزراعة المتأخرة وأن التراكيب الوراثية المتأخرة في تاريخ طرد السنابل أكثر ملائمة للزراعة المبكرة.

الكلمات المفتاحية: القمح، مواعيد الزراعة، الثبات، دليل الحساسية للحرارة

Supplement Tables

Table S1. Mean square values for days to booting (DB), anthesis (DA), heading (DH), and maturity (DM), grain filling period (GFP), and rate (GFR) and growing degree days (GDD) for the fourteen bread wheat genotypes.

Source of variations	df	Mean square						
		DB	DH	DA	DM	GFP	GFR	GDD
Year (Y)	1	2421.4**	2095.0**	2964.3**	2242.3**	50.3**	27445.1**	217.3**
Sowing date(SD)	3	7408.9**	9021.9**	13402.4**	33139.8**	6393.4**	89464.3**	1351050**
Y × SD	3	65.7**	100.7**	72.3**	36.7**	92.5**	14423.2**	17697.5**
Rep (SD×Y)	16	14.4**	6.9**	8.6**	5.7**	3.4	1277.2	1684.5**
Genotype (G)	13	1811.4**	1679.7**	1511.2**	373.8**	433.0**	9117.0**	369395.3**
Y × G	13	15.7**	10.3**	21.8**	6.8**	13.6**	2195.2**	2239.1**
SD × G	39	190.5**	191.4**	148.0**	40.9**	46.2**	5460.1**	26245.9**
Y × SD × G	39	21.1**	10.4**	8.0**	7.3**	6.4**	1137.7	1971.6**
Error	208	3.96	1.98	2.01	1.80	2.74	846.07	527.39
CV%	-	2.65	1.64	1.49	0.99	4.14	12.14	1.85

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

Table S2. Mean square values for plant height, grain yield, number of spikes per square meter (SM^{-2}), number of kernels per spike (KS^{-1}), 1000-kernel weight (TKW), straw yield and harvest index for the fourteen bread wheat genotypes.

Source of variations	df	Mean square						
		Plant height	Grain yield	SM^{-2}	KS^{-1}	TKW	Straw yield	Harvest index
Year (Y)	1	8034.1**	67.95**	1238060.3**	8990.01**	255.52**	678.70**	2591.96**
Sowing date(SD)	3	10738.6**	313.12**	105702.6**	995.22**	1821.87**	930.27**	263.62**
Y × SD	3	306.65**	23.99**	103302.4**	284.57**	230.48**	200.98**	685.01**
Rep (SD×Y)	16	49.61**	1.90	8901.18	114.26**	20.98	13.28**	26.92**
Genotype (G)	13	1060.4**	21.15**	64346.3**	599.25**	295.81**	79.51**	310.54**
Y × G	13	62.82**	3.55**	12155.8*	140.67**	49.55**	18.25**	34.88**
SD ×G	39	96.77**	3.92**	14825.1**	119.13**	34.24**	14.39**	78.86**
Y × SD × G	39	61.30**	1.73*	14751.1**	81.90**	32.09*	5.25	17.72
Error	208	22.84	1.13	6148.00	45.86	19.88	3.84	12.52
CV%	-	4.36	11.24	16.18	11.64	10.58	11.07	10.07

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

Table S3 . Mean values of days to booting , days to anthesis, plant height and straw yield for fourteen bread wheat genotypes grown under four sowing dates during 2018/2019 and 2019/2020 growing seasons.

Variables	Days to booting	Days to anthesis	Plant height (cm)	Straw yield (t ha-1)
Year				
2018/2019	77.7	98.3	114.4	19.125
2019/2020	72.4	92.3	104.7	16.283
F test	**	**	**	**
Sowing date				
Nov. 5th	74.4	102.7	117.8	20.118
Dec. 5th	86.1	107.0	118.4	20.660
Jan. 5th	76.3	93.1	107.8	16.473
Feb. 5th	63.2	78.5	94.2	13.564
LSD $_{0.05}$	0.60	0.43	1.44	0.59
Genotype				
Misr 1	74.2	94.7	106.9	17.814
Misr 2	79.8	100.1	119.2	19.446
Misr 3	75.4	95.2	106.3	20.164
Sakha 94	78.1	96.9	110.0	15.352
Sakha 95	78.9	97.1	113.5	17.594
Line 1	60.1	82.1	97.9	16.037
Line 2	59.0	81.0	103.8	14.943
Giza 163	94.3	113.8	120.0	18.129
Giza 171	74.4	94.6	112.3	18.630
Gemmiza 9	80.9	100.5	111.0	19.229
Gemmiza 12	73.9	93.0	105.0	17.108
Sids12	68.7	90.3	100.6	14.784
Sids 14	77.6	98.1	117.3	19.861
Shandaweel 1	75.3	97.0	109.8	18.763
LSD $_{0.05}$	1.12	0.80	2.70	1.11

Table S4. Mean squares of combined analysis of variance and proportion of sums of squares (SS%) for grain yield.

Source of variations	df	Mean squares	SS%
Environments (E)	7	154.18**	57.21
Error 1	16	1.90	1.61
Genotypes (G)	13	21.15**	14.57
GEI	91	2.93**	14.13
Error 2	208	1.13	12.48

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

Table S5. Mean values over two years (2018/19 and 2019/20) for days to booting, days to anthesis, plant height and straw yield of fourteen bread wheat genotypes grown under four sowing dates.

	Days to booting				Days to anthesis				Plant height (cm)				Straw yield (t ha.$^{-1}$)			
Genotype	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.	5th Nov.	5th Dec.	5th Jan.	5th Feb.
Misr 1	76	86	74	61	106	105	91	78	116	117	103	92	21.2	21.2	14.8	14.0
Misr 2	89	88	76	66	115	111	95	79	133	123	117	105	23.1	20.9	18.4	15.4
Misr 3	75	88	76	63	102	106	94	78	116	111	103	95	22.3	23.9	18.3	16.1
Sakha 94	82	89	77	65	108	108	93	79	123	118	105	94	18.9	16.6	14.6	11.3
Sakha 95	87	88	77	64	111	107	93	79	128	122	109	95	22.6	20.1	15.8	11.8
Line 1	48	71	68	53	78	95	85	70	100	110	100	82	17.5	20.2	14.3	12.2
Line 2	48	69	66	52	76	94	85	70	103	113	110	89	15.3	19.2	13.5	11.8
Giza 163	110	100	86	82	136	124	104	92	130	126	117	108	20.4	18.3	15.9	18.0
Giza 171	68	88	78	65	98	108	94	80	121	123	108	98	19.3	23.3	17.9	14.1
Gemmiza 9	83	91	83	67	110	112	98	83	119	118	116	91	23.5	21.0	18.4	14.1
Gemmiza 12	71	87	76	62	100	104	91	77	113	116	102	89	17.8	20.8	17.5	12.3
Sids12	59	84	73	59	93	103	90	75	103	115	98	87	17.2	18.0	13.6	10.4
Sids 14	77	90	79	65	107	110	95	81	128	128	113	101	21.0	25.5	19.0	14.0
Shandaweel 1	70	88	80	63	102	111	96	79	117	118	109	95	21.6	20.4	18.6	14.4
LSD $_{0.05}$	**2.3**				**1.6**				**5**				**2.2**			