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HETEROSIS AND COMBINIG ABILITY OF SOME RICE GENOTYPES UNDER NORMAL AND WATER DEFICIT CONDITIONS

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ABSTRACT

Rice is a major staple food crop worldwide, but its production is greatly affected by water deficit. Therefore developing rice drought tolerant genotypes is essential, especially, under current water shortage conditions. The present investigation was carried out at the Experimental Farm of Rice Research Department, Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during 2017 and 2018 summer seasons using seven diverse rice genotypes. All possible cross combinations excluding reciprocals were made among the seven genotypes, giving 21 F_1 crosses. The seven parental genotypes and their 21 F_1 crosses were evaluated in two separate experiments under normal and water deficit conditions. Randomized complete block design (RCBD) with three replications was used for each experiment. The objective was to estimate combining ability, heterosis and nature of gene action for nine traits under normal and water deficit conditions. The results indicated that water deficit significantly decreased the means of all studied traits for parents and their hybrids. Highly significant differences were found among genotypes, parents and crosses for all the studied traits under normal and stress conditions. Mean squares due to parents vs. crosses (average heterosis) were significant for all the studied traits. General (GCA) and specific (SCA) combining ability mean squares were highly significant for all the studied traits under both normal and stress conditions. The non-additive gene action played an important role in the inheritance of the majority of the studied traits. The parents Sakha 102 and Sakha 106 showed the best desirable GCA effects for earliness, whereas the parents Giza 178, Sakha 104 and IET 1444 appeared to be the best general combiners for grain yield/plant and some of its components. The seven crosses (Giza 178 × Sakha 102), (Sakha 104 × IET 1444), (IRAT 170 × IET 1444), (IRAT 170 × Moroberekan), (Moroberekan × Sakha106) and (Moroberekan × Sakha102) had the best SCA effects for grain yield/plant as well as one or more of its components under both conditions. Moreover, the three crosses (Sakha 104 × IET 1444), (IRAT 170 × IET 1444) and (Moroberekan × Sakha102) showed significant and desirable better parent heterosis (heterobeltiosis) for grain yield/plant under both conditions. Hence, these hybrids would be valuable in rice breeding for improving yielding ability under normal and water deficit conditions.

Key words: ***Rice, Water deficit, Combining ability, Heterosis, Type of gene action***.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major important cereal crops consumed by more than one-third of the world's population (Oladosu *et al* 2018). The production of rice is severely affected by several constraints, including drought or water deficit (Sahebi *et al* 2018). It is estimated that 50% of the world rice production is affected by drought (Boumanet *et al* 2005). Water deficit stress reduces the growth and development of rice plants and severely affects different traits (Wang *et al* 2019). These involve reduction of plant height, panicle length, leaf area, increased spikelet sterility, decreased photosynthetic capacity and reduced number of panicles per unit area (Yue *et al* 2006, Serraj *et al* 2009 and Farooq *et al* 2010). The reduced biomass at the vegetative stage and lower number of filled grains at the reproductive stage under drought stress severely reduce the final yields (Fukai 1999 and Verulkar *et al* 2010). It has been reported that grain yield of various rice genotypes is tremendously reduced by more than 50% under drought condition (Pantuwan *et al* 2002). This reduction depends on duration, timing and severity of the water stress (Kumar *et al* 2014). Increasing scarcity of water resources makings today objective of rice breeders in Egypt is developing new highly yielding varieties with efficient water use to save more water without significant fall in rice grain yield.

The development of such genotypes requires a good knowledge of the type of gene action controlling the inheritance of the contributing traits to drought tolerance. Diallel analysis is commonly used to gain information on gene action controlling traits of interest, and the combining ability of the parents (Griffing, 1956). The genetic parameters general (GCA) and specific (SCA) combining ability are necessary for selection of suitable parents for hybridization and identification of promising hybrids (Muthuramu *et al* 2010). The GCA and SCA are primarily attributed to additive and non-additive effects, respectively. In this concern, El-Refaey *et al* (2009), El-Hity *et al* (2016) and Farid *et al* (2016) found that the additive genetic effects play a major role in inheritance of grain yield/plant. On the contrary, Muhammad et al (2010), Sedeek *et al* (2012), Hasan *et al* (2015), Sathya and Jebaraj (2015), Elgamal *et al*. (2018) and El-Sayed *et al* (2018) reported that the non-additive gene effects were more important in the inheritance of rice grain yield and most of its components under normal and water deficit conditions.

The objectives of the present study were to: (1) evaluate the performance of seven rice genotypes and their F_1 crosses under normal and water deficit conditions (2) estimate combining ability, heterosis and type of gene action of the studied traits (3) identify the superior parents and F_1 crosses to be used in rice breeding programs under target environments.

MATERIALS AND METHODS

The present study was carried out at the Experimental Farm of Rice Research Department, Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, during 2017 and 2018 growing summer seasons. Seven rice (*Oryza sativa* L.) genotypes which represented a wide range of diversity were used as parents in this study (Table 1).

Table 1. Name, parentage, origin and type of the seven rice genotypes used in the present study.

Name	Parentage	Origin	Type
Giza 178	Giza 175 / Milyang 49	Egypt	Indica/Japonica
Sakha 104	GZ 4096-8-1/GZ4100-9-1	Egypt	Japonica
IRAT 170	IRAT13/Palawan	Cote dIvoire	Indica
IET 1444	TN 1/CO 29	India	Indica
Moroberekan	IR 8-24-6- (M307 H5)	Guinea (West Africa)	Tropical japonica
Sakha 106	Giza177/Hexi30	Egypt	Japonica
Sakha 102	GZ4096/Giza177	Egypt	Japonica

In 2017 season, the parental genotypes were sown at three different sowing dates in order to overcome the differences in flowering time. All possible cross combinations (excluding reciprocals) were made among the seven genotypes, to obtain seeds of 21 F_1 crosses. Bulk emasculation method was practiced by using hot water technique according to Jodan (1938) and modified by Butany (1961). In 2018 season, the 28 entries (seven parents and 21 F_1 hybrids) were evaluated in two separate irrigation experiments. The first experiment (normal condition) was irrigated normally with continuous flooding. The second was irrigated every 12 days without any standing water (water deficit condition). The parents and their F_1 crosses were sown in the nursery on the first week of May and the seedlings were transplanted individually after 30 days. The two experiments were designed in a randomized complete block design with three replications. Each plot consisted of three rows of each parent and F_1 cross in each replication. Each row was 5.0 m long and spaces between rows were 20 cm with 20 cm between plants. All other agricultural rice practices were applied at the proper time according to Rice Research and Training Center (RRTC, 2016). The studied characters were days to heading (day), plant height (cm), flag leaf area (cm^2), chlorophyll content (SPAD unit) measured by Hand-held chlorophyll meter (SPAD-502; Minolta Sensing Co., Ltd, Japan), No. of panicles/plant, panicle length (cm), spikelet fertility %, 100-grain weight (g) and grain yield/plant (g). Analysis of variance for each experiment (normal and stress conditions) was done according to Snedecor and Cochran (1989). Combining ability analysis was performed according to Griffing's (1956) method 2 model 1. Heterosis percentages relative to better parent (heterobeltiosis) were calculated according to Mather and Jinks (1982).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance (Table 2) showed that the mean squares due to genotypes, parents and F_1 crosses were highly significant for all studied traits under both normal and water deficit conditions. This indicates the presence of sufficient genetic variability among the studied genotypes, which is considered adequate for further biometrical assessment. High genetic divergence among rice parents and their F_1 crosses for different characters under normal and water deficit conditions was reported by El-Hity *et al* (2015), Farid *et al* (2016), Elgamal *et al* (2018) and El-Sayed *et al* (2018).

Mean squares due to parents *vs.* crosses were significant or highly significant for all the studied traits under both conditions, suggesting the presence of significant heterosis for all the studied traits.

Results in (Table 2) showed that both general (GCA) and specific (SCA) combining ability mean squares were highly significant for all the studied traits under normal and water deficit conditions. These results would indicate the importance of both additive and non-additive gene effects in the inheritance of these traits. The ratio of GCA/SCA was less than unity for all the studied traits, except plant height under both conditions and No. of panicles/plant under water deficit condition, indicating that these traits were predominantly controlled by the non-additive type of gene action.

Table 2. Mean squares from ordinary and combining ability analysis for all the studied traits under normal and water deficit conditions.

SOV	df	Days to heading		Plant height (cm)		Flag leaf area (cm^2)	
		Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	1.25	1.65	2.33	3.54	0.68	0.88
Genotypes (G)	27	99.54**	107.09**	356.81**	270.16**	139.26**	133.69**
Parents (P)	6	149.51**	157.05**	675.39**	291.31**	16.30**	30.87**
F_1 Crosses (C)	20	89.35**	95.39**	275.21**	266.03**	178.10**	164.99**
P *vs.* C	1	3.38*	41.36**	77.29**	225.89**	100.17**	124.73**
GCA	6	357.30**	389.38**	1051.46**	717.99**	233.57**	208.92**
SCA	21	25.89**	26.43**	158.33**	142.21**	112.32**	112.20**
Error	54	0.57	0.97	1.51	1.58	0.54	0.34
K^2GCA/K^2SCA		1.57	1.69	0.74	0.57	0.23	0.21
SOV	**df**	**Chlorophyll content (SPAD)**		**No. of panicles/plant**		**Panicle length (cm)**	
		Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	0.62	0.82	1.34	2.25	0.62	0.74
Genotypes (G)	27	52.99**	55.04**	28.22**	27.84**	10.30**	16.14**
Parents (P)	6	19.60**	22.64**	21.37**	34.21**	3.92**	12.85**
F_1 Crosses (C)	20	65.49**	67.39**	31.53**	27.15**	12.66**	17.82**
P *vs.* C	1	3.25**	2.46*	3.03*	3.41*	1.37*	2.31*
GCA	6	79.54**	88.48**	82.69**	95.68**	13.63**	25.91**
SCA	21	45.40**	45.48**	12.65**	8.46**	9.35**	13.35**
Error	54	0.32	0.57	0.74	0.81	0.32	0.37
K^2GCA/K^2SCA		0.20	0.22	0.76	1.38	0.16	0.22
SOV	**df**	**Spikelet fertility (%)**		**100-grain Weight (g)**		**Grain yield/plant (g)**	
		Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	1.19	1.75	0.03	0.05	1.55	2.13
Genotypes (G)	27	132.08**	87.33**	0.10**	0.10**	66.76**	54.72**
Parents (P)	6	15.72**	47.77**	0.07**	0.08**	100.09**	20.91**
F_1 Crosses (C)	20	121.52**	85.23**	0.12**	0.10**	54.29**	67.09**
P *vs.* C	1	1041.51**	366.78**	0.06*	0.22**	116.38**	10.10*
GCA	6	122.27**	176.50**	0.15**	0.13**	188.04**	89.05**
SCA	21	134.88**	61.86**	0.09**	0.09**	32.12**	44.91**
Error	54	0.91	1.08	0.01	0.02	1.29	1.51
K^2GCA/K^2SCA		0.10	0.32	0.20	0.18	0.67	0.22

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

These results are in general agreement with those obtained by Muhammad *et al* (2010), Saidaiah *et al* (2010), Abd El-Hadi *et al* (2014), Hasan *et al* (2015), Sathya and Jebaraj (2015), Elgamal *et al* (2018) and El-Sayed *et al* (2018). For the exceptional traits, the ratio of GCA/SCA was more than unity, indicating the preponderance of the additive gene action in controlling the inheritance of these traits. Similarly, El-Hity *et al* (2016) recorded predominance of the additive gene effects in controlling the inheritance of plant height and number of panicles/plant.

Mean performance

Mean performance of the seven parents and their 21 F_1 crosses under normal and water deficit conditions for all the studied traits are shown in Table 3. The results revealed that rice genotypes greatly differed in their responses under both conditions for all the studied traits. Moreover, water deficit caused great reductions in all the studied traits compared with normal irrigation. These results are in good agreement with those reported by Abd Allah *et al* (2010), Sedeek *et al* (2012) and Elgamal *et al* (2018).

For days to heading, the parents Sakha102, Sakha106 and Giza178 and the cross combinations (Giza 178 × Sakha 102), (Sakha 106 × Sakha 102), (IRAT 170 × Sakha106) and (IET 1444 × Sakha102) exhibited the desirable mean values towards the earliness under both normal and water deficit conditions.

Regarding plant height, Giza 178, IET 1444 and Sakha 106 were the shortest parents while, Moroberekan and IRAT 170 were the tallest ones under both normal and water deficit conditions. The three crosses (Sakha 104 × Sakha 106), (IRAT 170 × Sakha106) and (IET 1444 × Sakha102) had the lowest desirable mean values towards dwarfing under both conditions.

Meanwhile, the two crosses (IRAT 170 × Moroberekan) and (IET 1444 × Moroberekan) expressed the highest mean values under stress and non-stress conditions. A significant reduction in plant height was observed under water deficit condition in all of the studied rice genotypes compared to normal condition. The reduction of plant height in response to water deficit agree with previous results of Henry *et al* (2016) and El-Sayed *et al* (2018).

Table 3. Mean performance of the seven parental rice genotypes and their 21 F_1 for all studied traits under normal and stress conditions during 2018 season.

Genotypes	Days to heading		Plant height (cm)		Flag leaf area (cm^2)		Chlorophyll content (SPAD)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 178	104.30	102.90	100.50	93.63	30.90	27.50	44.92	40.50
Sakha 104	106.43	104.50	105.60	96.60	31.80	24.30	41.60	39.72
IRAT 170	106.89	103.20	128.50	110.30	35.26	28.10	39.81	36.37
IET 1444	107.88	101.30	104.50	90.80	31.14	24.13	41.02	35.80
Moroberekan	115.95	110.80	139.60	116.30	34.60	29.32	45.70	41.47
Sakha 106	97.60	93.20	102.30	92.00	35.14	30.12	43.04	35.23
Sakha 102	94.50	89.30	110.70	96.50	29.53	21.33	38.82	34.93
Giza 178 × Sakha 104	105.20	104.00	112.30	98.60	37.63	30.32	46.50	43.04
Giza 178 × IRAT 170	102.50	101.30	109.30	96.40	21.10	16.30	46.42	42.83
Giza 178 × IET 1444	105.20	103.50	122.70	105.70	21.54	13.81	40.41	37.80
Giza 178 × Moroberekan	112.00	110.60	117.60	102.80	19.70	12.73	49.80	43.52
Giza 178 × Sakha 106	100.80	96.30	118.80	100.40	20.73	14.73	38.57	36.07
Giza 178 × Sakha 102	94.20	93.00	113.30	94.60	19.21	13.12	33.43	30.47
Sakha 104 × IRAT 170	110.40	108.80	106.00	100.30	30.21	23.70	37.20	32.90
Sakha 104 × IET 1444	105.10	104.00	110.73	102.56	32.60	26.52	43.22	38.40
Sakha 104 ×	111.30	109.20	126.84	115.76	34.32	27.80	42.40	35.10
Sakha 104 × Sakha 106	100.60	98.50	97.20	91.50	27.40	20.70	40.50	37.04
Sakha 104 × Sakha 102	100.40	97.00	110.86	106.56	37.54	30.62	37.40	34.20
IRAT 170 × IET 1444	102.30	102.80	115.70	105.00	30.97	28.20	47.03	40.50
IRAT 170 × Moroberekan	104.60	103.50	132.00	122.30	40.30	33.60	49.30	45.52
IRAT 170 × Sakha106	98.50	95.00	102.60	91.00	41.80	33.20	50.26	46.60
IRAT 170 × Sakha102	103.60	100.70	115.60	100.40	32.23	27.58	40.93	35.31
IET 1444 × Moroberekan	113.20	111.43	130.00	121.00	30.92	24.02	43.90	34.20
IET 1444 × Sakha106	106.00	101.60	120.50	110.50	24.30	19.10	40.80	32.70
IET 1444 × Sakha102	100.10	98.30	103.00	95.00	19.92	13.23	39.40	32.57
Moroberekan × Sakha106	110.80	108.50	128.20	115.80	43.03	36.00	44.40	36.90
Moroberekan × Sakha102	109.52	108.03	122.00	102.00	32.20	24.62	36.70	30.82
Sakha 106 × Sakha 102	94.60	93.60	106.39	89.75	34.50	25.40	45.70	37.27
LSD 0.05	1.24	1.61	2.01	2.06	1.21	0.95	0.93	1.24
LSD 0.01	1.65	2.14	2.68	2.74	1.61	1.27	1.24	1.65

Table 3. Cont.

Genotypes	No. of panicles/plant		Panicle length (cm)		Spikelet fertility (%)		100–grain weight (g)		Grain yield/plant (g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 178	22.30	20.57	23.60	22.70	94.10	87.83	2.38	2.22	43.19	33.50
Sakha 104	21.50	19.15	23.92	18.00	95.70	84.70	2.72	2.63	46.50	31.30
IRAT 170	15.12	12.60	23.92	20.71	91.90	84.80	2.55	2.39	37.60	29.82
IET 1444	19.50	17.12	23.03	19.70	91.60	85.58	2.68	2.52	36.80	30.50
Moroberekan	16.70	14.50	25.20	23.30	89.80	79.50	2.76	2.62	29.60	25.30
Sakha 106	21.22	16.70	21.52	18.32	94.70	78.80	2.72	2.27	44.50	29.24
Sakha 102	18.32	11.30	22.80	19.20	95.75	77.50	2.82	2.32	41.83	27.54
Giza 178 × Sakha 104	25.23	20.80	27.03	22.80	92.20	83.70	2.83	2.68	47.00	33.41
Giza 178 × IRAT 170	16.50	14.20	24.70	21.00	88.70	81.60	2.79	2.64	39.61	36.71
Giza 178 × IET 1444	24.80	20.52	23.70	20.25	93.58	83.80	2.45	2.35	41.90	30.73
Giza 178 × Moroberekan	17.80	14.90	26.04	23.50	85.30	82.80	2.61	2.44	38.54	32.60
Giza 178 × Sakha 106	23.62	19.04	24.30	20.70	76.50	77.20	2.76	2.45	45.70	32.20
Giza 178 × Sakha 102	22.80	17.20	23.70	21.30	80.40	75.83	2.92	2.73	48.53	33.80
Sakha 104 × IRAT 170	21.54	18.50	24.00	20.80	92.50	83.60	2.89	2.75	39.52	31.20
Sakha 104 × IET 1444	24.59	20.78	23.89	22.52	94.87	87.56	2.91	2.69	48.91	38.50
Sakha 104 × Moroberekan	18.50	15.60	20.70	18.30	87.50	80.80	2.78	2.57	41.90	30.50
Sakha 104 × Sakha 106	21.60	17.54	21.12	17.50	90.53	69.70	2.92	2.61	47.84	28.84
Sakha 104 × Sakh 102	20.53	12.50	18.82	15.40	88.80	69.60	2.88	2.65	47.54	27.80
IRAT 170 × IET 1444	20.82	15.60	18.70	13.53	81.50	77.50	2.51	2.25	41.62	36.61
IRAT 170 × Moroberekan	17.20	12.90	22.70	19.10	80.70	78.20	2.88	2.64	37.20	30.80
IRAT 170 × Sakha106	20.50	15.80	23.21	22.30	81.80	71.56	2.73	2.60	43.60	22.94
IRAT 170 × Sakha102	15.80	12.60	21.80	18.60	72.50	70.40	2.30	2.17	32.94	19.53
IET 1444 × Moroberekan	16.71	13.30	24.60	20.10	80.20	77.50	2.56	2.44	39.50	30.80
IET 1444 × Sakha106	18.33	14.50	22.90	19.22	82.50	78.50	2.70	2.59	42.30	28.30
IET 1444 × Sakha102	15.20	11.92	23.12	20.50	74.50	70.70	2.30	2.18	38.92	22.62
Moroberekan × Sakha106	17.52	12.60	24.61	21.60	87.70	81.23	2.94	2.74	42.53	33.92
Moroberekan × Sakha102	15.10	13.42	23.50	20.82	88.20	79.90	2.70	2.59	44.60	29.79
Sakha 106 × Sakha 102	18.50	11.82	22.63	17.90	89.40	73.12	2.80	2.64	46.94	26.82
LSD 0.05	1.41	1.47	0.93	0.99	1.56	1.70	0.19	0.22	1.86	2.01
LSD 0.01	1.88	1.96	1.24	1.32	2.08	2.27	0.25	0.30	2.47	2.68

This reduction might be associated with a decline in cell division and expansion under water deficit conditions (Kamoshita *et al* 2008)

With respect to flag leaf area, the parents IRAT 170, Sakha 106 and Moroberekan as well as the crosses (Moroberekan × Sakha106), (IRAT 170 × Sakha106) and (IRAT 170 × Moroberekan) gave the highest mean values under both normal and stress conditions. Conversely, the parent Sakha 102 and the cross Giza 178 × Sakha 102 recorded the lowest mean flag leaf area under both conditions.

The two parents Morobreakeon and Giza 178 as well as the three crosses (IRAT 170 × Sakha106), (Giza 178 × Moroberekan) and (IRAT 170 × Moroberekan) had the highest mean values of chlorophyll content under normal and stress conditions. Water deficit decreased chlorophyll content in the leaves of all the tested genotypes. The reduced chlorophyll is constantly correlated with the deficiency of photosynthesis. Huang *et al* (2004) reported that drought stress decreased chlorophyll content and affected the photosynthetic rate in rice.

For number of panicles/plant, the three parents Giza 178, Sakha 104 and Sakha 106 as well as the three crosses (Giza 178 × Sakha 104), (Giza 178 × IET 1444) and (Sakha 104 × IET 1444) under both normal and water deficit conditions produced the highest number of panicles/plant. As shown in Table (3), among the parents IRAT 170 under normal condition, Giza 178 under stress condition and Moroberekan under both conditions showed the longest panicles. Moreover, the cross Giza 178 × Sakha 104 under normal condition and the cross Giza 178 × Moroberekan under stress condition had the longest mean panicle length. For spikelet fertility %, the parents Sakha 102 and Sakha 104 under normal condition and Giza 178 and IET 1444 under stress condition recorded the highest fertility mean values. Also, the highest mean values were obtained from the crosses (Sakha 104 × IET 1444) and (Giza 178 × IET 1444) under both conditions. Concerning 100-grain weight, results showed that the parent Sakha 102 under normal condition, Sakha 104 under stress condition and Moroberekan under both conditions showed relatively high mean values for such trait. Meanwhile, the parent Giza 178 showed the lowest mean values under both conditions. Regarding the crosses performance it is apparent that the crosses

(Moroberekan × Sakha106), (Sakha 104 × Sakha 106) and (Giza 178 × Sakha 102) gave the heaviest grains under both conditions.

For grain yield/plant among the parents Sakha 106 under normal condition, IET 1444 under stress condition and Sakha 104 and Giza 178 under both conditions exhibited the highest mean values for this trait. Moreover, the crosses (Sakha 104 × Sakha 106) and (Giza 178 × Sakha 102) under normal condition, (Giza 178 × IRAT 170) and (IRAT 170 × IET 1444) under stress condition and (Sakha 104 × IET 1444) under both conditions had the highest grain yield/plant. These parents and crosses could be used in rice breeding programs for improving grain yield under such conditions. These results are in harmony with those reported by El-Hity *et al* (2016) and El-Sayed *et al* (2018).

General combining ability (GCA) effects

Estimates of general combining ability ($\hat{g}_i$) effects of the seven parents under normal and stress conditions are presented in Table 4. High positive values of ($\hat{g}_i$) effects would be of interest for all studied traits in question, except days to heading and plant height where high negative values would be useful from the breeder point of view. The parental cultivar Giza 178 showed highly significant and negative ($\hat{g}_i$) effects for days to heading under normal condition and plant height under both conditions. Moreover, it showed significant and positive ($\hat{g}_i$) effects for chlorophyll content, number of panicles/plant, panicle length, spikelet fertility and grain yield/plant under both normal and stress conditions. This indicates that this parent could be considered as a good combiner for earliness and high grain yield/ plant. The parent Sakha 104 gave highly significant and negative ($\hat{g}_i$) effects for plant height and showed highly significant and positive ($\hat{g}_i$) effects for flag leaf area, number of panicles/plant, spikelet fertility, 100-grain weight and grain yield/plant under both normal and stress conditions. The parental genotype IRAT 170 exhibited highly significant and positive ($\hat{g}_i$) effects for flag leaf area and chlorophyll content under both conditions. However, it gave significant undesirable or insignificant ($\hat{g}_i$) effects for other traits.

Table 4. General combining ability ($\hat{g}_i$) effects of the seven parents for all the studied traits under normal and stress conditions.

Parent	Days to heading		Plant height (cm)		Flag leaf area (cm^2)	
	Normal	Stress	Normal	Stress	Normal	Stress
Giza 178	-0.78**	-0.13	-2.57**	-3.62**	-4.91**	-4.26**
Sakha 104	1.14**	1.65**	-4.77**	-1.09**	1.94**	1.55**
IRAT 170	0.01	0.31	2.23**	1.97**	2.36**	2.72**
IET 1444	1.34**	0.95**	-0.72**	0.34	-2.59**	-2.35**
Moroberekan	6.42**	6.35**	13.08**	10.44**	2.65**	2.57**
Sakha 106	-3.23**	-3.97**	-4.42**	-3.93**	1.80**	1.67**
Sakha 102	-4.90**	-5.16**	-2.84**	-4.11**	-1.24**	-1.90**
LSD 0.05 (g_i)	0.27	0.35	0.44	0.45	0.26	0.21
LSD 0.01(g_i)	0.36	0.47	0.58	0.60	0.35	0.28
LSD 0.05 (g_i-g_j)	0.41	0.54	0.67	0.69	0.40	0.32
LSD 0.01(g_i-g_j)	0.54	0.71	0.88	0.91	0.53	0.42
Parent	**Chlorophyll content (SPAD)**		**No. of panicles/plant**		**Panicle length (cm)**	
	Normal	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**
Giza 178	0.58**	1.71**	2.09**	2.52**	1.23**	1.67**
Sakha 104	-1.04**	0.08	2.05**	2.10**	-0.25*	-0.73**
IRAT 170	1.22**	1.89**	-1.55**	-1.15**	-0.30**	-0.35**
IET 1444	-0.33**	-1.29**	0.32*	0.64**	-0.30**	-0.49**
Moroberekan	2.01**	1.07**	-2.26**	-1.49**	0.77**	1.12**
Sakha 106	0.73**	-0.26	0.66**	-0.05	-0.43**	-0.45**
Sakha 102	-3.17**	-3.21**	-1.33**	-2.56**	-0.72**	-0.78**
LSD 0.05 (g_i)	0.20	0.27	0.31	0.32	0.20	0.22
LSD 0.01(g_i)	0.27	0.36	0.41	0.43	0.27	0.29
LSD 0.05 (g_i-g_j)	0.31	0.41	0.47	0.49	0.31	0.33
LSD 0.01(g_i-g_j)	0.41	0.55	0.62	0.65	0.41	0.44
Parent	**Spikelet fertility (%)**		**100-grain weight (g)**		**Grain yield/plant (g)**	
	Normal	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**
Giza 178	0.75**	3.13**	-0.06**	-0.04	1.26**	2.76**
Sakha 104	4.41**	1.33**	0.11**	0.12**	3.26**	1.25**
IRAT 170	-1.85**	0.00	-0.05*	-0.03	-2.96**	-0.46*
IET 1444	-0.86**	1.59**	-0.10**	-0.06*	-1.06**	0.77**
Moroberekan	-0.99**	0.78**	0.04*	0.06*	-3.65**	-0.29
Sakha 106	-0.03	-2.61**	0.07**	0.01	2.40**	-1.12**
Sakha 102	-1.42**	-4.21**	-0.01	-0.06*	0.76**	-2.91**
LSD 0.05 (g_i)	0.34	0.37	0.04	0.05	0.41	0.44
LSD 0.01(g_i)	0.45	0.50	0.05	0.07	0.54	0.58
LSD 0.05 (g_i-g_j)	0.52	0.57	0.06	0.08	0.62	0.67
LSD 0.01(g_i-g_j)	0.69	0.76	0.08	0.10	0.81	0.89

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

The parental genotype IET 1444 expressed highly significant and negative ($\hat{g}_i$) effects for plant height under normal condition. Also, it gave highly significant and positive ($\hat{g}_i$) effects for panicle length under both conditions as well as spikelet fertility and grain yield/plant under stress condition. The parental genotype Moroberekan seemed to be suitable combiner for flag leaf area, chlorophyll content, panicle length under both conditions and spikelet fertility under stress condition, since it had positive and significant ($\hat{g}_i$) values for these traits. The parent Sakha 106 showed highly significant and negative ($\hat{g}_i$) effects for days to heading and plant height under both conditions and gave highly significant and positive effects for flag leaf area under both conditions as well as chlorophyll content, number of panicles/plant, 100-grain weight and grain yield/plant under normal condition. The parent Sakha 102 exhibited highly significant and negative ($\hat{g}_i$) effects for days to heading and plant height under both conditions and showed positive and significant ($\hat{g}_i$) effects for grain yield/plant under normal condition. Such results indicated that these parents possess favorable genes and that improvement in respective traits may be attained if they are incorporated in rice hybridization program. It is worth noting that the parents which possessed high ($\hat{g}_i$) effects for grain yield exhibited desirable ($\hat{g}_i$) effects for one or more of the traits contributing to grain yield. These results are in agreement with those reported by Sedeek *et al* (2012) and Abd El-Hadi *et al* (2014).

Specific combining ability (SCA) effects

Estimates of specific combining ability ($\hat{S}_{ij}$) effects of the 21 F_1 crosses for all the studied traits under normal and stress conditions are presented in Table (5). For days to heading, ten and six cross combinations had highly significant and negative ($\hat{S}_{ij}$) effects under normal and stress conditions, respectively. The highest estimated negative values were recorded by the crosses (Giza 178 × Sakha 102), (Sakha 104 × Sakha 106), (IRAT 170 × Moroberekan) and (IRAT 170 × Sakha106) under both conditions. These crosses could be utilized in rice breeding program for improving earliness.

For plant height, the data showed that the eight crosses (Giza 178 × IRAT 170), (Giza 178 × Moroberekan), (Sakha 104 × IRAT 170), (Sakha 104 × Sakha 106), (IRAT 170 × Sakha106), (IET 1444 × Sakha102), (Moroberekan × Sakha102) and (Sakha 106 × Sakha 102) under both normal and stress conditions expressed highly significant and negative ($\hat{S}_{ij}$) effects towards shortness.

Regarding flag leaf area, the two crosses (IRAT 170 × IET 1444) and (IRAT 170 × Sakha102) under stress and the seven crosses (Giza 178 × Sakha 104), (Sakha 104 × IET 1444), (Sakha 104 × Sakha 102), (IRAT 170 × Moroberekan), (IRAT 170 × Sakha106), (Moroberekan × Sakha106) and (Sakha 106 × Sakha 102) under both conditions exhibited highly significant and positive ($\hat{S}_{ij}$) effects. Therefore, these crosses are considered as good specific combiners for improving this trait under such conditions. The eight crosses (Giza 178 × Sakha 104), (Giza 178 × IRAT 170), (Giza 178 × Moroberekan), (Sakha 104 × IET 1444), (IRAT 170 × IET 1444), (IRAT 170 × Moroberekan), (IRAT 170 × Sakha106) and (Sakha 106 × Sakha 102) had highly significant and positive ($\hat{S}_{ij}$) effects for chlorophyll content under both normal and stress conditions. Concerning number of panicles/plant, the results indicated that highly significant and positive ($\hat{S}_{ij}$) effects were observed in the three crosses (Giza 178 × Sakha 104), (IRAT 170 × IET 1444), (IRAT 170 × Moroberekan) under normal condition, the cross (Moroberekan × Sakha102) under stress condition and the six crosses (Giza 178 × IET 1444), (Giza 178 × Sakha 106), (Giza 178 × Sakha 102), (Sakha 104 × IRAT 170), (Sakha 104 × IET 1444) and (IRAT 170 × Sakha106) under both conditions. These crosses could be used in rice breeding program to improve number of panicles/plant under such conditions. For panicle length, the three crosses (Giza 178 × IRAT 170), (IET 1444 × Moroberekan), (Sakha 106 × Sakha 102) under normal condition and the seven crosses (Giza 178 × Sakha 104), (Giza 178 × Moroberekan), (Sakha 104 × IRAT 170), (Sakha 104 × IET 1444), (IRAT 170 × Sakha106), (IET 1444 × Sakha102) and (Moroberekan × Sakha106) under both normal and stress conditions had significant and positive ($\hat{S}_{ij}$) effects.

Table 5. Estimates of specific combining ability ($\hat{S}_{ij}$) effects of the 21 F_1 crosses for all the studied traits under normal and stress conditions.

Cross	Days to heading		Plant height (cm)		Flag leaf area (cm^2)		Chlorophyll content (SPAD)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 178 × Sakha 104	0.40	0.52	4.88**	1.02	9.87**	8.74**	4.49**	3.83**
Giza 178 × IRAT 170	-1.17**	-0.84	-5.13**	-4.24**	-7.09**	-6.45**	2.15**	1.81**
Giza 178 × IET 1444	0.20	0.72	11.22**	6.69**	-1.69**	-3.87**	-2.31**	-0.04
Giza 178 × Moroberekan	1.92**	2.42**	-7.68**	-6.31**	-8.77**	-9.87**	4.74**	3.32**
Giza 178 × Sakha 106	0.37	-1.55**	11.03**	5.66**	-6.89**	-6.98**	-5.21**	-2.80**
Giza 178 × Sakha 102	-4.56**	-3.67**	3.94**	0.04	-5.37**	-5.02**	-6.45**	-5.45**
Sakha 104 × IRAT 170	4.80**	4.88**	-6.22**	-2.86**	-4.82**	-4.86**	-5.45**	-6.50**
Sakha 104 × IET 1444	-1.83**	-0.56	1.46**	1.02	2.52**	3.03**	2.12**	2.18**
Sakha 104 × Moroberekan	-0.71*	-0.76	3.77**	4.12**	-1.00**	-0.61*	-1.05**	-3.47**
Sakha 104 × Sakha 106	-1.76**	-1.13*	-8.37**	-5.77**	-7.07**	-6.81**	-1.66**	-0.21
Sakha 104 × Sakha 102	-0.28	-1.44**	3.71**	9.47**	6.11**	6.68**	-0.86**	-0.10
IRAT 170 × IET 1444	-3.50**	-0.42	-0.58	0.41	0.47	3.55**	3.67**	2.48**
IRAT 170 × Moroberekan	-6.28**	-5.12**	1.92**	7.61**	4.56**	4.03**	3.59**	5.14**
IRAT 170 × Sakha106	-2.73**	-3.30**	-9.97**	-9.33**	6.91**	4.52**	5.84**	7.55**
IRAT 170 × Sakha102	4.05**	3.59**	1.44*	0.26	0.38	2.47**	0.41	-0.80*
IET 1444 × Moroberekan	0.99**	2.17**	2.87**	7.93**	0.13	-0.48	-0.26	-3.00**
IET 1444 × Sakha106	3.44**	2.66**	10.88**	11.80**	-5.64**	-4.51**	-2.07**	-3.17**
IET 1444 × Sakha102	-0.78*	0.55	-8.21**	-3.52**	-6.98**	-6.81**	0.43	-0.35
Moroberekan × Sakha106	3.17**	4.16**	4.78**	7.00**	7.85**	7.47**	-0.81**	-1.33**
Moroberekan × Sakha102	3.56**	4.85**	-3.01**	-6.62**	0.07	-0.34	-4.61**	-4.46**
Sakha 106 × Sakha 102	-1.71**	0.78	-1.11*	-4.50**	3.21**	1.34**	5.68**	3.32**
LSD 5% (s_{ij})	0.67	0.87	1.09	1.11	0.65	0.51	0.50	0.67
LSD 1% (s_{ij})	0.89	1.16	1.45	1.48	0.87	0.68	0.67	0.89
LSD 5% (s_{ij}-s_{ik})	1.17	1.52	1.90	1.94	1.14	0.90	0.88	1.17
LSD 1% (s_{ij}-s_{ik})	1.55	2.02	2.52	2.59	1.51	1.19	1.17	1.55
LSD 5% (s_{ij}-s_{kl})	1.09	1.42	1.77	1.82	1.06	0.84	0.82	1.09
LSD 1% (s_{ij}-s_{kl})	1.45	1.89	2.36	2.42	1.42	1.12	1.09	1.45

Table 5. Cont.

Cross	No. of panicles/plant		Panicle length (cm)		Spikelet fertility (%)		100–grain weight (g)		Grain yield/plant (g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 178 × Sakha 104	1.52**	0.54	2.85**	1.87**	-0.22	0.19	0.07	0.09	0.44	-0.80
Giza 178 × IRAT 170	-3.61**	-2.81**	0.57*	-0.31	2.53**	-0.59	0.19**	0.20**	-0.73	4.21**
Giza 178 × IET 1444	2.82**	1.72**	-0.43	-0.92**	6.43**	0.03	-0.10*	-0.06	-0.34	-3.00**
Giza 178 × Moroberekan	-1.60**	-1.77**	0.84**	0.72**	-1.72**	-0.16	-0.07	-0.09	-1.11*	-0.07
Giza 178 × Sakha 106	1.30**	0.93*	0.30	-0.51	-11.48**	-2.37**	0.04	-0.03	0.00	0.36
Giza 178 × Sakha 102	2.47**	1.60**	-0.01	0.42	-6.19**	-2.14**	0.29**	0.31**	4.47**	3.75**
Sakha 104 × IRAT 170	1.47**	1.91**	1.34**	1.89**	2.67**	3.22**	0.12*	0.14*	-2.83**	0.21
Sakha 104 × IET 1444	2.65**	2.40**	1.23**	3.75**	4.06**	5.59**	0.19**	0.12	4.67**	6.28**
Sakha 104 × Moroberekan	-0.86*	-0.65	-3.02**	-2.08**	-3.18**	-0.36	-0.07	-0.13*	0.25	-0.66
Sakha 104 × Sakha 106	-0.68	-0.15	-1.41**	-1.31**	-1.11*	-8.07**	0.03	-0.03	0.14	-1.49**
Sakha 104 × Sakha 102	0.24	-2.68**	-3.42**	-3.08**	-1.45**	-6.57**	0.08	0.07	1.48**	-0.74
IRAT 170 × IET 1444	2.48**	0.47	-3.91**	-5.62**	-3.05**	-3.14**	-0.05	-0.17**	3.60**	6.10**
IRAT 170 × Moroberekan	1.44**	-0.10	-0.97**	-1.66**	-3.73**	-1.63**	0.19**	0.10	1.77**	1.35*
IRAT 170 × Sakha106	1.82**	1.35**	0.73**	3.11**	-3.59**	-4.88**	0.00	0.11	2.12**	-5.67**
IRAT 170 × Sakha102	-0.89*	0.67	-0.39	-0.26	-11.49**	-4.45**	-0.34**	-0.26**	-6.90**	-7.30**
IET 1444 × Moroberekan	-0.93*	-1.49**	0.92**	-0.52	-5.21**	-3.92**	-0.09	-0.07	2.17**	0.11
IET 1444 × Sakha106	-2.23**	-1.73**	0.42	0.17	-3.87**	0.47	0.02	0.13*	-1.07*	-1.55**
IET 1444 × Sakha102	-3.36**	-1.79**	0.93**	1.78**	-10.48**	-5.73**	-0.30**	-0.21**	-2.81**	-5.45**
Moroberekan × Sakha106	-0.46	-1.50**	1.06**	0.94**	1.46**	4.01**	0.13*	0.16**	1.74**	5.13**
Moroberekan × Sakha102	-0.88*	1.83**	0.25	0.48	3.35**	4.28**	-0.03	0.07	5.45**	2.79**
Sakha 106 × Sakha 102	-0.40	-1.21**	0.57*	-0.86**	3.59**	0.89	0.04	0.18**	1.75**	0.65
LSD 5% (s_{ij})	0.76	0.79	0.50	0.53	0.84	0.92	0.10	0.12	1.00	1.09
LSD 1% (s_{ij})	1.01	1.06	0.67	0.71	1.13	1.23	0.13	0.16	1.34	1.45
LSD 5% (s_{ij}-s_{ik})	1.33	1.39	0.88	0.93	1.47	1.61	0.18	0.21	1.75	1.90
LSD 1% (s_{ij}-s_{ik})	1.77	1.85	1.17	1.24	1.96	2.14	0.23	0.28	2.33	2.52
LSD 5% (s_{ij}-s_{kl})	1.24	1.30	0.82	0.87	1.38	1.50	0.16	0.20	1.64	1.77
LSD 1% (s_{ij}-s_{kl})	1.66	1.73	1.10	1.16	1.84	2.00	0.22	0.26	2.18	2.36

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

Concerning spikelet fertility %, the three crosses (Giza 178 × IET 1444), (Sakha 106 × Sakha 102) and (Giza 178 × IET 1444) under normal condition as well as the four crosses (Sakha 104 × IRAT 170), (Sakha 104 × IET 1444), (Moroberekan × Sakha106) and (Moroberekan × Sakha102) under both normal and stress conditions exhibited highly significant and positive ($\hat{S}_{ij}$) effects. For 100-grain weight, the two crosses (Sakha 104 × IET 1444) and (IRAT 170 × Moroberekan) under normal condition and other two crosses (IET 1444 × Sakha106) and (Sakha 106 × Sakha 102) under stress condition manifested significant and positive ($\hat{S}_{ij}$) effects. In addition, significant and positive ($\hat{S}_{ij}$) effects were obtained by the four crosses Giza 178 × Sakha 102, Sakha 104 × IRAT 170, Moroberekan × Sakha106 and Giza 178 × IRAT 170 under both environments. Thus, these crosses are considered to be promising for improving this trait.

Regarding grain yield/plant, the data showed that the four crosses (Sakha 104 × Sakha 102), (IRAT 170 × Sakha106), (IET 1444 × Moroberekan) and (Sakha 106 × Sakha 102) under normal condition, the cross (Giza 178 × IET 1444) under stress condition and the six crosses (Giza 178 × Sakha 102), (Sakha 104 × IET 1444), (IRAT 170 × IET 1444), (IRAT 170 × Moroberekan), (Moroberekan × Sakha106) and (Moroberekan × Sakha102) under both conditions exhibited significant and positive ($\hat{S}_{ij}$) effects. It is notable that the crosses that showed high ($\hat{S}_{ij}$) effects for grain yield/plant also showed high SCA effects for one or more traits of yield components.

It could be concluded that the previous crosses might be of interest in rice breeding programs as most of them involved at least one good combiner for the traits in view. Also, these crosses might be of interest to develop new cultivars or produce pure lines under drought stress condition. These results are in agreement with those reported by El-Hity *et al* (2016) and Elgamal *et al* (2018)

Heterosis

Estimates of heterosis relative to the better parent (heterobeltiosis) for all the studied traits under normal and stress conditions are presented in Table (6). Favorable heterobeltiosis in the studied crosses was considered negative for days to heading and plant height and positive for the rest of the studied traits under both conditions.

Table 6. Estimates of heterosis (%) relative to the better parent (Heterobeltiosis) for all the studied traits under normal and stress conditions.

Cross	Days to heading		Plant height (cm)		Flag leaf area (cm^2)		Chlorophyll content (SPAD)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 178 × Sakha 104	0.86	1.07	11.74**	5.30**	18.33**	10.25**	3.52**	6.27**
Giza 178 × IRAT 170	-1.73**	-1.55	8.76**	2.95**	-40.16**	-41.99**	3.34**	5.75**
Giza 178 × IET 1444	0.86	2.17**	22.09**	16.41**	-30.83**	-49.78**	-10.04**	-6.67**
Giza 178 × Moroberekan	7.38**	7.48**	17.01**	9.79**	-43.06**	-56.57**	8.97**	4.94**
Giza 178 × Sakha 106	3.28**	3.33**	18.21**	9.13**	-41.01**	-51.10**	-14.14**	-10.94**
Giza 178 × Sakha 102	-0.32	4.14**	12.74**	1.03	-37.83**	-52.29**	-25.58**	-24.77**
Sakha 104 × IRAT 170	3.73**	5.43**	0.38	3.83**	-14.32**	-15.66**	-10.58**	-17.17**
Sakha 104 × IET 1444	-1.25*	2.67**	5.96**	12.95**	2.52	9.14**	3.89**	-3.32*
Sakha 104 × Moroberekan	4.58**	4.50**	20.11**	19.83**	-0.81	-5.18**	-7.22**	-15.36**
Sakha 104 × Sakha 106	3.07**	5.69**	-4.99**	-0.54	-22.03**	-31.27**	-5.90**	-6.75**
Sakha 104 × Sakha 102	6.24**	8.62**	4.98**	10.42**	18.05**	26.01**	-10.10**	-13.90**
IRAT 170 × IET 1444	-4.29**	1.48	10.72**	15.64**	-12.17**	0.36	14.65**	11.36**
IRAT 170 × Moroberekan	-2.14**	0.29	2.72**	10.88**	14.29**	14.60**	7.88**	9.77**
IRAT 170 × Sakha106	0.92	1.93*	0.29	-1.09	18.55**	10.23**	16.78**	28.13**
IRAT 170 × Sakha102	9.63**	12.77**	4.43**	4.04**	-8.59**	-1.85	2.81*	-2.91
IET 1444 × Moroberekan	4.93**	10.00**	24.40**	33.26**	-10.64**	-18.08**	-3.94**	-17.53**
IET 1444 × Sakha106	8.61**	9.01**	17.79**	21.70**	-30.85**	-36.59**	-5.20**	-8.66**
IET 1444 × Sakha102	5.93**	10.08**	-1.44	4.63**	-36.03**	-45.17**	-3.95**	-9.02**
Moroberekan × Sakha106	13.52**	16.42**	25.32**	25.87**	22.45**	19.52**	-2.84**	-11.02**
Moroberekan × Sakha102	15.89**	20.94**	10.21**	5.70**	-6.94**	-16.03**	-19.69**	-25.68**
Sakha 106 × Sakha 102	0.11	4.82**	4.00**	-2.45*	-1.82	-15.67**	6.18**	5.79**

Table 6. Cont.

Cross	No. of panicles/plant		Panicle length (cm)		Spikelet fertility (%)		100–grain weight (g)		Grain yield/plant (g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 178 × Sakha 104	13.14**	1.13	13.02**	0.44	-3.66**	-4.71**	4.04	1.90	1.08	-0.27
Giza 178 × IRAT 170	-26.01**	-30.96**	3.26	-7.49**	-5.74**	-7.10**	9.41*	10.46*	-8.29**	9.58**
Giza 178 × IET 1444	11.21**	-0.23	0.42	-10.79**	-0.55	-4.59**	-8.58*	-6.75	-2.98	-8.27**
Giza 178 × Moroberekan	-20.18**	-27.55**	3.33	0.86	-9.35**	-5.73**	-5.43	-6.87	-10.76**	-2.69
Giza 178 × Sakha 106	5.92	-7.42*	2.97	-8.81**	-19.22**	-12.11**	1.47	7.93	2.70	-3.88
Giza 178 × Sakha 102	2.24	-16.37**	0.42	-6.17**	-16.03**	-13.67**	3.55	17.67**	12.37**	0.90
Sakha 104 × IRAT 170	0.19	-3.39	0.33	0.43	-3.34**	-1.42	6.25	4.56	-15.01**	-0.32
Sakha 104 × IET 1444	14.37**	8.51*	-0.13	14.31**	-0.87	2.31*	6.99*	2.28	5.18*	23.00**
Sakha 104 × Moroberekan	-13.95**	-18.54**	-17.86**	-21.46**	-8.57**	-4.60**	0.72	-2.28	-9.89**	-2.56
Sakha 104 × Sakha 106	0.47	-8.41*	-11.71**	-4.48	-5.40**	-17.71**	7.35*	-0.76	2.88	-7.86*
Sakha 104 × Sakha 102	-4.51	-34.73**	-21.32**	-19.79**	-7.26**	-17.83**	2.13	0.76	2.24	-11.18**
IRAT 170 × IET 1444	6.77	-8.88*	-21.82**	-34.67**	-11.32**	-9.44**	-6.34	-10.71*	10.69**	20.03**
IRAT 170 × Moroberekan	2.99	-11.03*	-9.92**	-18.03**	-12.19**	-7.78**	4.35	0.76	-1.06	3.29
IRAT 170 × Sakha106	-3.39	-5.39	-2.97	7.68**	-13.62**	-15.61**	0.37	8.79	-2.02	-23.07**
IRAT 170 × Sakha102	-13.76**	0.00	-8.86**	-10.19**	-24.28**	-16.98**	-18.44**	-9.21	-21.25**	-34.51**
IET 1444 × Moroberekan	-14.31**	-22.31**	-2.38	-13.73**	-12.45**	-9.44**	-7.25*	-6.87	7.34**	0.98
IET 1444 × Sakha106	-13.62**	-15.30**	-0.56	-2.44	-12.88**	-8.27**	-0.74	2.78	-4.94*	-7.21*
IET 1444 × Sakha102	-22.05**	-30.37**	0.39	4.06	-22.19**	-17.39**	-18.44**	-13.49**	-6.96**	-25.84**
Moroberekan × Sakha106	-17.44**	-24.55**	-2.34	-7.30**	-7.39**	2.18*	6.52	4.58	-4.43*	16.01**
Moroberekan × Sakha102	-17.58**	-7.45	-6.75**	-10.64**	-7.89**	0.50	-4.26	-1.15	6.62**	8.17*
Sakha 106 × Sakha 102	-12.82**	-29.22**	-0.75	-6.77*	-6.63**	-7.21**	-0.71	13.79**	5.48*	-8.28*

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

For days to heading, only four crosses (Giza 178 × IRAT 170), (Sakha 104 × IET 1444), (IRAT 170 × IET 1444) and (IRAT 170 × Moroberekan) under normal condition expressed significant and negative heterotic values towards earliness. Significant and negative heterosis for earliness in rice were reported by Hassan *et al* (2016) and El-Sayed *et al* (2018).

Regarding plant height, the cross (Sakha 104 × Sakha 106) under normal condition and the cross (Sakha 106 × Sakha 102) under stress condition showed significant and negative heterotic effects towards shortness. Therefore, these hybrids could be of practical interest in rice breeding program for the short stature plant. For flag leaf area, the cross (Sakha 104 × IET 1444) under stress condition and the five crosses (Giza 178 × Sakha 104), (Sakha 104 × Sakha 102), (IRAT 170 × Moroberekan), (IRAT 170 × Sakha106) and (Moroberekan × Sakha106) under both conditions exhibited significant and positive heterotic effects. Significant and positive heterotic effects relative to the better parent for flag leaf area in rice crosses were reported by El-Sayed *et al* (2018).

For chlorophyll content, the two crosses (Sakha 104 × IET 1444) and (IRAT 170 × Sakha106) under normal condition and the seven crosses (Giza 178 × Sakha 104), (Giza 178 × IRAT 170), (Giza 178 × Moroberekan), (IRAT 170 × IET 1444), (IRAT 170 × Moroberekan), (IRAT 170 × Sakha106) and (Sakha 106 × Sakha 102) under both conditions expressed significant and positive heterosis over the better parent. Moreover, Significant and positive heterotic effects were recorded by the two crosses (Giza 178 × Sakha 104) and (Giza 178 × IET 1444) under normal condition and the cross (Sakha 104 × IET 1444) under both conditions for number of panicles/plant.

Concerning panicle length, the cross (Giza 178 × Sakha 104) under normal condition and the two crosses (Sakha 104 × IET 1444) and (IRAT 170 × Sakha106) gave highly significant and positive heterotic effects over the better parent. Only the two crosses (Sakha 104 × IET 1444) and (Moroberekan × Sakha106) under stress condition exhibited desirable and significant heterosis over the better parent for spikelet fertility percentage. With regard to 100-grain weight, significant and positive heterotic effects were detected by the crosses (Sakha 104 × IET 1444) and (Sakha 104 × Sakha 106) under normal condition, (Giza 178 × Sakha 102) and (Sakha 106 × Sakha 102) under stress condition and (Giza 178 × IRAT 170) under both conditions.

With respect to grain yield/plant, the three crosses (Giza 178 × Sakha 102), (IET 1444 × Moroberekan) and (Sakha 106 × Sakha 102) under normal condition and the two crosses (Giza 178 × IRAT 170) and (Moroberekan × Sakha106) under stress condition had significant and positive heterotic effects. Moreover, the three crosses (Sakha 104 × IET 1444), (IRAT 170 × IET 1444) and (Moroberekan × Sakha102) under both conditions expressed significant and positive heterotic effects for this trait. In this concern, Ushakumari *et al* (2014), El-Sayed *et al* (2018) and Elgamal *et al* (2018) reported positive and significant heterotic effects for grain yield/plant and some of its components in rice crosses under normal and water deficit conditions in their respective studies.

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قوة الهجين والقدرة على التآلف لبعض التراكيب الوراثية من الأرز تحت ظروف الري العادى و نقص المياه

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أجريت هذة الدراسة بالمزرعة البحثية لقسم بحوث الأرز– محطة البحوث الزراعية بسخا - كفر الشيخ خلال موسمى ٢٠١٧ و ٢٠١٨ بإستخدام سبعة تراكيب وراثية من الأرز. أجريت كل التهجينات الممكنة بين الاباء بدون الهجن العكسية للحصول على ٢١ هجين. تم تقييم الاباء والجيل الاول فى تجربتين منفصلتين تحت كلا من الرى العادى ونقص المياة. صممت كل تجربة بنظام القطاعات الكاملة العشوائية فى ثلاث مكررات بغرض تقدير قوة الهجين، القدرة العامة والخاصة على التآلف ولتحديد الفعل الجينى المتحكم فى وراثة تسعة صفات تحت كلا من المعاملتين. أوضحت النتائج ان نقص المياه أدى إلى خفض فى متوسطات التراكيب الوراثية المختلفة بالنسبة لجميع الصفات تحت الدراسة لكل من الاباء والهجن. كانت هناك إختلافات عالية المعنوية بين التراكيب الوراثية والاباء والهجن لجميع الصفات المدروسة. أظهرت النتائج أن التباين الراجع للاباء مقارنة بالهجن (قوة الهجين) كان عالى المعنوية لجميع الصفات تحت الدراسة. أشارت النتائج إلي أن التباين الراجع للقدرة العامة والخاصة على التآلف كان عالى المعنوية لجميع الصفات المدروسة تحت ظروف الري العادي ونقص المياه. كان الفعل الجينى غير المضيف هو الاكثر اهمية فى وراثة معظم الصفات تحت الدراسة. أظهرت الأباء سخا ١٠٢ وسخا ١٠٦ أفضل القيم لتأثيرات القدرة العامة على التآلف للتبكير بينما أظهرت الأباء جيزة ١٧٨ وسخا ١٠٤ و IET 1444 قدرة عامة جيدة على التآلف لصفة محصول الحبوب ومعظم مكوناته. أظهرت السبعة هجن (Giza 178 × Sakha 102) (Sakha 104 × IET 1444), (IRAT 170 × IET 1444), (IRAT 170 × Moroberekan) (Moroberekan × Sakha106), (Moroberekan × Sakha102) أفضل القيم لتأثيرات القدرة الخاصة على التآلف لصفة محصول الحبوب وبعض مكوناته. أشارت النتائج إلي أن الثلاثة هجن (Sakha 104 × IET 1444) (IRAT 170 × IET 1444), (Moroberekan × Sakha102) أظهرت قوة هجين معنوية ومرغوبة (بالنسبة للأب الأفضل) لصفة محصول الحبوب/نبات تحت كل من المعاملتين مما يدل على امكانية استخدام هذه الهجن فى برامج التربية لتحسين القدرة المحصولية تحت ظروف الرى العادى ونقص المياة.

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