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RESEARCH ARTICLE

Combining ability in some genotypes of bread wheat (*Triticum aestivum* L.) under different sowing dates

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Abstract

Sixty four genotypes (28 F_1's, 28 F_2-populations and their 8 parents) were evaluated for days to heading, plant height, 100-grain weight and grain yield/plant under two sowing dates (Nov., 22nd , normal sowing date and Dec., 30th, late sowing date) in 2017/2018 growing season at the Exp. Farm of South Valley Uni., Qena, Egypt. The differences among parents, F_1's, F_2-populations and parents vs crosses were highly significant at both planting dates for all studied traits. Delaying sowing date reduced performance all studied traits. The parents; P_3, P_4, P_6 and P_8 and the crosses; $P_1 \times P_3$, $P_1 \times P_6$, $P_1 \times P_8$, $P_2 \times P_3$, $P_2 \times P_5$, and $P_3 \times P_8$ displayed HSI and S less than one and they were relatively heat tolerant and less sensitive to heat of F_1 and F_2-generations. Highly significant differences due to general (GCA) and specific (SCA) combining abilities were detected for all studied traits. The ratio of GCA to SCA was less than one for all studied traits, indicating that the major effect in the control of these traits was by non-additive gene action, except plant height. The parent P_3 was considered as the best combiner for heading, plant height and grain weight, but the parent P_2 was considered as the best combiner of F_1's and F_2-generations for 100-grain weight and grain yield/plant under both dates. The cross $P_2 \times P_8$ could be considered as the best combination of F_1's and F_2-generations for all studied traits under both planting dates.
Key words: Bread wheat; Combining ability; Sowing dates

Introduction

Wheat is considered as the first strategic food crop all over the world as well as in Egypt. Exposure wheat plants to various stresses during the growing season caused reductions in crop yield. Wheat cultivars that can with stand abiotic stresses particularly terminal heat tolerance will be able to fulfill the food demand in coming years (Iqbal *et al*, 2017).

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. For improvement of wheat yield, study of the genetic structure and plant behavior under heat stress condition is a great important. Also, knowledge of general and specific combining ability along with the mode of gene action in the available breeding material is very important to start the effective wheat breeding programs (Kumar *et al*; 2017).

Hayman (1954 a and b), Jinks (1954) and Griffing (1956) stated that half diallel mating as an effective strategy to evaluate genotypes used as parents to study combining ability effects in order to select suitable parents for developing new cultivars.

General and specific combining ability effects for yield and its components in bread wheat were reported by several workers (Dueby et al, 2001; Wahid et al, 2007; Ahmed and Mohamed, 2009; Kapoor et al, 2011; Ankita et al, 2012 and Kumar et al, 2017). Furthermore, each of Ali (2006), Farhad et al (2011), Yao et al (2011), Ezatollah et al (2013), Hassan (2015), Khaled and Abd El-Dayem (2016) and Kumar (2017) found that each of additive and non-additive gene effects were equal in their importance in the control of most traits such as, plant height, grain yield, number of spikes/plant, number of grain/spike and 100-grain weight. Additive and non-additive gene effects were more important in controlling the genetic system for plant height, grain yield, number of spikes/plant, number of grain/spike and 100-grain weight (Hamada and Tawfeleis (2001), El-Sayed (2004), Abdel-Nour, Nadya, et al (2009), Moussa (2010) and El-Awady, Wafaa (2011). The main objectives of the present study were: 1- To determine the general and specific combining abilities in bread wheat genotypes under heat stress condition. 2- To identify the best combiners and its combinations under heat stress conditions.

Materials and Methods

The current research was performed at the Experimental Farm of Faculty of Agric., South Valley Univ., Qena, Egypt during 2015/2016 – 2017/2018 growing seasons. The parental materials used in this study were eight genotypes of bread wheat (Tritium aestivum L.) namely; Line158 (P_1), Shamiss-3 (P_2), Gemmiza-11 (P_3), Sakha-93 (P_4), Misr-2 (P_5), Shandweel-1 (P_6), Sids-1 (P_7) and Giza-168 (P_8) representing a wide range of genetic diversity for several traits were selected for this study.

In 2015/2016 growing season, the eight parents were used in a half diallel cross mating design and seeds of 28 F_1's were produced. In 2016/2017 growing season, ten seeds per each cross were sown to produce seeds of generation.

In 2017/2018 growing season, all genotypes (the parents, F_1-crosses and F_2-populations) were evaluated under to sowing dates; normal (22nd of Nov.) and late (30th of Dec.) in two separate traits. In each trail, the genotypes were grown in a randomized complete block design (RCBD) with three replicates. Each replicate included one row, 3 m, long and 30 cm apart with 10 cm between plants within row. All recommended cultural practices were applied.

Fifteen guarded plants for each genotype were taken randomly from each replicate to recording observation on days to heading, plant height, 100-grain weight and grain yield/plant. Some physical and chemical properties of the soil of the experimental site are shown in Table 1. Minimum and maximum and mean daily temperatures at Qena of 2017/2018 season are shown in Table 2.

Statistical analysis

The analysis of variance for randomized complete block design for each experiment was done according to Snedecor and Cochran (1967). The diallel analysis was conducted according to Griffing (1956) method II model I (without reciprocal cross). Heat susceptibility index (HSI) was calculated according to Fischer and Maurer (1978). In addition, the sensitivity of any genotype or cross was estimated according to Falconer (1990).

Results and Discussion

The results obtained from the analysis of variance for all studied traits of 64 genotypes (8 parents, 28 F_1 hybrids and 28

F_2-progenies) under normal and late planting dates (Table 3) revealed highly significant differences among genotypes for all studied traits indicating that the importance of evaluation these traits over environments. The differences among parents, F_1-crosses and F_2-generations were highly significant for all studied traits under both sowing dates, this indicates that a wide diversity was found among the parental materials used in the present study. In addition, mean squares due to parents vs. crosses were highly significant for all studied traits, reflecting the average heterotic effect for these traits.

Days to heading date (day):

The average of days to heading for parents was 85.33 days at normal date, while it was reduced to 75.25 days under late date. The earliest parents were Sakha-93 (P_4) and Gemmiza-11 (P_3) under normal and late sowing dates which headed after 81.33 and 70.33 days from sowing date, respectively. While, the latest parents; Shamiss-3 (P_2) and Sids-1 (P_7) were headed after 89.33 and 81.00 days from sowing under normal and late sowing dates, respectively (Table 4).

The earliest F_1-hybrids were Sakha-93 × Sids-1 and Sakha-93 × Giza-168 under normal date and Shamiss-3 × Gemmiza-11, Gemmiza-11 × Sakha-93 and Gemmiza-11 × Giza-168 under late date headed after 77.67 and 68.67 days from sowing, respectively. While the latest F1-hybrid was Shamiss-3 × Misr-2 that headed after 85.00 and 72.33 days from sowing at normal and late dates, respectively. Late planting date reduced days to heading over all F1-hybrids from 81.11 (normal date) to 71.05 days (late date), (Table 4).

The average days to heading for F_2-generations ranged from 73.00 for Line 158 × Shandweel-1 to 80.00 for Line158 × Misr-2 with an average of 75.35 days under normal date and from 68.33 for Sakha-93 × Giza-168 to 72.33 for Shandweel-1 × Sids-1 with an average of 70.40 days under late planting date (Table 4).

In general, late planting date decreased average days to heading by 12.10 and 9.97% over all genotypes compared with normal date for F_1's and F_2-populations, respectively. However, days to heading of the F_2-populations were affected greatly than the F_1-hybrids by stress condition. Most of the F_2-populations of parent 4 (Sakha-93) headed earlier than the population of the other parents. These results are also in line with those obtained by Hassan (2015), Hassan (2016), Jaiswal *et al* (2017), Asmaa *et al* (2018), Sharma *et al* (2019) and Bajaniya *et al* (2019).

Plant height (cm):

Concerning plant height, the average of parents ranged from 56.91 for Shamiss-3 (P_2) and 47.96 for Sakha-93 (P_4) to 75.64 and 63.11 for Sids-1 (P_7) with an average of 66.57 and 56.15 cm, under normal and late planting dates, respectively (Table 4).

Mean of plant height for F_1-hybrids showed that the tallest plants were Gemmiza-11 × Sids-1 by 80.78 cm, and Misr-2 × Sids-1 by 59.53 cm. , but the shortest plants were Line158 × Sakha-93 by 63.13 cm. and Sakha-93× Giza-168 by 48.64 cm. under normal and late planting dates, respectively (Table 4). The average of plant height for F_2-generations ranged from 60.71 and 49.53 cm. for Shamiss-3 × Sakha-93 to 80.07 cm. for Sids-1 × Giza-168 and 66.21 cm. for Line158 × Gemmiza-11 with an average of 71.43 and 57.50 cm. under normal and late planting dates, respectively. The reduction was about

19.58 % and 17.65% in plant height for F_1 and F_2- generations, respectively. This result may be due to the Sids-1 (P_7) reveal to be the tallest parent and passed it target genes to this cross (Table 4). These results are in agreement with those obtained by Wajid *et al.* (2011), Nassar (2013), Hassan (2015), Hassan (2016), Jaiswal *et al.* (2017), Asmaa *et al* (2018), Sharma *et al* (2019) and Bajaniya *et al* (2019).

100-grains weight (g):

Regarding 100-grains weight, mean of the parents ranged from 3.49 and 3.15 g for Line 158 (P_1) to 5.87 and 4.66 g for Gemmiza-11 (P_3) with an average of 4.73 and 3.54 g at normal and late planting dates, respectively (Table 5).

With respect to the average of 100-grain weight for F_1-hybrids, it noticed that the heaviest F_1-hybrids were Shamiss-3 × Sids-1 (6.41) and Line158× Gemmiza-11 (4.93), while the lightest were Misr-2 × Shandweel-1 (4.02) and Gemmiza-11 × Sakha-93 (2.93) under normal and late planting dates, respectively (Table 4).

The F_2-population performance ranged from 3.93 for Gemmiza-11 × Sakha-93 and 3.00 for Line158 × Giza-168 to 5.45 and 4.86 for Shamiss-3 × Gemmiza-11 with an average of 4.57 and 3.58 g under normal and late planting dates, respectively.

100-grain weight overall genotypes was decreased by heat stress, the decrease reached to 24.95 and 22.56% from normal date in F_1's and F_2-populations, respectively. This reduction may be due to the effects of the high temperature during grain filling period (Table 4). In this connection, Samra et al. (1989) showed that high temperature and strong dry winds during month of maturity may have a forced effect on maturity of late plant crop and result low weight. These

findings are in line with those reported by Darwish *et al* (2006), Nassar (2013), Hassan (2015), Hassan (2016), Jaiswal *et al* (2017), Asmaa et al (2018), Sharma *et al* (2019) and Bajaniya *et al* (2019).

Grain yield/plant (g):

Concerning grain yield/plant, the average overall parents were 16.07 and 10.65 g under both planting dates, respectively. The parental genotypes Line158 (P_1) and P_3 had the highest yield (19.46 g) and (12.08 g) under normal and late planting dates, respectively. While under both growing dates, the parent P_6 gave the lowest values; 12.84 and 9.36, respectively (Table 5).

The average of grain yield/plant for F_1-hybrids showed that the high averages were 24.66 gm for Shamiss-3 × Giza-168 and 16.14 g for Line158× Sids-1, while the low averages were 13.13 gm for Gemmiza-11 × Giza-168 and 7.26 g for Sakha-93 × Misr-2 at both sowing dates, respectively. The average grain yield/plant for the F_1-hybrids was 18.29 and 12.01 g under both planting dates, respectively.

With regard to grain yield/plant, the average F_2-populations showed that the high averages were 17.83 and 13.68 g for Shandweel-1× Sids-1, while the low averages were 9.55 g for Line158 × Misr-2 and 6.26 gm for Sakha-93 × Misr-2 under normal and late planting dates, respectively. The average grain yield/plant for the F_2-populations were 14.34 and 10.25 g under normal and late planting dates, respectively. Grain yield/plant overall genotypes was decreased by heat stress, the decrease reached to 34.20 and 29.88% from normal date in the F_1's and F_2-populations, respectively. This reduction may be because of high temperature on grain production rate. These results are in line with

those obtained by Dencic *et al* (2000), Hoffman and Burucs (2005), Mohamed (2007), Nassar (2013), Hassan (2015), Hassan (2016), Jaiswal *et al.* (2017), Asmaa *et al* (2018), Sharma *et al* (2019) and Bajaniya *et al* (2019).

Heat susceptibility index (HSI) and sensitivity (S):

Heat susceptibility index and sensitivity were used to estimate relative stress injury where it accounted for variation in yield potential and stress intensity. Low both heat susceptibility index (HSI < 1) and sensitivity (S < 1) are indication to high stress tolerance (Fischer and Maurer; 1978) and less sensitive to heat according to sensitivity test of Falconer (1990). Heat susceptibility index for grain yield/plant (Table 5), indicated that the most tolerant parents were Gemmiza 11 (P3), Sakha 93 (P4), Shandweel 1(P6) and Giza 168 (P8). In addition, the most tolerant of both F_1-hybrids and F_2-crosses were ; Line 158 × Gemmiza 11, Line 158 × Shandweel 1 , Line 158 × Giza 168, Shamiss 3 × Gemmiza 11, Shamiss 3 × Misr 2, and Gemmiza 11× Giza 168 . These parents and both F_1-hybrids and F_2 crosses could be considered moderately sensitive to heat according to sensitivity test of Falconer (1990). Similar results were obtained by Zakaria (1999), Taghian and Abo-Elwafa (2003), Nassar (2013) and Hassan (2015).

Combining ability:

The data in Table 3 presented that mean squares due to GCA and SCA were highly significant for all studied traits under both dates, except grain yield/plant for GCA in F_1 and F_2-generations under normal and late dates. These results indicated that differences due to additive and non-additive gene actions were influencing the most

studied traits. GCA/SCA ratio was less than one for days to heading, 100-grain yield and grain yield/plant in the F_1 and F_2-generations under both environments, indicating that dominance genetic effects were predominant and played the major effect in the control mechanism of these traits. In the same time, plant height exhibited more additive effects. Similar results were reached in other studies (Nayeem and veer, 2000; Khieralla *et al*, 2001; Ashoush *et al*, 2001; Ahmed, 2003; Ali, 2006; El-Karamity *et al*, 2007; Ahmed and Mohamed; 2009and Hassan 2015).

Days to heading date (day):

The parents Gemmiza 11 (P_3) and Sakha 93 (P_4) showed highly significant negative GCA effects under both planting dates at F_1 and F_2-generations (Table 6). This indicates that these two parents were good combiners for days to heading date. Thus, these parents may possess favorable genes which could be utilized in breeding programs to improve the earliness trait in wheat. On the other hand, the two parents, Shamiss 3 (P_2) and Misr 2 (P_5), showed highly significant positive GCA effects at normal and late planting dates in both generations.

Estimates of SCA effects, Table (5) for F_1 and F_2 generations showed that six crosses ; Shamiss-3 × Gemmiza-11, Shamiss-3 × Sids-1, Shamiss-3 × Giza-168, Gemmiza-11 × Misr-2, Sakha-93 × Sids-1 and Misr-2 × Sids-1 showed negative and significant or highly significant SCA effects for both generations at both planting dates. Thus, these crosses could be considering the best combinations in both generations for days to heading date, so they might be exploited for breeding earlier varieties. These results are in agreement with those reported by Akinci (2009), Nassar (2013), Hassan (2015), Hassan (2016), Jaiswal *et al* (2017), Asmaa *et al*

(2018), Sharma *et al* (2019) and Bajaniya *et al* (2019).

Plant height (cm):

Concerning plant height, three parents; Gemmiza-11 (P_3), Misr-2 (P_5) and Giza-168 (P_8) had highly significant and positive GCA effects in F_1 and F_2-generations under both planting dates (Table 6). This indicates that these parents could be the good combiners for plant height at both generations and different dates. On the other hand, the parents Line158 (P_1), Shamiss-3 (P_2) and Sakha-93 (P_4) showed negative and highly significant GCA effects in F_1 and F_2 under both sowing dates.

With respect to SCA for plant height, the cross Shamiss-3 × Giza-168 gave positive and highly significant SCA effects of both generations under both sowing dates. Also, the hybrid Misr-2 × Shandweel-1 showed the same trend under late planting date. Few number of either F_1's or F_2-populations exhibited SCA negative effects under both environments (Table 6). Most of these hybrids were shorter than over all means, revealing that these crosses could be considered for breeding program for developing semi-dwarf under area conditions. Similar results were obtained by Ahmed, 2003, Ali, 2006, El-Karamity *et al*, 2007, Hassan 2015, Jaiswal *et al* (2017), Asmaa *et al* (2018), Sharma *et al* (2019) and Bajaniya *et al* (2019).

100-grain weight (gm):

With respect to 100-grain weight, the parents Shamiss-3 (P_2) and Gemmiza-11 (P_3) were positive and highly significant GCA of F_1,s and F_2-populations at both environments (Table 7). Therefore, it could be considered good combiner for 100-grain weight.
Three crosses; Line158 × Gemmiza-11 , Shamiss-3 × Sakha-93 and Shamiss-3× Giza-

168 were highly significant and positive SCA of F_1,s and F_2-populations under both planting dates (Table 7). It is noticed that, these crosses involved low × high and high × low general combiner parents for this trait. Similar results were obtained by Nagwa (2007),), Nassar (2013), Hassan (2015), Hassan (2016), Jaiswal *et al.* (2017), Asmaa *et al* (2018), Sharma *et al* (2019) and Bajaniya *et al* (2019).

Grain yield/plant (g):

Concerning grain yield/plant, only one parent (P_2) had highly significant and positive GCA of both generations under two planting dates (Table 7). This parent could be seen as a good combiner for grain yield/plant. The two crosses Shamiss-3 × Giza-168 and Sakha-93× Giza-168 gave highly significant and positive SCA effects of F_1 and F_2-generations at both planting dates (Table 7). These two crosses included high × low and low × low general combiner parents. These results were agree with those concluded by Nayeem and Veer (2000), Ahmed and Mohamed (2009), Akinci (2009), Nassar (2013), Hassan (2015), Hassan (2016), Jaiswal *et al* (2017), Asmaa *et al* (2018), Sharma *et al* (2019) and Bajaniya *et al* (2019). From previous, it is reveal that the parent Gemmiza-11 (P_3) was considered as the best combiner for heading date , plant height and 100-grain weight, but the parent Shamiss-3 (P_2) was considered as the best combiner of F_1,s and F_2-generations for 100-grain weight and grain yield/plant under both dates. The cross Shamiss-3 × Giza-168 could be considered as the best combination in F_1 and F_2 generations for the studied characters at both growing dates.

Table 1. Some physical and chemical properties of the experimental site.

CaCO3 (%)	Silt (%)	Clay (%)	Soil texture	pH (1:1)	Organic matter (%)	EC (ds m-1)	CaCO3 (%)	Soluble ions (m mol L^{-1})						
								SO--4	K+	Ca++	Mg++	H CO-3	Cl-	SO--4
66.70	21.30	12	Sandy loam	7.93	0.3	9.95	5.8	52.3	0.80	11.5	11.3	20.00	27.50	23.2

Table 2. Maximum, minimum and average monthly temperature (˚C) at Qena from heading date to physiological maturity stage during 2017/2018 season.

Season		2017/2018		
Month	Day	Maximum	Minimum	Average
	22 - 30	21.61	17.26	19.39
Average		21.61	17.26	19.39
December	1 - 10	18.82	15.68	16.70
	11 – 20	16.27	12.59	14.37
	21 - 31	18.34	12.35	13.98
Average		17.81	13.54	15.02
January	1 - 10	16.39	13.03	14.81
	11 – 20	17.12	13.19	15.04
	21 - 31	15.37	11.95	14.03
Average		16.29	12.72	14.63
February	1 - 10	24.78	14.71	20.22
	11 – 20	24.51	14.91	18.09
	21 - 28	25.25	18.98	21.71
Average		24.85	16.20	20.01
March	1 - 10	27.03	21.3	24.17
	11 – 20	28.58	21.28	24.51
	21 - 31	31.06	22.1	26.15
Average		28.89	21.56	24.94
April	1 - 10	34.43	25.05	28.08
	11 – 20	30.67	23.31	27.00
	21 - 30	32.83	27.54	30.73
Average		32.64	25.30	28.60
May	1 - 15	35.70	28.48	31.59
Average		35.70	28.48	31.59

Source: Meteorological Authority, Qena station, at South Valley University**.**

Table 3. Mean squares from ANOVA combining ability analysis in the F_1-hybrids and F_2-populations of bread wheat crosses under normal (N) and late (L) planting dates during 2017/2018 season.

S.O.V	df	Days to heading (days)				Plant height (cm)			
		F_1		F_2		F_1		F_2	
		N	L	N	L	N	L	N	L
Reps	2	38.62**	4.34*	4.15*	3.45	47.90**	12.62*	195.26**	71.52**
Genotypes(G)	35	21.51**	23.31**	61.84**	26.18**	79.31**	38.65**	88.07**	69.10**
Parents (P)	7	26.57**	52.17**	26.57**	52.17**	138.99**	64.72**	138.99**	64.72**
Crosses (C)	27	8.64**	4.49**	4.31**	4.18**	54.75**	30.93**	61.82**	71.53**
P vs C	1	333.40**	329.65**	1862.22**	438.22**	324.58**	64.77**	440.37**	34.13**
GCA	7	11.14**	12.47**	6.43**	11.28**	93.69**	47.89**	109.67**	52.42**
SCA	28	6.18**	6.60**	24.16**	8.09**	9.62**	4.13**	9.28	15.69**
Error	70	1.61	1.22	1.25	1.17	8.27	3.50	8.85	4.66
$\Sigma g_i^2/\Sigma S_{ij}^2$	-	0.19	0.19	0.03	0.14	1.32	1.58	1.69	0.36

S.O.V	df	100-grain weight (g)				Grain yield/plant (g)			
		F_1		F_2		F_1		F_2	
		N	L	N	L	N	L	N	L
Reps	2	0.23	0.38**	0.41*	0.20**	47.66**	4.14	29.14**	7.33**
Genotypes(G)	35	1.15**	0.49**	0.73**	1.03**	42.31**	10.20**	16.55**	9.31**
Parents (P)	7	1.28**	0.68**	1.28**	0.68**	29.94*	8.37**	29.94**	8.37**
Crosses (C)	27	1.14**	0.45**	0.59**	1.15**	42.32**	10.43**	12.48**	9.46**
P vs C	1	0.52*	0.44**	0.63*	0.25*	128.90**	16.95**	32.57**	12.00**
GCA	7	0.43**	0.15	0.45**	0.68**	12.02	3.63	1.99	4.65
SCA	28	0.37**	0.17**	0.19*	0.26**	14.62*	3.34	6.40**	2.72*
Error	70	0.13	0.07	0.11	0.04	8.06	2.59	1.69	1.55
$\Sigma g_i^2/\Sigma S_{ij}^2$	-	0.12	0.08	0.27	0.27	0.08	0.11	0.02	0.19

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

Table 4. Mean performance of the eight parents, F_1's hybrids and F_2's populations for days to heading, plant height and 100-grain weight under normal (N) and late (L) planting dates in 2017/2018 season.

Genotypes	Days to heading (days)				Plant height (cm)				100-grain weight (g)			
	F_1		F_2		F_1		F_2		F_1		F_2	
	N	L	N	L	N	L	N	L	N	L	N	L
P_1	87.00	78.33	87.00	78.33	66.49	53.41	66.49	53.41	3.49	3.15	3.49	3.15
P_2	89.33	78.00	89.33	78.00	56.91	53.73	56.91	53.73	4.78	3.22	4.78	3.22
P_3	83.00	70.33	83.00	70.33	69.11	56.45	69.11	56.45	5.87	4.66	5.87	4.66
P_4	81.33	70.67	81.33	70.67	57.11	47.96	57.11	47.96	4.59	3.44	4.59	3.44
P_5	88.67	78.33	88.67	78.33	73.40	58.24	73.40	58.24	4.76	3.39	4.76	3.39
P_6	84.00	71.33	84.00	71.33	65.26	55.92	65.26	55.92	4.72	3.42	4.72	3.42
P_7	86.67	81.00	86.67	81.00	75.64	63.11	75.64	63.11	5.06	3.39	5.06	3.39
P_8	82.67	74.00	82.67	74.00	68.65	60.36	68.65	60.36	4.57	3.62	4.57	3.62
Mean (p)	85.33	75.25	85.33	75.25	66.57	56.15	66.57	56.15	4.73	3.54	4.73	3.54
P_1 x P_2	82.00	70.00	75.67	70.67	65.13	51.53	66.49	53.11	4.42	3.30	4.22	3.30
P_1 x P_3	80.00	69.33	74.33	68.67	68.49	56.49	72.38	66.21	5.53	4.93	5.25	4.57
P_1 x P_4	81.00	69.33	75.00	69.33	63.13	48.66	62.44	50.12	5.23	3.77	4.30	3.29
P_1 x P_5	82.00	70.67	80.00	69.33	70.91	55.88	73.38	65.60	5.25	3.91	4.62	3.19
P_1 x P_6	78.33	72.00	73.00	68.67	66.22	52.73	71.18	55.35	5.06	3.83	4.39	3.31
P_1 x P_7	82.33	72.00	75.00	70.00	68.13	51.17	71.75	52.49	5.04	3.72	4.64	3.46
P_1 x P_8	80.33	70.00	74.00	69.33	65.20	54.53	71.20	57.03	4.84	3.77	4.37	3.00
P_2 x P_3	81.00	68.67	75.00	68.67	69.62	55.05	70.02	55.36	5.06	3.78	5.45	4.86
P_2 x P_4	82.00	70.67	76.00	69.33	66.07	49.98	60.71	49.53	6.13	3.80	5.27	4.58
P_2 x P_5	85.00	72.00	75.67	71.33	72.56	55.78	68.96	55.30	5.69	3.87	4.96	3.21
P_2 x P_6	83.00	72.00	74.00	70.00	68.82	52.09	69.80	52.50	4.86	3.85	5.03	3.48
P_2 x P_7	82.33	72.00	75.00	70.00	71.31	54.22	69.60	52.91	6.41	4.30	4.65	3.67
P_2 x P_8	81.33	70.67	76.00	70.67	74.18	52.63	73.04	64.91	5.83	4.06	5.16	4.51
P_3 x P_4	82.00	68.67	74.33	69.33	68.22	53.82	71.84	65.72	4.49	2.93	3.93	3.82
P_3 x P_5	81.00	70.00	75.33	70.00	74.16	59.33	74.29	65.63	4.87	3.85	4.52	3.25
P_3 x P_6	79.67	72.00	75.00	69.33	72.73	57.78	70.67	55.87	4.61	3.47	4.48	3.17
P_3 x P_7	81.67	72.00	76.67	71.33	80.78	58.32	76.06	57.60	4.91	3.69	5.40	4.62
P_3 x P_8	78.00	68.67	75.00	70.00	74.40	58.53	71.98	57.83	4.09	3.42	4.16	3.40
P_4 x P_5	82.33	72.00	75.67	72.00	69.71	53.80	69.85	57.13	4.31	3.37	3.98	3.37
P_4 x P_6	81.00	72.00	74.67	71.33	67.60	49.24	66.07	53.41	4.44	4.01	4.03	3.31
P_4 x P_7	77.67	71.33	75.00	70.00	70.11	52.20	70.47	53.17	4.58	3.70	4.63	3.22
P_4 x P_8	77.67	71.33	75.00	70.00	65.73	48.64	65.31	54.96	4.59	3.55	4.11	3.25
P_5 x P_6	81.67	72.00	76.00	72.00	72.91	59.53	74.82	60.42	4.02	3.03	4.02	3.36
P_5 x P_7	79.67	72.00	75.00	72.00	77.47	58.45	78.60	60.26	4.35	3.38	5.02	3.36
P_5 x P_8	81.67	72.00	76.00	72.00	77.69	57.49	77.11	62.49	5.48	3.41	4.82	3.95
P_6 x P_7	82.33	72.00	75.67	72.00	75.29	53.56	77.27	57.37	4.26	3.41	4.26	3.41
P_6 x P_8	82.33	72.00	75.67	72.00	70.84	53.64	74.67	59.67	4.54	3.64	4.12	3.12
P_7 x P_8	81.67	72.00	76.00	72.00	73.36	54.93	80.07	58.08	4.22	3.61	4.55	4.22
Mean (C)	81.11	71.05	75.35	70.40	70.74	54.29	71.43	57.50	4.90	3.69	4.57	3.58
Mean (G)	83.22	73.15	80.34	72.33	68.66	55.22	69.00	56.82	4.81	3.61	4.61	3.57
LSD'0.05 P	2.21	1.86	1.88	1.82	5.05	3.17	5.22	3.78	0.65	0.47	0.56	0.37
LSD'0.05(C)	2.17	1.90	2.06	1.86	4.65	2.91	4.81	3.34	0.57	0.43	0.51	0.31
LSD'0.05 G)	1.94	1.63	1.61	1.59	4.42	2.88	4.57	3.31	0.56	0.44	0.51	0.31
Red.%	12.10		9.97		19.58		17.65		24.95		22.56	

Table 5. Mean performance, heat susceptibility index (HSI) and sensitivity (S) for grain yield/plant of parents, F$_1$-hybrids and F$_2$-populations under normal (N) and late (L) planting dates during 2017/2018 season.

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Genotypes	Grain yield/plant (gm)				HSI		S	
	F$_1$		F$_2$					
	N	L	N	L	F$_1$	F$_2$	F$_1$	F$_2$
P$_1$	19.46	9.78	19.46	9.78	1.72		1.85	
P$_2$	17.91	10.46	17.91	10.46	1.43		1.42	
P$_3$	13.59	12.08	13.59	12.08	0.38		0.29	
P$_4$	13.70	10.29	13.70	10.29	0.86		0.65	
P$_5$	19.13	11.70	19.13	11.70	1.34		1.42	
P$_6$	12.84	9.36	12.84	9.36	0.93		0.66	
P$_7$	17.38	10.25	17.38	10.25	1.41		1.36	
P$_8$	14.51	11.27	14.51	11.27	0.77		0.62	
Mean p	16.07	10.65	16.07	10.65	-	-	-	-
P$_1$ x P$_2$	18.18	11.80	15.36	10.80	1.03	1.02	1.02	1.11
P$_1$ x P$_3$	13.72	11.90	12.68	9.85	0.39	0.77	0.29	0.69
P$_1$ x P$_4$	19.14	11.00	14.26	7.77	1.25	1.57	1.30	1.59
P$_1$ x P$_5$	20.27	13.50	9.55	9.53	0.98	0.01	1.08	0.00
P$_1$ x P$_6$	18.13	12.28	13.63	9.89	0.95	0.95	0.93	0.91
P$_1$ x P$_7$	18.34	12.14	16.14	8.48	0.99	1.64	0.99	1.87
P1 x P$_8$	15.30	11.06	15.29	11.43	0.82	0.87	0.68	0.94
P$_2$ x P$_3$	14.52	13.15	13.69	12.15	0.28	0.39	0.22	0.38
P$_2$ x P$_4$	14.01	13.32	14.40	10.07	0.14	1.04	0.11	1.06
P$_2$ x P$_5$	14.64	10.88	15.36	12.67	0.76	0.60	0.60	0.66
P$_2$ x P$_6$	18.21	10.73	12.56	10.62	1.21	0.53	1.19	0.47
P$_2$ x P$_7$	24.46	10.61	12.65	11.35	1.67	0.35	2.21	0.32
P$_2$ x P$_8$	24.66	12.80	14.66	11.92	1.41	0.64	1.89	0.67
P$_3$ x P$_4$	14.70	9.94	13.38	8.94	0.95	1.14	0.76	1.09
P$_3$ x P$_5$	19.94	12.36	16.29	11.10	1.12	1.10	1.21	1.27
P$_3$ x P$_6$	17.51	10.61	14.44	11.09	1.16	0.80	1.10	0.82
P$_3$ x P$_7$	16.28	11.93	15.21	8.72	0.79	1.47	0.69	1.59
P$_3$ x P$_8$	13.13	11.90	12.16	9.30	0.28	0.81	0.20	0.70
P$_4$ x P$_5$	14.11	7.26	13.50	6.26	1.43	1.85	1.09	1.77
P$_4$ x P$_6$	19.56	12.34	16.90	10.18	1.09	1.37	1.15	1.64
P$_4$ x P$_7$	24.28	11.43	10.33	9.85	1.56	0.16	2.05	0.12
P$_4$ x P$_8$	24.58	12.51	16.29	12.87	1.44	0.72	1.92	0.84
P$_5$ x P$_6$	15.61	8.64	12.37	7.64	1.31	1.32	1.11	1.16
P$_5$ x P$_7$	20.06	16.12	13.55	8.88	0.58	1.19	0.63	1.14
P$_5$ x P$_8$	18.62	12.31	14.18	11.73	1.00	0.60	1.00	0.60
P$_6$ x P$_7$	24.11	14.68	17.83	13.68	1.15	0.80	1.50	1.01
P$_6$ x P$_8$	22.24	15.85	17.49	8.16	0.85	1.84	1.02	2.28
P$_7$ x P$_8$	13.73	13.10	17.36	12.10	0.13	1.04	0.10	1.29
Mean C	18.29	12.01	14.34	10.25	-	-	-	-
Mean (G)	17.75	11.68	14.76	10.35	-	-	-	-
LSD' (P)	7.84	3.25	2.19	2.17	-	-	-	-
LSD' (C)	6.57	2.79	2.10	1.92	-	-	-	-
LSD' (G)	6.51	2.76	1.99	1.98	-	-	-	-
Red.%	34.20		29.88		-	-	-	-

Table 6. General (GCA) and specific (SCA) combining ability effects for days to 50% heading and plant height of the parents and their F_1-hybrids and F_2-populations under normal (N) and late (L) planting dates in 2017/2018 season.

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Genotypes	Days to heading date (day)				Plant height (cm)			
	F_2		F_1		F_2		F_1	
	L	N	L	N	L	N	L	N
P_1	-0.07	0.29	0.22	0.16	-0.81*	-1.14*	-1.45**	-2.81**
P_2	0.33*	0.79**	0.42*	1.69**	-2.37**	-4.07**	-1.35**	-2.68**
P_3	-1.53**	-0.64**	-1.78**	-0.91**	2.23**	1.23*	1.99**	1.83**
P_4	-1.07**	-0.97**	-1.12**	-1.21**	-3.48**	-5.22**	-4.00**	-4.35**
P_5	1.20**	1.29**	0.95**	1.23**	2.85**	3.07**	2.44**	3.39**
P_6	-0.53**	-0.61**	-0.12	-0.21	-0.84*	0.18	-0.19	-0.34
P_7	1.60**	0.36	1.75**	0.26	0.33	4.20**	1.68**	3.94**
P_8	0.07	-0.51**	-0.32	-1.01**	2.09**	1.75**	0.88**	1.04*
P_1 x P_2	-1.08	-2.98**	-2.61**	-1.90**	-0.91	1.35	-0.36	0.81
P_1 x P_3	-1.21*	-2.88**	-1.08	-1.30*	7.58**	1.93	1.25	-0.34
P_1 x P_4	-1.01	-1.88**	-1.75**	0.00	-2.79**	-1.55	-0.59	0.49
P_1 x P_5	-3.28**	0.85	-2.48**	-1.43*	6.36**	1.10	0.18	0.52
P_1 x P_6	-2.21**	-4.25**	-0.08	-3.66**	-0.20	1.78	-0.34	-0.44
P_1 x P_7	-3.01**	-3.21**	-1.95**	-0.13	-4.23**	-1.66	-3.76**	-2.81
P_1 x P_8	-2.15**	-3.35**	-1.88**	-0.86	-1.45	0.23	0.39	-2.84
P_2 x P_3	-1.61**	-2.71**	-1.95**	-1.83**	-1.70	2.51	-0.29	0.66
P_2 x P_4	-1.41*	-1.38*	-0.61	-0.53	-1.81	-0.35	0.63	3.29**
P_2 x P_5	-1.68**	-3.98**	-1.35*	0.04	-2.38*	-0.39	-0.01	2.04
P_2 x P_6	-1.28*	-3.75**	-0.28	-0.53	-1.49	3.34*	-1.07	2.03
P_2 x P_7	-3.41**	-3.71**	-2.15**	-1.66*	-2.25*	-0.88	-0.80	0.24
P_2 x P_8	-1.21*	-1.85**	-1.41*	-1.40*	7.99**	5.01**	2.58**	6.01**
P_3 x P_4	0.45	-1.61**	-0.41	2.07**	9.78**	5.49**	1.13	0.93
P_3 x P_5	-1.15*	-2.88**	-1.15*	-1.36*	3.35**	-0.36	0.19	-0.87
P_3 x P_6	-0.08	-1.31*	1.92**	-1.26	-2.73*	-1.10	1.28	1.43
P_3 x P_7	-0.21	-0.61	0.05	0.27	-2.16	0.29	-0.05	5.19**
P_3 x P_8	-0.01	-1.41*	-1.21*	-2.13**	-3.69**	-1.36	0.96	1.72
P_4 x P_5	0.39	-2.21**	0.19	0.27	0.56	1.65	0.66	0.86
P_4 x P_6	1.45*	-1.31*	1.25*	0.37	0.53	0.76	-1.27	2.48
P_4 x P_7	-2.01**	-1.95**	-1.28*	-3.43**	-0.88	1.15	-0.17	0.71
P_4 x P_8	-0.48	-1.08	0.79	-2.16**	-0.84	-1.57	-2.93**	-0.76
P_5 x P_6	-0.15	-2.25**	-0.81	-1.40*	1.21	1.22	-1.59	0.05
P_5 x P_7	-2.28**	-4.21**	-2.68**	-3.86**	-0.12	0.99	-0.37	0.33
P_5 x P_8	-0.75	-2.35**	-0.61	-0.60	0.35	1.94	-0.54	3.45*
P_6 x P_7	-0.55	-1.65**	-1.61**	0.24	0.68	2.54	-2.63**	1.87
P_6 x P_8	0.99	-0.78	0.45	1.50*	1.22	2.38	-1.76	0.33
P_7 x P_8	-1.15*	-1.41**	-1.41*	0.37	-1.54	3.77*	-2.32*	-1.43
S.E. gi	0.17	0.20	0.20	0.22	0.37	0.51	0.32	0.49
S.E. sij	0.57	0.58	0.57	0.66	1.13	1.56	0.98	1.51
S.E. (gi-gj)	0.28	0.28	0.28	0.33	0.56	0.77	0.48	0.74
S.E. (sij-sik)	0.84	0.87	0.85	0.98	1.67	2.30	1.45	2.23

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

Table 7. General (GCA) and specific (SCA) combining ability effects for 100-grain weight and grain yield/plant of the parents and their F_1's and F_2-populations under normal (N) and late (L) planting dates during 2017/2018 season.

Genotypes	100-grain weight (g)				Grain yield/plant (g)			
	F_2		F_1		F_2		F_1	
	L	N	L	N	L	N	L	N
P_1	0.05	-0.22**	-0.25**	-0.14*	-0.65**	0.41	-0.29	0.27
P_2	0.06*	0.20**	0.24**	0.42**	0.66**	0.61**	1.24**	1.67**
P_3	0.25**	0.51**	0.29**	0.16**	0.14	-0.67**	-0.02	-2.23**
P_4	-0.09**	-0.08	-0.20**	-0.08	-0.73**	-0.52**	-0.78**	-0.16
P_5	-0.13**	-0.22**	0.02	-0.03	-0.26	0.14	-0.17	0.22
P_6	-0.08**	-0.26**	-0.15**	-0.25**	-0.39	-0.08	-0.23	0.17
P_7	-0.03	0.04	0.16**	0.02	1.27**	0.28	0.44	0.52
P_8	-0.02	0.04	-0.12**	-0.10	- 0.03	-0.17	- 0.19	-0.45
P_1 x P_2	-0.47**	-0.30	-0.35*	-0.72**	0.36	0.04	0.49	-0.31
P_1 x P_3	0.97**	0.66**	0.62**	0.65**	-0.07	-1.70*	0.42	-2.01
P_1 x P_4	0.14**	-0.03	0.16	0.59**	-1.27*	-0.26	0.27	1.33
P_1 x P_5	0.32**	0.00	0.26	0.55**	0.04	-5.65**	2.16**	2.08
P_1 x P_6	0.19**	0.17	0.21	0.59**	0.50	-1.34*	1.01	-0.01
P_1 x P_7	0.04	0.01	0.14	0.30	-1.26	0.48	0.20	-1.29
P_1 x P_8	0.07*	-0.44**	0.15	0.22	0.39	0.42	-1.68*	-2.22
P_2 x P_3	-0.17**	1.12	-0.27*	-0.38*	0.91	-0.56	1.57	-1.46
P_2 x P_4	0.18**	0.83**	0.64**	0.92**	-0.29	0.01	2.50**	-4.05**
P_2 x P_5	0.29**	-0.40*	0.11	0.43*	1.85**	0.31	-0.55	-3.80*
P_2 x P_6	0.22**	-0.08	0.36**	-0.17	-0.08	-2.28**	-0.64	-0.18
P_2 x P_7	0.63**	-0.20	-0.34*	1.11**	0.29	-2.87**	-1.43	4.57**
P_2 x P_8	0.64**	0.45**	0.37**	0.65**	3.67**	2.66**	2.68**	4.57**
P_3 x P_4	-0.13**	-0.86**	-0.89**	-0.45**	-0.90	-0.07	-1.06	-0.61
P_3 x P_5	-0.67**	-0.38*	0.07	-0.12	0.79	2.19**	0.75	4.26**
P_3 x P_6	-0.70**	-0.25	-0.35*	-0.16	0.91	0.56	-0.93	1.87
P_3 x P_7	0.45**	0.35*	-0.18	-0.12	-1.83**	0.63	-0.28	-0.86
P_3 x P_8	-0.77**	-0.61	-0.46**	-0.82**	-2.54**	-1.63*	-1.11	-1.88
P_4 x P_5	0.04	-0.43**	-0.07	-0.45**	-3.17**	-0.74	-3.59**	-3.66*
P_4 x P_6	0.03	-0.21	0.53**	-0.09	0.87	2.87**	1.56	1.84
P_4 x P_7	-0.37**	0.07	0.16	-0.21	0.19	-4.40**	-0.02	5.06**
P_4 x P_8	-0.33**	-0.17	0.01	-0.09	1.91**	2.36**	3.04**	7.48**
P_5 x P_6	0.22**	-0.43**	-0.41**	-0.56**	-2.14**	-2.32**	-2.76**	-2.49
P_5 x P_7	-0.09**	0.25	-0.12	-0.50**	-1.25	-1.83**	4.06**	0.47
P_5 x P_8	0.50**	0.34*	-0.10	0.74**	0.29	-0.42	-0.56	1.15
P_6 x P_7	0.01	-0.34*	-0.13	-0.36*	-0.44	-0.08	-0.04	6.89**
P_6 x P_8	-0.28**	-0.20	0.09	0.03	-3.14**	3.11**	0.25	4.82**
P_7 x P_8	0.84**	-0.41*	0.01	-0.55**	0.44	2.28**	-0.37	-5.18**
S.E. gi	0.03	0.06	0.04	0.06	0.22	0.22	0.28	0.49
S.E. sij	0.10	0.17	0.14	0.17	0.65	0.68	0.84	1.49
S.E. (gi-gj)	0.05	0.1	0.07	0.10	0.32	0.33	0.41	0.73
S.E. (sij-sik)	0.14	0.26	0.20	0.57	0.96	1.00	1.24	0.57

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

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