

LINE BY TESTER ANALYSIS FOR YIELD AND YIELD COMPONENTS IN HYBRID RICE

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ABSTRACT

This study was conducted to investigate combining ability and gene action of rice hybrids and their parental lines. Four CMS lines as female parents and three restorers' lines as male parents were hybridized to produce 12 F₁ hybrids were used in a line x tester mating design. The resulted genotypes were used to estimate combining ability, heterosis, and gene action for yield and yield components characters. The results indicated that most characters were largely governed by additive gene action. General and specific combining ability effects of the genotypes for the characters under study were estimated. The results showed that the characters were controlled both general combining ability (GCA) and specific combining ability (SCA). The CMS and restorer lines showed variable effects for GCA. The study also indicated the presence of heterosis over the better parent (BP), Mid-parents (MP) and over the best check variety Giza 178 for nine characters of yield and yield components.

INTRODUCTION

Rice has become one of the main factors of food security for the world population. Hybrid rice offers from 15-20% yield advantage over the high-yielding inbred varieties under similar cultivation conditions. In order to obtain good hybrids, it is essential to understand the nature of gene action that controls yield and its components. Combining ability estimation is a powerful tool available to select the desirable parents and crosses for the exploitation of heterosis. General combining ability (GCA) effects largely involves additive gene effects, whereas specific combining ability (SCA) effects represent only non-additive gene action including dominance. The presence of non-additive genetic variance offers scope for exploration of heterosis (Yadav *et al.*, 1999). The parents with good GCA and SCA could good hybrids (Yan *et al.*, 2000). The rice researchers around the world carried out many studies on combining ability of different lines of rice among them, (Sun *et al.*, 1993; Gong *et al.*, 1993; Chen *et al.*, 1997). Their achievements in this aspect Could recommend the use of hybrid rice by selecting good parents in hybridization breeding program. In addition, heterosis and combining ability of hybrid rice were studied by Zhang *et al.*, (2002). Line x tester analysis provides information about GCA and SCA effects of parents and is helpful in estimating various types of gene actions (Rashid *et al.*, 2007). Identification of suitable parents through line x tester analysis in rice has been studied by Singh & Kumar (2004).

The present study included the utilization of four CMS lines x three testers to produce 12 F1s. All the hybrids and the seven rice genotypes were used to estimate combining ability, heterosis, as well as gene action for yield and yield components.

MATERIALS AND METHODS

Four cytoplasmic male sterility lines (CMS) viz., IR68885A mutant type, IR69625A possessing wild abortive type (WA), G46A possessing Gambiaca type and Large stigma A possessing Kalinga type of cytoplasm, were used as female lines (Table 1). These CMS lines were crossed with three elite lines/varieties Giza 178R, Giza 182R and GZ5121-5-2R to generate 12 hybrid combinations in line x tester mating design. The hybrids were evaluated along with parents in a randomized complete block design with three replications at Rice Research Training Center during 2006 season. Thirty-day-old seedlings were transplanted (Each plot was made of seven rows 5m long and spaced at 20 cm apart, 20 cm interplant distance). Days to flowering, plant height, panicle length, panicle weight, filled grains panicle⁻¹, spikelets panicle⁻¹, spikelet fertility percentage, 1000-grain weight and grain yield tha⁻¹ were noted. Combining ability analysis was carried out following the method of Kempthorne (1957).

Table (1): Cytoplasmic male sterile lines and restorer lines used for the study.

Genotypes	Cytoplasm source	Origin
CMS lines (female)		
IR68885A	Mutant IR62829A	IRRI
IR69625A	WA	IRRI
G46A	Gambiaca	China
Large stigma A	Kalinga	China
Restorer lines (male)		
Giza 178R	Restorer	Egypt
Giza 182R	Restorer	Egypt
GZ5121-5-2R	Restorer	Egypt

RESULTS AND DISCUSSION

The analysis of variance revealed that the variation in genotypes (parents and hybrids) was highly significant for all the studied characters (Table 2). The parents, hybrids and interaction between parents and hybrids showed highly significant differences for all characters. The analysis of variance for combining ability (Table 2) also showed highly significant differences among the lines for all the characters. While the testers exhibited highly significant differences for all the characters except for spikelets panicle⁻¹, which was non-significant. The significance of the mean of sum squares due to lines and testers indicated a prevalence of additive variance. However, means of sum of squares due to line x testers were also significant for all the characters except for 1000-grain weight, which indicating that the importance of both additive and non-additive variance. Several workers reported the predominance of dominant gene action for a majority of the yield traits (Ramaligan *et al.*, 1993; Peng and Virmani 1990 and Stayanarayana *et al.*,

1998). Also EL-Mowafi 2001a, EL-Mowafi and AbouShoush (2003), Singh and Kumar (2004), EL-Mowafi *et al.*, (2005), Abd EL-Hadi and EL-Mowafi (2005) and EL-Diasty *et al.*, (2008) have reported the same results.

Genetic Parameters:

The estimates of genetic parameters viz, additive variance ($\sigma^2 A$), dominance variance ($\sigma^2 D$), environmental variance ($\sigma^2 E$), genotypic variance ($\sigma^2 G$), and phenotypic variance ($\sigma^2 P$), broad sense heritability (h^2_b), narrow sense heritability (h^2_n), relative importance of GCA % and relative importance of SCA % for all nine studied characters are presented in Table (3). It is revealed that the estimation of additive genetic variance ($\sigma^2 A$) and relative importance of GCA % for all studied characters except for grain yield were higher than non-additive or dominance genetic variance ($\sigma^2 D$) and relative importance of SCA % for these characters. These results indicated that the former characters were largely governed by additive gene action. The importance of additive gene action for the inheritance of these characters was supported with similar results obtained by Lokaprakash *et al.* (1991), EL-Mowafi (1994), Sharma and Koranne (1995), EL-Mowafi (2001a), Attia. (2001), EL-Refaei (2002), EL-Mowafi and Abou shousha (2003), Ahmed (2004), EL-Mowafi *et al.* (2005), Abd EL-Hadi and EL-Mowafi (2005) and EL-Diasty *et al.* (2008). On the other hand, high estimate of dominance genetic variance and its relative magnitude of SCA % were found to be more than that of additive variance for grain yield characters. This result indicated that dominance genetic variance played a major role in the inheritance of this character, which was in general agreement with the results reported by Sharma and Koranne (1995), Ramalingam *et al.* (1997) and EL-Refaei (2002), and EL-Mowafi and Abou-Shousha (2003). Heritability estimation in broad sense was high for all characters under study as given in Table (3). Heritability estimates were high for plant height, panicle length, filled grains panicle⁻¹, spikelets panicle⁻¹, spikelet fertility % and 1000-grain weight and moderate for heading date and panicle weight, indicating that a major part of the total genotypic is additive, while heritability estimation in the narrow sense for grain yield t ha⁻¹ was low.

Estimation of General Combining Ability (GCA) Effects:

The estimation of the general combining ability (GCA) effects of lines and testers revealed that the parents: IR68885A and IR69625A, Giza 178R and Giza 182R were good combiners for earliness and dwarfness (Tables 4 and 5). While, IR68885A, Giza 182R were found to be better combiners for panicle length. Whereas, G46A, IR69625A, Giza 182R and Giza 178R appeared to be better combiner for panicle weight. Large stigma, G46A, Giza 178R, and Giza 182R were good for filled grains panicle⁻¹; and spikelets panicle⁻¹. The lines : IR69625A, Giza 182R and Giza 178R had high GCA effects for spikelet fertility %; Large stigma A. Also, the lines : G46A, Giza 182R and Giza 178 were found to be better combiners for 1000-grain weight. While, IR69625A, G46A, and Giza 178R were identified as better combiners for grain yield.

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Estimation of Specific Combining Ability (SCA) Effects:

The usefulness of a particular cross in exploiting heterosis is judged by the specific combining ability (SCA) effect. The estimation of SCA of 12 crosses for nine characters are presented in Table 6. It is observed that out of 12 hybrid combinations, there were three hybrids exhibited positive and significant SCA for grain yield. The promising combinations for grain yield along with other characters were : IR68885A/GZ5121R, IR69625A/GZ5121R and G46A/Giza 182R. It was observed that the majority of these crosses had high SCA for grain yield involved with higher/low or average/low general combining parents, while there was one hybrid combination showed low/low general combiners with high SCA. The hybrid combinations that showed high negative SCA for days to heading (earliness) were : IR69625A/GZ5121R, Large stigma A/Giza 182R, G46A/Giza 182R and IR68885R/Giza 178R. For plant height, estimates of SCA were obtained where among these hybrids desirable and the good specific combiners for this were: G46A/GZ5121R, IR69625A/Giza 182R, Large-stigma A/GZ5121R, IR68885A/Giza 178R, and IR68885A/Giza 182R. The hybrid combinations, G46A/GZ5121R, IR69625A/Giza 182R/Giza 182R and large-stigma A/Giza 178R were good combiners for panicle length. The best specific combiners for panicle weight were G46A/Giza 178R, IR69625A/ GZ5121R, IR68885A/Giza 182R, large-stigma A/Giza 178R, and IR68885A/ GZ5121R. The hybrid combinations, IR68885A/ GZ5121R and IR69625A/Giza 182R showed higher SCA for filled grains panicle⁻¹ and spikelets panicle⁻¹. For spikelet fertility %, the hybrid of IR68885A/ GZ5121R, IR69625A/Giza 182R, G46A/Giza 178R, and large-stigma A/Giza 178R exhibited high SCA.

Heterosis

Heterosis percent over better parent (BP), Mid-parents (MP), and over best check variety Giza 178 was calculated for nine yield and yield component characters (Tables 7,8,9). The degree of heterosis varied from hybrid to hybrid, also from character to character. Many scientists have observed varying degrees of heterosis for yield and its related characters (EL-Mowafi *et al.*, 2001 b; Alam *et al.*, 2004, Abd EL-Hadi and El-Mowafi 2005 and EL-Mowafi *et al.*, 2005). For days to heading and plant height, negative heterosis was desirable but for the rest of the characters positive heterosis was desirable. Positive as well as negative BP, MP, and SH % were observed for all the characters (Tables 7, 8, 9). Some of the hybrids flowered earlier than their early parents. There were also some the hybrids flowered later than late parents. Among the earlier hybrid there was : IR68885A/Giza 178R which exhibited the highest significant heterosis of -9.00% over the BP, -7.40% over MP and -9.00% over standard variety (SH %) for earliness. Three other hybrids viz. IR69625A/Giza 178R, IR69625A/Giza 182R and G46A/Giza 178R also manifested BP, MP, and SH % for earliness. Regarding plant height, it was found that the hybrids were mostly tall in height to be classified into either medium tall or tall types. The results indicated that the mean heterosis effects for grain yield were significant and positive in 9 out 12 hybrids, as deviation from the better parent value (Table 7).

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The highest estimates were detected for the hybrids : G46A/Giza 182R (31.89%), G46A/Giza 178R (27.98%), IR69625A/Giza178R (26.6) and IR69625A/Giza 182R (21.82%). Moreover, significant and positive values of heterosis were estimated for 11 hybrids also as deviation from the MP. The highest heterotic effects over MP were (46.00%), (41.81%), (31.89%) and (29.41%) for hybrids (G46A/Giza 182R, G46A/Giza 178R, Large stigma A/Giza 178R, and IR69625A/Giza178R), respectively. However, out of 12 hybrids, the same nine hybrids exhibited highly significant and positive heterotic effects as deviation from the standard variety (Giza 178R). The highest heterotic effects were 31.63%, 27.98%, 26.60% and 21.58% for the above mentioned hybrids. Significant heterosis for yield and yield characters were also reported by EL-Mowafi (2001 b), EL-Refaee (2002), EL-Mowafi *et al.*, (2005) Rashid *et al.*, (2007) and EL-Diasty *et al.*, (2008).

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تحليل السلالة X الكشاف للمحصول ومكوناته فى الأرز الهجين.

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أجرى هذا البحث بغرض دراسة إمكانية استغلال قوة الهجين والقدرة على الإنتلاف فى بعض سلالات الأرز الهجين وذلك باستخدام تحليل السلالة X الكشاف لأربعة سلالات عقيمة ذكريا استخدمت كأباء مؤنثة وثلاث أصناف وسلالات مصرية معيدة للخصوبة (Restorers) وتحت دراسة قوة الهجين القياسية مقارنة بالصنف الأعلى محصولا من الأباء المصرية والمستخدم كصنف تجارى (جيزة ١٧٨) كما تمت دراسة القدرة على الإنتلاف والارتباط بين قوة الهجين وكلا من القدرة العامة على الإنتلاف والقدرة الخاصة على الإنتلاف لكلا الأبوين الداخلين فى الهجين وكذلك دراسة فعل الجين لإمكانية متابعة التربية والإنتخاب لهجن تستخدم فى الأجيال الإنعزالية المتقدمة لتحسين السلالات الأبوية فى الصفات المرغوبة . قد أوضحت نتائج تحليل القياسات الوراثية أن ال additive هو الذى يتحكم فى صفات التراكيب الوراثية المستخدمة بصورة كبيرة وكذلك أوضحت النتائج أن القدرة العامة على الإنتلاف (GCA) كانت أكثر تأثيرا.

Table (2): Analysis of variance for combining ability.

Source of variance	d.f	Heading date (days)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains panicle ⁻¹	Spikelets panicle ⁻¹	Spikelet fertility %	1000-grain weight (g)	Grain yield (t/ha)
Replications	2	0.070	0.348	0.389	0.029	34.185	20.363	2.009	0.364	0.054
Genotypes	18	149.193**	226.476**	8.789**	1.932**	1140.893**	1831.816**	74.219**	19.938**	8.251**
Parents	6	246.984**	105.142**	6.713**	0.949**	700.878**	1278.217**	65.325**	27.550**	2.904**
Hybrids	11	106.513**	180.475**	2.475**	1.532**	1126.101**	1432.038**	67.466**	11.898**	6.033**
Parents vs hybrids	1	31.930**	1460.495**	90.702**	12.229**	3943.696**	9550.972**	201.856**	62.697**	64.732**
Females(F)	3	63.583**	304.630**	8.982**	2.884**	2716.707**	4354.894**	122.147**	37.890**	7.351**
Males(M)	2	321.528**	429.778**	6.314**	1.609**	936.721**	197.877	113.660**	6.942**	6.017**
Females x Males (F x M)	6	56.306**	35.296**	0.942**	0.829**	393.924**	381.997**	24.726**	0.554	5.379**
Error	36	0.959	1.144	0.127	0.026	41.991	48.389	1.282	0.353	0.049
CV %		0.960	1.000	1.450	3.690	4.640	4.250	1.320	2.140	2.070

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (3): Genetic parameters for the nine studied characters.

parameter	Heading date (days)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains panicle ⁻¹	Spikelets panicle ⁻¹	Spikelet fertility (%)	1000-grain weight (g)	Grain yield (t/ha)
Additive variance ($\sigma^2 A$)	22.910	62.800	0.675	0.293	303.240	425.990	18.240	4.680	0.272
Dominant variance ($\sigma^2 D$)	18.450	11.380	0.272	0.268	117.310	111.200	7.820	0.067	1.780
Environmental variance ($\sigma^2 E$)	0.959	1.140	0.127	0.026	41.990	48.389	1.280	0.353	0.049
Genotypic variance ($\sigma^2 G$)	41.360	74.180	0.947	0.561	420.550	537.190	26.060	4.750	2.052
Phenotypic variance ($\sigma^2 P$)	42.320	75.320	1.074	0.587	462.540	585.580	27.340	5.100	2.100
Broad sense heritability (h^2_b) %	0.980	0.990	0.882	0.956	0.910	0.920	0.950	0.930	0.980
Narrow sense heritability (h^2_n) %	0.540	0.834	0.628	0.499	0.650	0.730	0.670	0.92	0.130
Relative importance of gca %*	55.390	84.660	71.300	52.230	72.110	79.300	70.000	98.530	13.260
Relative importance of sca %**	44.610	15.340	28.700	47.770	27.890	20.700	30.010	1.410	86.750

*, ** Relative importance gca = $\sigma^2 A / \sigma^2 G \times 100$ and Relative importance sca = $\sigma^2 D / \sigma^2 G \times 100$, respectively.

Table (4): General combining ability effects of CMS lines (A lines).

Lines	Heading date (days)	Plant height (cm)	Panicle length(cm)	Panicle weight(g)	Filled grains panicle	Spikelets panicle	Spikelet fertility %	1000-grain weight(g)	Grain yield t/ha
IR68885A	-2.9167**	-1.1667**	0.6611**	-0.7428**	-25.1181**	-27.2333**	-1.5972**	-2.6806**	-0.9267**
IR69625A	-1.4722**	-6.8333**	0.1722	0.3717**	1.8419	-8.3000**	5.4361**	-0.5028*	0.9744**
G46A	2.8611**	7.2778**	-0.1167	0.5039**	11.2075**	15.5556**	-1.1306**	1.3417**	0.5422**
Large stigmaA	1.5278**	0.7222*	-7.167**	-0.1328**	12.0686**	19.9778**	-2.7083**	1.8417**	-0.5900**
LSD 5%	0.66	0.721	0.24	0.108	4.37	4.69	.0673	0.401	0.15
1%	0.88	0.964	0.321	0.145	5.84	6.27	1.02	0.536	0.199

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (5): General combining ability effects of testers.

Tester	Heading date (days)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains panicle ⁻¹	Spikelets panicle ⁻¹	Spikelet fertility (%)	1000-grain weight(g)	Grain Yield (t/ha)
Giza 178R	-2.7778**	-4.5556**	0.02780	0.1975**	5.8856**	3.1389	1.5167**	-0.8778**	0.7489**
Giza182R	-3.1944**	-2.2222**	0.71110**	0.2250**	4.2739*	1.4472	2.0250**	0.4139*	-0.0903**
GZ 5121R	5.9722**	6.7778**	-0.7389**	-0.4225**	-10.1594**	-4.5861*	-3.5417**	0.4639**	-0.6586**
LSD 5%	0.5700	0.6240	0.2080	0.0940	3.7800	4.0600	0.6610	0.3470	0.1300
1%	0.7600	0.8350	0.2780	0.1250	5.0600	5.4300	0.8840	0.4640	0.1700

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (6): Specific combining ability of hybrid combinations.

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains panicle ⁻¹	Spikelets panicle ⁻¹	Spikelet fertility (%)	1000-grain weight(g)	Grain yield (t/ha)
IR68885A /Giza178R	-1.667**	-1.333*	-0.261	-0.610**	-8.49778*	-3.55000	-3.0611**	0.12222	-0.15000
/Giza182R	2.750**	-1.333*	0.189	0.403**	-6.51944	-5.25833	-1.40278*	-0.00278	-1.55417**
/GZ 5121R	-1.083	2.667**	0.072	0.207*	15.01722**	8.80833*	4.46389**	-0.11944	1.70417**
IR69625A /Giza178R	3.556**	-0.333	-0.339	-0.218*	11.54222**	13.71667**	-0.42778	0.17778	-0.33444*
/ Giza182R	2.639**	-3.333**	0.478*	-0.228*	-8.17611*	-12.05833**	2.03056**	-0.31389	-0.00861
/ GZ 5121R	-6.194**	3.667**	-0.139	0.446**	-3.36611	-1.65833	-1.60278*	0.13611	0.34306*
G46A/ Giza 78R	-1.111	1.556*	0.183	0.540**	-5.39000	-10.17222*	1.97222**	-0.66667	0.23444
/Giza182R	-2.361**	2.556**	-0.767**	0.053	7.63500*	10.08611*	-0.86944	0.50833	1.44694**
/ GZ 5121R	3.472**	-4.111**	0.583**	-0.593**	-2.24500	0.08611	-1.10278	0.15833	-1.68139**
Large stigma A /Giza178R	-0.778	0.111	0.417*	0.287**	2.34556	0.00556	1.51667**	0.36667	0.25000
/Giza182R	-3.028**	2.111**	0.100	-0.227*	7.06056	7.23056	0.24167	-0.19167	0.11583
/ GZ 5121R	3.806**	-2.222**	-0.517*	-0.060	-9.40611*	-7.23611	-1.75833*	-0.17500	-0.36583**
LSD 5%	1.14300	1.24800	0.41600	0.18700	7.56000	8.12000	1.32000	0.69400	0.26000
1%	1.53000	1.67000	0.55700	0.25000	10.12000	10.86000	1.77000	0.92800	0.35000

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (7): Estimates of heterosis over better-parent (BP) for 9 characters of 12 hybrid combinations.

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains panicle ⁻¹	Spikelets panicle ⁻¹	Spikelet fertility (%)	1000-grain weight(g)	Grain yield (t/ha)
IR68885A / Giza178R	-9.00**	-0.39	7.90**	-2.70	-12.80**	-12.20**	0.73	8.04	9.75**
/Giza182R	1.33	9.30**	13.10**	24.30**	-16.40**	-10.40**	-6.60**	3.70	-12.24**
/GZ5121R	-2.20**	15.60**	13.80**	-9.40*	-6.10	2.03	-8.00**	3.66	12.22**
IR69625A / Giza178R	-2.60**	-4.80**	5.50**	36.50**	17.90**	9.60**	11.10**	22.30	26.60**
/ Giza182R	-2.80**	1.30**	12.20**	37.00**	1.50	-2.80	5.20**	3.30	21.82**
/ GZ5121R	-5.60**	11.00**	10.70**	23.30**	0.30	7.80*	-6.90**	5.10	20.60**
G46A / Giza 178R	-2.90**	10.61**	6.70**	60.50**	16.20**	9.61**	6.00**	26.8*	27.98**
/Giza182R	2.00**	22.00**	5.60**	48.10**	19.20**	26.14**	-5.50**	13.2	31.89**
/ GZ5121R	7.50**	17.10**	12.50**	1.50	8.10**	25.15**	-13.60**	12.10	-3.78**
Large stigma A / Giza178R	-3.8**	2.90**	5.00**	36.50**	22.50**	18.40**	3.60**	33.50*	16.95**
/Giza182R	0.00	14.80**	6.80**	23.20**	19.50**	27.15**	-6.10**	12.50	7.60**
/GZ5121R	6.50**	12.70**	4.90**	-1.20	3.40	23.20**	-16.10**	12.50	-1.99

LSD 5%	1.62	1.98	0.59	0.27	10.69	11.48	1.87	5.89	0.37
1%	2.16	2.65	0.79	0.36	14.31	15.36	2.5	7.88	0.49

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (8): Estimates of heterosis mid-parents (MP) for 9 characters of 12 hybrid combinations.

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains panicle ⁻¹	Spikelets panicle ⁻¹	Spikelet fertility (%)	1000-grain weight(g)	Grain yield (t/ha)
IR68885A / Giza178R	-7.40**	3.60**	5.70**	5.60	-6.90	-5.20	-2.00	8.30	17.88**
/Giza182R	-0.20	9.90**	15.30**	35.30**	-9.70*	-5.30	-3.60**	6.10	-5.83**
/GZ5121R	0.67	19.70**	12.30**	3.90	-0.40	4.10	-4.20**	6.05	23.19**
IR69625A / Giza178R	-3.30**	-6.60**	5.00**	29.50**	23.30**	18.10**	3.80**	10.30	29.41**
/Giza182R	-1.50*	-4.10**	11.20**	30.00**	5.00	2.70	2.90**	3.30	24.40**
/GZ5121R	5.30**	8.40**	6.00**	24.20**	0.83	9.80**	-8.14**	5.10	22.67**
G46A / Giza 178R	-4.70**	11.10**	10.30**	44.90**	14.20**	10.10**	3.60**	13.00	41.81**
/Giza182R	-3.30**	18.40**	9.10**	33.70**	19.80**	23.98**	-3.40**	12.20	46.00**
/GZ5121R	6.60**	17.10**	12.50**	-2.60	5.50	18.30**	-11.00**	11.10	6.15**
Large stigma A / Giza178R	7.70**	10.00**	14.40**	48.50**	41.90**	44.53**	-3.30**	12.80	31.89**
/Giza182R	8.60**	18.70**	16.40**	34.10**	40.80**	52.60**	-8.10**	6.10	21.25**
/GZ5121R	20.40**	19.90**	10.90**	13.30**	19.10**	43.40**	-17.20**	6.10	10.06**
LSD 5%	1.40	1.72	0.51	0.23	9.26	9.94 13.30	1.62	5.10	0.32
1%	1.87	2.29	0.68	0.31	12.3		2.17	6.82	0.42

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (9): Standard heterosis for 9 characters of 12 hybrid combinations.

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains panicle ⁻¹	Spikelets panicle ⁻¹	Spikelet fertility (%)	1000-grain weight(g)	Grain yield (t/ha)
IR68885A / Giza178R	-9.00**	-0.39	7.90**	-2.70	-12.80**	-12.20**	-0.73	8.04	9.75**
/Giza182R	-5.20**	1.93**	12.90**	24.30**	-14.22**	-14.22**	2.00	17.40	-12.41**
/GZ5121R	-2.20	14.50**	6.30**	1.10	-8.00	-9.41**	2.30*	17.40	14.10**
IR69625A / Giza178R	-2.60**	-4.80**	5.50**	36.50**	17.90**	9.60**	11.10**	22.30	26.60**
/Giza182R	-3.80**	-5.50**	12.10**	37.00**	6.04	-6.94*	14.80**	25.90	21.58**
/GZ5121R	-3.50**	9.90**	3.30**	37.60**	-1.03	-4.29	3.60**	28.10**	19.41**
G46A / Giza 178R	-2.90**	10.61**	6.70**	60.50**	16.20**	9.60**	6.00**	26.80*	27.98**
/Giza182R	-4.50*	13.80**	5.40**	48.10**	24.60**	20.80**	3.20**	38.00**	31.63**
/GZ5121R	9.80**	16.00**	5.00**	13.20**	6.70	11.12**	-3.90**	36.60**	-4.73**
Large stigma A / Giza178R	-3.80**	2.90**	5.00**	36.50**	22.50**	18.40**	3.60**	33.50**	16.95**
/Giza182R	-6.40**	7.04**	6.70**	23.20**	24.80**	21.70**	2.60**	37.10**	7.39**
/GZ5121R	8.90**	11.60**	-2.10	10.30**	2.10	8.57**	-6.60**	37.10**	-2.96
LSD 5%	1.62	1.98	0.59	0.27	10.69	11.48	1.87	5.89	0.37
1%	2.16	2.65	0.79	0.36	14.31	15.36	2.5	7.88	0.49

*, ** Significant at 0.05 and 0.01 levels, respectively.