EXPLOITATION OF RICE HETEROSIS UNDER EGYPTIAN CONDITIONS

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Abstract

Studies of heterosis and combining ability of ten cytoplasmic genic male sterile lines and five Egyptian testers (restorer) were estimated using line x tester analysis for some agronomic characters and yield and its components to get useful information for hybrid rice program in Egypt.

Hybrids with a yield advantage of >1.5 t/ha over the highest yielding check variety, Giza 178R were considered as promising. Among 50 hybrid combinations evaluated, 15 were most promising with mean performance of grain yield ranging from 12.491 t/ha for IR 69625A/ Giza 182R (SK 2058H) to 13.920 t/ha for IR70368A/ Giza 181R (SK 2047H) with an average of 13.384 t/ha. The yield values over the best local inbred check, Giza 178R ranged from 1.999 to 3.428 t/ha. with an average of 2.792 t/ha. Mean standard heterosis estimates ranged from 19.1% to 32.7% with the average of 26.6%.

Among the ten cytoplasmic male sterile (CMS) lines, IR 68899 A, G46 A,IR 58025 A, and IRA69625 A were the best general combiners for grain yield. The restorers, Giza 178 R and Giza 181 R were the best general combiners among testers for grain yield and most studied characters.

From the breeding point of view, some crosses were identified to be the best ones for recombination breeding, among them were the crosses IR 68888 A / Giza 178 R (for earliness), IR 68885 A / Giza 178 R (for short stature), IR 68885 A / GZ 5121 R (for productive tillers plant^{-1}), IR 58025A / Giza 178 R (for panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1}, and grain yield) and IR 70368 A / Giza 181 R (for 1000-grain weight and spikelet fertility).

INTRODUCTION

Exploitation of heterosis has played a significant role in increasing productivity and production of several crops world over. Availability of suitable pollination control systems and the extent of outcrossing between female and male parents, existence of exploitable level of heterosis and feasibility of hybrid seed production on large scale are the key factors determining the success of commercial exploitation of heterosis in any crop.

China is the first country to commercially exploit heterosis in rice. Hybrid rice technology was successfully developed in 1976 using male sterility-fertility restoration system (Anonymous, 1977). However, the success story of commercial hybrid rice cultivation in China, India, Vietnam, Philippines, and Bangladesh has encouraged Egypt to adopt this technology (Bastawisi *et al.*, 2003).

Hybrid rice technology is such one innovative breakthrough that can further increase rice production leading to food security and reduction of poverty in Egypt. Hybrid rice varieties can outyield conventional cultivars by at least 15% under the same input levels. Hence, this technology can be used to break the current yield plateau in rice, where yield levels of the conventional released cultivars have stabilized.

The development of hybrid rice technology and the adoption of hybrid rice cultivars to Egyptian environments offer one approach to the problem of matching food supply to expected demand.

Combining ability is a measure of gene action (additive and non- additive) where the general combining ability (GCA) effects largely involve additive gene effects and additive type of epistasis , whereas specific combining ability (SCA) represents only non- additive gene action. The presence of non- additive genetic variance offers scope for exploration of heterosis (Yadav *et al.*, 1999). The parents with good GCA can be used to obtain hybrids with srtong heterosis in all the crosses developed from them and is function of the two parents of a hybrid (Yan *et al.*, 2000 and El-Mowafi, 2001and 2003). Rice researchers around the world carried out studies on the combining ability of different kinds of rice (Sun *et al.*, 1993; Li *et al.*, 1990 a&b; Gong *et al.*, 1993 and Chen *et al.*, 1997) and their achievements in this aspect can guide the use of heterosis in rice and the selection of parents in hybridization breeding. To develop hybrid rice with higher yield, better grain quality and multi-resistance is very important, and the key is to breed CMS lines with good combining ability in good adapted varieties.

The aim of the present study is to estimate standard heterosis (economic heterosis) and combining ability for yield and its components in F_1 hybrids developed using male sterility-fertility restoration system using cytoplasmic male sterile lines (CMS) and five Egyptian restorer lines.

MATERIALS AND METHODS

The experiment comprised hybrid progenies derived from 50 cross combinations generated through line x tester mating design. Ten cytoplasmic male sterile lines (CMS) viz., IR 58025 A, IR68886 A, IR68888 A, IR 68897 A, IR 68899 A, IR 68902 A, IR 69625 A, and IR70368 A, possessing wild abortive (WA) type, IR68885 A mutant type and G46 A possessing Gambaica type of cytoplasm, were used as female lines. Five diverse restorer varieties/lines viz., Giza 178R, Giza 181 R, Giza 182R, GZ 5121R and IR25571 R were used as pollen parents (testers) (Table 1). The F_1 hybrid combinations along with their respective parents were grown in a randomized block design with four replications at Rice Research and Training Center (RRTC), Sakha, Kafr El- Sheikh, Egypt, in 2002 summer season. Thirty day-old seedlings were transplanted with one seedling hill^{-1} adopting a spacing of 20 cm between rows and 20 cm between plants. Each test entry consisted of seven rows of 5m length.

Table 1. Cytoplasmic male sterile and restorer lines used for the experiment

Genotype	Cytoplasm source	Origin
CMS lines (female):		
IR 58025 A	Wild Abortive (WA)	IRRI
IR 68885 A	Mutant IR 62829 A	IRRI
IR 68886 A	WA	IRRI
IR 68888 A	WA	IRRI
IR 68897 A	WA	IRRI
IR 68899 A	WA	IRRI
IR 68902 A	WA	IRRI
IR 69625 A	WA	IRRI
IR 70368 A	WA	IRRI
G 46 A	Gambiaca	China
Restorer lines (male):		
Giza 178 R	Restorer	Egypt
Giza 181 R	Restorer	Egypt
Giza 182 R	Restorer	Egypt
GZ 5121 R	Restorer	Egypt
IR 25571 R	Restorer	IRRI

Observations were recorded on ten plants plot^{-1}taken at random from each entry in each replication for heading date (days to 50% flowering), plant height, panicle length, productive tillers plant^{-1}, panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1}, spikelet fertility, and 1000 grain weight. Five guarded rows ($5m^2$) were harvested from each entry in each replication to determine grain yield (t/ha).

Standard heterosis (over the best inbred variety, Giza178) was calculated for the studied characters while combining ability analysis was carried out as suggested by Kempthorne model (1957) for random lines representing certain population. The present represents selected set of males and females. Therefore, the expected MS should be adjusted as:

$$K^2M = \frac{(\text{M.S.M} - \text{M.S Error})}{r \times F}$$

$$K^2F = \frac{(\text{M.S.F} - \text{M.S Error})}{r \times M}$$

$$K^2gca = \frac{(M-1)\,K^2M + (F-1)\,K^2F}{(M-1) + (F-1)}$$

$$K^2sca = \sigma^2FM = \frac{MSFM - MS\ Error}{r}$$

$$\text{the relative imp} = \frac{k^2gca}{k^2sca}$$

where:
Males :M, Females : F and Replications : r

RESULTS AND DISCUSSION

Mean Performance

Mean performance of 15 parental lines (ten CMS and five restorers) and their 50 hybrid combinations of line x tester for the ten studied characters are presented in Table 2.

As revealed in the Table (2), the mean performance of the studied traits varied from one combination to another. For heading date, the F_1 mean values of 22 hybrid combinations were towards the lower parents (early flowering parents), while six only tended to the higher parents (late flowering parents). However, the F_1 means of the rest (22 hybrids) were intermediate between the two parents involved.

With respect to plant height (Table 2), the most desirable mean values towards short stature were found in seven hybrid combinations. Complete to over-dominance was observed in most of crosses towards the taller parents for plant height, longest panicle, higher productive tillers plant^{-1}, heavier panicle weight, and higher grain yield. However, nearly half of the crosses showed the same dominance effects towards the higher filled grain panicle^{-1}, higher rate of spikelet fertility, and heavier 1000- grain weight. Some hybrid combinations exhibited dominance effect towards the lower parents viz., for panicle length (three hybrids), for productive tillers (five hybrids), for panicle weight (eight hybrids), for filled grains panicle^{-1} (four hybrids), for spikelets panicle^{-1} (three hybrids), for spikelet fertility (three hybrids), for 1000 -grain weight (one hybrid) and for grain yield t/ha (eleven hybrid combinations). However, the rest of the hybrid combinations showed intermediate mean values between the parents for all studied characters.

Table 2. Mean performance of parental lines (CMS and restorer lines) and hybrid combinations for the ten studied characters

Genotype	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
CMS lines (female):										
IR 58025 A	112.0	109.5	24.9	14.6	3.84	201.6	246.8	82.0	23.0	9.84
IR 68885 A	101.2	94.5	23.4	20.8	3.02	121.8	141.2	86.5	22.4	9.77
IR 68886 A	115.5	117.4	23.5	19.2	4.12	195.1	236.6	82.6	25.7	11.21
IR 68888 A	99.5	107.5	25.1	17.7	3.57	123.1	142.1	86.6	22.6	9.88
IR 68897 A	105.0	106.9	24.8	20.1	4.08	141.8	179.0	79.7	26.4	10.69
IR 68899 A	102.5	99.2	23.7	18.6	3.80	152.4	177.7	86.5	23.0	10.56
IR 68902 A	108.7	110.2	24.0	18.4	4.18	146.8	179.4	81.9	22.5	10.58
IR 69625 A	106.7	109.0	24.4	19.1	4.13	123.5	137.0	90.1	27.8	10.38
IR 70368 A	108.2	107.7	22.8	16.7	3.47	130.1	158.9	81.9	29.3	10.58
G 46 A	86.5	105.4	23.2	17.1	4.32	166.4	193.2	86.2	28.6	8.14
Restorer lines(males) :										
Giza 178 R	104.2	102.8	23.1	17.8	3.48	133.7	164.6	81.7	22.6	10.49
Giza 181 R	114.7	107.4	24.4	19.9	4.09	132.1	161.1	82.2	27.6	10.99
Giza 182 R	101.5	99.2	25.1	18.9	3.77	131.5	152.3	86.5	27.4	10.75
GZ 5121 R	106.0	102.3	22.3	20.1	4.31	126.8	143.3	88.5	29.1	10.62
IR 25571 R	96.5	94.4	24.5	14.7	5.19	163.3	195.2	83.9	27.2	9.91
Hybrid gombinations :										
IR 58025 A/ Giza 178 R	101.5	102.7	25.4	17.6	4.78	167.2	216.3	77.2	25.2	12.99
IR 68885 A/	95.0	98.1	25.3	21.8	3.74	134.2	168.7	81.3	24.0	11.84
IR 68886 A/	98.7	109.3	25.1	22.3	4.12	150.6	188.6	79.6	24.3	11.73
IR 68888 A/	96.0	104.6	24.4	25.4	4.14	144.3	166.7	86.7	22.9	12.49
IR 68897 A/	101.0	104.5	26.6	18.2	4.57	166.3	210.6	79.2	24.2	11.90
IR 68899 A/	98.7	97.9	25.1	22.1	4.19	144.2	171.3	84.5	23.8	12.16
IR 68902 A/	101.7	101.4	26.5	22.8	4.57	154.7	182.4	85.5	23.5	12.72
IR 69625 A/	102.0	108.3	25.5	18.7	4.97	140.1	158.3	88.0	27.4	12.98
IR 70368 A/	101.7	107.2	24.7	17.1	4.21	154.6	179.7	85.7	27.1	10.84
G 46 A /	101.5	117.7	26.5	16.9	5.89	184.8	220.3	84.2	28.2	13.28
IR 58025 A/ Giza 181 R	110.7	108.7	28.9	18.0	5.22	188.7	226.7	83.5	28.9	13.51
IR 68885 A/	104.7	98.6	26.4	21.9	3.74	134.9	156.8	86.1	26.4	12.76
IR 68886 A/	119.2	108.6	25.4	21.4	3.39	161.1	179.1	85.7	28.0	10.67
IR 68888 A/	102.7	109.5	27.3	17.8	4.45	143.2	179.0	79.6	27.8	12.66
IR 68897 A/	107.7	110.5	23.8	18.7	3.62	145.0	167.6	86.8	26.8	9.62
IR 68899 A/	100.5	106.7	28.6	21.3	4.87	156.5	187.0	83.1	28.4	10.20
IR 68902 A/	109.5	110.3	28.0	17.2	4.28	150.3	178.1	85.2	27.6	12.55
IR 69625 A/	103.7	110.6	27.6	19.2	4.15	133.3	153.2	86.4	28.9	12.79
IR 70368 A/	105.7	107.8	27.6	18.4	4.64	178.4	208.7	85.3	29.4	13.92
G 46 A /	100.5	108.7	25.4	19.4	3.26	154.8	173.6	90.2	28.7	11.35

Table 2. Cont. mean performance of parental lines (CMS and restorer lines) and hybrid combinations for the ten studied characters.

Genotype	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
IR 58025 A/Giza 182 R	102.2	112.9	26.6	19.1	4.91	153.7	194.3	78.9	26.8	9.32
IR 68885 A/	99.7	98.3	25.9	23.4	4.34	147.5	179.6	82.0	26.2	8.10
IR 68886 A/	107.0	102.8	26.0	18.2	4.74	150.9	183.3	82.3	28.1	11.71
IR 68888 A/	97.2	103.6	25.1	18.0	4.29	132.4	158.3	83.7	26.5	12.66
IR 68897 A/	104.2	111.1	27.1	20.2	4.62	141.8	173.2	81.9	27.7	12.34
IR 68899 A/	98.0	103.4	25.9	17.6	4.50	134.9	164.3	81.8	26.6	12.41
IR 68902 A/	104.0	103.0	26.2	21.5	4.20	138.9	168.4	82.5	27.3	11.11
IR 69625 A/	100.2	107.2	25.1	19.6	4.64	130.7	141.8	92.1	28.5	12.49
IR 70368 A/	100.5	111.4	24.7	17.1	4.70	137.4	161.2	85.0	29.8	13.05
G 46 A /	100.5	126.4	26.0	17.8	5.43	160.6	195.7	82.0	30.6	13.57
IR 58025 A/GZ 5121 R	105.5	118.7	22.8	22.5	4.51	156.7	191.3	82.0	25.9	13.83
IR 68885 A/	104.7	114.1	25.5	21.0	3.71	134.4	161.5	83.1	26.1	13.72
IR 68886 A/	114.5	116.5	25.0	22.0	3.11	145.8	178.8	81.5	26.5	8.71
IR 68888 A/	105.0	120.9	25.0	22.6	3.96	145.9	173.1	84.4	25.3	13.06
IR 68897 A/	105.5	117.1	25.6	23.3	3.51	141.1	168.1	83.9	29.5	12.18
IR 68899 A/	103.2	117.5	25.2	22.6	4.34	149.4	169.3	88.2	25.5	13.48
IR 68902 A/	108.2	114.1	24.8	19.9	4.35	145.7	177.6	82.0	26.5	13.42
IR 69625 A/	101.0	115.8	24.8	23.8	5.03	129.2	156.2	82.8	28.7	12.50
IR 70368 A/	102.7	114.1	24.9	18.5	5.41	146.5	165.9	85.6	29.0	11.72
G 46 A /	112.5	122.3	25.4	20.4	3.20	120.2	152.9	78.7	30.5	9.16
IR 58025 A/GZ 25571 R	97.7	104.6	26.2	20.0	5.35	167.8	220.3	76.1	27.6	10.72
IR 68885 A/	100.2	98.3	25.1	22.8	3.50	167.3	195.0	85.6	27.1	6.32
IR 68886 A/	98.5	109.8	25.2	20.6	2.60	147.7	178.0	83.4	28.3	5.35
IR 68888 A/	97.7	115.8	26.1	19.8	4.05	143.7	168.4	85.1	26.3	12.62
IR 68897 A/	102.0	114.2	24.0	22.9	3.25	138.9	184.2	75.4	26.7	10.83
IR 68899 A/	98.5	104.8	25.8	20.1	5.02	150.9	171.9	87.5	27.9	13.08
IR 68902 A/	99.0	114.9	26.0	21.5	5.20	147.0	186.5	78.8	27.9	9.34
IR 69625 A/	98.2	104.9	24.2	19.5	4.25	159.6	181.2	87.6	27.7	12.32
IR 70368 A/	99.7	98.8	24.1	18.8	4.63	135.3	157.8	85.8	27.8	7.71
G 46 A /	100.0	114.8	26.2	17.1	5.63	169.9	197.3	86.4	29.2	13.64
LSD 5%	2.5	1.9	1.3	2.4	0.5	23.4	27.1	4.9	0.3	0.8
1%	3.3	2.6	1.7	3.1	0.7	30.8	35.8	6.5	0.4	1.0

The highest mean values of grain yield (t/ha) were obtained by the hybrid combinations IR 70368A/Giza 181R, IR 58025A/GZ 5121R, IR 68885A/ GZ 5121R, G 46A/ IR 25571R and G 46A/ Giza 182R, and ranged between 13.929 to 13.572 t/ha,respectively. The lowest values were estimated for the hybrid IR 68886A/ IR 25571R and IR 68885A/ IR 25571R. The parental lines Giza 181R, Giza 182R, GZ 5121R, and Giza 178R, manifested highest mean performance of 10.999, 10.750, 10.625 and 10.492 t/ha, respectively for grain yield t/ha.

Standard heterosis :

The standard heterosis is especially important because the hybrid to be released is expected to outperform the existing superior local variety or hybrid. The data for standard heterosis in fifty hybrid combinations are presented in Table 3. Evaluation based on the standard heterosis revealed that 24 hybrids recorded significant negative standard heterosis for early heading date. The hybrids IR 68885A/ Giza 178R, IR 68888A/ Giza 178R, and IR 68885A/ Giza 182R, were the earliest to flower within 95, 96 and 97 days, respectively. These findings indicated that heterosis effects can be used to get earliness in rice hybrids (Singh *et al* 1980, Dwivedi *et al* 1998) Mamata *et al.* 1999, Rajesh and Singh 2000, El-Mowafi 2001 and El-Mowafi 2003).

Six hybrids recorded significant negative standard heterosis for short stature plant, 45 for panicle length, 22 for productive tillers plant^{-1}, 37 for panicle weight, 11 for filled grains panicle^{-1}, 10 for spikelets panicle^{-1}, 8 for spikelet fertility and all the 50 hybrid for 1000-grain weight. However, positive and significant standard heterosis was recorded in 38 hybrid combinations for grain yield (t/ha). The outstanding hybrid combinations for grain yield were IR 70368A/ Giza 181R (32.7%) with significant standard heterosis for panicle length, panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1}, and 1000-grain weight. In the mean time, IR 58025A/ GZ 5121R (31.8%) gave significant desirable standard heterosis for productive tillers plant^{-1}, panicle weight, and 1000-grain weight. Also, IR 69625A/Giza 178R (23.8%) with significant standard heterosis for panicle length, panicle weight spikelet fertility %, and 1000-grain weight. G 46A/Giza 178R (26.6%) gave significant desirable standard heterosis for heading date, panicle length, panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1} and 1000-grain weight, IR 68888A/Giza 178R (19.1%) had significant standard heterosis for heading date, panicle length, productive tillers plant^{-1}, panicle weight, spikelets fertility %, and 1000-grain weights. IR 58025A/ Giza 181R (28.8%) gave significant standard heterosis for panicle length, panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1} and 1000-grain weight. However, G 46A/Giza 182R (24.4%) gave

Table 3. Standard heterosis for 10 characters of 50 hybrid combinations.

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
IR 58025 A/Giza 178 R	-2.6*	0.0	9.62**	-1.3	37.4**	25.1**	31.4**	-5.5	11.5**	23.9**
IR 68885 A/	-8.9**	-4.5**	9.5**	22.6**	7.9	0.4	2.5	-0.5	6.4**	12.9**
IR 68886 A/	-5.3**	6.4**	8.5**	25.2**	18.4*	12.7	14.6	-2.6	7.9**	11.9**
IR 68888 A/	-7.9**	1.75	5.5**	42.9**	19.1*	7.9	1.3	6.1*	1.7*	19.1**
IR 68897 A/	-3.1*	1.7	15.1**	2.5	31.4**	24.4**	27.9**	-3.1	7.3**	13.4**
IR 68899 A/	5.3**	-4.7**	8.4**	24.3**	20.5**	7.9	4.1	3.4	5.3**	15.9**
IR 68902 A/	-2.4	-1.3	14.4**	28.3**	31.4**	15.7	10.8	4.6	4.1**	21.3**
IR 69625 A/	-2.2	5.4**	10.1**	5.2	42.8**	4.8	-3.8	7.7*	21.3**	23.8**
IR 70368 A/	-2.4	4.3**	6.8*	-3.9	21.1**	15.7	9.2	4.9	20.2**	3.4
G 46 A /	-2.6*	14.5**	14.4**	-4.6	69.3**	38.2**	33.9**	3.1	24.8**	26.6**
IR 58025 A/Giza 181 R	6.2**	5.8**	24.9**	1.1	50.0**	41.2**	37.7**	2.2	27.9**	28.8**
IR 68885 A/	0.5	-4.0**	14.1**	23.3**	7.5	0.9	-4.7	5.4	16.9**	21.7**
IR 68886 A/	14.4**	5.7**	9.8**	20.1**	-2.4	20.5*	8.8	4.9	23.9**	1.8
IR 68888 A/	-1.4	6.5**	17.8**	0.4	27.9**	7.1	8.7	-2.6	23.3**	20.7**
IR 68897 A/	3.4**	7.5**	2.7	5.3	4.0	8.5	1.8	6.2*	18.9**	-8.3*
IR 68899 A/	-3.6**	3.8**	23.5**	19.8**	39.9**	17.1	13.6	1.7	25.9**	-2.8
IR 68902 A/	5.0**	7.4**	24.6**	-3.4	22.9**	12.4	8.2	4.3	22.3**	19.7**
IR 69625 A/	-0.5	7.6**	19.4**	7.7	19.4*	-0.3	-6.9	5.7	27.9**	22.0**
IR 70368 A/	1.4	4.9**	19.4**	3.2	33.3**	33.5**	26.8**	4.4	30.3**	32.7**
G 46 A /	-3.6**	5.8**	9.6**	9.1	-6.26	15.8	5.5	10.4**	27.3**	8.2*
IR 58025 A/Giza 182 R	-1.9	9.9**	15.1**	7.2	41.1**	14.9	18.0*	-3.4	18.6**	-11.17**
IR 68885 A/	-4.3**	-4.4**	12.1**	31.4**	24.9**	10.3	9.1	0.4	16.0**	-22.8**
IR 68886 A/	2.6*	0.0	12.3**	2.4	36.2**	12.9	11.4	0.7	24.4**	11.6**
IR 68888 A/	-6.7**	0.8	8.4**	1.1	23.3**	-0.9	-3.8	2.4	17.3**	20.7**
IR 68897 A/	0.0	8.1**	17.3**	13.4	32.8**	6.1	5.22	0.2	22.8**	17.6**
IR 68899 A/	-6.0**	0.6	12.1**	-1.1	29.5**	0.9	-0.2	0.1	17.7*	18.3**
IR 68902 A/	-0.2	0.3	13.3**	20.8**	20.6**	3.9	2.3	1.0	20.9**	6.7
IR 69625 A/	-3.8**	4.3**	8.4**	10.4	33.3**	-2.3	-13.9	12.8**	26.4**	19.1**
IR 70368 A/	-3.6**	8.4**	6.7**	-3.9	35.0**	2.8	-2.1	4.1	32.2**	24.4**
G 46 A /	-3.6**	22.9**	12.5**	0.1	55.9**	20.1*	18.9*	0.4	35.5**	29.4**

Table 3. Cont. standard heterosis for 10 characters of 50 hybrid combinations .

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
IR 58025 A/GZ 5121 R	1.2	15.5**	-1.6	28.3**	29.7**	17.2	16.2	0.4	14.8**	31.8**
IR 68885 A/	0.5	11.1**	10.3**	18.0**	6.7	0.5	-1.9	1.7	15.8**	30.7**
IR 68886 A/	9.8	13.4**	7.9**	23.9**	-10.7	9.1	8.6	-0.2	17.6**	-16.9**
IR 68888 A/	0.7	17.7**	8.0**	27.1**	13.9	9.1	5.1	3.3	11.9**	24.4**
IR 68897 A/	1.2	13.9**	10.6**	30.8**	0.9	5.6	2.1	2.7	30.6**	16.1**
IR 68899 A/	-1.0	14.4**	8.9**	27.0**	24.6**	11.8	2.8	8.0**	12.8**	28.5**
IR 68902 A/	3.8**	11.1**	7.4**	11.7	24.9**	8.9	7.9	0.4	17.4**	27.9**
IR 69625 A/	-3.1*	12.7**	7.4**	33.8**	44.4**	-3.3	-5.1	1.3	26.9**	19.1**
IR 70368 A/	-1.4	10.9**	7.7**	4.2	55.5**	9.6	0.8	4.7	28.4**	11.7**
G 46 A /	7.9**	19.0**	9.9**	15.0*	-8.1	-10.1	-7.1	3.7	35.1**	-12.7**
IR 58025 A/IR 25571 R	-6.2**	1.8	13.2**	12.4	53.7**	25.5**	33.8**	-6.9*	22.2**	2.2
IR 68885 A/	-3.8**	-4.4**	8.6**	28.4**	0.4	25.1**	18.5*	4.8	20.0**	-39.8**
IR 68886 A/	-5.5**	6.9**	9.0**	16.2*	-25.3**	10.5	8.1	2.1	25.4**	-48.9**
IR 68888 A/	-6.2**	12.7**	12.9**	11.5	16.3*	7.5	2.3	4.1	16.6**	20.3**
IR 68897 A/	-2.2	11.1**	3.6	28.8**	-6.7	3.9	11.9	-7.7*	18.5**	3.3
IR 68899 A/	-5.5**	2.0*	11.7**	12.8	44.3**	12.9	4.5	7.1*	23.5**	24.7**
IR 68902 A/	-5.0**	11.9**	12.5**	20.7**	49.4**	9.9	13.3	-3.5	23.7**	-10.9**
IR 69625 A/	-5.8**	2.1*	4.4	9.4	21.9**	19.4*	10.1	7.2*	22.8**	17.4**
IR 70368 A/	-4.3**	-3.9**	4.2	6.0	32.9**	1.2	4.1	5.0	23.2**	-26.5**
G 46 A /	-4.1**	12.4**	13.3**	-3.7	61.8**	27.1**	19.9*	5.8	29.4**	30.0**
LSD 5%	2.50	1.99	1.25	2.38	0.53	23.36	27.15	4.91	0.36	0.41
1%	3.30	2.63	1.65	3.14	0.70	30.81	35.80	6.48	0.47	0.54

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

significant standard heterosis for heading date, panicle length, panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1} and 1000-grain weight. Also, IR69625A/Giza182R gave significant desirable standard heterosis for heading date, panicle length, panicle weight, spikelet fertility % and 1000-grain weight.

Several hybrids evaluated under the present study have shown encouraging yield superiority of 16-32% over the best check variety (Giza178). Two hybrids namely SK 2034H (IR 69625A/Giza 178R) and SK 2046H (IR 69625A/Giza 181R) which have already been tested in multilocation yield trail (MYT) for three years and have given consistently good performance under both normal and saline conditions in station trails were considered for large scale field level demonstrations and verification trails in season 2003. Singh *et al.* 1980), Kim and Rutger (1988), Devaraj and Nadarajan (1996), Mishra and Pandey (1998), El-Mowafi (2001) and El-Mowafi (2003) also observed negative and positive standard heterosis for these traits.

Analysis of variance:

Analysis of variance (Table 4) revealed highly significant differences among the 65 genotypes (50 hybrids, 10 CMS lines and 5 restorers) tested for all studied characters. The parental lines and the hybrids showed highly significant differences for all characters. Parents vs crosses mean square indicated that average heterosis was significant in all crosses for all studied characters under investigation except filled grains panicle^{-1} and spikelet fertility percentage.

The analysis of variance for combining ability given in Table 4 revealed significant differences among the CMS lines for heading date, plant height, productive tillers plant^{-1}, filled grains panicle^{-1}, spikelet fertility %, and 1000- grain weight. On the other hand the testers exhibited significant differences for all the traits except panicle weight, spikelet fertility %, and grain yield t/ha. The highly significant mean squares of lines x testers for all traits, indicated that they interacted and produced markedly different combining ability effects, and this might be due to the wide genetic diversity of lines and testers. The estimate of variance due GCA was higher than that due to SCA for heading date, plant height, spikelets panicle^{-1} and 1000 -grain weight suggesting greater importance of additive genetic variance which is in agreement with the results of Sardana and Borthakur (1987), Lokaprakash *et al.* 1991), El-Refaee (2002) and El Mowafi (2003).

In case of panicle length, productive tillers plant^{-1}, panicle weight, filled grains panicle^{-1}, spikelet fertility %, and grain yield, preponderance of non-additive gene action was recorded by virtue of low GCA/SCA variance ratios in agreement to reports of Ram *et al.* (1991), Singh and Singh (1991) and El Mowafi (2002).

Table 4. Mean square estimates of ordinary analysis for studied characters

Source of variation	d.f.	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
Replications	3	2.910 ns	4.761 ns	1.692 ns	10.883*	0.150 ns	559.438 ns	62.405 ns	28.319 ns	0.108 ns	0.023 ns
Genotypes	64	119.667**	191.953**	7.607**	20.076**	1.886**	1193.586**	2079.837**	44.726**	17.786**	3.387**
Parents	14	216.707**	154.653**	3.173**	13.959**	1.436**	2608.658**	4414.660**	36.072**	29.199**	0.539**
Hybrids	49	178.210**	188.317**	6.105**	18.152**	1.991**	799.455**	1421.307**	47.411**	12.720**	13.421**
Parents vs hybrids	1	90.747**	892.313**	143.264**	199.960**	3.039**	694.985 ns	1660.296**	34.295 ns	106.281**	21.308**
Females (F)	9	118.700**	348.263**	3.201 ns	28.550*	4.106 ns	1338.742*	3676.927**	95.989*	28.750**	4.596 ns
Males (M)	4	501.607**	829.858**	24.730**	39.913*	2.02 ns	1583.006*	2119.492*	31.604 ns	59.719**	7.334 ns
Females x Males(FxM)	36	38.108**	77.048**	4.762**	13.135**	2.372**	577.572**	779.825**	37.023**	3.490**	3.255**
Error	192	3.216	2.053	0.811	2.915	0.145	280.669	379.073	12.418	0.068	0.088
CV %		1.7	1.3	3.6	8.7	8.9	11.3	11.0	4.2	1.0	5.2
$\square^2$ GCA/$\square^2$ SCA		1.791	1.726	0.424	0.563	0.036	0.851	1.780	0.457	3.105	0.215
K^2_{gca}/K^2_{sca}		0.898	0.979	0.273	0.459	0.273	0.628	1.273	0.494	1.694	3.523

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

Table 5. Estimates of GCA effects of the CMS lines for the 10 studied characters

Line	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
IR 58025 A	0.915*	0.258 ns	0.257	-0.728	0.599**	17.800**	31.049**	-4.048**	-0.329**	0.204**
IR 68885 A	-1.735**	-7.798**	-0.048	1.978**	-0.549**	-5.369	-6.391	0.032	-1.229**	-0.559**
IR 68886 A	4.965**	0.123 ns	-0.374	0.698	-0.763**	0.690	2.844	-1.098	-0.144*	-1.015**
IR 68888 A	-2.885**	1.593**	-0.134	0.533	-0.176*	-7.124	-9.626*	0.292	-1.429**	0.515**
IR 68897 A	1.465**	2.193**	-0.294	0.453	-0.442**	-2.404	2.024	-2.148**	-0.194**	-0.146*
IR 68899 A	-2.835**	-3.218**	0.417*	0.523	0.229**	-1.859	-4.441	1.422	-0.774**	0.281**
IR 68902 A	1.865**	-0.498 ns	0.767**	0.353	0.163	-1.714	-1.111	-0.798	-0.633**	-0.089
IR 69625 A	-1.585**	0.078 ns	-0.279	-0.058	0.250**	-10.469**	-20.566**	3.777**	1.040**	0.474**
IR 70368 A	-0.535 ns	-1.438*	-0.504*	-1.898**	0.362**	-1.410	-4.046	1.867*	1.445**	-0.109
G 46 A	0.365 ns	8.708**	0.192	-1.853**	0.325**	9.040*	9.264*	0.702	2.245**	0.267**
LSD 5%	**0.790**	**0.631**	**0.397**	**0.752**	**0.168**	**7.380**	**8.577**	**1.552**	**0.114**	**0.131**
1%	**1.041**	**0.832**	**0.523**	**0.992**	**0.221**	**9.729**	**11.306**	**2.046**	**0.151**	**0.172**

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

General combining ability effects (GCA) :

Significant differences of GCA effects were observed among the CMS lines for the studied characters(Table 5). The CMS line IR 58025A was best combiner for panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1}, and good combiner for grain yield. IR68888 A was a best combiner for heading date and grain yield, IR 68899A was best combiner for panicle length and good combiner for panicle weight and grain yield, IR 69625A was best combiner for spikelet fertility % and good combiner for heading date, panicle weight, 1000-grain weight and grain yield. G 46A was best combiner for 1000-grain weight and good combiner for panicle weight, filled grains panicle, spikelets panicle^{-1} and grain yield. IR68885 A was best combiner for plant height and productive tillers plant^{-1} and good combiner for heading date, which illustrated that it is worthwhile to transfer its male sterility into genetic background of elite lines having good GCA for yield and its components. IR70368 A was a good combiner for plant height, panicle weight, spikelet fertility % and 1000-grain weight.

Among the testers or restorer lines (Table 6), Giza 178 R was the best general combiner for plant height, filled grains panicle^{-1}, spikelets panicle^{-1} and grain yield. Giza 181 R was the best general combiner for panicle length, spikelets fertility % and 1000- grain weight and a good combiner for grain yield. GZ 5121 R was best combiner for productive tillers plant^{-1} and good combiner for 1000-grain weight and grain yield. According to the ranking numbers of the GCA proposed by Wang (1981), the data in Table (7) showed that the female lines (CMS), IR 68899 A, G46 A, IR 58025 A, and IR 69625 A and also the male lines, Giza 178R and Giza 181 R were the best general combiners.

Specific combining ability effects (SCA):

The data of the SCA given in Tables (8 and 9) revealed that there are some superior combinations that could be useful in the local breeding program to get good recombinants. With respect to heading date and plant height, 10 and 21 crosses showed significant effects in the desired direction for the two traits, respectively. For panicle length, 8 hybrids had superior SCA effects, 9 hybrids for productive tillers plant^{-1}, 13 for panicle weight, 5 for filled grains panicle^{-1}, 9 for spikelets panicle^{-1}, 4 for spikelets fertility, 18 for 1000- grain weight, and 19 hybrids combinations for grain yield were superior in SCA effects. The hybrid IR 70368A/ Giza 181R excelled others with significantly higher SCA effects for panicle length, filled grains panicle^{-1}, spikelets panicle^{-1}, and grain yield. It was followed by IR 68886 A/ Giza 182 R for plant height, panicle weight, 1000- grain weight, and grain yield, IR 58025 A / Giza 181 R for panicle weight, filled grains panicle^{-1}, 1000-grain weight, spikelets panicle^{-1}, and grain yield, G 46A/ Giza 182R for panicle weight, 1000- grain weight, and grain yield, G 46A/ IR 25571R for plant height, panicle weight, and grain yield then G 46A/ Giza 178R for panicle weight, filled grains panicle^{-1}, and 1000- grain weight.

Table 6. General combining ability effects of pollen parents for the studied characters

Tester	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
Giza 178 R	-2.835**	-4.107**	-0.206	0.250	0.163**	5.073	7.581*	-0.408	-2.130**	0.315**
Giza 181 R	3.890**	-1.275**	1.259**	-0.877**	-0.192**	4.850	2.254	1.589**	0.905**	0.159**
Giza 182 R	-1.260**	-1.270**	0.164	-0.970**	0.281**	-6.159*	-5.946	-0.370	0.610**	0.007
GZ 5121 R	3.665**	7.840**	-0.806**	1.485**	-0.242**	-7.539**	-9.241**	-0.380	0.150**	0.254**
IR 25571 R	-3.460**	-1.187**	-0.411**	0.113	-0.009	3.775	5.351	-0.430	0.463**	-0.737**
LSD 5%	0.559	0.446	0.281	0.532	0.118	5.218	6.064	1.098	0.080	0.092
1%	0.736	0.588	0.370	0.701	0.156	6.879	7.995	1.447	0.106	0.121

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

Table 7. Comparative overall ranking of the parental lines based on desirable GCA effects for various characters

Line	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha	Total	Rank
CMS lines :												
IR 58025 A	7	7	3	8	1	1	1	10	6	5	49	3
IR 68885 A	3	1	5	1	9	8	8	6	9	9	59	7
IR 68886 A	10	6	9	2	10	3	3	8	4	10	65	9
IR 68888 A	1	8	6	3	7	9	9	5	10	1	59	7
IR 68897 A	8	9	8	5	8	7	4	9	5	8	71	10
IR 68899 A	2	2	2	4	5	6	7	3	8	3	42	1
IR 68902 A	9	4	1	6	6	5	5	7	7	6	56	6
IR 69625 A	4	5	7	7	4	10	10	1	3	2	53	5
IR 70368 A	5	3	10	10	2	4	6	2	2	7	51	4
G 46 A	6	10	4	9	3	2	2	4	1	4	45	2
Restorer lines :												
Giza 178 R	2	1	3	2	2	1	1	4	5	1	22	1
Giza 181 R	5	2	1	4	4	2	3	1	1	3	26	2
Giza 182 R	3	3	2	5	1	4	4	2	2	4	30	3
GZ 1521 R	4	5	5	1	5	5	5	3	4	2	39	5
IR 25571 R	1	4	4	3	3	3	2	5	3	5	33	4

Table 8. Standard heterosis (SH %) and sca range for 10 characters of 50 hybrid combinations

Character		Standard heterosis over Giza 178		Specific combining ability effects	
		SH%	No.	sca	No.
Heading date	A	-8.90 to 14.4	50	-6.39 to 7.76	50
(days)	B	2.6 to 14.4	8	1.78 to 7.76	9
	C	-2.6 to -8.9	24	-2.04 to -6.39	10
	A	-4.7 to 22.9	50	-8.0 to 9.67	50
Plant height (cm)	B	2.0 to 22.9	34	1.59 to 9.67	17
	C	-3.9 to -4.7	6	-1.43 to -8.0	21
	A	-1.6 to 24.9	50	-2.91 to 1.55	50
Panicle length (cm)	B	5.5 to 24.9	45	0.92 to 1.55	8
	C	-	-	-1.04 to -2.91	5
	A	-4.6 to 42.9	50	-2.68 to 4.42	50
Productive tillers plant^{-1}	B	5.5 to 24.9	22	1.84 to 4.42	8
	C	-	-	-1.69 to -2.68	8
Panicle weight (g)	A	-25.3 to 69.3	50	-1.24 to 1.05	50
	B	16.3 to 69.3	37	0.40 to 1.05	13
	C	-25.3	1	-0.55 to -1.24	7
Filled grains panicle^{-1}	A	-10.1 to 41.2	50	-30.30 to 23.13	50
	B	20.1 to 41.2	11	17.04 to 23.13	5
	C	-	-	-18.93 to -30.30	2
Spikelets panicle^{-1}	A	-13.9 to 33.9	50	-2.91 to 1.66	50
	B	18.0 to 33.9	10	0.92 to 1.66	9
	C	-	-	-0.95 to -2.91	6
Spikelets fertility%	A	-7.7 to 12.8		-5.90 to 5.12	50
	B	6.1 to 121.8	50	3.76 to 5.12	4
	C	-6.9 to 7.7	8	-3.48 to -5.90	5
			2		
1000-grain weight (g)	A			-1.61 to 2.34	50
	B	1.7 to 35.5		0.26 to 2.34	18
	C	1.7 to 35.5	50	-0.28 to -1.61	-
		-	50		
			-		
Grain yield t/ha	A			-1.78 to 1.46	50
	B	-48.9 to 32.7		0.33 to 1.46	19
	C	8.2 to 32.7	50	-0.32 to -1.78	16
		-8.3 to -48.9	35		
			8		

A = Overall range B = Positively significant range

C = Negatively significant range Standard Parent = Giza 178

Table 9. Specific combining ability of hybrid combinations

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
IR 58025 A/Giza 178 R	0.78	-2.71**	-0.39	-2.17*	-0.338	-4.69	-0.39	-1.92	0.430**	0.146
IR 68885 A/	-3.06**	0.73	-0.11	-0.62	-0.232	-14.52	-0.11	-1.92	0.180	0.332*
IR 68886 A/	-6.01**	4.01**	-0.01	1.10	0.365	-4.16	-0.01	-2.49	-0.579**	0.735**
IR 68888 A/	-0.91	-2.20**	-0.95	4.42**	-0.200	-2.64	-0.95*	3.22	-0.694**	-0.416**
IR 68897 A/	-0.26	-2.87**	1.42**	-2.67**	0.495**	14.58	1.42**	-1.84	-0.654**	-0.053 ns
IR 68899 A/	1.78*	-4.06**	-0.84	1.13	-0.553**	-8.03	-0.84	-0.14	-0.524**	-0.384*
IR 68902 A/	0.08	-3.23**	0.19	2.00*	-0.110	2.29	0.19	3.08	-0.933**	0.124
IR 69625 A/	3.78**	3.06**	0.23	-1.69*	0.197	-3.55	0.23	1.06	1.285**	-0.131
IR 70368 A/	2.48**	3.45**	-.0.28	0.15	-0.668**	-0.90	-0.28	0.62	0.630**	-0.616**
G 46 A /	1.33	3.83**	0.76	-1.64	1.045**	21.66*	0.76	0.33	0.855**	0.227
IR 58025 A/Giza 181 R	3.31**	0.45 ns	1.66	-0.62	0.457*	17.04*	1.66**	2.36	1.119**	0.557**
IR 68885 A/	-0.04	-1.57*	-0.53	0.62	0.126	-13.58	-0.53	0.88	-0.480**	0.948**
IR 68886 A/	7.76**	0.46	-1.18**	1.33	-0.005	-0.94	-1.18**	1.59	0.009	0.361*
IR 68888 A/	-0.89	-0.13	0.42	-2.00*	0.465*	-3.52	0.42	-5.90**	1.169**	-0.180
IR 68897 A/	-0.24	0.31	-2.91**	-1.04	-0.103	-6.44	-2.91**	3.76*	-1.065**	-1.036**
IR 68899 A/	-3.19**	1.92**	1.17**	1.45	0.475*	4.45	1.17**	-3.48*	1.114**	-1.266**
IR 68902 A/	1.11	2.83**	1.10*	-2.49**	-0.046	-1.88	1.10*	0.84	0.147	0.196
IR 69625 A/	-1.19	2.53**	0.92*	-1.11	-0.258	-10.13	0.92*	-2.59	-0.275*	-0.070
IR 70368 A/	-0.24	1.19	1.14*	0.92	0.115	23.13**	1.14*	-1.75	-0.130	1.075**
G 46 A /	-6.39**	-8.00**	-1.79*	1.93*	-1.122**	-8.14	-1.79**	4.31*	-1.605**	-0.585**
IR 58025 A/Giza 182 R	-0.04	4.64**	0.50	0.55	-0.326	-6.99	0.50	-0.25	-0.710**	-1.387**
IR 68885 A/	0.11	-1.95**	0.11	2.14*	0.257	9.97	0.11	-1.23	-0.385**	-1.231**
IR 68886 A/	0.66	-5.34**	0.48	-1.72	0.865**	7.31	0.48	0.17	0.429**	1.027**
IR 68888 A/	-1.24	-5.99**	-0.65	-1.78	-0.170	-3.34	0.65	0.18	0.089	-0.026
IR 68897 A/	1.41	0.91	1.55**	0.47	0.424*	1.33	1.55**	0.82	0.104	0.473**
IR 68899 A/	-0.54	-1.40	-0.35	-2.17*	-0.361	-6.13	-0.35	-2.87	-0.465	0.080
IR 68902 A/	0.76	-4.47**	-0.42	1.89*	-0.602**	-2.22	-0.42	0.07	0.117	-0.337*
IR 69625 A/	0.46	-0.92	-0.50	0.44	-0.249	-1.77	-0.50	5.12**	-0.305*	-0.071
IR 70368 A/	-0.34	4.86**	-0.68	-0.25	-0.301	-6.87	-0.68	-0.07	0.589**	0.793**
G 46 A /	-1.24	9.67**	-0.02	0.42	0.462*	8.69	-0.02	-1.93	0.539**	0.678**

Table 9. Cont. Specific combining ability of hybrid combinations .

Hybrid combination	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers $plant^{-1}$	Panicle weight (g)	Filled grains $panicle^{-1}$	Spikelets $panicle^{-1}$	Spikelet fertility %	1000-grain weight (g)	Grain yield T/ha
IR 58025 A/GZ 5121 R	-1.71	1.36	-2.39**	1.84*	-0.197	-2.56	-2.39**	2.83	-1.100**	0.623**
IR 68885 A/	0.18	4.81**	0.65	-2.68**	0.149	-1.71	0.65	-0.15	0.024	1.329**
IR 68886 A/	3.23**	-0.73	0.43	-0.35	-0.242	3.59	0.43	-0.59	-0.660**	-0.719**
IR 68888 A/	1.58	2.25**	0.21	0.38	0.028	11.51	0.21	0.89	-0.650**	-0.077
IR 68897 A/	-2.26*	-2.25**	0.97*	1.11	-0.158	2.01	0.97*	2.86	2.339**	0.150
IR 68899 A/	-0.21	3.63**	-0.10	0.37	-0.004	9.77	-0.10	3.59*	-1.105**	0.370*
IR 68902 A/	0.08	-2.48**	-0.83	-2.18*	0.068	5.90	-0.83	-0.42	-0.222	0.534**
IR 69625 A/	-3.71**	-1.43*	0.21	2.15*	0.661**	-1.81	0.21	-4.22*	0.279*	-0.315*
IR 70368 A/	-3.01**	-1.62*	0.51	-1.26	0.935**	3.57	0.51	0.47	0.199	-0.118
G 46 A /	5.83**	-3.54**	0.34	0.62	-1.240**	-30.30**	0.34	-5.24**	0.899**	-1.778**
IR 58025 A/IR 25571 R	-2.34**	-3.73**	0.63	0.39	0.404	-2.80	0.63	-3.02	0.261*	0.060
IR 68885 A/	2.81**	-2.03**	-0.11	0.53	-0.301	19.84*	-0.11	2.43	0.661**	-1.378**
IR 68886 A/	-5.64**	1.59*	0.28	-0.35	-0.983**	-5.81	0.28	1.33	0.801**	-1.404**
IR 68888 A/	1.46	6.07**	0.97*	-1.01	-0.122	-2.00	0.97*	1.62	0.086	0.698**
IR 68897 A/	1.36	3.90**	-1.04*	2.13*	-0.657**	-11.49	-1.04*	-5.59**	-0.723*	0.466**
IR 68899 A/	2.16*	-0.08	0.12	-0.78	0.444	-0.06	0.12	2.91	0.981**	1.164**
IR 68902 A/	-2.04*	7.36**	-0.02	0.78	0.690**	-4.08	-0.03	-3.57*	0.890**	-0.517**
IR 69625 A/	0.66	-3.23**	-0.85	-0.80	-0.351	17.26*	-0.85	0.63	-0.983**	0.588**
IR 70368 A/	1.11	-7.89**	-0.68	0.43	-0.080	-18.93*	-0.68	0.74	-1.288**	-1.134**
G 46 A /	0.46	-1.96**	0.72	-1.33	0.958**	8.08	0.72	2.53	-0.688**	1.457**
LSD 5%	1.766	1.41	0.88	1.68	0.375	16.50	0.88	3.47	0.259	0.293
1%	2.329	1.86	1.17	2.21	0.495	21.75	1.17	4.57	0.337	0.386

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

Best hybrid combinations:

Evaluation of hybrid combinations for heterosis breeding based on three considerations, mean performance, standard heterosis and SCA effects (Table 10) would be meaningful from this point of view. Out of 50 hybrid combinations, 17 recorded significant positive values for all three sabovementioned considerations.

Hybrids with a yield advantage of >1.5 t/ha over the highest yielding check variety, Giza 178R were considered as promising combinants. Among the 50 hybrids, 15 were most promising. Among the 15 best selected hybrids, mean performance of grain yield t/ha ranged from 12.491 t/ha for IR 69625A/ Giza 182R to 13.284 t/ha for IR 70368A/ Giza 181R with an average of 13.319 t/ha. The yield values over best local inbred check, Giza 178R ranged from 1.999 to 3.428 t/ha with an average of 2.792 t/ha. Mean estimates standard heterosis ranged from 19.1% to 32.7% with an average of 26.94%. Two hybrids of the 15 mentioned in Table (10) viz. IR 69625A/Giza 178R and IR 69625A/ Giza 181R are under the evaluation in verification yield trials and On-farm demonstration during 2003 season (Bastawisi *et al*, 2003).

Furthermore, the parents having higher GCA exhibited high standard heterosis in hybrids. The hybrids with lower GCA for grain yield, showed negative standard heterosis. Superior hybrid vigor for grain yield was obtained more frequently at IRRI when at least one of the parents had high GCA effects (Peng and Virmani, 1990) although occasionally heterotic combinations derived from combinations having both parents with low GCA effects.

Table (11) demonstrates the relation between the standard heterosis and each of SCA effects and GCA effects of female and male parent for ten studied traits. The results, in general, showed that there were significant positive correlation among the standard heterosis of the hybrid and each of SCA effects and GCA effects of female and male parents of all hybrid combinations for all characters except filled grains panicle^{-1} and spikelets panicle^{-1}, SCA effects and spikelet fertility % with GCA effects of male parents.

Genetic Parameters:

The estimates of genetic parameters for the ten studied traits (Table 12) revealed that the additive variance (σ^2 A) and relative importance of GCA% for heading date, plant height, spikelets panicle^{-1}, and 1000- grain weight, were greater than dominance variance (σ^2 D) and relative importance of SCA%, respectively for these characters. These results indicate that the former characters were largely governed by additive gene action. The importance of the additive gene action for the inheritance of these traits was in agreement with the findings of Lokaprakash *et al* (1991), Sharma and Koranne (1995), El Mowafi (2001) and El Mowafi (2003). On the other hand, high estimates of dominance genetic variance and its relative magnitude of SCA% were found to be more than those of the additive variances for the rest of the characters, such as panicle length, productive tillers plant^{-1}, panicle weight, filled grains panicle^{-1}, spikelets fertility %, and grain yield t/ha. These results indicate that dominance variance played a major role in the inheritance of these characters which are in general agreement with the results reported by Ramalingram *et al* (1997) and El-Mowafi (2003).

Hybrids for recombination breeding:

Recombination breeding makes use of fixable additive gene action. To get outstanding recombinants in segregating generations, the parents of hybrids must be good general combiners with the SCA effect should not be significant because selection of superior recombinants will be hindered by significant SCA effect. Therefore it will be useful to select only such hybrids with nonsignificant SCA effects and having parents with significant GCA effects (Nadarajan, 1986 and Devaraj and Nadarajan, 1996). Based on the aforesaid considerations, the 50 hybrids were evaluated for recombination breeding. For each of the biometrical traits studied, the lines and testers with significant GCA effects, possible cross combinations and the promising crosses for recombination breeding are presented in Table (13). Overall, the best crosses were IR 68888A/Giza 178R (for earliness), IR 68885A/Giza 178R (for short stature), IR68885A/GZ5121R (for productive tillers plant^{-1}), IR 58025A/Giza 178R (for panicle weight, filled grains panicle^{-1}, spikelets panicle^{-1}, and grain yield) and IR 70368A/Giza 181R (for 1000-grain weight and spikelet fertility).

Table 10. Best hybrid combinations for grain yield along with their heterosis, yield advantage, standard heterosis, specific combining ability (SCA) and general combining ability (GCA) of their male and female parents

Hybrid combination	Grain yield T/ha	Yield advantage T/ha	Standard heterosis SH %	SCA effect	GCA effect of female (Line)	GCA effect of male (Tester)
IR 70368 A/Giza 181 R	13.920	3.428**	32.7**	1.075**	-0.109	0.159**
IR 58025 A/GZ 5121 R	13.832	3.340**	31.8**	0.623**	0.204**	0.254**
IR 68885 A/GZ 5121 R	13.717	3.225**	30.7**	1.329**	-0.559**	0.254**
G 46 A /IR 25571 R	13.643	3.152**	30.0**	1.457**	0.267**	-0.737**
G 46 A /Giza 182 R	13.573	3.081**	29.4**	0.678**	0.267**	0.007
IR 58025 A/Giza 181 R	13.511	3.019**	28.8**	0.557**	0.204**	0.159**
IR 68899 A/GZ 5121 R	13.481	2.989**	28.5**	0.370*	0.281**	0.254**
IR 68902 A/GZ 5121 R	13.423	2.931**	27.9**	0.534**	-0.089	0.254**
G 46 A /Giza 178 R	13.288	2.796**	26.6**	0.227	0.267**	0.315**
IR 68899 A/IR 25571 R	13.084	2.592**	24.7**	1.164**	0.281**	-0.737**
IR 58025 A/Giza 178 R	12.999	2.507**	23.9**	0.146	0.204**	0.315**
IR 69625 A/Giza 178 R	12.999	2.507**	23.8**	-0.131	0.474**	0.315**
IR 69625 A/Giza 181 R	12.798	2.306**	22.0**	-.070	0.474**	0.159**
IR 68888A/Giza 178 R	12.499	2.007**	19.1**	-0.416**	0.515**	0.315**
IR 69625 A/Giza 182 R	12.491	1.999**	19.1**	-0.071	0.474**	0.007
Average (Hybrids)	13.384	2.792	26.6	-	-	-
Giza 178 (Check)	10.492	Local inbred check				
LSD 5%	-	**0.820**	-	**0.293**	**0.131**	**0.092**
1%	-	**1.080**	-	**0.386**	**0.172**	**0.121**

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

Table 11. Phenotypic correlation coefficients among standard heterosis (SH) and each of specific combining ability effects (SCA) and general combining ability effects (GCA) of female and male parents for studied characters

Parameters	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
SCA effects	0.577**	0.548**	0.754**	0.714**	0.732**	0.232	0.231	0.762**	0.394**	0.790**
GCA of female parent	0.426**	0.547**	0.315**	0.555**	0.259**	0.335*	0.676**	0.636**	0.639**	0.464**
GCA of male parent	0.620**	0.608**	0.556**	0.416**	0.287*	0.347*	0.425**	0.179	0.632**	0.398**

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

Table 12. Genetic parameters for 10 economic traits of hybrid rice

Parameter	Heading date (days)	Plant height (cm)	Panicle length (cm)	Productive tillers plant^{-1}	Panicle weight (g)	Filled grains panicle^{-1}	Spikelets panicle^{-1}	Spikelet fertility %	1000-grain weight (g)	Grain yield t/ha
Additive variance (σ^2 A)	15.62	32.38	0.42	1.44	0.08	63.19	178.35	2.81	2.67	0.17
Dominant variance (σ^2 D)	8.72	18.75	0.99	2.56	2.23	74.23	100.19	6.15	0.86	0.79
Environmental variance (σ^2 E)	3.22	2.05	0.81	2.92	0.15	280.67	379.07	12.42	0.07	0.09
Genotypic variance (σ^2 G)	24.34	51.13	1.41	3.99	2.30	137.42	278.53	8.96	3.52	0.96
Phenotypic variance (σ^2 P)	27.56	53.18	2.22	6.91	2.45	418.09	657.61	21.38	3.59	1.05
Broad sense heritability (h^2_b) %	88.33	96.14	63.48	57.82	94.08	32.87	42.36	41.92	98.11	91.61
Narrow sense heritability (h^2_n) %	56.67	60.89	18.96	36.97	3.18	15.11	27.12	13.16	74.29	16.12
Relative importance of gca % *	64.16	63.33	29.87	26.05	3.38	45.99	64.03	31.38	75.73	17.59
Relative importance of sca % **	35.84	36.67	70.13	72.96	96.62	54.01	35.97	68.62	24.27	82.41

*, ** Relative importance of gca = σ^2 A / σ^2 G x 100 and Relative importance of sca = □^{2} D / □^{2} G x 100, respectively.

Table 13. Hybrids for recombination breeding

Character	Good combining line	GCA effect of line	Good combining tester	GCA effect of tester	Promising crosses for recombination breeding	SCA effects
	IR 68888 A	-2.89**	Giza 178 R	-2.84**	IR 68888 A/Giza 178 R	-0.91 ns
Heading date (days)	IR 68888 A	-2.89**	IR 25571 R	-3.46**	IR 68888 A/IR 25571 R	1.46 ns
	IR 68885 A	-7.80**	Giza 178 R	-4.11**	IR 68885 A/Giza 178 R	0.73 ns
Plant height (cm)	IR 68885 A	1.98**	GZ 5121 R	1.49**	IR 68885 A/GZ 5121 R	0.18 ns
Productive tillers plant^{-1}	IR 58025 A	0.60**	Giza 182 R	0.28**	IR 58025 A/Giza 182 R	-0.33 ns
Panicle weight (g)	IR 58025 A	0.60**	Giza 178 R	0.16**	IR 58025 A/Giza 178 R	-0.34 ns
	IR 70368 A	0.36**	Giza 182 R	0.28**	IR 70368 A/Giza 182 R	-0.30 ns
	IR 58025 A	17.80**	Giza 178 R	5.07	IR 58025 A/Giza 178 R	-4.69 ns
Filled grains panicle^{-1}	IR 58025 A	31.05**	Giza 178 R	7.58*	IR 58025 A/Giza 178 R	-0.39 ns
Spikelets panicle^{-1}	IR 69625 A	3.78**	Giza 181 R	1.59**	IR 69625 A/Giza 181 R	-2.59 ns
Spikelet fertyility %	IR 70368 A	1.87**	Giza 181 R	1.59**	IR 70368 A/Giza 181 R	-1.75 ns
	IR 70368 A	1.45**	Giza 181 R	0.91**	IR 70368 A/Giza 181 R	0.13 ns
1000-grain weight (g)	IR 68888 A	0.52**	GZ 5121 R	0.25**	IR 68888 A/GZ 5121 R	-0.08 ns
Grain yield (t/ha)	IR 69625 A	0.47**	Giza 178 R	0.32**	IR 69625 A/Giza 178 R	-0.13 ns
	IR 58025 A	0.20**	Giza 178 R	0.32**	IR 58025 A/Giza 178 R	-0.15 ns

*, ** : Significant at 0.05 and 0.01 levels probability, respectively.
ns : Not significant .

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استغلال ظاهرة قوة الهجين فى الأرز تحت الظروف المصرية

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أجري هذا البحث بغرض دراسة إمكانية استغلال قوة الهجين فى الأرز باستخدام نظام العقم الذكرى السيتوبلازمى الوراثى الثلاثى (السلالة العقيمة A والسلالة المحافظة على خصوبة السلالة العقيمة B والسلالة المعيدة للخصوبة R والتى تنتج الهجين) وذلك باستخدام تحليل السلالة X الكشاف لعشر سلالات عقيمة ذكريا من ثلاثة مصادر عقم وراثية مختلفة ومتنوعة استخدمت كآباء مؤنثة (A) وخمسة أصناف وسلالات مصرية معيدة للخصوبة Restorers و تمت دراسة قوة الهجين مقارنة بالصنف الأعلى محصولاً من الأباء المصرية والمستخدم كصنف تجاري كما تمت دراسة القدرة على الائتلاف والارتباط بين قوة الهجين وكلا من القدرة الخاصة على الائتلاف والقدرة العامة على الائتلاف لكلا الأبوين الداخلين فى الهجين وكذا دراسة فعل الجين لإمكانية متابعة التربية والانتخاب لهجن تستخدم فى الأجيال الانعزالية المتقدمة لتحسين السلالات الأبوية فى الصفات المرغوبة .

وقد تقرر أن الهُجن التى تحقق تفوق وزيادة محصوليه أكثر من ١,٥ طن/هكتار مقارنة بأعلى الأصناف المحلية التجارية الداخلة فى الدراسة (جيزه ١٧٨) تعتبر هجنا مبشرة ويمكن استغلالها فى زراعة الأرز الهجين .

وقد أظهرت الدراسة أنه من بين ٥٠ هجينا كان هناك خمسة عشر هجينا مبشراً يتراوح محصولها ما بين ١٢,٤٩ – ١٣,٩٢ طن/هكتار بمتوسط عام للهجن ١٣,٣٨ طن/ هكتار فى حين كان محصول الصنف جيزه ١٧٨ المقارن ١٠,٤٩ طن/هكتار. وأظهرت الدراسة أن التفوق المحصولى لأحسن الهجن المختارة مقارنة بالصنف جيزه ١٧٨ تراوح من ٢-٣ طن/هكتار كما تراوحت قيم قوة الهجين من ١٩,١ – ٣٢,٧ % مقارنة بالصنف جيزه ١٧٨.

كما أظهرت الدراسة أنه من بين عشرة سلالات عقم ذكرى سيتوبلازمى وراثى كانت السلالات IR 68899A, G 46A, IR 58025A, IR 69625A ، هي الأفضل فى قدرتها العامة على الائتلاف لمحصول الحبوب ومعظم الصفات الرئيسية فى حين كانت الأصناف جيزة ١٧٨ وجيزة ١٨١ أحسن الأصناف المعيدة للخصوبة فى قدرتها العامة على الائتلاف فى صفة المحصول ومعظم الصفات الرئيسية .

على الجانب الآخر أظهرت الدراسة أنه يمكن استغلال الهجن IR 68888A/Giza 178R للتربية للتبكير و IR 68885A/ Giza 178R للتربية لقصر الساق و IR 68885A/ GZ 5121R لزيادة التفريع الحامل للسنابل و Giza 178R /IR 58025A لصفات وزن السنبلة -عدد الحبوب الممتلئة فى السنبلة -عدد السنيبلات - محصول الحبوب الأفضل والهجين IR 70368A/ Giza 181R لصفات وزن ١٠٠٠ حبة - خصوبة السنيبلات الأفضل باستخدامها فى التربية بالانتخاب لتحسين السلالات الأبوية فى الصفات المرغوبة ولإعادة استخدامها مرة أخرى كآباء محسنة فى برنامج تربية الأرز الهجين.