Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL
Volume 5, Issue 2, 2022, Pages 191–212

Available online at www.agricuta.edu.eg

DOI: https://dx.doi.org/10.21608/aasj.2022.150230.1126

Combining ability and heterosis estimates for yield and its components in bread wheat (*Triticum aestivum* L.) under different sowing dates

Mahdy A. G. M.[a*], Abdel-Haleem S. H. M.[a], Haridy M. H.[a], Mohi M. M.[b]

[a]*Department of Agronomy, Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt*
[b]*Department of Wheat Research, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt*

Abstract

The present investigation was carried out at El-Mattana Agricultural Research Station, Agricultural Research Center, Egypt, during the seasons 2017/2018 and 2018/2019. Seven diverse cultivars of wheat (*Triticum aestivum* L.) namely, Gemmeiza 11, Misr 1, Sids12, Giza 171, Sakha 93, Shandaweel 1 and Sids13 and their 21 F_1 hybrids were sown in two sowing dates to study the effect of heat stress on gene action of yield and its components i.e. number of spikes/ plant, biological yield/plant, number of grains/spike, grain yield/plant, 1000-grain weight, harvest index and straw yield /plant under both conditions. The differences among genotypes, parents, crosses, and parents versus crosses were highly significant under both conditions for most studied traits. Highly significant differences due to general (GCA) and specific (SCA) combining abilities were detected for all assessed traits in both environments as well as the combined analysis. GCA/SCA estimates were less than unity in most of the study traits in each environment and combined analysis. Results showed that both additive and non-additive types of gene effects were affected by planting date conditions. Five parents (P_5, P_4, P_7, P_1 and P_6) gave highly significant positive GCA effects for biological yield /plant, number of grains/spike and harvest index traits under both conditions. Six crosses $P_1 \times P_3$, $P_1 \times P_6$, $P_1 \times P_7$, $P_3 \times P_4$, $P_3 \times P_5$ and $P_5 \times P_6$ had highly significant SCA effects under both conditions. The estimates of heterosis showed that there were positive and significant or highly significant heterotic effects over better parent under normal and late sowing dates in all studied traits and were recorded for no. of spikes/plant (6 and 17 crosses), biological yield/plant (7 and 21 crosses), no of grains/spike (6 and 6 crosses), harvest index (8 and 3crosses) and straw yield/plant (7 and 19 crosses) respectively. Four crosses ($P_2 \times P_4$), ($P_4 \times P_5$), ($P_4 \times P_6$) and ($P_4 \times P_7$) including Giza 171 (P_4) have heat susceptibility index (HSI) values less than unity. This indicates that the tolerant parent (P_4) transmitted its genes controlling tolerance to heat stress to its hybrids. Such results cleared that high-temperature stress caused a reduction for all studied traits.

Keywords: Diallel cross analysis, bread wheat, heat stress conditions, combining ability and heterosis.

*Corresponding author: Mahdy A. G. M.,
E-mail address: ahmedgabermahdy@gmail.com

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the important strategic crops all over the world, and in Egypt. In Egypt all people approximately depend on wheat in their food. Despite the importance of wheat, the national production is not sufficient to meet the local demand due to the high increase in population, especially in the recent years. The cultivated area of wheat in Egypt is about 1.37 million hectares with a production of approximately 9.2 million tons as in (FAO, 2019). Although, the importance of wheat for the food security of Egyptian people, the local production that reached to 9 million tons produced from 1370235 ha is not sufficient (FAO, 2020). Delaying sowing date exposes the wheat crop to high temperature in the end of growing duration. This could expose the wheat crop to some damages. Iqbal *et al.* (2017) confirmed that wheat cultivars that can with stand abiotic stresses particularly terminal heat tolerance will be able to fulfill the food demand in coming years. Therefore, development of new improved wheat cultivars with high genetic potential for yield under stress environment has become a major objective in wheat breeding programs. Many studies were carried out and confirmed the adverse effects of late sowing on yield and, Singh and Pal (2003) emphasized that sowing date is playing an important role among various agronomic factors, which influencing the quality and yield of wheat. Sowing date is one of the most important factors that govern the crop phonological development and efficient conversion of biomass into economic yield. Normal sowing date has longer growth during which consequently provides an opportunity to accumulate more biomass as compared to late sowing, hence manifested in higher grain and biological yields. Tolba (2000) reported that high temperature stress is a major environmental factor that limits yield in wheat. Every 1^{o}C increase over a mean temperature of 23^{o}C reduces wheat yield by 10%. Zhongfu *et al.* (2014) showed that delay in planting usually decreases individual plant growth and tillering potential and reduction in grain yield of wheat due to reduction in number of spikes/unit area, number of fertile spikes/plant and number of grains/spike. Wollenweber *et al*. (2003) reported that high temperature stress caused reduction in grain weight. Wiegard and Cuellar (1981) mentioned that the period of grain filling of wheat decreases by three days with an increase of 1.0 C^o in mean daily air temperature during grain filling. Therefore, more breeding efforts are required to improve new high yielding cultivars resistant/and or tolerant to heat stress. The study of combining ability and identification of gene action such as additive, dominance and epistatic effects are very important for the choice of the parents for any breeding program. Also, the magnitude of genetic variability for the different studied traits are very useful to identify the best progenies in the breeding program. Kumar *et al*. (2017) reported that knowledge of general and specific combining ability along with the mode of gene action in the available breeding materials are very important to start the effective wheat breeding program. The main objectives of the study were: to determine the combining ability and heterosis in bread wheat genotypes under normal and late sowing dates, and to identify the best combiners and its combinations under heat stress conditions.

2. Materials and methods

2.1 Experimental site and treatments description

The present investigation was carried out at El-Mattana Agricultural Research Station, Agricultural Research Center, Egypt, during 2017/2018 and 2018/2019 seasons. Seven varied bread wheat (*Triticum aestivum* L.) genotypes were used as parental lines in this study, their pedigree and origin are given in Table (1).

2.2 Hybridization and field procedure

In 2017/2018 season, the seven parents were sown on three different dates, 15th November 25th November and 5th December, to avoid differences in flowering time, and to secure enough hybrid seed. Hybridization was made by hand for at least 25 spikes for each cross after 2-4 *days* from hand emasculation. All possible crosses among parents, excluding reciprocals were made.

Table (1): Pedigree and origin of the seven parental genotypes used in the present investigation.

Name	Pedigree	Origin
Gemmeiza 11 (P_1)	B0W"S"/KVZ"S"//7C/SERI82/3/GIZA168/SAKHA61.CGM7892-2GM—1GM-2GM-1GM0GM	Egypt
Masr 1 (P_2)	OASIS/SKAUZ//4*BCN/3/2*PASTOR	Egypt
Sids 12 (P_3)	BUC//7C/ALD/5/MAYA74/ON//1160-147/3/BB/GLL/4/ CHAT "S" /6/MAYA/VUL//CMH74A.630/4*SX, SD7096-4SD- LSD-0SD	Egypt
Giza 171 (P_4)	SAKHA 93 / GEMMEIZA 9 S.6-1GZ-4GZ-1GZ-2GZ-0S	Egypt
Sakha 93(P_5)	SAKHA 92/TR 810328:	Egypt
Shandaweel 1 (P_6)	SITE//MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC	Egypt
Sids 13 (P_7)	ALMAZ-19=KAUZ "S" // TSI/SNB "S" ICW94-0375-4AP-2AP-030AP-0APS-3AP-0APS-050AP-0AP-0SD	Egypt

In the season of 2018/2019, hundred eighty grains of each of the 7 parents and the twenty-one F_1 hybrids were grown in two sowing dates *i.e*., 20th November (normal sowing date) and 20th December (late sowing date). The experiment was designed in a randomized complete block design with three replications. Each of the parents and F_1 hybrids were represented by one row per block. The plants were grown in three-meter-long rows, spaced 30 cm apart and plants spaced 10 cm between plants within rows, within each row. The recommended agricultural practices were applied from sowing to harvest. The following characteristics were measured on 10 guarded plants from the parents and F_1 hybrids in each plot in the two planting dates.

2.3 Data collected for yield and its components

The following characters were recorded on plot basis for each of the parents and their 21 F_1 hybrids i.e. number of spikes/ plant (NS/P) was calculated by counting the number of effective or fertile tillers for spikes/plant, Biological yield/plant (BY/P, g) was determined by the total biomass produced of the plant during the season (excluding the roots),number of grains/spike (NG/S) was estimated by counting the number of grains per spike as average of 10 random spikes, grain yield/plant (GY/P, g) average grain weight of individual guarded plants after sun dried then were weighted at 13% moisture,1000-grain weight (GW, g), the weight of 1000-grains of each sample/plot, harvest index (HI, %), was estimated as the ratio between grain yield per plant (economic) and biological yield per plant *i.e.*, total biomass (excluding the roots) as the following formula: harvest index = (grain yield per plant / biological yield per plant)×100 and straw yield /plant (SY/P, g), was estimated by the difference between the biological yield /plant and grain yield /plant.

2.4 Statistical analysis

Statistical analysis was made on plot mean basis.

2.4.1 Combining ability analysis

Estimates of general and specific combining ability variances and their effects were calculated using the ordinary method for analysis of variance in a randomized block design. If the differences between genotypes were significant, further analysis for general and specific combining ability were made according to Griffing (1956), Method 2, Model 1 (Fixed effects for the parents), the degrees of freedom and expectation of mean squares for general and specific combining ability for one date and combined over two dates are presented in Table (2).

Where, d, r, g and p are number of dates, replications, genotypes and parents, respectively.

Estimates of the combining abilities are obtained as follows:

$GCA_{SS} = 1/(n+2)\ [\sum_i (Yi.+Yii)^2 - (4/n)Y..^2]$

$SCA_{SS} = \sum_{iSJ} Yij^2 - 1/n + 2\sum_i (Yi.+Yii)^2 + 2/(n+1)\ (n+2)\ Y..^2$

The general (gi) and specific (sij) combining ability effects were computed for each parent and cross as follows:

$gi = 1/n+2\ [\ \sum(Yi+Yii) - 2/nY..]$

$sij = Yij - 1/n+2[Yi+Yii+Yj+Yjj]+[2/(n+1)(n+2)]Y..$

Standard error of estimates of components and effects for F_1's were computed as follows:

$S.E.\ (gi) = [(n-1)\ \sigma^2_e /n\ (n+2)]\ ½$

$S.E.\ (gi-gj) = [2\ \sigma^2_e / (n+2)]\ ½$

$S.E.\ (sij) = [(n^2+n+2)\ \sigma^2_e / (n+1)\ (n+2)]\ ½$

$S.E.\ (sij-sik) = [2(n+1)\ \sigma^2_e / (n+2)]\ ½$

$S.E.\ (sij-skl) = [2n\ \sigma^2_e / (n+2)]\ ½$

Table (2): Analysis of variance for the seven parents and their 21 F_1 crosses as well as expected mean (E.M.S) squares according to Griffing (1956), Method II, Model I.

S.O.V	D.F	M.S	E.M.S
One date			
Reps (R)	(r-1) = 2		
Genotypes (G)	(g-1) = 27		
Parents (P)	(P-1) = 6		
Crosses (C)	{P(P-1)/2}-1 = 20		
P. vs. C.	=1	Mg	σ^2_e +(P+2) (1/P-1)$\sum g_i^2$
GCA	(P-1) = 6	Ms	σ^2_e +{2/P(P-1)} $\sum_i \sum jS^2_{ij}$
SCA	{P(P-1)/2} = 21	Me	σ^2_e
Pooled error	(r-1) (g-1) = 54		
Over dates			
Dates (D)	(d-1) = 1		
Reps/Dates	d(r-1) = 4		
Genotypes (G)	(g-1) = 27		
Parents (P)	(P-1) = 6		
Crosses (C)	{P(P-1)/2}-1 = 20	Mg	σ^2_e + r$\sum Sd^2{}_{ijd}$ +rd (2/n(n-2) $\sum s^2_{ij}$ + r$\sum g^2$ di +rd (n+2) (1/n-1)$\sum g_i^2$
P. vs. C.	= 1		
GCA	(p-1) = 6		σ^2_e + r$\sum Sd^2{}_{ijd}$ + rd (2/n(n-2) $\sum s^2_{ij}$
SCA	{P(P-1)/2} = 21	Ms	
G × D	(g-1) (d-1) = 26		
P × D	(P-1) (d-1) = 6		σ^2_e + r$\sum g^2{}_{id}$
C × D	{P(P-1)/2-1} (d-1) = 20		σ^2_e + r$\sum Sd^2{}_{ijd}$
GCA × D	(P-1) (d-1) = 6	Mgd	σ^2_e
SCA × D	{P(P-1)/2} (d-1) = 21	Msd	
Pooled error	d (r-1) (g-1) = 108	Me	

L.S.D. = $S_{\bar{d}}$ x tα. $S_{\bar{d}}$ for mid-parent = [3 Mse/2r]^{½}, $S_{\bar{d}}$ for better parent = [2 Mse/r]^{½}. t = tabulated value at the degree of freedom for the error. Mse = Mean squares for error or pooled error. r = number of replications.

2.4.2 Heterosis for better parent

Heterosis was calculated as a deviation of percentage of F_1 mean from the mean of higher parent according to following formula:

$$\text{Heterosis (B.P)} = [(\overline{F1} - \overline{B.P.}) / \overline{B.P.}] \times 100$$

$\overline{F1}$ =Mean performance of F_1 cross. $\overline{B.P.}$ =Mean performance of the better parent. Significance of heterosis: L.S.D. (least significant differences) was used to test the significance of heterosis.

2.4.3 Calculation of heat susceptibility index (HSI)

Heat susceptibility index (HSI) was calculated according to the method of Fisher and Maurer (1978) as follows:

$$\text{HSI} = (1 - \overline{Yd} / \overline{Yp}) / \text{SI}$$

Where, Yd = Mean yield in stress environment. Yp = Mean yield in non-stress environment. SI= Environmental stress intensity. SI= 1- (Mean of Yd for all genotypes in stress / Means of Yp for all genotypes in non-stress environments).

2.4.4 Meteorological data

As shown in Table (3), meteorological data *i.e*, monthly temperature (C°) and relative humidity (%) at Mattana agricultural experimental station from two planting dates which were on 20th November (normal sowing date) and 20th

December (late sowing date) to physiological maturity date, during winter season 2018/2019. Source of these data is the Egyptian Ministry of Agriculture and Land Reclamation; Agricultural Research Center (ARC).

Table (3): Monthly maximum, minimum and daily mean temperature (C°) and relative humidity (%) at Mattana agricultural experimental station, during winter season 2018/2019.

Season		Temperature (C°)			Relative humidity (%)
Month	Day	Maximum	Minimum	Daily mean	
November	22 – 30	24.3	13.1	18.7	42.78
	Average	24.3	13.1	18.7	42.78
December	1 – 10	23.3	11.0	17.2	49.1
	11 – 20	23.2	8.7	16.0	49.00
	21 – 31	21.7	8.9	15.3	53.36
	Average	22.7	9.5	16.1	50.49
January	1 – 10	20.1	6.4	13.3	44.80
	11 – 20	18.7	6.2	12.5	40.00
	21 – 31	19.5	4.7	12.1	40.55
	Average	19.4	5.8	16.6	41.78
February	1 – 10	23.4	7.7	15.6	37.9
	11 – 20	24.5	10.5	17.5	38.6
	21 – 28	19.5	7.6	13.6	33.75
	Average	22.5	8.6	15.5	36.75
March	1 – 10	24.5	9.4	17.0	32.50
	11 – 20	28.0	11.9	20.0	27.40
	21 – 31	28.0	14.5	21.3	24.18
	Average	26.8	11.9	19.4	28.03
April	1 – 10	30.9	15.8	23.4	34.20
	11 – 20	32.1	16.5	24.3	30.25
	21 – 30	34.9	18.1	26.5	23.40
	Average	32.6	16.8	24.7	29.28
May	1 – 10	37.61	22.89	30.25	24.82
	11 – 20	38.11	23.10	30.58	23.36
	21 – 31	44.14	26.36	35.24	23.10
	Average	39.95	24.12	32.02	23.76

Source : Meteorological Authority at El-Mattanaa, Luxor governorate, Egypt.

3. Results and discussion

3.1 Analysis of variance and mean performance

Analysis of variance for yield and its components *i.e.*, number of spikes/plant (NS/P), biological yield/plant (BY/P, g), number of grains/spike (NG/S), grain yield/plant (GY/P, g), 1000-grain weight (GW, g), harvest index (HI, %) and straw yield/plant (SY/P, g) of the 7×7 half dialell cross are presented in Table (4). The results showed that were highly significant except (P *vs* C) for NS/P in normal sowing date and crosses and (P *vs* C) for HI in late sowing date only, confirming the presence of differences among the varied genotypes and their F_1 hybrids and ranked differently in the two sowing date treatments. Variances of both GCA and SCA were also highly significant for all studied traits in both separate and combined analysis, except GCA for HI in late sowing date, indicating both additive and non-additive gene action controlled in the inheritance of all traits. The σ^2 GCA / σ^2 SCA ratio was less than unity for most cases including both separate and combined for all studied traits, except for GW trait which was more than unity in both two sowing dates and combined. These results showed that the largest part of the total genetic variance due to non-additive gene action effect than additive. Baker (1978) stated that if the ratio of σ^2 GCA / σ^2 SCA equal one or more, parents of high performance transmit their characteristics to their hybrids. If this ratio is less than unity, the performance of the hybrids could not be predicted. Results in Table (4) showed that the mean squares of dates and genotypes × dates were significant or highly significant, indicating differential response of genotypes from date to another. Variances of the interaction between dates and both types of combining abilities were significant or highly significant for all studied traits revealing that the magnitude of all types of gene action effects and varied from date to another. The results indicated that the ratio of (GCA × Dates / GCA) was higher than (SCA × Dates / SCA) for NS/P and BY/P, while the ratio of (SCA × Dates / SCA) was higher than (GCA × Dates / GCA) for both NG/S and G Y/P, but both ratios were equal (= 0.50) for GW , HI and SY/P, confirming that both additive and non-additive type of gene effects were affected by sowing date conditions. Gilbert (1958) reported that the specific combining ability was more sensitive to environmental changes than general combining ability. Concerning the means of yield and its components traits for the seven parental varieties and their 21 F_1-hybrids under normal and late sowing dates are presented in Table (5). For NS/P, the parental average was 11.29 in the normal sowing date and reduced to 5.57 under late sowing date (heat stress conditions), indicating 50.66% reduction in NS/P. The average NS/ P of the F_1-hybrids decreased from 11.40 in the normal sowing date to 6.89 under heat stress condition making 39.56% reduction in NS/P. In the two sowing dates, however, the variety Sakha 93 (P_5) was the best in NS/P (15 and 6) under normal and late sowing dates, respectively. Whereas the variety Sids 12 (P_3) displayed the lowest N S/P (9.67 and 5.0) under normal and late sowing dates, respectively. The average of BY/P of the hybrids decreased from 77.54 in the normal environment to 42.06 in the late sowing dates, demonstrating 45.76 reduction in the BY/P. Also, the variety Sakha 93(P_5) was the highest in BY/P (95.33 and 33.33) under normal and late sowing dates, respectively. Shandaweel 1 (P_6) was the lowest performance for the BY/P (68.17 and 28.67) in both normal and late sowing dates, respectively. Regarding the average NG/S of the F1 hybrids decreased from 68.02 in the normal environment to 58.51 in the stressed environment.

Table (4): Mean squares of the studied traits under normal (N), late (L) sowing dates and their combined of 7 bread wheat varieties and their 21 F_1 hybrids during 2018/2019 season.

S.O.V	D.F	M.S																				
		Number of spikes/plant			Biological yield/plant			Number of grains/spike			Grain yield/plant			1000-grain weight			Harvest index			Straw yield /plant		
		N	L	Comb.	N	L	Comb.	N	L	Comb.	N	L	Comb.	N	L	Comb.	N	L	Comb.	N	L	Comb.
Rep	2	0.73	0.62	------	15.88	2.94	-------	6.08	1.23	---------	0.23	0.30	-------	38.19	7.56	------	0.59	0.59	------	12.74	1.46	------
Genotypes	27	7.07**	3.34**	6.03**	198.3**	75.02**	163.8**	125.2**	71.58**	103.8**	18.86**	7.03**	18.73**	56.91**	58.50**	88.86**	15.56**	7.36**	12.65**	133.6**	39.73**	92.40**
Parents	6	14.27**	2.48**	------	387.9**	17.75**	--------	111.4**	48.64**	-------	4.53**	2.60**	---------	61.47**	120.9**	------	21.29**	21.03**	------	318.4**	14.71**	------
Crosses	20	5.25**	3.01**	------	131.0**	41.69**	---------	135.4**	59.51**	-------	16.21**	3.29**	--------	49.21**	30.31**	-------	12.07**	3.19	-------	81.35**	23.80**	-------
Parents *vs* Crosses	1	0.19	14.97**	------	406.7**	1085.2**	-------	4.00**	450.6**	--------	157.9**	108.4**	--------	183.6**	247.9**	--------	50.98**	8.67	------	69.80**	508.5**	-------
GCA	6	21.17**	3.15**	68.57**	473.4**	50.34**	321.51**	279.1**	40.44**	229.05**	33.52**	4.07**	27.02**	187.9**	175.7**	292.79**	42.69**	4.72	27.92**	356.4**	28.10**	235.04**
SCA	21	3.04**	3.3.9**	11.95**	119.7**	82.08**	132.53**	81.26**	80.48**	79.48**	14.67**	7.87**	16.54**	30.91**	25.03**	30.53**	7.81**	8.11**	8.27**	69.96**	43.06**	51.33**
Error	54	1.17	0.73	------	3.20	3.84	--------	12.19	3.88	--------	1.30	0.82	--------	8.58	10.55	-----	1.75	2.83	-----	2.61	3.34	-----
Dates	1	-----	------	971.5**	-------	-------	5292.2**	---------	------	4080.9**	-------	--------	2963.5**	-----	-----	2028.8**	------	------	295.9**	------	------	2651.9**
Rep. (dates)	4	-----	------	0.67	-------	---------	10.69*	--------	--------	0.60	---------	--------	0.76	-----	------	33.04**	-----	-----	1.09	------	------	6.97*
Genotypes × Dates	27	-----	-----	4.38**	--------	--------	109.5**	---------	--------	76.22**	--------	-------	7.15*	------	-----	26.55**	-----	------	10.27**	-----	------	80.93**
GCA × Dates	6	-----	------	9.25**	--------	-------	174.7**	--------	--------	88.22**	--------	-------	82.16**	-----	-----	146.6**	-----	------	13.96*	------	-----	118.0**
SCA × Dates	21	------	-----	1.23**	------	-------	55.42**	--------	----------	41.55**	---------	---------	170.7**	-----	-----	15.28**	------	------	4.14**	--------	--------	25.68**
Error (Comb.)	108	-------	------	0.95	---------	--------	3.47	-------	--------	4.82	---------	----------	1.04	------	-----	9.19	-------	------	2.27	-------	------	2.48
σ^2 GCA / σ^2 SCA	------	0.87	0.27	0.94	0.65	1.5	0.35	0.98	0.14	0.24	0.65	1.5	0.05	1.74	2.01	1.71	1.56	0.17	0.40	1.46	0.19	0.52
GCA × Dates / GCA	-			0.13			0.54			0.39			3.04			0.50			0.50			0.50
SCA × Dates / SCA				0.10			0.42			0.52			10.32			0.50			0.50			0.50

The Shandaweel 1 (P_6) was the highest in NG/S (71.33 and 61.00) under normal and late sowing dates, respectively. Meanwhile, the Sakha 93 (P_5) was the lowest one for NG/S (62.67 and 48.00) under normal and late sowing dates, respectively. Concerning GY/P, the parental average reached 17.67 in the optimum sowing date but was reduced to 9.52 g. under late sowing dates, indicating 46.12% reduction in GY/P. The average GY/P of the F1 hybrids decreased from 20.63 under normal sowing date down to 12.14 under late sowing dates with 41.15% reduction in GY/P. The average 1000-grain weight (GW, g.) of parental varieties reached 58.48g under normal sowing date and down to 50.37 in late sowing date, 13.87% average reduction in 1000-GW. Also, Sids 12 (P_3) was the heaviest for GW (66.83 and 54.29) under normal and late sowing dates, respectively. Whereas the parent variety Sids 13 (P_7) was the lightest in GW (53.23 and 42.77) under both normal and late sowing dates, respectively. The average of GW of the F1-hybrids decreased from 61.67 in the normal sowing date down to 54.55g in late sowing dates with 11.55% reduction in GW. For HI trait, the parental average reached to 28.10g. in the normal sowing date but was reduced to 24.66 in late sowing date with 12.24% reduction in HI. The variety Shandaweel 1 (P_6) was the great grain size among the set of parents, while the cultivar Sakha 93 (P_5) was the lowest parent (29.and 21.37) in the normal and late sowing dates, respectively. The average HI of the F1 hybrids decreased from 28.84 in the optimum environment down to 26.45 in late sowing dates with reduction 8.29%. For the average SY/P, the parental variety reached to 54.81g. in optimum sowing date but was reduced to 24.24g. in late sowing dates with reduction 55.77%. Meanwhile, the cultivar Sakha 93 (P_5) was the highest in SY/P (75.00 and 23.53) under normal and stressed conditions, respectively. The cultivar Shandaweel 1 (P_6) displayed the lowest performance for SY/P (52.17 and 19.63) under normal and late sowing dates, respectively. The average SY/P of the F1-hybrids decreased from 56.91 in the normal sowing date down to 29.92 under stress environment making 47.43% reduction in SY/P. Such reduction under heat stress conditions agree with those reported by Rao *et al*. (1980) stated that late sowing have a high day temperature during the grain filling stage, it could be responsible for low yield, as it adversely affect the number of grains and grain weight. These results are in line with those obtained by Motawea (2006), Ahmed *et al.* (2009), Hassan (2015), Hassan (2016), Shrief *et al.* (2017), Ahmed *et al*. (2017), Jaiswal *et al.* (2017), Asmaa *et al.* (2018), Sharma *et al.* (2019) and Ali *et al* (2020), while Moshref (1996) cleared that sowing date did not affect number of grains/spike.

Table (5): Mean performance of the parental varieties and their F_1-hybrids grown under normal (N) and (L) sowing dates and their combined (Comb.) and reduction (Red. %) for the studied traits during 2018/2019 season.

Parents & Crosses	Number of spikes/plant				Biological yield/plant				Number of grains/spike				Grain yield/plant				1000-grain weight				Harvest index				Straw yield /plant			
	N	L	Comb.	Red.%	N	L	Comb.	Red.%	N	L	Comb.	Red .%	N	L	Comb.	Red.%	N	L	Comb.	Red.%	N	L	Comb.	Red.%	N	L	Comb.	Red.%
P_1	10.00	6.00	8.00	40.00	63.33	35.67	49.5	43.68	64.00	54.33	59.17	15.11	18.33	10.00	14.17	45.44	61.00	48.01	54.51	21.30	28.87	28.17	28.52	2.42	45.00	25.67	35.34	42.96
P_2	12.67	5.67	9.17	55.25	76.87	35.00	55.94	54.47	65.33	51.00	58.17	21.93	16.67	8.67	12.67	48.00	56.03	52.03	54.03	7.14	24.67	21.66	23.17	12.20	60.20	26.33	43.27	56.26
P_3	9.67	5.00	7.34	48.29	67.00	35.00	51.00	47.76	63.67	54.67	59.17	14.14	16.90	10.33	13.62	38.88	66.83	54.29	60.56	18.76	29.20	25.17	27.19	13.80	50.11	24.67	37.39	50.77
P_4	9.33	5.33	7.33	42.87	74.03	35.33	54.68	52.28	68.67	53.00	60.84	22.82	19.03	10.67	14.85	43.93	62.77	54.01	58.39	13.96	30.00	25.88	27.94	13.73	55.00	24.67	39.84	60.66
P_5	15.33	6.00	10.67	60.86	95.33	33.33	64.33	65.04	62.67	48.00	55.34	23.41	20.37	9.81	15.09	51.84	58.60	52.11	55.36	11.10	29.00	21.37	25.19	26.31	75.00	23.53	49.27	68.63
P_6	10.00	5.33	7.67	46.70	68.17	28.67	48.42	57.94	71.33	61.00	66.17	14.48	16.00	9.02	12.51	43.63	50.91	49.40	50.16	2.97	31.33	23.55	27.44	24.83	52.17	19.63	35.90	62.37
P_7	12.00	5.67	8.84	52.75	62.50	33.33	47.92	46.67	66.00	52.00	59.00	21.21	16.37	8.13	12.25	50.34	53.23	42.77	48.00	19.65	26.09	24.33	25.21	6.75	46.17	25.20	35.84	45.42
Parent mean	11.29	5.57	8.43	50.66	72.46	33.76	53.11	53.41	67.24	53.43	60.34	20.54	17.67	9.52	13.60	46.12	58.48	50.37	54.43	13.87	28.10	24.66	26.38	12.24	54.81	24.24	39.53	55.77
$P_1 \times P_2$	12.00	8.00	10.00	33.33	73.00	41.00	57.00	43.84	58.67	56.00	57.34	4.55	18.73	12.67	15.70	32.35	64.63	53.75	59.19	16.83	30.67	25.67	28.17	16.31	54.27	28.33	41.30	47.80
$P_1 \times P_3$	11.33	7.33	9.33	35.30	82.67	41.00	61.84	50.41	64.00	53.67	58.84	16.14	23.00	11.67	17.34	49.26	65.97	59.97	62.97	9.10	28.33	27.70	28.02	2.22	59.67	29.33	44.50	50.85
$P_1 \times P_4$	10.67	5.67	8.17	46.86	73.33	37.33	55.33	49.10	64.67	53.33	59.00	17.54	21.67	11.00	16.34	49.24	64.03	63.43	63.73	0.94	29.47	29.33	29.40	0.48	51.67	26.33	39.00	49.04
$P_1 \times P_5$	13.33	6.67	10.00	49.96	83.33	47.00	65.17	43.60	64.67	56.00	60.34	13.41	24.00	14.00	19.00	41.67	61.87	53.80	57.83	13.04	29.67	28.33	29.00	4.52	59.33	33.00	46.17	44.38
$P_1 \times P_6$	13.67	6.00	9.84	56.11	86.57	38.67	62.62	55.33	64.33	55.67	60.00	13.46	25.23	11.33	18.28	55.10	59.47	52.49	55.98	11.74	29.33	28.83	29.08	1.70	61.33	27.33	44.33	55.44
$P_1 \times P_7$	14.00	6.67	10.34	52.36	82.00	41.67	61.84	49.18	72.00	58.00	65.00	19.44	23.33	12.33	17.83	47.15	56.83	50.59	53.71	10.98	30.00	28.23	29.12	5.90	58.67	29.33	44.00	50.01
$P_2 \times P_3$	10.00	5.67	7.84	43.30	72.67	41.67	57.17	42.66	57.67	56.67	57.17	1.73	18.03	12.00	15.02	33.44	66.13	54.71	60.42	17.27	28.67	24.67	26.67	13.95	54.63	29.33	41.98	46.31
$P_2 \times P_4$	10.33	7.33	8.83	29.04	75.33	36.33	55.83	51.77	62.67	62.00	62.34	1.10	18.43	10.67	14.55	42.11	61.67	54.33	58.00	11.90	29.33	24.33	26.83	17.05	56.90	25.67	41.29	54.89
$P_2 \times P_5$	13.00	6.33	9.67	51.31	79.33	45.67	62.5	42.43	62.33	60.33	61.33	3.21	21.63	13.33	17.48	38.37	60.50	53.31	56.91	11.88	29.00	27.23	28.12	6.10	57.70	32.33	45.02	43.97
$P_2 \times P_6$	11.00	6.00	8.5	45.45	78.33	38.33	58.33	51.10	74.67	50.67	62.67	32.14	16.47	11.67	14.07	29.14	56.83	51.01	53.92	10.24	30.00	21.00	25.50	30.00	61.87	26.67	44.27	56.89
$P_2 \times P_7$	12.00	6.67	9.34	44.42	71.77	42.33	57.05	41.02	78.33	61.00	69.67	22.12	19.17	12.67	15.92	33.91	56.47	51.17	53.82	9.39	30.00	26.33	28.17	12.23	52.60	30.00	41.30	42.97
$P_3 \times P_4$	10.00	5.00	7.5	50.00	79.00	42.00	60.50	46.84	66.00	53.33	59.67	19.20	22.00	12.00	17.00	45.45	64.57	63.07	63.82	2.32	28.67	27.60	28.14	3.73	57.00	30.00	43.50	47.37
$P_3 \times P_5$	10.67	6.67	8.67	37.49	85.00	43.33	64.17	49.02	73.00	66.00	69.50	9.59	20.80	12.33	16.57	40.72	63.63	55.26	59.45	13.15	28.33	24.33	26.33	14.12	64.20	31.10	47.65	51.56
$P_3 \times P_6$	10.33	6.67	8.50	35.43	74.33	43.00	58.67	42.15	79.33	58.67	69.00	26.04	18.33	11.33	14.83	38.19	62.57	58.62	60.60	6.31	26.33	24.53	25.43	6.84	56.00	31.67	43.84	43.45
$P_3 \times P_7$	10.67	7.33	9.00	31.30	74.17	36.33	55.25	51.02	76.00	53.67	64.84	29.38	19.67	10.33	15.00	47.48	61.90	54.67	58.29	11.68	28.67	26.33	27.50	8.16	54.50	26.00	40.25	52.29
$P_4 \times P_5$	10.33	8.00	9.17	22.56	79.67	51.00	65.34	35.99	63.33	57.67	60.50	8.94	21.67	14.00	17.84	35.39	67.43	55.93	61.68	17.10	27.10	27.67	27.39	1.01	58.00	37.00	47.50	36.21
$P_4 \times P_6$	9.33	6.33	7.83	32.15	75.67	39.33	57.50	48.02	69.00	60.00	64.50	13.04	20.67	11.00	15.84	46.78	60.07	56.41	58.24	6.09	27.67	27.30	27.49	1.34	55.00	28.33	41.67	48.49
$P_4 \times P_7$	10.33	8.00	9.17	22.56	63.23	45.67	54.45	27.77	69.00	62.33	65.67	9.67	17.33	13.67	15.50	21.12	61.80	52.17	56.99	15.58	29.67	27.23	28.45	8.22	45.90	32.00	38.95	30.28
$P_5 \times P_6$	12.00	7.33	9.67	38.92	93.73	42.67	68.20	54.48	72.00	64.67	68.34	10.18	22.83	12.00	17.42	47.44	62.50	51.90	57.20	16.96	28.00	24.17	26.10	13.68	70.90	30.67	50.79	56.74
$P_5 \times P_7$	12.33	9.33	10.83	24.33	74.23	46.67	60.45	37.13	66.00	62.67	64.34	5.05	20.50	13.00	16.75	36.59	58.47	48.33	53.40	17.34	27.67	27.57	27.62	0.36	53.73	33.67	43.70	37.33
$P_6 \times P_7$	12.00	7.67	9.84	36.10	71.00	42.33	56.67	40.38	74.00	63.00	68.50	14.86	19.67	12.00	15.84	39.00	58.23	50.58	54.41	13.14	28.67	27.50	28.10	4.08	51.33	30.33	40.83	40.91
Cross mean	11.40	6.89	9.15	39.56	77.54	42.06	59.80	45.76	68.02	58.51	63.27	13.98	20.63	12.14	16.39	41.15	61.67	54.55	58.11	11.55	28.84	26.45	27.65	8.29	56.91	29.92	43.42	47.43
P +C mean	11.37	6.56	8.47	42.30	76.27	39.99	58.13	47.57	67.62	57.44	62.53	15.10	19.89	11.49	15.69	42.23	60.67	53.72	57.20	11.46	28.66	26.00	27.33	9.28	56.39	28.50	42.45	49.46

3.2 Combining ability analysis

3.2.1 General combining ability

Results in Table (6) showed that Sakha 93 (P_5) has a desirable significant ($P\leq0.01$) GCA effects for NS/P, BY/P, GY/P and also it had significant GCA effects for NG/S under both normal and late sowing date conditions, so (P_5) could be considered a good combiner to improve these traits under both environment conditions. Also, Giza 171 (P_4), has a desirable highly significant GCA effects for GW and HI in both conditions, and was significant GCA effects for BY/P and GY/P in late sowing date only. So (P4), is considered a good combiner for improving GW and HI under both environment conditions. The parental variety Sids 13 (P_7), gave highly significant GCA effects for NS/P and NG/S under both environment conditions revealed that the Sids 13 (P_7) is the best GCA combiner among the parents to improve NS/P and NG/S traits under both conditions. The variety Gemmeiza 11 (P_1) had highly significant GCA effects for NS/P, GY/P, GW and HI under normal sowing date, and also gave highly significant GCA effects for GW and HI under late sowing date, so (P_1) has GCA effects for improving these traits under normal and late sowing dates, respectively. Shandaweel 1 (P_6) showed highly significant GCA effects for BY/P, NG/S and HI traits under both conditions. The results showed none of the parent was the good combiner for all traits, but the parent Sakha 93 (P_5) was the good combiner for three traits i.e. NS/P, BY/P and GY/P at both environments.

3.2.2 Specific combining ability

Specific combining ability effects are presented in Table (6). Five and ten crosses showed favourable positive and highly significant SCA effects for NS/P under normal and late sowing dates, respectively. These crosses involved one or more parents of positive GCA effects under both environments. Two crosses, ($P_1 \times P_3$) and ($P_6 \times P_7$) gave the favourable positive and significant SCA effects for NS/P under both conditions, indicating non-additive genetic variance. However, one cross ($P_2 \times P_3$) gave negative and significant SCA effects under both conditions. Regarding to BY/P trait, ten and eighteen crosses had highly significant SCA effects under normal and late sowing dates, respectively. Seven crosses ($P_1 \times P_3$), ($P_1 \times P_6$), ($P_1 \times P_7$), ($P_2 \times P_6$), ($P_2 \times P_7$), ($P_3 \times P_4$) and ($P_3 \times P_5$) gave a desirable positive and highly significant SCA effects for BY/P under both environments. On the other hand, one cross $P_1 \times P_4$ was the worse one in both conditions. Concerning to the NG/S trait, eight and twelve crosses had favourable positive and highly significant SCA effects for NG/S under favourable and heat stress conditions, respectively.

Table (6): General (GCA) and specific (SCA) combining ability effects of seven bread wheat varieties and their F1 hybrids under normal and late planting dates for the studied traits during 2018/2019 season.

Genotype	Number of spikes/plant		Biological yield/plant		Number of grains/spike		Grain yield/plant		1000-grain weight		Harvest index		Straw yield /plant	
	N	L	N	L	N	L	N	L	N	L	N	L	N	L
P_1	0.45**	-0.02	-0.29*	-o.21	-3.03**	-1.73**	1.50**	-0.12*	0.10	0.98**	2.00**	0.49**	-1.80**	-0.33**
P_2	0.30**	0.13*-	-0.67**	-0.51**	-2.40**	-0.58**	-1.48**	-0.17**	0.06	-1.68**	-1.72**	-0.25*	-0.81**	-0.34**
P_3	0.96**-	0.42**-	-0.93**	-0.29*	0.15	-0.80**	-0.39**	0.17**-	2.79**	3.67**	-0.28**	-0.21	-0.54**	-0.14
P_4	1.25**-	0.16**-	-1.76**	0.27*	-1.00**	-0.50**	0.08	0.20**	2.69**	2.12**	0.75**	0.34**	-1.85**	0.07
P_5	1.27**	0.43**	8.42**	2.57**	-2.18**	1.02**	1.45**	0.71**	-0.78**	-0.89**	-0.73**	-0.10	6.97**	1.87**
P_6	0.29**-	0.20**-	0.64**	-2.03**	5.89**	1.68**	0.43**-	0.50**-	-0.77**	-2.99**	-0.84**	0.38**	1.07**	-1.53**
P_7	0.49**	0.50**	-5.42**	0.20	2.56**	0.94**	0.74**-	0.18**-	-4.10**	-2.80**	0.82**	-0.66**	-4.67**	0.41**
S.E gi	0.07	0.06	0.12	0.13	0.24	0.13	0.10	0.10	0.20	0.22	0.10	0.11	0.11	0.10
S.E (gi-gj)	0.22	0.17	0.36	0.40	0.70	0.40	0.23	0.18	0.59	0.66	0.27	0.34	0.33	0.31
$P_1 \times P_2$	0.12-	1.58**	-2.32**	1.73**	-6.19**	3.53**	1.18**-	1.23**	-0.13	4.66**	-0.61**	1.77**	-1.13**	0.50**
$P_1 \times P_3$	0.47**	1.21**	7.61**	1.51**	-0.74	-1.25**	2.00**	0.23*-	3.36**	0.64	-0.20	-0.61**	5.62**	1.31**
$P_1 \times P_4$	0.10	0.71**-	-0.89**	-2.71**	1.07**	-1.84**	0.19	-0.81**	7.52**	-0.34	0.72**	-0.16	-1.08**	-1.90**
$P_1 \times P_5$	0.25*	0.31**-	-1.07**	4.66**	2.26**	-0.73**	1.16**	1.68**	0.76*	-0.48	1.06**	0.62**	-2.23**	2.97**
$P_1 \times P_6$	2.14**	-0.34**	9.94**	0.92**	-6.15**	-1.73**	4..28**	0.23*	-0.56	0.81*	1.68**	-0.19	5.67**	0.70**
$P_1 \times P_7$	1.69**	-0.38**	11.44**	1.69**	4.85**	1.34**	2.69**	0.91**	0.86**	-2.2**	-0.58*	-1.51**	8.75**	0.76**
$P_2 \times P_3$	-0.71**	-0.34**	-2.01**	2.47**	-8.70**	1.60**	0.01	0.86**-	-1.87**	3.46**	0.66**	0.47*	-2.02**	1.31**
$P_2 \times P_4$	-0.08	1.07**	1.49**	-3.42**	-1.56**	5.68**	-0.1	-0.84**	-2.14**	0.55	-0.70**	0.58**	1.55**	-2.57**
$P_2 \times P_5$	0.07	-0.53**	-4.69**	3.62**	-2.70**	4.45**	1.77**	1.31**	0.30	0.81*	3.68**	0.70**	-6.47**	2.30**
$P_2 \times P_6$	-0.38**	-0.23*	2.09**	0.88**	3.56**	-7.88**	-1.51**	0.86**	-2.01**	0.83	-2.44**	1.21**	3.60**	0.03
$P_2 \times P_7$	-0.16	-0.27**	1.58**	2.66**	10.56**	3.19**	1.50**	1.53**	1.46**	0.27	1.23**	2.25**	0.08	1.42**
$P_3 \times P_4$	0.84**	-0.97**	5.42**	2.03**	-0.78*	-2.77**	2.42**	0.49**	3.88**	1.90**	1.12**	-0.13	3.00**	1.57**
$P_3 \times P_5$	-1.01**	0.10	1.23**	1.07**	7.41**	8.34**	-0.16	0.31**	-0.47	-1.40**	-0.66**	-0.02	1.38**	0.87**
$P_3 \times P_6$	0.21	0.73**	-1.66**	5.32**	5.67**	0.34	-0.74**	0.52**	2.88**	1.21**	-0.35*	-2.50**	-0.92**	4.83**
$P_3 \times P_7$	-0.23	0.69**	4.24**	3.57**-	5.67**	-3.92**	0.91**	-0.80**	2.24**	0.36	-0.21	0.87**	3.33**	-2.77**
$P_4 \times P_5$	-1.05**	1.18**	-3.26**	8.18**	-1.11**	-0.25	-0.25	1.61**	0.31	3.95**	1.07**	-1.23**	-3.51**	6.56**
$P_4 \times P_6$	-0.49**	0.14	0.52*	1.10**	-3.52**	1.42**	1.13**	-0.18	0.77*	0.26	1.39**	-1.71**	-0.61**	1.29**
$P_4 \times P_7$	-0.27*	1.10**	-5.86**	5.21**	-0.19	4.49**	-1.89**	2.16**	-0.16	1.81**	-0.34*	1.33**	-3.97**	3.02**
$P_5 \times P_6$	-0.34**	0.55**	8.40**	2.14**	0.67	4.53**	1.93**	0.31**	-0.27	4.13**	-0.27	-0.93**	6.46**	1.83**
$P_5 \times P_7$	-0.79**	1.84**	-5.04**	3.92**	-5.33**	6.60**	-0.10	0.98**	-0.53	-0.10	1.47**	-0.23	-4.96**	2.89**
$P_6 \times P_7$	0.44**	0.81**	-0.50*	4.18**	-2.07**	2.94**	0.96**	1.20**	1.71**	3.35**	1.52**	0.29	-1.46**	2.95**
S.E sij	0.12	0.10	0.20	0.22	0.40	0.22	0.13	0.10	0.33	0.37	0.15	0.20	0.18	0.17
S.E (sij-sik)	0.33	0.24	0.51	0.56	1.00	0.56	0.33	0.23	0.84	0.93	0.38	0.48	0.46	0.44

Three crosses (P_1 × P_7), (P_2 ×P_7) and (P_3 × P_5) were highly significant positive SCA effects under both conditions, two out of them involved two parents, P_1 and P_7, confirming that these parents were good combiners for this trait. The SCA effects for GY/P showed eleven and fourteen crosses were highly significant positive under normal and late sowing dates, respectively. Seven crosses (P_1 × P_5), (P_1 × P_7), (P_2 × P_5), (P_2 × P_7), (P_3 × P_4), (P_5 × P_6) and (P_6 × P_7) gave highly significant positive under both environments. Four out of them involved P_1 or P_7 proving that these parents could be recommended under two environment conditions for GY/P trait. Some crosses (P_1 × P_2, P_2 × P_6, P_3 × P_6, P_4 × P_7) and (P_1 × P_4, P_2 × P_3, P_2 × P_4, P_3 × P_7) showed negative significant SCA effects for GY/P under normal and late sowing dates, respectively. These crosses included one or more parents had positive GCA effects under one environment or both, confirming that GY/P in the preponderance of non-additive performance could not be expected. For 1000-grain weight (GW, g), eight hybrids in each environment had a desirable and highly significant SCA effects. Three crosses P_3 × P_4, P_3 × P_6 and P_6 × P_7 gave a desirable positive and highly significant SCA effects under both environments. These crosses involved two or one parent had positive GCA effects under both environments, confirming that the performance of GW depend on both additive and non-additive gene effects. The SCA effects of HI showed eleven and eight crosses were favourable significant ($P \leq 0.01$) SCA effects under normal and stress condition, respectively. Three crosses P_1 × P_5, P_2 × P_5 and P_2 × P_7 gave highly significant positive SCA effects under both conditions, these crosses included two parents P_2 and P_5 had highly significant positive GCA effects under both conditions. Also, two crosses P_2 × P_6 and P_3 × P_5 under normal and five crosses P_1 × P_7, P_3 × P_6, P_4 × P_5, P_4 × P_6 and P_5 × P_6 under late sowing date gave highly significant negative SCA effects, despite of the three parents P_1, P_5 and P_6 gave highly significant positive GCA effects under late conditions. These results state that the presence of dominance and epistasis effects in the inheritance for HI. Regarding SY/P nine and seventeen crosses gave a desirable positive and highly significant SCA effects under normal and late sowing dates, respectively. Six crosses P_1 × P_3, P_1 × P_6, P_1 × P_7, P_3 × P_4, P_3 × P_5 and P_5 × P_6 had a desirable and highly significant SCA effects under both conditions, five out of them included two parents P_1 and P_3 which gave highly significant negative GCA effects under both conditions. Two crosses P_1×P_4 and P_2×P_4 gave highly significant negative SCA effects under both conditions. The results of HI indicate that presence of both additive and non-additive gene effects. The results indicated that in the presence of non-additive makes the performance of the hybrids could not be expected according to GCA effects. These results agree with the findings of Baker (1978), El-Borhamy (2004), Ahmed *et al.* (2009), Hassan (2016), Ahmed *et al.* (2017), Asmaa *et al.* (2018), Sharma *et al.* (2019) and Ali *et al* (2020). Singh and Pal (2003) and Hassan (2015) reported that SCA mean square was greater than GCA mean square for 1000-kernel weight, number of tillers/plant, number of grains /spike, and grain yield /plant.

3.3 Heterosis

Heterosis or hybrid vigor can be regarded as the converse of the deterioration that accompanies inbreeding. Fehr (1987) recognized heterosis as the superiority in performance of hybrid individual compared with their parents. Better-parent heterosis is a comparison of the performance of a hybrid with that of its better parent. Heterosis estimates over better parent for NS/P, BY/P, NG/S, GY/P, GW, HI and SY/P under both environments are shown in Table (7). Estimates of heterosis for NS/P over the better parent (BP) under normal and late sowing dates and late sowing dates showed that there are 6 and 17 crosses gave significantly higher than its BP under normal and late sowing dates, respectively. The highest crosses in NS/P were (P_1 × P_3) and (P_5 × P_7) they gave 44.33 and 55.55 of heterosis under normal and late sowing dates, respectively. These results go with highly significant positive SCA effects of these two crosses. With respect to BY/P the estimates of heterosis showed that there are 7 and 20 crosses significantly higher than its BP under normal and late sowing dates, respectively. Two crosses (P_1 × P_7) and (P_4 × P_5) were the highest hybrids in BY/P, and they gave 29.47 and 44.34% of heterosis under normal and late sowing dates, respectively. For NG/S estimates of heterosis demonstrated that there are 5 and 9 crosses significantly higher than its BP under normal and late sowing dates, respectively. The higher crosses in NG/S were (P_2 × P_7) and (P_3 × P_5) they gave 18.68 and 20.72 of heterosis under normal and late sowing dates, respectively. Results of heterosis estimates for GY/P showed clearly that there are 15 and 17 crosses significantly higher than its BP under normal and late sowing dates, respectively. The (P_1 × P_6) and (P_2 × P_7) were the best hybrids, they gave 37.64 and 46.14 of heterosis under normal and late sowing dates, respectively. Estimates of heterosis for GW showed that there are 4 and 5 crosses were highly significantly than its BP under normal and late sowing dates, respectively. The greatest crosses in GW were (P_6 × P_7) and (P_3 × P_4), it gave 9.39 and 12.36 of heterosis under normal and late sowing dates, respectively. With regard to HI estimates of heterosis showed that there are 7 and 3 crosses significantly higher than its BP under normal and late sowing dates, respectively. The great grain size among the set of crosses in HI were (P_2 × P_5) and (P_2 × P_7), it gave 25.75 and 21.62 of heterosis under normal and late sowing dates, respectively.

Table (7): Heterosis percentage over better parent for yield and its components traits under recommended (N) and late sowing dates (L) in 2018/2019 season.

Crosses	Number of spikes/ plant		Biological yield/plant		Number of grains/spike		Grain yield/plant		1000-grain weight		Harvest index		Straw yield /plant	
	N	L	N	L	N	L	N	L	N	L	N	L	N	L
$P_1 \times P_2$	-5.29**	33.33**	-5.03**	14.95**	-9.69**	3.07	2.18	26.70**	5.96*	3.31	-11.09**	8.88**	-9.86**	7.59**
$P_1 \times P_3$	44.33**	22.22**	23.38**	14.95**	0.00	-1.83	25.48**	12.97**	-1.30	10.46**	-4.04**	-2.97**	19.08**	14.29**
$P_1 \times P_4$	6.70**	-5.55**	-0.95	4.67**	-5.82**	-1.84	13.87**	3.09	1.06	11.09**	2.08	-2.22	-6.06**	2.60**
$P_1 \times P_5$	-13.05**	11.22**	-12.59**	31.78**	1.05	3.07	17.82**	40.00**	1.42	3.24	-1.85	2.30	-20.89**	28.57**
$P_1 \times P_6$	36.70**	0.00	26.99**	8.41**	-9.82**	-8.74**	37.64**	13.30**	-2.51	6.26*	-0.12	-6.38**	17.57**	6.49**
$P_1 \times P_7$	16.67**	11.12**	29.47**	16.82**	9.09**	6.76**	27.28**	23.30**	-6.83**	5.37**	-2.19**	6.51**	27.08**	14.29**
$P_2 \times P_3$	-21.07**	0.00	-5.46**	19.05**	-11.22**	-3.05	6.69**	16.17**	-1.05	0.77	-1.99	-1.83	-9.25**	11.39**
$P_2 \times P_4$	-18.47**	29.40**	-1.99	2.83*	-8.74**	16.98**	-3.15	0.00	-1.75	0.59	-5.98**	-2.22	-5.48**	-2.53**
$P_2 \times P_5$	-15.20**	5.55**	-16.78**	30.48**	-4.59	13.73**	6.19**	35.88**	-3.61	2.30	25.75**	0.00	-23.07**	22.78**
$P_2 \times P_6$	-13.18**	5.88**	1.91	9.52**	4.68	-16.93**	-1.20	29.38**	9.22**	-1.96	-10.82**	-4.26**	2.77**	1.27
$P_2 \times P_7$	-5.29**	17.65**	-6.63**	20.95**	18.68**	17.31**	15.00**	46.14**	6.07*	-1.65	0.95	21.62**	-12.62**	13.92**
$P_3 \times P_4$	3.41**	-6.24**	6.71**	18.87**	-3.89	-2.45	15.61**	12.46**	-3.39	12.36**	6.65**	-4.44**	3.64**	21.62**
$P_3 \times P_5$	-30.40**	11.12**	--10.84**	23.81**	14.65**	20.72**	2.11	19.36**	-4.79*	1.79	-3.31**	-2.97*	-14.40**	26.08**
$P_3 \times P_6$	3.30**	25.01**	9.05**	22.86**	11.21**	-3.82*	8.46**	9.68**	-6.38**	7.98**	-2.52**	-15.96**	7.35**	28.38**
$P_3 \times P_7$	-11.08**	29.40**	10.70**	3.81**	15.15**	-1.83	16.39**	0.00	-7.38**	0.70	0.95	-1.83	8.77**	3.17**
$P_4 \times P_5$	-32.62**	33.33**	-16.43**	44.34**	-7.78**	8.81**	6.38**	31.21**	7.43**	3.55	4.71**	-7.78**	-22.67**	50.00**
$P_4 \times P_6$	-6.70**	18.75**	2.21	11.32**	-3.27	-1.64	8.62**	3.09	-4.30	4.44	5.49**	-11.70**	0.00	14.86**
$P_4 \times P_7$	-13.92**	41.17**	-14.59**	29.25**	0.48	17.60**	-8.93	28.12**	-1.54	-3.41	4.40**	-1.11	-16.55**	26.98**
$P_5 \times P_6$	-21.72**	22.22**	-1.68	28.00**	0.93	6.02**	12.08**	22.32**	6.66**	-0.40	2.63*	-3.45*	-5.47**	30.31**
$P_5 \times P_7$	-19.57**	55.55**	-22.13**	40.00**	0.00	20.52**	0.64	32.52**	-0.23	-7.25**	5.67**	-4.60**	-28.36**	33.60**
$P_6 \times P_7$	0.00	35.29**	4.16**	27.00**	3.74	3.28*	20.16**	33.04**	9.39**	2.39	5.42**	-8.51**	-1.60	20.37**
L.S.D 0.05	1.77	1.40	2.64	2.50	5.70	3.22	2.92	3.21	4.78	5.31	2.16	2.75	1.86	1.48
L.S.D 0.01	2.35	1.86	3.51	3.32	7.58	4.28	3.88	4.26	6.36	7.06	2.87	3.65	2.48	1.97

Regarding for SY/P estimates of heterosis showed that there are 7 and 19 crosses were highly significantly than its BP under normal and late sowing dates, respectively. The higher crosses in SY/P were ($P_1 \times P_7$) and ($P_4 \times P_5$), it gave 27.08 and 50.00 of heterosis under normal and late sowing dates, respectively. The results showed that there is no hybrid gave positive values over better parent under two environment conditions for all studied traits, but the cross Gemmeiza 1 × Sids 13 ($P_1 \times P_7$) was the best one for all studied traits, except for GW and HI traits under normal sowing date. This result is confirmed by positive favorable significant SCA effects of this hybrid ($P_1 \times P_7$) for all traits under two environment conditions except for NS/P trait under late sowing date, HI under both conditions and GW trait under late sowing date. This cross could be considered the best hybrid and it can be used in breeding program as promising hybrids for tolerant to heat under late sowing date. Variable estimates of heterosis were found from planting date to another which could be due to the highly significant interaction between genotypes × sowing dates and P *vs* C. Furthermore, the sensitivity of the parents to heat stress which was one of the major causes of heterosis fluctuations. It is of interest to indicate that the highest yielding hybrids were not always the highest in heterosis because of the sensitivity of parents which are taken as a measure of heterosis. These results are in line with those obtained by Zaied (1995), Moshref (1996), El-Sayed (1997), Tammam and Abdel-Gawad (1999), Jahanzeb and Ihsan (2004), Darwish *et al.* (2006), Abd-El-kader (2006), Akinci (2009), Nassar (2013), Hassan (2015), Sherif *et al.* (2017), Asmaa *et al.* (2018) and Ali *et al.* (2020).

3.4 Heat susceptibility index (HSI)

High temperature stress is a major environmental factor that limits yield in wheat. Every 1^{o}C increase over a mean temperature of 23^{o}C reduces wheat yield by 10% (Tolba, 2000). Delaying in planting usually decreases individual plant growth and tillering potential and reduction in grain yield of wheat due to reduction in number of spikes/unit area, number of fertile spikes/plant and number of grains/spike (Zhongfu *et al.*, 2014). Therefore, more breeding efforts are required to develop new high yielding cultivars tolerant to heat stress. Heat susceptibility index (HSI) was calculated for NS/P, NG/S, GY/P and GW are given in Table (8). For NS/P values of heat susceptibility index (HSI) of the parental genotypes ranged from 0.95 for Gemmeiza 11 (P_1) to 1.44 for Sakha 93 (P_5), indicating that Gemmeiza 11 (P_1) were relatively stress tolerant. However, the most susceptible parents were Misr 1 (P_2), Sids 12 (P_3), Giza 171 (P_4), Sakha 93 (P_5), Shandaweel 1 (P_6) and Sids 13 (P_7) while the F_1 hybrids ranged from 0.53 for both crosses ($P_4 \times P_5$) and ($P_4 \times P_7$) to 1.33 for cross ($P_1 \times P_6$). Some crosses ($P_1 \times P_2$), ($P_1 \times P_3$), ($P_2 \times P_4$), (P_3

× P_5), (P_3 × P_6), (P_3 × P_7), (P_4 × P_5), (P_4 × P_6), (P_4 × P_7), (P_5 × P_6), (P_5 × P_7) and (P_6 × P_7) showed relatively stress tolerant. For NG/S heat susceptibility index (HSI) of the parental genotypes ranged from 0.87 for Sids 12 (P_3) to 1.44 for Sakha 93 (P_5). These results indicating that Gemmeiza 11 (P_1), Sids 12 (P_3) and Shandaweel 1 (P_6) were relatively stress tolerant. However, the most susceptible parents were Masr 1 (P_2), Giza 171 (P_4), Sakha 93 (P_5) and Sids 13 (P_7).

Table (8): Mean performance for number of spikes/plant, number of grains/spike, grain yield/plant and 1000-grain weight under normal (N) and late sowing dates (L) and estimates of heat susceptibility index (HSI) of 7 bread wheat varieties and their 21 F_1 crosses, during 2018/2019 season.

Parents & Crosses	NS/P			NG/S			GY/P			GW		
	N	L	HSI	N	L	HSI	N	L	HSI	N	L	HSI
P_1	10.00	6.00	0.95	64.00	54.33	0.93	18.33	10.00	1.08	61.00	48.01	1.71
P_2	12.67	5.67	1.31	65.33	51.00	1.35	16.67	8.67	1.14	56.03	52.03	0.57
P_3	9.67	5.00	1.14	63.67	54.67	0.87	16.90	10.33	0.92	66.83	54.29	1.51
P_4	9.33	5.33	1.01	68.67	53.00	1.40	19.03	10.67	1.04	62.77	54.01	1.12
P_5	15.33	6.00	1.44	62.67	48.00	1.44	20.37	9.81	1.23	58.60	52.11	0.89
P_6	10.00	5.33	1.10	71.33	61.00	0.89	16.00	9.02	1.03	51.00	49.40	0.25
P_7	12.00	5.67	1.25	66.00	52.00	1.30	16.37	8.13	1.19	53.23	42.77	1.58
$P_1 \times P_2$	12.00	8.00	0.79	59.00	56.00	0.31	18.73	12.67	0.77	64.63	53.75	1.35
$P_1 \times P_3$	11.33	7.33	0.83	64.00	53.67	0.99	23.00	11.67	1.17	65.97	59.97	0.73
$P_1 \times P_4$	10.67	5.67	1.11	64.67	53.33	1.08	21.67	11.00	1.17	64.03	60.00	0.51
$P_1 \times P_5$	13.33	6.67	1.18	64.67	56.00	0.82	24.00	14.00	0.99	61.87	53.80	1.05
$P_1 \times P_6$	13.67	6.00	1.33	64.33	55.67	0.83	25.23	11.33	1.30	59.47	52.49	0.94
$P_1 \times P_7$	14.00	6.67	1.24	72.00	58.00	1.19	23.33	12.33	1.12	56.83	50.59	0.88
$P_2 \times P_3$	10.00	5.67	1.02	58.00	53.00	0.53	18.03	12.00	0.79	66.13	54.71	1.39
$P_2 \times P_4$	10.33	7.33	0.69	62.67	62.00	0.07	18.43	10.67	1.00	61.67	54.33	0.96
$P_2 \times P_5$	13.00	6.33	1.21	62.33	58.00	0.43	21.63	13.33	0.91	60.50	53.31	0.95
$P_2 \times P_6$	11.00	6.00	1.07	74.67	50.67	1.98	16.47	11.67	0.69	56.83	51.01	0.82
$P_2 \times P_7$	12.00	6.67	1.05	78.33	61.00	1.36	19.17	12.67	0.80	56.47	51.17	0.75
$P_3 \times P_4$	10.00	5.00	1.18	66.00	53.33	1.18	22.00	12.00	1.08	64.57	61.00	0.44
$P_3 \times P_5$	10.67	6.67	0.89	73.00	66.00	0.59	20.80	12.33	0.96	63.63	55.26	1.06
$P_3 \times P_6$	10.33	6.67	0.84	79.33	58.67	1.60	18.33	11.33	0.90	62.57	58.62	0.51
$P_3 \times P_7$	10.67	7.33	0.74	76.00	53.67	1.81	19.67	10.33	1.12	61.90	54.67	0.94
$P_4 \times P_5$	10.33	8.00	0.53	63.33	57.67	0.55	21.67	14.00	0.84	67.43	55.93	1.37
$P_4 \times P_6$	9.33	6.33	0.76	69.00	60.00	0.80	20.67	11.00	1.11	60.07	56.41	0.49
$P_4 \times P_7$	10.33	8.00	0.53	69.00	62.33	0.59	17.33	13.67	0.50	61.80	52.17	1.25
$P_5 \times P_6$	12.00	7.33	0.92	72.00	64.67	0.63	22.83	12.00	1.12	62.50	51.90	1.36
$P_5 \times P_7$	12.33	9.33	0.57	66.00	62.67	0.31	20.50	13.00	0.87	58.47	48.33	1.39
$P_6 \times P_7$	12.00	7.67	0.85	74.00	63.00	0.91	19.67	12.00	0.92	58.23	50.58	1.05
Mean	11.37	6.56	1.00	67.64	56.91	0.98	19.89	11.49	1.00	60.89	53.31	1.00

While the F_1 hybrids ranged from 0.07 (near zero) for crosses (P_2 × P_4) to 1.98 for cross (P_2 × P_6). Some crosses (P_1 × P_2), (P_1 × P_3), (P_1 × P_5), (P_1 × P_6), (P_2 × P_3), (P_2 × P_4), (P_2 × P_5), (P_3 × P_5), (P_4 × P_5), (P_4 × P_6), (P_4 × P_7), (P_5 × P_6), (P_5 × P_7) and (P_6 ×P_7) showed relatively stress tolerant. Regarding to GY/P values of heat susceptibility index (HSI) of the parental genotypes ranged from 0.92 for Sids 12 (P_3) to 1.23 for Sakha 93 (P_5), while the F_1 hybrids ranged from 0.50 for crosses (P_4 × P_7) to 1.30 for cross (P_1 × P_6), results indicating that Sids 12 (P_3) was relatively stress tolerant. However, the most susceptible parents were Gemmeiza 11 (P_1), Masr1 (P_2), Giza 171 (P_4), Sakha 93 (P_5), Shandaweel 1 (P_6) and Sids 13 (P_7). Some crosses (P_1 × P_2), (P_1 × P_5), (P_2 × P_3), (P_2 × P_5), (P_2 × P_6), (P_2 × P_7), (P_3 × P_5), (P_3 × P_6), (P_4 × P_5), (P_4 × P_7), (P_5 × P_7) and (P_6 × P_7) showed relatively stress tolerant. For GW values of heat susceptibility index (HSI) of the parental genotypes ranged from 0.25 for Shandaweel 1 (P_6) to 1.71 for Gemmeiza 11 (P_1), while the F_1 hybrids ranged from 0.44 for crosses ($P_3 \times P_4$) to 1.39 for both crosses ($P_2 \times P_3$) and ($P_5 \times P_7$), results indicating that Masr1 (P_2), Sakha 93 (P_5) and Shandaweel 1 (P_6) were relatively stress tolerant. However, the most susceptible parents were Gemmeiza 11 (P_1), Sids 12 (P_3), Giza 171 (P_4), and Sids 13 (P_7). Some crosses ($P_1 \times P_3$), ($P_1 \times P_4$), ($P_1 \times P_6$), ($P_1 \times P_7$) , ($P_2 \times P_4$) , ($P_2 \times P_5$), ($P_2 \times P_6$) , ($P_3 \times P_7$), ($P_3 \times P_4$), ($P_3 \times P_6$), ($P_3 \times P_7$), and ($P_4 \times P_6$) showed relatively stress tolerant. It could be concluded that the most tolerant parents for most traits were Gemmeiza 11 (P_1), Sids 12 (P_3) and Shandaweel 1 (P_6). However, ($P_1 \times P_2$), ($P_1 \times P_3$), ($P_2 \times P_4$), ($P_3 \times P_5$), ($P_3 \times P_6$), ($P_4 \times P_5$), ($P_4 \times P_6$), ($P_4 \times P_7$), ($P_5 \times P_7$) and ($P_6 \times P_7$) showed relatively stress tolerant for most studied traits. It is of interest to note that 4 crosses ($P_2 \times P_4$), ($P_4 \times P_5$), ($P_4 \times P_6$) and ($P_4 \times P_7$) including Giza 171 (P_4) have (HSI) values less than unity as previously mentioned. This indicates that the tolerant parent (P_4) transmitted its genes controlling tolerance to heat stress to its hybrids and these mentioned crosses above could be considered promising hybrids, and selection for heat tolerance could be feasible in their segregating generations. These results are agreed with those obtained by Moshref (1996), Zakaria (1999), Dencic *et al.* (2000), El-Morshidy *et al*. (2001), Taghian and Abo-Elwafa (2003), Hoffman and Burucs (2005), Motawea (2006), Khan *et al.* (2007), Ahmed *et al.* (2009), Nassar (2013), Hassan (2015), Hassan (2016), Ahmed *et al.* (2017), Jaiswal *et al.* (2017), Bajaniya *et al.* (2019) and Ali *et al.* (2020).

References

Abdel-Kader, M. N. (2006), *Genetical studies on grain yield and some agronomic characters in some durum wheat crosses*, M.Sc. Thesis, Faculty of Agriculture, El-Minia University, El-Minia, Egypt.

Ahmed, M. S. H. and Mohamed, S. M. S. (2009), "Diallel crosses of bread wheat (*Triticum aestivum* L.) at two sowing dates 1. Genetic analysis of yield and its components", *Egyptian Journal of Plant Breeding*, Vol. 13, pp. 281–301.

Ahmed, N., Khan A. S., Kashif, M. and Rehman, A. (2017), "Genetic studies of biomass partitioning in wheat under water stress conditions", *The Journal of Animal Plant Sciences*, Vol. 27, pp. 144–152.

Akinci, C. (2009), "Heterosis and combining ability estimates in 6x6 half-diallel crosses of durum wheat (*Triticum durum* Desf)", *Bulgarian Journal of Agricultural Science*, Vol. 15 No. 3, pp. 214–221.

Ali, M. A., Hassan, M. S. and Ali, I. A. (2020), "Combining ability of some wheat genotypes under different environments", *SVU-International Journal of Agricultural Science*, Vol. 2 No. 2, pp. 291–306.

Ashoush, H. A., Hamada, A. A. and Darwish, I. H. (2001), "Heterosis and combining ability in F_1 and F_2 diallel crosses of wheat (*Triticum aestivum* L. em. Thell)", *Mansoura Journal Agriculture Research*, Vol. 26 No. 5, pp. 2579–2592.

Badr Asmaa, M., Ahmed, M. F., Esmail, A. M. and Rashed, M. A. (2018), "Heat tolerance in some bread wheat genotypes under two sowing dates", *Arab University Journal of Agriculture Sciences*, Vol. 26 No. 2A, pp. 987–1000.

Bajaniya, N., Pansuriga A. G., Vekaria, D. M., Singh, C. and Savaliga J. J. (2019), "Combining ability for grain yield and its components in durum wheat (*Triticum durum* L.)", *Indian Journal Pure Applied Bioscience*, Vol. 7, pp. 217–224.

Baker, R. J. (1978), "Issues in diallel analysis", *Crop Science*, Vol. 18, pp. 533–536.

Darwish, I. H. I., El-Sayed, E. and El-Awady, Waffa (2006), "Genetical studies of heading date and some agronomic characters in wheat", *Annals of Agriculture Science, Moshtohor*, Vol. 44 No. 2, pp. 427–452.

Dencic, S., Kastori, R. K. and Duggan, B. (2000), "Evaluation of grain yield and its components in wheat cultivars and landraces under optimal and drought conditions", *Euphitica*, Vol. 113, pp. 43–52.

El-Borhamy, H. S. A. (2004), "Genetic analysis of some drought and yield related characters in spring wheat varieties (*Triticum aestivum* L. em. Thell)", *Journal of Agricultural Sciences*, Vol. 29 No. 7, pp. 3719–3729.

El-Morshidy, M. A., Kheiralla, K. A. A. and Zakaria, M. M. (2001), Studies on grain filling under different planting dates in wheat, The Second Plant Breeding Conference, Assiut University, Assiut, Egypt, Vol. 2, pp. 241–263.

El-Sayed, E. M. A. (1997), *Quantitative inheritance of yield and some of its contributory characters in common wheat*, M.Sc. Thesis, Faculty of Agriculture, Menofiya University, Egypt.

FAO (2019), *Global information and Early Warning System*, Food and Agriculture Organization of the United Nations, available at https://www.fao.org/giews/countrybrief/country.jsp?code=EGY.

FAOSTAT (2020), *FAOSTAT statistical database*, Food and Agriculture Organization of the United Nations, Rome, Italy.

Fischer, R. A. and Maurer, R. (1978),

"Drought resistance in spring wheat cultivars, 1. Grain yield responses", *Assiut Journal of Agricultural Sciences*, Vol. 29 No. 5, pp. 897–912.

Gilbert, N. E. G. (1958), "Dialell cross in plant breeding heredity", *Heredity*, Vol. 12, pp. 477–492.

Griffing, B. (1956), "Concept of general and specific combining ability in relation to diallel crossing systems", *Assiut Journal of Biology Science*, Vol. 9, pp. 463–493.

Hassan, M. I. (2016), "Assessment of genetic diversity in bread wheat genotypes based on heat tolerance and SSR markers", *Assiut Journal of Agricultural Science*, Vol. 47 No. 5, pp. 37–55.

Hassan, M. O. M. (2015), *Combining ability and genetic components in durum wheat under heat stress conditions in reclaimed soils*, M.Sc. Thesis, Faculty of Agriculture, Assiut University, Egypt.

Hoffmann, B. and Burues, Z. (2005), "Adaptation of wheat (*Triticum aestivum* L.) genotypes and related species to water deficiency", *Cereal Research Communication*, Vol. 33 No. 4, pp. 681–687.

Iqbal, M., Raja, N. I., Yasmeen, F., Hussain, M., Ejaz, M. and Shah, M. A. (2017), "Impact of heat stress on wheat: A critical review", *Advances in Crop Science and Technology*, Vol. 5 No. 1, pp. 1–9.

Jahanzeb, F. and Ihsan, K. (2004), "Estimation of heterosis and heterobeltiosis of some quantitative characters in bread wheat crosses", *Asian Journal of Plant Science*, Vol. 3 No. 4, pp. 508–511.

Jaiswal, B. S., Prasad R., Dwivedi S.; Singh R., Shrivastava R., S. A. Kumar and Yadav, R. K. (2017), "Study of yield and yield components of wheat (*Triticum aestivum* L.) genotypes at grain filling stage under heat regimes", *International Journal Pure Applied Bioscience*, Vol. 5 No. 4, pp. 331–340.

Khan, M. I, Mohammad, T., Subhan, M. A. and Shah, S. T. (2007), "Agronomic evaluation of different bread wheat (*Triticum aestivum* L.) genotypes for terminal heat stress", *Pakistanian Journal Botany*, Vol. 39 No. 7, pp. 2415–2425.

Kumar, J., Singh, S. K., Singh L., Kumar M., Srivastava, M., Singh, J. and Kumar, A. (2017), "Combining ability analysis for yield and its components in bread wheat (*Triticum aestivum* L.) under abiotic stress", *International Journal of Current Microbiology and Applied Sciences*, Vol. 6 No. 3, pp. 24–39.

Moshref, M. K. (1996), *Genetical and statistical studies in wheat*, Ph.D. Thesis, Faculty of Agriculture, Al-Azhar University, Egypt.

Motawea, M. H. (2006), "Inheritance of earliness, yield and yield components in wheat (*Triticum aestivum* L. em. Thell)", *Assiut Journal of Agricultural Sciences*, Vol. 37 No. 2, pp. 35¬52.

Nassar, S. M. A. M. (2013), *Genetic variance and combining ability in bread wheat under drought stress conditions*, Ph.D. Thesis, Faculty of Agriculture, Assiut University, Egypt.

Rao, M. H., Sinha, M. N. and Rai, R. K. (1980), "Effect of dates of sowing and phosphorus levels on wheat yield and phosphorus utilization", *Indian Journal of Agriculture Science*, Vol. 50, pp. 236–239.

Sarker, S. and Torofder, M. G. S. (1992), "Effect of date of sowing and seed rate on wheat (*Triticum aestivum* L. em. Thell) under rainfed condition", *Indian Journal of Agronomy*, Vol. 37, pp. 352–354.

Sharma, V., Dodiya N. S., Dubey R. B. and Khan, R. (2019), "Combining ability analysis in bread wheat (*Triticum aestivum* L. em. Thell) under different environmental conditions", *Bangladesh Journal Botany*, Vol. 48, pp. 89–93.

Shrief, S. A., Abd-El-Shafi, M. A. M. and Sawsan, A. E. (2017), "Heterosis, gene action and combining ability of grain yield and its components in six bread wheat crosses", *Bioscience Research*, Vol. 14 No. 4, pp. 1204–1215.

Singh, S. and Pal, M. (2003), "Growth, yield and phonological response of wheat cultivars to delayed sowing", *Indian Journal of Plant Physiology*, Vol. 8 No. 3, pp. 277–286.

Taghian, A. S. and Abo-Elwafa, A. (2003), "Multivariate and RAPD analysis of drought tolerance in spring wheat (*Triticum aestivum* L.", *Assiut Journal of Agricultural Science*s, Vol. 34 No. 5, pp. 1–22.

Tammam, A. M. and Abd EL-Gawad, Y. G. (1999), "Heterosis and combining ability for bread wheat under new valley conditions", *Egypt Journal Applied Science*, Vol. 14 No. 10, pp. 122–135.

Tolba, A. M. (2000), "Diallel analysis of yield and its attributes in bread wheat (*Triticum aestivum* L.)", *Egypt Journal Plant Breeding*, Vol. 4, pp. 71–87.

Wiegand, C. L. and Cuellar, J. A. (1981), "Duration of grain filling and kernel weight of wheat as affected by temperature", *Crop Science*, Vol. 21, pp. 95–101.

Wollenweber, B., Porter J. R. and Schellberg, J. (2003), "Lack of interaction between extreme high temperature events at vegetative and reproductive growth stages in wheat", *Journal of Agronomy and Crop Sciences*, Vol. 189, pp. 142–150.

Zaied, H. M. M. (1995), *Combining ability in diallel cross of wheat (Triticum aestivum L.)*, Ph.D. Thesis, Faculty of Agriculture, El-Minia University, Egypt.

Zakaria, M. M. (1999), *Genetical and agronomic studies on heat tolerance and yield in wheat (Triticum aestivum L.)*, M.Sc. Thesis, Faculty of Agriculture, Assiut University, Egypt.

Zhongfu, N., Yao, Y., Peng, H., Hu, Z. and Qixin, S. (2014), "Genomics and Heterosis in Hexaploid Wheat", *Journal of Crop Sciences*, Vol. 23, pp. 215–220.