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RESPONSE OF SOME BREAD WHEAT GENOTYPES TO HEAT STRESS

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ABSTRACT

The present investigation was undertaken to understand the impact of higher temperature on yield attributing traits and to select higher heat stress tolerant genotypes for future breeding program. To fulfill the requirement of this objective, the experiment was conducted in three successive seasons 2015/2016, 2016/2017 and 2017/2018. At each season three sowing dates were used i.e. normal (20th Nov.), 10th Dec. and late sown (30th Dec.) as heat stress conditions with 12 diverse genotypes. The analysis of variance combined across the three successive seasons of strip plot design for studied traits revealed that the seasons (S), dates (D), genotypes (G), SD, SG, DG, SDG had highly significant variation ($p \leq 0.01$) for all studied traits, except SD and SDG were insignificant for grain yield. In the present study, genotypes were classified arbitrarily into four different categories according to heat susceptible index (HSI) i.e. highly heat tolerant (HSI < 0.50), heat tolerant (HSI: 0.51-0.75), moderately heat tolerant (HSI: 0.76 – 1.00) and heat susceptible (HSI > 1.00). Results revealed that on the basis of HSI, the local cultivar Misr 2 was the most desirable under heat stress as it attained high to moderate HSI values for yield and its attributing traits. Similarly, Sids 4 was found desirable as it attained moderate HSI values for four traits (plant height, days to maturity, No. of kernels spike^{-1} and 1000-kernel weight). However, Sids 1, Shandaweel 1, Sids 12 and Line#3 were desirable as they attained moderate HSI values for three traits. Meanwhile, Misr 1 Sakha 95, line#1 and line#2 exhibited only two traits moderate to HIS values. The last place for genotypes was shown by Giza 168 and Gemmiza 1, which exhibited only one trait moderate to HSI values. Therefore, Misr 2, Sids 4, Sids 1, Shandaweel 1, Sids 12 and Line#3 may perform as potential donor for heat tolerance. Relative heat tolerance (RHT) for the studied traits of the genotypes in the late sowing date (heat stress) with respect to their corresponding normal sowing date, showed that Misr 2 was the lowest RHT in No. of kernels spike^{-1} and grain yield (-11.18% and -26.27%, respectively). The correlation between No. of kernels spike^{-1} and grain yield showed significantly positive association (r = 0.225*). The coefficient of determination (R^2) revealed that 5.1% of total variability in grain yield was due to its association with No. of kernels spike. The correlation between 1000-kernel weight and grain yield showed significantly positive association (r=0.441**). The coefficient of determination (R^2) revealed that 19.4% of total variability in grain yield was due to its association with 1000-kernel weight. Based on simple regression analysis, unit increase of No. of kernels spike^{-1} and 1000-kernel weight it leads to increase the grain yield plant^{-1} by 1.99 and 1.901 units, respectively.

Key words: ***Bread wheat, Triticum aestivum L., Heat stress, Heat Susceptibility Index, Simple correlation.***

INTRODUCTION

Beard wheat is considered one of the most important cereal crops, where it is a stable food for large areas of the world including Egypt. The demand for wheat across the world is increasing due to many reasons such as: (1) rapid population growth, (2) rising incomes, (3) higher relative prices, (4) changing consumer tastes (Hede *et al* 1999). International Food

Policy Research Institute (IFPRI) projections indicate that the world demand for wheat will annually increase by 2% (Rosegrant *et al* 1997). Therefore, to meet this demand, productivity of wheat whatever in favorable or in marginal environments, needs to be increased.

In tropical or subtropical areas across the world there are about 7 million hectares in approximately 50 countries are sown wheat. The area planted to wheat in these high temperature regions can be classified into two types of environments depending on (1) relative humidity and (2) disease problems (Curtis 1988).

Wheat is a temperate crop grows well with temperatures ranging from 15 and 25 C^o, but the productivity decreases under higher temperatures (Hede *et al* 1999). High temperature is a major determinant of wheat development and growth and causes yield loss in many regions of the world. Moreover, genetic stability and diversity are two of the key factors for the improvement of many crop plants. Al-Khatib & Paulsen (1984) reported that high temperatures (more than 34^0C), decreases final grain weight by shortening the duration of grain filling due to repression of photosynthesis. Also, Jenner (1994) and Keeling *et al* 1993 mentioned that decreasing yield under higher temperatures may be due to restraining starch biosynthesis in the endosperm. Many morphological and physiological traits found to be correlated with yield potential in environments with high temperatures as follows: Shortening of the period of photosynthetic activity (Al-Khatib & Paulsen 1984), reduced grain-filling period (Wardlaw *et al* 1980), above-ground biomass at maturity, grains/m^2, days to anthesis, and maturity (Reynolds et al., 1994), canopy temperature depression, membrane thermo stability, leaf chlorophyll content during grain filling, leaf conductance, and photosynthesis (Reynolds *et al* 1998). Fisher and Muarer (1978) produced formula as heat susceptibility index (HSI) which was used as a measure of heat tolerance. HSI measured the reduction in yield caused by stress versus normal environments. Values of HSI less than 1.0 indicate less susceptibility and greater resistance to heat. Meanwhile, a values of HSI=0 indicate maximum possible heat tolerance (no effect of heat on yield).

The main objective for a plant breeder is to produce new cultivars with higher yield. However, yield is a complex trait, where it is highly affected with many genetic factors and environment. Moreover, direct selection for yield may be misleading. Correlation studies among yield and its components is considered prerequisite techniques to determine the influence of environment on yield potential (Leilah and Al-Khateeb 2005 and Abd El-Mohsen and Abd El-Shafi, 2014). Moreover, results on the nature and magnitude of correlation analysis help the breeders to determine the selection criteria which lead towards successful wheat improvement program. Dixet & Dubey (1984) and Abd El-Mohsen and Abd El-Shafi (2014) mentioned that correlation coefficients help to obtain best combinations of attributes for obtaining higher return per unit area.

The objective of the present study was to (1) evaluate a group of bread wheat cultivars and promising lines for heat tolerance on yield and its attributing traits, (2) select higher heat stress tolerant genotypes for future breeding program, (3) determine the dependence relationship between grain yield and its component traits by using certain statistical procedures under Upper Egypt region conditions.

MATERIALS AND METHODS

Experimental site and plant materials

Twelve bread wheat genotypes (nine local cultivars and three introduced promising lines) were evaluated across three successive seasons 2015/2016, 2016/2017 and 2017/2018 at Kom ombo Agriculture Research Station, Agriculture Research center, Aswan Governorate. In each season three different sowing dates were used (20th of November, 10th of December and 30th of December). Details of genotypes are given in Table (1).The maximum and minimum air temperature (C^0) during the three wheat growing seasons is presented in Fig. 1.

Layout and experimental design

The trials were established in a strip-block design with randomized complete blocks arrangement in 3 replications. Horizontal plots were assigned to the two sowing dates and vertical-plots were assigned to the 12 genotypes. Each experimental unit consisted of 6 rows, 3 m long and 20 cm wide. The plants were subjected to recommended package of agronomic, fertilization and plant protection practices to obtain a healthy crop. Calcium super phosphate (15.5% P_2O_5) was applied during soil preparation at the rate of 100 kg feddan^{-1} P_2O_5. Six irrigations were added during growth by flooding system. Total nitrogen fertilization was applied at a rate of 75 kg feddan^{-1} N was applied in three equal doses at seeding and before first and second irrigations.

Table 1. Name, pedigree and origin of the studied wheat genotypes.

No.	Name	Pedigree	Origin
G_1	Sids 1	HD 2172/pavon "s" // 1158.57 / Maya 74 "s"	Egypt
G_2	Sids 4	Maya"S"/Man"S"//CMH74A-592/3/Giza157*2	Egypt
G_3	Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR	Egypt
G_4	Misr 2	SKAUZ/BAV92	Egypt
G_5	Shandaweel 1	SITE//M0/4/NAC/TH.AC//3*PVN/3/MIRLO/Bue	Egypt
G_6	Giza 168	MIL/BUC/Seri	Egypt
G_7	Sakha 95	PASTOR//SITE/MO/3/CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/4/WBLL1	Egypt
G_8	Sids 12	BUC//7C/ALD/5/MAYA74/ON//1160,1473 //BB/Gll/4/CHAT"s"/6/MAYA/VUL//CMH74A.630/4/* SX.	Egypt
G_9	Gemmeiza 11	BOW"S"/KVZ//7C/SER182/3/GIZA 168/SAKHA61. GM7892-2GM-1GM-2GM-1GM-0GM.	Egypt
G_{10}	Line#1	WBLL*2/KKTS//KBIRD	CIMMYT
G_{11}	Line#2	PBW343*2/KUKUNA*2//FRTL/PIFED-3	CIMMYT
G_{12}	Line#3	KATILA-15//MNCH/3*BCN	ICARDA

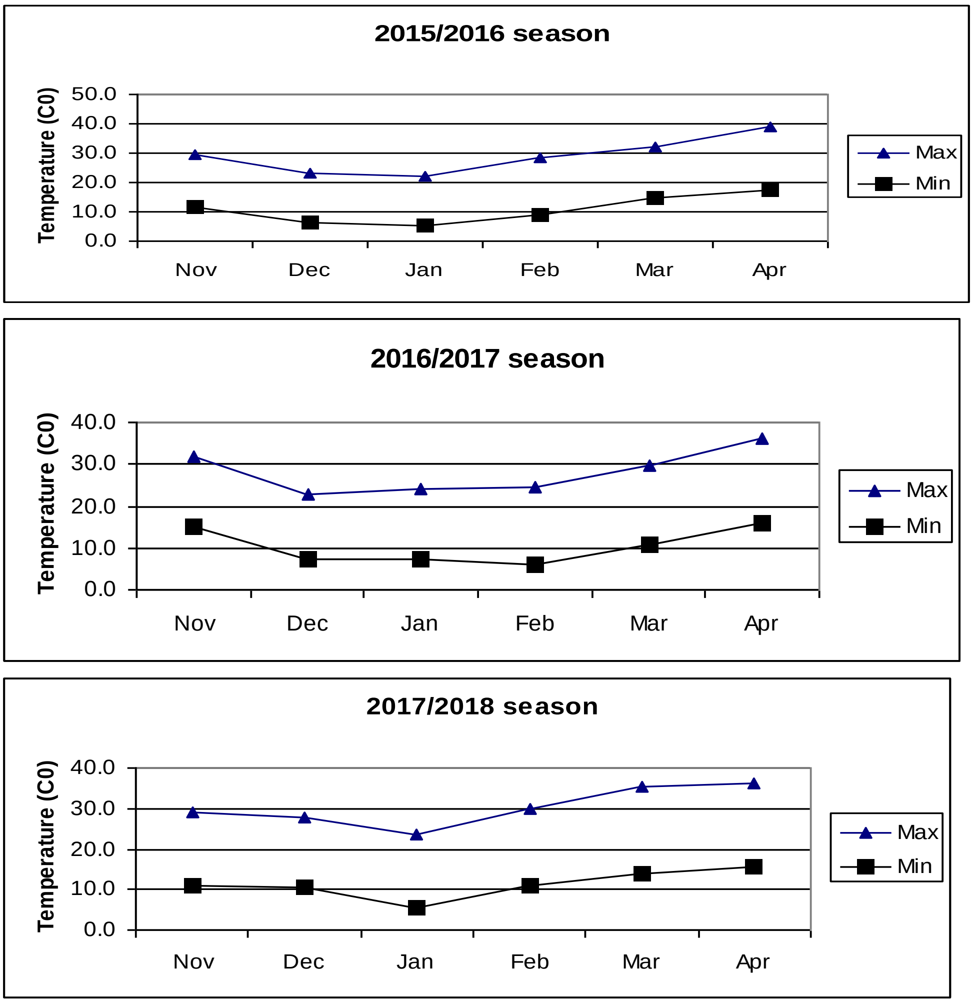

Fig. 1. Maximum and minimum air temperature (C^0) for the three wheat growing seasons.

Recording of observations

Data were recorded on days to heading and maturity estimated on plot basis by visual observations. Observations were recorded on ten randomly selected plants from the two middle rows in each cultivar per replication for the following traits viz., days to heading, days to maturity, plant height (cm), number of kernels spike^{-1}, 1000-kernel weight (g) and grain yield plant^{-1} (g). At harvest the four middle area of each plot was taken to determine grain yield/plot (plot size = 2.4 m^2) and then converted to grain yield (ton/hectare). All other agricultural practices were followed according to the recommendations of ARC, Egypt.

Statistical analyses

In each season Wilk Shapiro test (Neter *et al* 1996) were used to check out for normality distributions. Also, for each season analysis of variance (ANOVA) was done separately. Then a combined analysis of variance was done from the mean data of each environment (combination between seasons x sowing dates). Homogeneity test of experimental errors variances were done by Gomez and Gomez (1984). All statistical analyses were carried out using MSTAT-C software package (Freed *et al* 1989), GENES computer software (Cruz 2013) and MS Excel.

Heat susceptibility index (HSI) was calculated for grain yield and other quantitative traits over high temperature stress (very late sown) and non-stress environment (normal sown) by using the formula as suggested by Fisher and Maurer, 1978.

$HSI = [l\text{-}Y_D/Y_P]/D$

Where: Y_D = mean of the genotypes in heat stress (very late sown).

Y_P = mean of the genotypes under non-stress (normal sown).

$D = 1\text{-}[\text{mean } Y_D$ of all genotypes/mean Y_P of all genotypes].

The relative heat tolerance (RHT) was calculated by the formula $\mathbf{RHT = \frac{Y_h - Y_c}{Y_c} x 100}$ as described by Haque *et al* (2009), where

Yh is grain yield in the heat stressed condition (late season),

Yc is grain yield in the control (normal season).

To analyze the relation between grain yield and yield components, simple correlation coefficient was done for all genotypes. The data combined across the three seasons were subjected to estimate correlation coefficient among measured traits (Steel *et al* 1997).

RESULTS AND DISCUSSION

Analysis of variance

Statistical analysis according to the technique of analysis of variance (ANOVA) for the data combined across three successive seasons of strip plot design for studied traits are summarized in Table 2. Based on the results obtained, statistical analysis revealed that the seasons (S), dates (D), genotypes (G), SD, SG, DG, SDG included in the study had highly significant variation (*p≤ 0.01*) for all traits under study, except DG for No. of kernels spike^{-1} and grain yield were significant only (*P≤ 0.05)*. However, SD and SDG were insignificant for grain yield. Results in Table 3 concluded that differences between wheat genotypes may be due to genetical differences among genotypes and indicating high amount of diversity among the genotypes for these traits. Also, these results provide evidence for sufficient variability and selection on the basis of these traits can be useful. The obtained results in this study were in agreement with those obtained by Abd El-Mohsen and Abd El-Shafi, (2014) and Mohiy, (2016).

Table 2. Mean squares of the 6 traits of bread wheat combined across three seasons.

SOV	df	PH	DTH	DTM	K/S	1000	GY
		MS					
Seasons (S)	2	5414.333**	2564.231**	3087.448**	430.235**	799.114**	39.807**
R (S)	6	2.824	1.802	3.432	10.738	2.481	0.585
Dates (D)	2	8042.620**	11130.028**	17607.873**	3140.688**	1879.022**	154.812**
SXD	4	560.009**	691.037**	493.975**	808.179**	129.031**	1.220ns
Error	12	2.986	2.617	4.261	6.344	3.773	0.610
Genotypes (G)	11	481.953**	1203.651**	1394.198**	3233.911**	520.885**	28.350**
SXG	22	55.175**	136.117**	55.410**	552.470**	86.660**	1.025**
Error	66	8.242	5.136	3.385	13.000	4.279	0.333
DXG	22	33.654**	21.378**	18.089**	18.944*	11.072**	0.584 *
SXDXG	44	19.694**	20.135**	13.327**	27.066**	9.975**	0.485ns
Error	132	6.399	4.087	4.199	10.556	3.758	0.341

**** = Significant at 1% level. * = Significant at 5% level. ns = Non-Significant. PH = Plant height. DTH = Days to heading. DTM = Days to maturity. No. of K/S = Number of kernels spike^{-1}. 1000-KW = 1000 kernels weight. GY = Grain yield.**

Mean performance

Mean performances combined across the three seasons under heat stress, as well as combined data for studied traits of 12 bread wheat genotypes are presented in Tables 3, 4, 5, 6, 7 and 8. It is clear that all traits increased significantly with normal conditions compared with stress conditions. For plant height, (Table 3) at normal conditions (normal sowing date) Misr 2 followed by Sids 1 were the tallest genotypes (119.80 and 116.60 cm, respectively). On the other hand, Misr 2 followed by Line#3 were the tallest genotypes (103.70 and 101.20, respectively) under heat stress (last date), while Giza 168 (87.00 cm) followed by Sids 12 (90.90 cm) were the shortest genotypes. Also, results in Table 3 showed that the reduction % in plant height due to heat stress (late date) was 15.28%. Regarding days to heading, the lowest days (earliness) was recorded by Sids 4 and Gemmiza 11 under normal conditions, while Sids 4 and sids 12 were the lowest genotypes at heat stress with reduction 23.22% compared to normal conditions. Concerning, days to maturity, the lowest days (earliness) was recorded by Sids 4 and Sids 12 under normal conditions, while Sids 4 and Gemmiza 11 were the lowest genotypes at heat stress with reduction 18.31% compared to normal conditions. The highest No. of kernels spike^{-1} was observed with Sids 4 at both normal and heat stress conditions (98.90 and 86.60, respectively), with reduction 15.84% due to heat stress. Concerning 1000-kerenels weight, genotypes Gemmiza 11 and Sids 4 recorded the highest values under stress and normal conditions, while Sids 1 was the lowest at both environments. However, heat stress causes reduction on 1000-kernel weight by 18.84% compare to normal conditions. On the other hand, Line**#3** was the lowest genotype for grain yield **(**ton ha^{-1}) at normal and stress conditions. Meanwhile, Misr 1 and Misr 2 recorded the highest values for grain yield ton ha^{-1} under normal and stress conditions with reduction 35.89% due to heat stress.

Evaluating a genotype under heat condition is a tool enabling to differentiate tolerant versus sensitive genotypes and select the tolerant one(s). Under heat stress, however, all agronomic traits were affected by heat (last sowing date)). The performance of the studied genotypes agrees with numerous reports of many researchers on impact of heat stress on wheat. Tewolde *et al* 2006 reported that exposure to higher temperatures can significantly reduce grain yield.

Table 3. Mean performance of plant height for seasons, dates and genotypes and their interaction combined across three seasons and reduction% of late sowing date.

Seasons	Dates	Plant height (cm)												
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	Mean
2015/2016		111.00	102.20	109.00	116.90	105.30	100.70	105.40	108.40	105.10	105.70	108.00	107.80	107.13
2016/2017		112.90	103.80	110.90	119.60	108.40	101.00	109.00	108.70	108.90	107.90	106.40	109.40	108.91
2017/2018		99.30	93.00	91.80	103.40	91.80	87.80	100.40	91.70	93.60	95.70	97.10	104.70	95.86
LSD 0.05		2.71												0.56
20^{th} of Nov.		116.60	105.00	113.60	119.80	107.10	103.80	113.70	113.70	111.60	112.00	111.30	113.00	111.77
10^{th} of Dec.		108.10	102.60	103.90	116.40	103.70	98.70	108.10	104.20	103.40	104.00	104.70	107.70	105.46
30^{th} of Dec.		98.60	91.40	94.20	103.70	94.80	87.00	93.10	90.90	92.60	93.20	95.60	101.20	94.69
LSD0.05		2.36												0.51
Reduction %														15.28
Genotypes		107.73	99.67	103.90	113.30	101.83	96.50	104.93	102.93	102.53	103.10	103.83	107.30	
LSD 0.05		1.56												
2015/2016	20^{th} of Nov.	118.00	106.70	118.30	123.00	110.30	107.70	114.00	118.70	115.30	115.70	114.30	115.30	114.78
	10^{th} of Dec.	111.70	104.70	105.00	117.30	104.00	100.30	103.70	106.30	103.30	103.70	105.00	108.00	106.08
	30^{th} of Dec.	103.30	95.30	103.70	110.30	101.70	94.00	98.70	100.30	96.70	97.70	104.70	100.00	100.53
2016/2017	20^{th} of Nov.	120.00	108.30	117.70	126.30	112.30	107.30	115.70	116.70	117.70	116.30	114.70	115.70	115.73
	10^{th} of Dec.	111.30	105.00	110.00	120.00	108.00	101.70	110.00	110.00	109.30	108.30	106.30	109.00	109.08
	30^{th} of Dec.	107.30	98.00	105.00	112.30	105.00	94.00	101.30	99.30	99.70	99.00	98.30	103.70	101.91
2017/2018	20^{th} of Nov.	111.70	100.00	104.70	110.00	98.70	96.30	111.30	105.70	101.70	104.00	105.00	108.00	104.76
	10^{th} of Dec.	101.30	98.00	96.70	112.00	99.00	94.00	110.70	96.30	97.70	100.00	102.70	106.00	101.20
	30^{th} of Dec.	85.00	81.00	74.00	88.30	77.70	73.00	79.30	73.00	81.30	83.00	83.70	100.00	81.61
LSD 0.05		4.09												0.89

G1 = Sids 1, G2 = Sids 4, G3 = Misr 1, G4 =Misr 2, G5 = Shandaweel 1, G6 = Giza 168, G7 = Sakha 95, G8- Sids 12, G9 = Gemmiza 11, G10 = Line#1, G11 = Line#2, G12 = Line#3.

Table 4. Mean performance of days to heading for seasons, dates and genotypes and their interaction combined across three seasons and reduction% of late sowing date.

Seasons	Dates	Days to heading (days)												
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	Mean
2015/2016		82.60	60.10	86.40	80.40	74.20	73.70	79.20	78.10	82.20	77.60	79.90	81.80	78.02
2016/2017		85.10	61.70	82.20	92.40	84.90	85.80	75.60	75.40	74.00	91.10	82.30	87.20	81.48
2017/2018		75.40	52.60	73.70	76.40	70.60	74.00	73.80	68.80	68.20	77.70	76.10	75.10	71.87
LSD 0.05		2.14												0.45
	20^{th} of Nov.	90.30	64.80	90.70	90.90	83.80	87.00	87.90	83.20	83.10	90.20	89.10	92.30	86.11
	10^{th} of Dec.	82.80	60.10	83.90	85.10	79.70	79.80	76.80	75.70	77.70	83.60	82.70	82.00	79.16
	30^{th} of Dec.	70.00	49.40	67.80	73.30	66.20	66.70	63.90	63.40	63.70	72.60	66.60	69.80	66.12
LSD0.05		1.89												0.48
Reduction%														23.22
Genotypes		81.03	58.13	80.77	83.07	76.57	77.83	76.20	74.10	74.80	82.13	79.43	81.37	
LSD 0.05		1.23												
2015/2016	20^{th} of Nov.	94.70	70.70	99.00	92.00	85.70	86.70	93.70	93.70	95.00	91.70	93.30	98.30	91.21
	10^{th} of Dec.	81.70	59.30	85.00	78.30	72.70	72.00	76.00	75.70	82.00	76.30	78.00	79.00	76.33
	30^{th} of Dec.	71.30	50.30	75.30	71.00	64.30	62.30	68.00	65.00	69.70	64.70	68.30	68.00	66.52
2016/2017	20^{th} of Nov.	95.00	68.70	94.00	97.70	90.00	94.70	90.00	85.00	84.30	96.30	93.30	96.70	90.48
	10^{th} of Dec.	84.30	64.70	85.70	94.30	87.30	86.70	73.70	75.00	74.00	90.00	87.30	84.30	82.28
	30^{th} of Dec.	76.00	51.70	67.00	85.30	77.30	76.00	63.00	66.30	63.70	87.00	66.30	80.70	71.69
2017/2018	20^{th} of Nov.	81.30	55.00	79.00	83.00	75.70	79.70	80.00	71.00	70.00	82.70	80.70	82.00	76.68
	10^{th} of Dec.	82.30	56.30	81.00	82.70	79.00	80.70	80.70	76.30	77.00	84.30	82.70	82.70	78.81
	30^{th} of Dec.	62.70	46.30	61.00	63.70	57.00	61.70	60.70	59.00	57.70	66.00	65.00	60.70	60.13
LSD 0.05		3.27												0.83

G1 = Sids 1, G2 = Sids 4, G3 = Misr 1, G4 =Misr 2, G5 = Shandaweel 1, G6 = Giza 168, G7 = Sakha 95, G8- Sids 12, G9 = Gemmiza 11, G10 = Line#1, G11 = Line#2, G12 = Line#3.

Table 5. Mean performance of days to maturity for seasons, dates and genotypes and their interaction combined across three seasons and reduction% of late sowing date.

Seasons	Dates	Days to maturity (days)												
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	Mean
2015/2016		133.90	108.00	131.90	134.70	132.30	128.90	129.90	132.10	135.80	131.60	132.30	130.80	130.18
2016/2017		130.70	105.30	129.40	133.00	131.70	132.80	130.10	129.40	125.90	133.70	133.70	129.10	128.73
2017/2018		123.20	99.10	118.90	123.90	121.80	125.40	121.30	116.60	116.80	125.60	125.10	125.70	120.28
LSD 0.05		1.73												0.62
20th of Nov.		141.20	113.20	139.80	142.00	141.10	139.90	139.60	137.00	137.10	142.20	141.90	140.60	137.97
10th of Dec.		132.70	105.10	127.80	132.10	131.60	131.30	129.10	128.90	129.40	133.00	131.90	129.40	128.53
30th of Dec.		113.90	94.10	112.70	117.40	113.10	115.90	112.70	112.20	111.90	115.60	117.30	115.60	112.70
LSD0.05		1.91												0.61
Reduction%														18.31
Genotypes		129.27	104.13	126.73	130.53	128.60	129.03	127.10	126.03	126.17	130.30	130.37	128.53	
LSD 0.05		1.00												
2015/2016	20th of Nov.	146.00	117.70	147.00	148.00	146.00	141.00	143.00	145.00	145.30	147.00	147.00	146.30	143.28
	10th of Dec.	134.00	108.30	132.00	133.00	132.00	128.70	129.30	132.30	137.70	130.00	131.00	130.30	129.88
	30th of Dec.	121.70	98.00	116.70	123.00	119.00	117.00	117.30	119.00	124.30	117.70	119.00	115.70	117.37
2016/2017	20th of Nov.	144.70	116.70	144.30	148.30	146.30	146.00	144.70	144.00	142.30	146.70	146.30	144.70	142.92
	10th of Dec.	135.70	105.30	128.30	133.70	133.70	133.00	129.30	128.70	125.00	136.00	133.70	126.30	129.06
	30th of Dec.	111.70	94.00	115.70	117.00	115.00	119.30	116.30	115.70	110.30	118.30	121.00	116.30	114.22
2017/2018	20th of Nov.	133.00	105.30	128.00	129.70	131.00	132.70	131.00	122.00	123.70	133.00	132.30	130.70	127.70
	10th of Dec.	128.30	101.70	123.00	129.70	129.00	132.30	128.70	125.70	125.70	133.00	131.00	131.70	126.65
	30th of Dec.	108.30	90.30	105.70	112.30	105.30	111.30	104.30	102.00	101.00	110.70	112.00	114.70	106.49
LSD 0.05		3.31												1.06

G1 = Sids 1, G2 = Sids 4, G3 = Misr 1, G4 =Misr 2, G5 = Shandaweel 1, G6 = Giza 168, G7 = Sakha 95, G8- Sids 12, G9 = Gemmiza 11, G10 = Line#1, G11 = Line#2, G12 = Line#3.

Table 6. Mean performance for No. of kernels spike^{-1} for seasons, dates, genotypes and their interaction combined across three seasons and reduction% of late sowing date.

Seasons	Dates	No. of kernels spike^{-1}												
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	Mean
2015/2016		49.20	97.00	63.90	58.20	57.60	75.10	57.70	59.60	71.00	44.80	54.90	37.80	60.57
2016/2017		48.90	91.70	61.90	66.10	56.20	55.30	56.80	77.20	72.10	55.80	60.30	70.60	64.41
2017/2018		48.20	88.30	56.00	64.00	57.70	58.80	59.20	66.30	55.80	54.00	61.00	69.60	61.58
LSD 0.05		3.40												1.09
20th of Nov.		54.30	98.90	67.20	67.10	63.60	69.70	61.40	71.70	72.60	57.20	65.20	64.80	67.81
10th of Dec.		47.30	91.60	59.40	61.70	56.10	61.80	59.40	70.10	66.70	49.10	58.20	58.70	61.68
30th of Dec.		44.70	86.60	55.10	59.60	51.80	57.80	52.80	61.30	59.70	48.20	52.80	54.40	57.07
LSD0.05		3.03												0.75
Reduction%														15.84
Genotypes		48.77	92.33	60.60	62.77	57.17	63.07	57.90	67.70	66.30	51.53	58.73	59.33	
LSD 0.05		1.96												
2015/2016	20th of Nov.	56.30	108.00	74.30	68.00	65.30	83.30	67.30	70.00	79.70	51.30	61.70	45.70	69.24
	10th of Dec.	46.70	95.70	60.30	53.30	56.70	72.30	54.70	56.30	69.70	41.30	54.00	35.30	58.03
	30th of Dec.	44.70	87.30	57.00	53.30	50.70	69.70	51.00	52.30	63.70	41.70	49.00	32.30	54.39
2016/2017	20th of Nov.	56.30	98.70	68.70	74.70	65.70	66.30	64.70	83.70	87.30	63.70	70.70	78.30	73.23
	10th of Dec.	47.30	89.70	60.30	64.00	53.00	52.30	55.70	76.70	66.30	53.30	57.30	68.70	62.05
	30th of Dec.	43.00	86.70	56.70	59.70	50.00	47.30	50.00	71.30	62.70	50.30	53.00	64.70	57.95
2017/2018	20th of Nov.	50.30	90.00	58.70	58.70	59.70	59.30	52.30	61.30	50.70	56.70	63.30	70.30	60.94
	10th of Dec.	48.00	89.30	57.70	67.70	58.70	60.70	68.00	77.30	64.00	52.70	63.30	72.00	64.95
	30th of Dec.	46.30	85.70	51.70	65.70	54.70	56.30	57.30	60.30	52.70	52.70	56.30	66.30	58.83
LSD 0.05		5.25												1.29

G1 = Sids 1, G2 = Sids 4, G3 = Misr 1, G4 =Misr 2, G5 = Shandaweel 1, G6 = Giza 168, G7 = Sakha 95, G8- Sids 12, G9 = Gemmiza 11, G10 = Line#1, G11 = Line#2, G12 = Line#3.

Table 7. Mean performance for 1000-kernels weight for seasons, dates, genotypes and their interaction combined across three seasons and reduction% of late sowing date.

Seasons	Dates	1000-kernels weight (g)												
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	Mean
2015/2016		33.80	49.00	38.20	38.10	38.00	41.60	38.60	34.20	42.20	37.10	36.30	36.70	38.65
2016/2017		36.20	52.40	48.90	39.60	37.40	37.40	44.90	44.40	54.90	36.40	38.60	44.70	42.98
2017/2018		33.40	43.30	38.20	33.30	35.30	37.20	39.70	37.70	44.80	35.70	32.40	44.70	37.98
LSD 0.05		1.95												0.52
20th of Nov.		37.40	52.90	46.00	41.00	42.60	43.70	44.30	41.40	54.20	40.90	39.60	46.30	44.19
10th of Dec.		34.60	48.30	41.30	36.30	35.90	38.40	40.70	38.70	45.90	36.60	35.70	42.30	39.56
30th of Dec.		31.40	43.60	38.00	33.70	32.30	34.10	38.10	36.20	41.80	31.80	32.10	37.30	35.87
LSD0.05		1.81												0.58
Reduction %														18.84
Genotypes		34.47	48.23	41.77	37.00	36.90	38.73	41.07	38.77	47.30	36.40	35.77	42.03	
LSD 0.05		1.13												
2015/2016	20th of Nov.	38.00	55.00	44.30	44.30	49.30	48.30	43.00	40.70	52.30	43.00	42.30	42.00	45.21
	10th of Dec.	33.30	48.00	37.00	36.70	35.30	40.30	38.00	32.30	40.00	36.30	36.30	36.30	37.48
	30th of Dec.	30.00	44.00	33.30	33.30	29.30	36.00	34.70	29.70	34.30	32.00	30.30	31.70	33.22
2016/2017	20th of Nov.	39.30	54.70	53.00	45.00	41.00	43.00	50.30	47.00	58.70	42.00	40.30	50.00	47.03
	10th of Dec.	36.30	52.00	48.00	38.00	36.70	36.00	43.00	44.70	54.70	35.30	39.00	44.00	42.31
	30th of Dec.	33.00	50.70	45.70	35.70	34.70	33.30	41.30	41.70	51.30	32.00	36.30	40.00	39.64
2017/2018	20th of Nov.	35.00	49.00	40.70	33.70	37.30	39.70	39.70	36.70	51.70	37.70	36.00	47.00	40.35
	10th of Dec.	34.00	45.00	39.00	34.30	35.70	39.00	41.00	39.00	43.00	38.00	31.70	46.70	38.87
	30th of Dec.	31.30	36.00	35.00	32.00	33.00	33.00	38.30	37.30	39.70	31.30	29.70	40.30	34.74
LSD 0.05		3.13												1.00

G1 = Sids 1, G2 = Sids 4, G3 = Misr 1, G4 =Misr 2, G5 = Shandaweel 1, G6 = Giza 168, G7 = Sakha 95, G8- Sids 12, G9 = Gemmiza 11, G10 = Line#1, G11 = Line#2, G12 = Line#3.

Table 8. Mean performance for grain yield ton ha^{-1} for seasons, dates, genotypes and their interaction combined across three seasons and reduction% of late sowing date.

Seasons	Dates	grain yield ton ha^{-1}												
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	Mean
2015/2016		5.68	4.04	6.90	7.31	5.11	6.07	5.82	5.91	6.70	4.21	4.92	3.92	5.55
2016/2017		5.64	4.56	7.46	7.65	4.71	6.81	6.32	6.80	7.02	4.93	5.11	4.14	5.93
2017/2018		4.94	4.04	5.33	5.89	4.31	5.36	5.29	5.31	5.18	3.74	3.93	3.57	4.74
LSD 0.05		0.54												0.25
20th of Nov.		6.77	5.22	7.83	8.09	5.78	7.62	7.08	7.81	7.58	5.56	5.82	4.67	6.65
10th of Dec.		5.15	4.22	6.39	6.80	4.47	5.83	5.82	5.78	6.37	4.20	4.64	3.94	5.30
30th of Dec.		4.33	3.20	5.48	5.96	3.89	4.79	4.52	4.43	4.95	3.12	3.50	3.02	4.26
LSD0.05		0.55												0.23
Reduction %														35.89
Genotypes		5.42	4.22	6.56	6.95	4.71	6.08	5.81	6.01	6.30	4.29	4.65	3.88	
LSD 0.05		0.31												
2015/2016	20th of Nov.	7.54	5.38	8.13	8.88	6.57	7.56	6.96	7.24	8.18	5.35	6.24	4.71	6.89
	10th of Dec.	5.36	3.71	6.54	6.94	4.87	5.89	5.80	5.83	6.79	4.20	4.96	3.98	5.41
	30th of Dec.	4.14	3.04	6.03	6.10	3.89	4.76	4.69	4.67	5.13	3.06	3.57	3.08	4.35
2016/2017	20th of Nov.	6.85	5.15	8.74	8.96	5.47	8.96	7.82	9.59	8.02	6.87	6.25	4.77	7.29
	10th of Dec.	5.22	4.88	7.38	7.64	4.68	6.17	6.40	6.24	7.28	4.75	5.13	4.51	5.86
	30th of Dec.	4.85	3.65	6.26	6.34	3.99	5.30	4.74	4.57	5.76	3.18	3.94	3.14	4.64
2017/2018	20th of Nov.	5.92	5.14	6.61	6.42	5.29	6.34	6.45	6.62	6.56	4.46	4.97	4.52	5.78
	10th of Dec.	4.88	4.07	5.24	5.82	3.86	5.44	5.27	5.27	5.04	3.64	3.83	3.34	4.64
	30th of Dec.	4.00	2.92	4.14	5.44	3.79	4.30	4.14	4.04	3.95	3.11	2.98	2.84	3.80
LSD 0.05		------------												-------

G1 = Sids 1, G2 = Sids 4, G3 = Misr 1, G4 =Misr 2, G5 = Shandaweel 1, G6 = Giza 168, G7 = Sakha 95, G8- Sids 12, G9 = Gemmiza 11, G10 = Line#1, G11 = Line#2, G12 = Line#3.

Rahman *et al* (2009) reported that, there was significant reduction due to higher temperature in the No. of days to heading, flowering, and maturity. Also, Singh *et al* (2007) mentioned that heat stress had negative impact on the plant height of wheat. Al-Otayk (2010) found that a genotype with stable and high yield across different environments would be a more suitable cultivar and perhaps a donor parent for further breeding for heat tolerance. Mohiy, (2016) reported that delaying sowing date reduced No. of spikes m^{-2}, No. of kernels $spike^{-1}$, 1000 kernels weight and grain yield by an average of 25.86, 24.32, 16.59 and 40.24%, respectively, compared with recommended sowing date.

Heat susceptibility index

In the present study, genotypes were classified arbitrarily into four different categories i.e. highly heat tolerant (HSI < 0.50), heat tolerant (HSI: 0.51-0.75), moderately heat tolerant (HSI: 0.76 – 1.00) and heat sensitive (HSI > 1.00). Results in Table (9) revealed that on the basis of HSI, the cv. Misr 2 was the most desirable one under heat stress as it attained high to moderate HSI values for yield and its attributing traits. Similarly, Sids 4 was found to be desirable as it attained moderate HSI values for four traits (plant height, days to maturity, No. of kernels $spike^{-1}$ and 1000-kernel weight). However, Sids 1, Shandaweel 1, Sids 12 and Line**#3** were desirable as they attained moderate HSI values for three traits. Meanwhile, Misr 1 Sakha 95, line**#1** and line**#2** exhibited only two traits moderate to HIS values. The last place was for genotypes Giza 168 and Gemmiza 1, which exhibited only one trait moderate to HSI values. Therefore, Misr 2, Sids 4, Sids 1, Shandaweel 1, Sids 12 and Line**#3** may perform as potential donor for heat tolerance. These genotypes should be further exploited for improvement of grain yield under late and very late sown conditions. Also, HSI values should be taken as an important criterion for breeding wheat genotypes suitable for heat stress environment. Similar results were also observed by El-shawy (2008), Vaezi *et al* (2010), Amer *et al* (2011), Modhej *et al* (2015), Mohidy, (2016) and Sultan *et al* (2016)**.**

Table 9. Heat susceptibility indices for yield and its attributes in late sown comparison to normal sown across three seasons.

Genotypes	PH		DTH		DTM		No. of K/S		1000-KW		GY		Fr
Sids 1	1.01	S	0.97	M	1.06	S	1.12	S	0.85	M	1.00	M	3
Sids 4	0.85	M	1.02	S	0.92	M	0.79	M	0.93	M	1.08	S	4
Misr 1	1.12	S	1.09	S	1.06	S	1.14	S	0.92	M	0.84	M	2
Misr 2	0.88	M	0.83	M	0.95	M	0.71	H	0.95	M	0.73	H	6
Shandaweel 1	0.75	H	0.90	M	1.08	S	1.17	S	1.28	S	0.91	M	3
Giza 168	1.06	S	1.01	S	0.94	M	1.08	S	1.17	S	1.04	S	1
Sakha 95	1.19	S	1.18	S	1.05	S	0.88	M	0.74	H	1.01	S	2
Sids 12	1.31	S	1.03	S	0.99	M	0.92	M	0.67	H	1.21	S	3
Gemmeiza 11	1.11	S	1.01	S	1.00	S	1.12	S	1.21	S	0.97	M	1
Line#1	1.10	S	0.84	M	1.02	S	0.99	M	1.18	S	1.22	S	2
Line#2	0.92	M	1.09	S	0.95	M	1.20	S	1.01	S	1.11	S	2
Line#3	0.68	H	1.05	S	0.97	M	1.01	S	1.03	S	0.98	M	3

PH = Plant height. DTH = Days to heading. DTM = Days to maturity. No. of K/S = Number of kernels spike^{-1}. 1000-KW = 1000 kernels weight. GY = Grain yield. H =Heat tolerance. M = Moderate heat tolerance. S = Heat sensitive. *Fr.* =frequency of the number of traits showing heat tolerance for each genotype.

Relative heat tolerance (RHT) of wheat germplasm

Figure 2 showed the studied traits of the genotypes in the late sowing date (heat stressed) with respect to their corresponding normal sowing date. The RHT for plant height ranged from -10.40% in genotype Lin#3 to -20.05% in genotype Sids 12. For days to heading it ranged from -19.36% in genotype Misr 2 to -27.30% in genotype Sakha 95, while it ranged from -16.87% in Sids 4 to -19.84% in Sandaweel 1. However, Misr 2 was the lowest RHT in No. of kernels spike^{-1} and grain yield (-11.18% and -26.27%, respectively). The most heat tolerant genotype for No. of kernels spike^{-1} and grain yield was Misr 2. Similar results were obtained by Emeka *et al* 2016 who found the RHT ranged from -33.69% in genotype 168 to -77.95% in genotype 167 for grain yield**.**

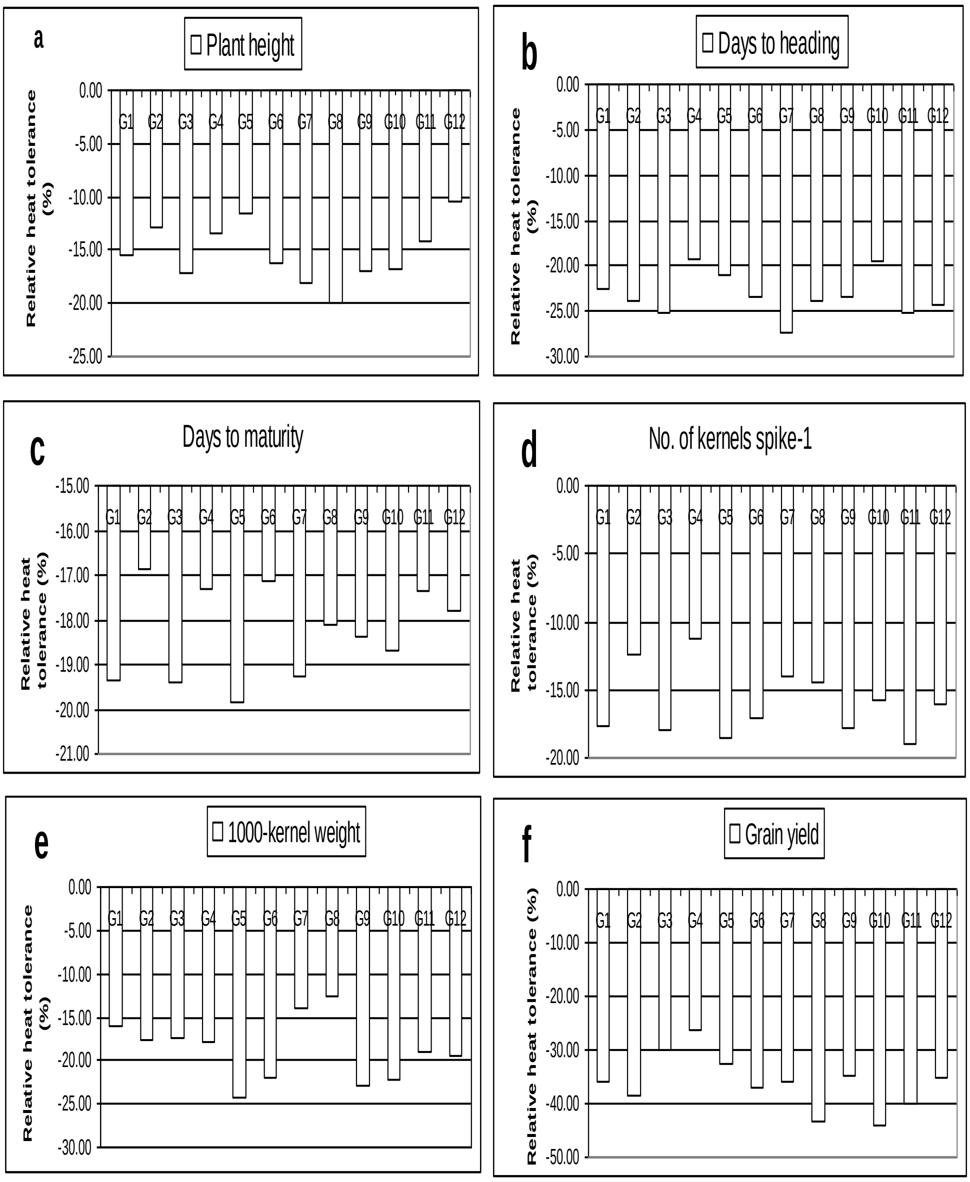

Fig. 2. Relative heat tolerance (%) for the studied traits.

Simple correlation coefficients

Correlation analysis is widely used and it shows the relationship between two traits. According to the results shown in Table 10, the correlation coefficients (r values) were positively and significantly correlated with grain yield, indicating that increase in these traits would increase the grain yield.

Table 10. Correlation (r), regression coefficients (b) and coefficient of determination (R^2) of various traits in wheat genotypes.

Character association	Correlation coefficient (r)	Regression coefficient (b)	Coefficient of determination (R^2)
Plant height vs. grain yield ton ha^{-1}	**0.644 ****	**4.501**	**0.415**
Days to heading vs. grain yield ton ha^{-1}	**0.615 ****	**4.867**	**0.378**
Days to maturity vs. grain yield ton ha^{-1}	**0.669 ****	**5.978**	**0.447**
No. of kernels $spike^{-1}$ vs. grain yield ton ha^{-1}	**0.225 ***	**1.991**	**0.051**
1000-grain weight vs. grain yield ton ha^{-1}	**0.441 ****	**1.901**	**0.194**

****Significant at P < 0.01 according to the t-test.**

Based on simple regression analysis, linear regression of No. of kernels $spike^{-1}$ and 1000-kernel weight they leads to increase the grain yield $plant^{-1}$ by 1.99 and 1.901 units, respectively.

Positive and significant association (r = 0.644**) was found between plant height and grain yield revealed that increase in plant height will increase correspondingly the grain yield. About 41.5% of total variability in grain yield was due to its association with plant height; while regression coefficient indicated that plant height increase of one cm will simultaneously give increase of 0.64 ton in grain yield. The correlation between days to heading and grain yield showed significantly positive association (r=0.615**). The coefficient of determination (R^2) revealed that 37.8% of total variability in grain yield was due to its association with days to heading. The correlation between days to maturity and grain yield showed significantly positive association (r = 0.669**). The coefficient of determination (R^2) revealed that 44.7% of total variability in grain yield was due to its association with days to heading.

The correlation between No. of kernels $spike^{-1}$ and grain yield showed significantly positive association (r = 0.225*) which indicated that increase in No. of kernels $spike^{-1}$ will markedly increase grain yield. The coefficient of determination (R^2) revealed that 5.1% of total variability in grain yield was due to its association with No. of kernels spike. The correlation between 1000-kernel weight and grain yield showed significantly positive association (r = 0.441**) which indicated that increase in 1000-kernel weight will markedly increase grain yield. The coefficient of determination (R^2) revealed that 19.4% of total variability in grain yield was due to its association with 1000-kernel weight.

Kashif and Khaliq (2004) reported that kernels spike^{-1} and 1000-kernel weight were main contributors to grain yield in wheat. It was also reported that grain yield showed significantly positive association with number of productive tillers plant, plant height, 1000-grain weight and spike length (Aycicek and Yildirim 2006).

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استجابة بعض التراكيب الوراثية من قمح الخبز للاجهاد الحرارى

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تم إجراء البحث الحالي لفهم تأثير درجات الحرارة المرتفعة على الصفات وثيقة الصلة بالمحصول ولتحديد التراكيب الوراثية التي تتحمل الإجهاد الحراري العالي لبرامج التربية في المستقبل. ولتحقيق هذا الهدف ، أجريت التجربة في ثلاثة مواسم متتالية ٢٠١٦/٢٠١٥ و ٢٠١٧/٢٠١٦ و ٢٠١٨/٢٠١٧. في كل موسم ، تم استخدام ثلاثة مواعيد للزراعة ، ميعاد الزراعة المثالى فى (٢٠ نوفمبر) و ١٠ ديسمبر و ميعاد زراعة متأخر (٣٠ ديسمبر) كبيئة للاجهاد الحراري مع ١٢ تركيب وراثى متنوعًا. كشف نتائج تحليل التباين التجميعى عبر ثلاثة مواسم متتالية لتصميم الشرائح المنشقة للصفات المدروسة أن المواسم (S) ومواعيد الزراعة (D) والتركيب الوراثية (G)

والتفاعلات بينهممثل SD و SG و DG و SDG كانت لها تاثير عالى المعنوية ($p\leq 0.01$) لجميع الصفات المدروسة ، باستثناء SD و SDG كانت غير معنوية لصفة محصول الحبوب. في هذه الدراسة ، تم تصنيف التراكيب الوراثية إلى أربع فئات مختلفة وفقًا لدليل الحساسية للحرارة (HIS) الفئة الاولى تتحمل الحرارة العالية (HSI <٠,٥٠) ، الفئة الثانية تتحمل الحرارة (HSI: 0.51-0.75) ، الفئة الثالثة ذات تحمل متوسط للحرارة (HSI: 0.76 - 1.00) والفئة الرابعة حساس للحرارة (HSI> ١,٠٠). أظهرت نتائج دليل الحساسية للحرارة إن الصنف مصر ٢ كان الافضل فى تحمل للحرارة حيث كانت قيم HSI عالية إلى معتدلة لصفات المحصول ومكوناته. وايضاوجد أن سدس ٤ حقق قيم HSI معتدلة لأربع صفات (ارتفاع النبات ،عدد ألايام حتى النضج ، عدد حبوب السنبلة ووزن ١٠٠٠ حبة). ومع ذلك ، كانت التراكيب سدس١ و وشندويل ١ و سدس ١٢و Line# 3 مرغوبة لأنها حققت قيم HSI معتدلة لثلاث صفات. وفي الوقت نفسه ، اظهرت التراكيب مصر ١ سخا ٩٥ ، Line#1 و Line#2 قيم معدلة لدليل الحاسية للحرارة وذلك لصفتين. بينما كانت التراكيب الوراثية جيزة ١٦٨ والجميزة ١ ، معتدلة لقيم HIS وذلك لصفة واحدة فقط. وبناء على ذلك يمكن اعتبار مصر ٢ ، سدس ٤ و سدس ١و شندويل ١ و سدس ١٢ و Line # 3 كتراكيب محتملة للحرارة. تم استخدام مقياس تحمل الحرارة النسبي (RHT) للصفات المدروسة للتراكيب الوراثية بين ميعاد الزراعة المتأخر (كبيئة للاجهاد الحرارى) مقارنة بميعاد الزراعة المثالى. واشارت النتائج الى ان مصر ٢ اعطى اقل قيم لـ RHT لصفتى عدد حبوب السنبلة ومحصول الحبوب (-١١,١٨٪ و -٢٦,٢٧٪ على التوالي). وبينت نتائج معامل الارتباط البسيط بين عدد حبوب السنبلة ومحصول الحبوب ارتباطًا إيجابيًا ومعنويا ($r = 0.225^*$). وكشف معامل التحديد (R^2) أن ٥,١٪ من التباين الكلي في غلة الحبوب يرجع إلى ارتباطها بعدد حبوب السنبلة. أظهر معامل الارتباط البسيط بين وزن ١٠٠٠ حبة ومحصول الحبوب ارتباطًا إيجابيًا وعالى المعنوية ($r = 0.441^{**}$). وكشف معامل التحديد (R^2) أن ١٩,٤٪ من التباين الكلي في إنتاج الحبوب يرجع إلى ارتباطه بوزن ١٠٠٠ حبة. استنادًا إلى تحليل الانحدار البسيط ، فإن زيادة صفتى عدد عدد حبوب السنبلة ووزن ١٠٠٠ حبة وحدة واحدة يؤدي إلى زيادة محصول الحبوب بنسبة ١,٩٩ و ١,٩٠١ وحدة على التوالي.