GENETICAL ANALYSIS AND DETECTION FOR WIDE COMPATIBILITY TRAITS OF SOME RICE GENOTYPES UNDER EGYPTIAN CONDITIONS

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ABSTRACT

The present study was carried out at the Experimental Farm of Sakha Agricultural Research Station, Sakha, Kafr El-Sheikh, Egypt, during 2012 and 2013 rice growing seasons to study the genetical analysis and detection of wide compatibility traits in some lines as well as to extent combining ability, gene action and three types of heterosis i.e. heterosis over better-parent (BP), mid-parent heterosis (MP) and standard heterosis for traits : yield and its components in some lines to improveme and utilize for some lines in hybrid rice production. The experiment comprised twenty two cross progenies derived from two varieties/lines namely; Giza 177 (Japonica) and Giza 182 (Indica) as female parents with 11 lines as pollinated parents (testers) namely; Yabni M55, Giza 178, Improved Sabramati, Yen Geng 135, TNAU 6464, TNAU 831358, TNAU 831399, IR47686-18-6-1, Millie, 85040-TR 853-4-1 and Pecos, were evaluated in a randomized complete block design (RCBD) with three replications. The results showed that the analysis of variance of combining ability revealed significant differences among parents, crosses and line x tester interaction for all the traits. The ratio of K^2 GCA / K^2 SCA was more than unity for days to heading, plant height, number of panicles/plant, panicle length, number of spikelets/panicle, pollen fertility percentage, spikelet fertility percentage, number of filled grains/panicle, 1000 – grain weight and grain yield, indicated the preponderance of additive gene effects in the expression of these traits. The rice varieties; Yabni M55, Giza 178, TNAU 831358, IR47686-18-6-1, Millie and Pecos showed highly spikelet fertility (> 70%) when they were crossed with japonica and indica testers, indicated that these lines can be identified as wide compatible genotypes. Moreover, the crosses of Giza 177 X Giza 178 and Giza 177 X Pecos were the best specific combiner for grain yield and 1000–grain weight. The parental lines proved to be utilized in hybrid rice development and production. The F_1 hybrid combinations showed highly significant and significant values in three types of heterosis for all traits studied except pollen and spikelet fertility percentage.

Key words: F_1 rice crosses, grain yield, heterosis, genetic parameters, yield components, wide compatibility, Oryza sativa

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop in the world and it is a staple food for more than half of the world's population **(Marathi *et al*., 2012)**. The genetic improvement of rice is more important for meeting the increase demand of the world population and ensuring a sustainable agricultural development. It is obvious that the increase of the world population is main factor of reduction of the available arable land. Therefore, scientists have tried to find a genetic approach that can increase yield. Finally, Heterosis exploitation is considered as one of the major keys to reach this achievement. Heterosis is described as a greatest outstanding genetic tool which played an important role in various breeding program to increase grain crop yield **(Brandle *et al*., 1990). Nevame *et al.* (2014)** mentioned the magnitude of heterosis to be depended on the distinctiveness of the parental lines used. **Ikehashi and Araki (1984)** discovered a genetic tool, designated as wide compatibility gene (s), to overcome this hybrid sterility problem. The key to this approach is to introduce widely compatible genes into the CMS lines for developing the widely compatible CMS lines. Additional strategies need to be deployed to develop widely compatible restorer (WCR) lines which show strong heterosis and good restoration ability, and compatibility to both indica CMS lines (WA cytoplasm) and japonica CMS lines (BT cytoplasm). The combining ability analysis has been the efficient tool in choosing the desirable parents for hybridization programmes. Combining ability analysis is one of the powerful tools available to estimate the gene action effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis (**Bhadru *et al,.* 2013**). The main objective of this investigation was to identify the best widely compatible (WC) lines which show strong heterosis and cross combinations for high yielding ability under Egyptian conditions.

MATERIALS AND METHODS

The present study was carried out at the Experimental Farm of Sakha Agricultural Research Station, Sakha, Kafr El-Sheikh, Egypt, during 2012 and 2013 rice growing seasons. The experiment comprised cross progenies derived from two lines namely; Giza 177 (Japonica) and Giza 182 (Indica) as female parents with 11 lines as pollinated parents (testers) namely Yabni M55, Giza 178, Improved Sabramati, Yen Geng 135, TNAU 6464, TNAU 831358, TNAU 831399, IR47686-18-6-1, Millie, 85040-TR 853-4-1 and Pecos. At flowering time, hybridization between parents was carried out, twenty two crosses combinations generated through line x tester mating design of two lines as female parents with 11 lines as pollinated parents in 2012 season. The F_1 hybrid combinations along with their respective parents were grown in the nursery during the second week of May 2013. Seedlings at 30-days old for all genotypes were individually transplanted in a RCBD with three replications. Each replicate consisted of 35 genotypes, while each genotype grown in one row. The rows were five meters length with 20 x 20 cm between rows plants, each row had 25 plants. The package of recomindation was applied as recommended by RRTC (2011). The data were recorded on pollen and spikelet fertility. The varieties showing more than 70% fertility in crosses to the indica testers and japonica testers are selected as WC varieties **(Araki *et al.,* 1988, Ikehashi 1991)**.

The entire grain yield and its contributing traits were estimated according to Standard Evaluation System for Rice (SES) of IRRI 2002. The studied traits were:

days to 50% of heading, plant height (cm), number of panicles/plant, panicle length (cm), number of spikelets/panicle, pollen fertility (%), spikelet fertility (%), number of filled grains/panicle, panicle weight (g), 1000 – grain weight (g) and grain yield / plant (g).

Statistical analysis: The data were analyzed by using the analysis of variances for RCBD as suggested by **Panse and Sukhatme (1954)** to test the significance of differences among the genotypes. The genetic analysis was performed using line x tester analysis according to **Kempthorne (1957)**. Additionally, the procedures described by **Singh and Chaudhary (1977)** were used to estimate general combining Ability (GCA) effects for each female and male parents and Specific Combining Ability (SCA) effects for hybrid combinations.

Genetic Components: The genetic components were estimated based on the expectations of mean squares according to **EL-Rouby (2009)**.

$$K^2g\,(L) = \frac{M.S.L - M.S.E}{r\,t}$$

$$K^2g\,(t) = \frac{M.S.t - M.S.E}{r\,L}$$

$$K^2GCA = \frac{TK^2L + LK^2T}{T + L}$$

$$K^2SCA = \frac{M.S.L*T - M.S.E}{r}$$

Estimation of heterosis: In general, the heterosis was determined as the percentage for increase or decrease in the performance of the hybrid over better parent (BP), over mid-parents (MP) and standard heterosis (SH), (**Mather 1949 and Mather and Jinks 1982**). Appropriate L.S.D. values were calculated to test the significance of the heterosis effects for better-parent and mid-parent heterosis, according to the method, suggested by **Wyanne *et al.* (1970)**.

RESULTS AND DISCUSSION

The mean performances of the morphological characters of the genotypes studied are presented in Table 1. For **days to 50% of heading** the data revealed that Giza 177 and Giza 182 were early, and the number of the days to 50% of heading was 95 and 96 days respectively. Testers, Pecos and Yabni M55 were the earlier and the number of the days to 50% of heading recorded 94 and 96 days, respectively. The crosses Giza 177 X Pecos, and Giza 182 X Pecos were earlier, and the number of the days to 50% of heading were 86 and 95 days, respectively. Concerning **plant height**, Giza 177 showed the shortest plant height and gave the lowest mean values (75.1 cm). However, the testers Pecos and Improved Sabramati gave lowest values 86.7 and 96.3 cm, respectively. The most desirable mean values towards shortness were found in the F_1 crosses Giza 182 X TNAU 831358 (85 cm) and Giza 177 X Giza 178 (86 cm). Concerning **number of panicles/plant** the genotypes Improved Sabramati and TNAU 831358 gave the highest mean values. The values were 19.3 and 17.1, respectively. The crosses Giza 182 X TNAU 6464, Giza 177 X Giza 178 and Giza 182 X TNAU 6464 gave the highest mean values (21.4, 19.5 and 19.4 respectively). For the mean values of **panicle length**; the lines Giza 177 and Giza 182 gave the highest mean values of the panicle length (19.7 and 19.7 cm). The testers IR47686-18-6-1, TNAU 831358 and Yen Geng 135 gave the highest mean values of the panicle length (23.6 , 23.6 and 23.3 cm), while the crosses G182 X IR47686-18-6-1 and Giza 182 X Yen Geng 135 gave the highest mean values of the panicle length (27.9 and 27.4 cm). For **number of spikelets/panicle**, the highest mean value was recorded in Giza 177 (104.6). The testers; Yen Geng 135 and IR47686-18-6-1 gave the highest mean values (189.9 and 168.6, respectively) for the number of spikelets/panicle. The crosses of Giza 182 X Yen Geng 135 and G 177 X Improved Sabramati, gave the highest mean values of number of spikelets/panicle. Number of productive tillers are an important yield component in rice. The trait number of panicle bearing tillers/ plant is believed to be closely associated with high grain yield/plant so, the hybrids with more number of panicle bearing tillers/plant to be identified.

Table 1: Mean performance for morphological traits of the studied genotypes during 2013 season

Traits / Genotypes	Days to heading	Plant height (cm)	No. of panicles /plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)
Giza 177	95	75.1	11.6	19.7	104.6	97.7
Giza 182	96	79.1	13.9	19.7	98.7	93.4
85040-TR 853-4-1	105	112.1	13.2	16.4	124.6	86.4
Giza 178	101	104.3	13.7	23.1	165.2	97.1
Improved Sabramati	102	96.3	19.3	22.8	156.7	96.3
IR47686-18-6-1	107	120.9	10.5	23.6	168.6	88.0
Millie	102	109.8	11.5	20.0	121.0	93.3
Pecos	94	86.7	9.5	16.7	124.9	96.6
TNAU 6464	107	105.7	16.6	22.4	136.3	95.1
TNAU 831358	108	105.4	17.1	23.6	125.1	97.8
TNAU 831399	106	111.1	13.2	23.1	103.3	96.9
Yabni M55	96	103.2	14.8	19.2	103.0	95.2
Yen Geng 135	101	123.1	9.3	23.3	189.9	85.0
G 177 X 85040-TR 853-4-1	99	114.6	10.8	19.4	165.2	77.2
G 182 X 85040-TR 853-4-1	110	130.4	14.6	21.0	186.2	58.5
Giza 177 X Giza 178	101	86.0	19.5	23.5	136.8	97.4
Giza 182 X Giza 178	100	88.0	11.2	23.0	111.4	95.6
G 177 X Impro. Sabramati	102	125.5	18.5	25.6	215.8	69.8
G182 X Impro. Sabramati	101	86.4	16.0	23.0	150.3	77.7
G 177 X IR47686-18-6-1	96	122.8	8.4	24.7	153.6	95.0
G182 X IR47686-18-6-1	108	140.0	10.7	27.9	189.4	92.2
Giza 177 X Millie	104	120.2	8.8	24.3	172.2	91.7
Giza 182 X Millie	102	122.8	16.0	26.0	168.0	74.8
Giza 177 X Pecos	86	98.7	11.2	18.5	123.0	98.0
Giza 182 X Pecos	95	106.8	11.4	22.4	142.6	78.7
Giza 177 X TNAU 6464	102	91.0	19.4	22.4	87.8	86.7
Giza 182 X TNAU 6464	103	88.2	21.4	22.8	122.2	52.4
Giza 177 X TNAU 831358	106	116.2	11.2	23.6	135.8	84.3
Giza 182 X TNAU 831358	103	85.0	14.0	22.0	118.0	94.0
Giza 177 X TNAU 831399	103	129.0	15.8	24.4	132.0	87.4
Giza 182 X TNAU 831399	102	102.2	16.2	23.4	132.4	50.1
Giza 177 X Yabni M55	111	105.6	11.8	21.0	115.0	96.7
Giza 182 X Yabni M55	102	96.0	16.0	24.7	139.0	96.1
Giza 177 X Yen Geng 135	105	117.5	11.0	22.2	196.2	90.7
Giza 182 X Yen Geng 135	102	126.6	14.8	27.4	245.4	62.3
L.S.D 5%	1.33	4.29	1.88	1.45	11.04	2.48
1%	1.77	5.69	2.50	1.93	14.67	3.29
CV	1.35	4.15	14.08	6.68	7.89	2.96

Table 2: Mean performance for morphological traits of the studied genotypes during 2013 season

Genotypes \ Traits	Spikelet fertility (%)	No. of filled grains /panicle	Panicle weight (g)	1000 grain weight (g)	Grain yield /plant (g)
Giza 177	94.0	98.3	3.1	28.5	19.3
Giza 182	89.3	88.1	2.4	23.0	28.3
85040-TR 853-4-1	78.1	97.4	3.3	29.9	19.6
Giza 178	94.6	156.2	4.0	20.7	26.9
Improved Sabramati	94.2	147.5	3.6	23.9	37.1
IR47686-18-6-1	82.7	139.0	4.6	33.3	14.0
Millie	88.3	106.6	3.7	27.5	18.3
Pecos	94.0	117.3	3.4	24.6	21.3
TNAU 6464	92.6	126.1	3.2	22.8	32.5
TNAU 831358	95.7	119.8	3.1	23.6	31.6
TNAU 831399	94.2	102.7	3.3	23.9	28.3
Yabni M55	90.3	93.1	2.3	22.5	21.2
Yen Geng 135	79.8	151.4	5.5	33.5	24.1
G 177 X 85040-TR 853-4-1	72.6	120.1	4.6	29.0	24.4
G 182 X 85040-TR 853-4-1	53.1	98.9	3.6	30.5	44.2
Giza 177 X Giza 178	93.4	127.9	3.7	25.1	68.5
Giza 182 X Giza 178	91.6	102.1	3.0	26.2	24.1
G 177 X Impro. Sabramati	66.1	142.6	4.1	26.4	40.5
G182 X Impro. Sabramati	73.4	110.3	3.1	23.6	26.7
G 177 X IR47686-18-6-1	91.8	141.1	4.7	30.8	23.5
G182 X IR47686-18-6-1	88.1	166.8	6.5	32.8	42.8
Giza 177 X Millie	87.6	150.9	4.5	28.1	17.8
Giza 182 X Millie	70.7	118.8	4.1	30.3	38.0
Giza 177 X Pecos	95.1	117.1	3.4	27.0	21.3
Giza 182 X Pecos	74.5	106.2	3.2	26.8	17.8
Giza 177 X TNAU 6464	82.5	72.5	2.3	28.5	26.0
Giza 182 X TNAU 6464	48.1	58.9	2.8	25.8	25.0
Giza 177 X TNAU 831358	80.4	109.3	4.2	27.3	34.9
Giza 182 X TNAU 831358	91.5	108.1	3.2	26.8	30.0
Giza 177 X TNAU 831399	83.5	110.3	3.1	25.7	26.1
Giza 182 X TNAU 831399	46.1	61.1	2.2	25.5	13.1
Giza 177 X Yabni M55	93.9	108.1	3.1	26.9	23.7
Giza 182 X Yabni M55	92.6	128.7	4.0	28.6	37.0
Giza 177 X Yen Geng 135	86.7	170.1	5.9	32.2	39.0
Giza 182 X Yen Geng 135	58.3	143.1	4.2	29.4	27.3
L.S.D 5%	2.99	10.92	0.43	0.86	3.75
1%	3.98	14.50	0.58	1.14	4.98
CV	3.75	9.59	12.20	3.26	13.62

The sterilities of the inter-varietal rice hybrids are mainly the pollen sterilities and the spikelet sterilities are mainly caused by the pollen sterilities. The results of the present study confirm the existence of wide compatibility germplasm, which exhibits the tendency to produce more fertile hybrids when crossed to both indica and japonica varieties than ordinary rice varieties, Yabni M55, Giza 178, TNAU

831358, IR47686-18-6-1, Millie and Pecos which showed highly spikelet fertility more than 70% when they were crossed with japonica and indica testers, indicated that these lines can be identified as wide compatibility ones**.** Furthermore, Improved Sabramati showed highly spikelet fertility more than 70% when crossed with indica tester while, showed spikelet fertility less than 70% (66.05±3.63) when crossed with japonica tester. As well as Yen Geng 135 and 85040-TR853-4-1 showed highly spikelet fertility more than 70% when they were crossed with japonica tester while, they showed spikelet fertility less than 70% when crossed with indica tester, indicated that these lines can be identified a weak wide compatibility lines, this result agreed with the findings of **Guiquen *et al.,* (1994)** which they reported that the sterility in the inter-varietal hybrids of cultivated rice is caused by the allelic interaction at the F_1 pollen sterility loci. Six loci of genes controlling F_1 pollen sterility in rice have been reported **(Guiquen *et al*., 1994).** The finding of the F_1 hybrids had the heterozygote Si/Sj at the six loci, the higher they showed the pollen sterility and the spikelet sterility. It suggests that origin and pedigree of test lines are important characters to be considered in analyzing the pollen and spikelet in rice.

The mean performances of the morphological characters of the genotypes studied are presented in Table 1. For **pollen fertility** the genotypes TNAU 831358, Giza 177 and Giza 178 gave the highest mean values. The values were 97.8, 97.7 and 97.1 respectively. The crosses Giza 177 X Pecos, Giza 177 X Giza 178 and Giza 177 X Yabni M55 gave the highest mean values. The values were 98.0, 97.4 and 96.7 respectively. For the mean values of **spikelet fertility**; the genotypes TNAU 831358 and Giza 178 gave the highest mean values (95.7 and 94.6 respectively), while the crosses of Giza 177 X Pecos, Giza 177 X Yabni M55 and Giza 177 X Giza 178 gave the highest mean values of the panicle length (95.1, 93.9 and 93.4 respectively). Concerning the **number of filled grains/panicle**, Giza 177 showed the highest mean with values (98.3). Testers Giza 178 and Yen Geng 135 gave the highest mean values (156.2 and 151.4). The crosses Giza 177 X Yen Geng 135 and G182 X IR47686-18-6-1 gave the highest mean values (170.1 and 166.8) respectively. Concerning the **panicle weight**, Giza 177 gave the highest values (3.1 g) of the panicle weight. The testers Yen Geng 135 and the crosses G182 X IR47686-18-6-1, Giza 177 X Yen Geng 135 gave the highest mean values. Values were 5.5, 6.5 and 5.9g respectively. For **1000–grain weight**, the highest values were recorded for Giza 177 (28.5g). The testers; Yen Geng 135, IR47686-18-6-1, 85040-TR 853-4-1 and Millie gave the highest mean values of the 1000–grain weight. Values were 33.5, 33.3, 29.9 and 27.5g, respectively. The crosses of Giza 182 X IR47686-18-6-1, Giza 177 X Yen Geng 135, Giza 177 X IR47686-18-

6-1 and Giza 182 X 85040-TR 853-4-1 gave the highest mean values of the 1000–grain weight. Values were 32.8, 32.2, 30.8 and 30.5g, respectively. Concerning the **grain yield/plant**, the results indicated that the genotypes/line Giza 182 showed the highest mean values (28.3 g) of grain yield/plant. The testers; Improved Sabramati, TNAU 6464 and TNAU 831358 showed the highest values 37.1, 32.5 and 31.6g, respectively. The crosses of Giza 177 X Giza 178, Giza 182 X 85040-TR 853-4-1, Giza 182 X IR47686-18-6-1 and Giza 177 X Improved Sabramati gave the highest mean values of the grain yield/plant. Values were 68.5, 44.2, 42.8 and 40.5g, respectively.

With regarded to contributing traits and grain yield the genotypes Giza 177, Improved Sabramati, IR47686-18-6-1, Pecos, Giza 177 X Pecos and Giza 182 X TNAU 831358, recorded good desirable traits such as earliness, shortness, number of panicles/plant, panicle length, number of spikelets/panicle, number of filled grains/panicle, panicle weight, 1000 – grain weight and grain yield. So, we can use some of these genotypes as a source for developing new hybrid combinations widely compatible in rice breeding program, under Egyptian conditions.

The results of the analysis of variance for grain yield and contributing traits, are presented in Table 2. The results showed that the mean squares of the genotypes for grain yield and contributing traits showed highly significant values. This finding indicated the presence of large variations among them. Similarly, the results cleared that, the mean squares of the parents, parents Vs crosses (except for number of filled grains/panicle and significant for number of panicles/plant), crosses, lines (except for panicle weight and significant for grain yield / plant), testers and line x tester are showed highly significant differences. Parents Vs. crosses mean squares is an indication to average heterosis overall crosses. Similar results were obtained by **Koli *et al.,* (2013) and Awad-Allah *et al.,* (2015)**.

Estimation of ratio K^2 GCA (additive gene effects) and K^2 SCA (non-additive gene effects) for the grain yield and contributing traits are presented in Table 3. The ratio of K^2 GCA / K^2 SCA was more than unity for contributing traits and grain yield, indicated preponderance of additive gene effects in the expression of these traits, except panicle weight, the ratio of K^2 GCA / K^2 SCA was less than unity indicated preponderance of non-additive gene effects in the expression of panicle weight **Hasan *et al.*, (2015)**.

Table 3: Analysis of variance and combining ability for the morphological traits for the studied genotypes during 2013 season

Source of variance	d.f	Days to heading	Plant height (cm)	No. of Panicles / plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)
Replications	2	0.5 ns	3.4 ns	2.4 ns	0.3 ns	18.3 ns	3.2 ns
Genotypes	34	76.6**	807.9**	34.4**	20.6**	3790.7**	543.7**
Parents	12	74.0**	648.3**	26.9**	20.0**	2551.4**	58.9**
P. vs. Crosses	1	8.8**	1049.8**	9.97*	129.1**	9134.9**	3313.7**
Crosses	21	81.3**	887.5**	39.9**	15.8**	4244.4**	688.9**
Lines	1	23.0**	406.9**	34.6**	26.8**	697.1**	2765.1**
Tester	10	102.7**	1260.1**	55.2**	20.7**	7179.8**	764.1**
Line x Tester	10	65.6**	563.1**	25.2**	9.7**	1663.8**	406.0**
Error	68	0.9	9.2	1.78	1.1	61.3	3.1

Source of variance	d.f	Spikelet fertility (%)	No. of filled grains /panicle	Panicle weight (g)	1000 grain weight (g)	Grain yield /plant (g)
Replications	2	2.5 ns	30.5 ns	0.04 ns	0.4 ns	3.1 ns
Genotypes	34	580.8**	2184.7**	2.9**	31.4**	339.2**
Parents	12	107.3**	1660.1**	2.1**	52.0**	131.8**
P. vs. Crosses	1	3293.9**	78.7 ns	2.2**	87.2**	800.7**
Crosses	21	722.2**	2584.7**	3.3**	16.9**	435.7**
Lines	1	2892.9**	3789.7**	2.1**	0.04 ns	53.4*
Tester	10	815.5**	4268.6**	5.2**	29.8**	337.5**
Line x Tester	10	411.9**	780.4**	1.6**	5.7**	572.2**
Error	68	4.5	59.9	0.1	0.4	7.1

** : Highly significant at 1% * : significant at 5% ns : Non significant.

Table 4: Ratio between K^2 GCA and K^2 SCA for the morphological traits for the studied genotypes during 2013 season

Traits / Genetic components	Days to heading	Plant height (cm)	No. of Panicles / plant	Panicle length (cm)	No. of spikelets / panicle	Pollen fertility (%)
K^2 GCA	0.7	12.1	1	0.8	19.3	83.7
K^2 SCA	17	208.5	8.9	3.3	1186.4	126.8
K^2 GCA / K^2 SCA	21.6	184.6	7.8	2.9	534.2	134.3

Table 4: Continued

Traits / Genetic components	Spikelet fertility (%)	No. of filled grains /panicle	Panicle weight (g)	1000 grain weight (g)	Grain yield /plant (g)
K^2 GCA	87.5	113	0.1	-0.01	1.4
K^2 SCA	135.2	701.4	0.8	4.91	55.1
K^2 GCA / K^2 SCA	135.8	240.2	0.5	1.79	188.4

Therefore, the selection procedures based on the accumulation of additive effect would be successful in improving contributing traits and grain yield. **Awad-Allah *et al.,* (2015)** they found that the preponderance of additive gene effects in the expression of the traits : grain yield, number of panicles/plant, number of filled grains/panicle, days to heading, spikelets/panicle and spikelet fertility percentage. On the contrary, preponderance of non-additive gene effects in the expression of the traits panicle weight and 1000–grain weight.

General combining ability (GCA) analysis is presented in Tables 4 and 5. For **days to heading data** revealed that the line Giza 177 (-0.6) gave highly significant negative values. While, highly significantly negative values were shown by testers Pecos (11.5) and Giza 178 (-1.5), while the tester Improved Sabramati (-0.5) was showed significant negative value. This finding indicated that these lines and testers are considered as good combiners to develop early wide compatibility, maintainer, restorer lines and hybrids. Thus GCA estimate could help in identifying the lines and testers which would give hybrids and improve parental lines for desirable traits. Concerning **plant height**, the line Giza 182 (-2.5) showed highly significant negative GCA effects. While, the testers Giza 178 (-22.1), TNAU 6464 (-19.5), TNAU 831358 (-8.5), Yabni M55 (-8.3), Pecos (-6.3), and Improved Sabramati (-3.1) showed highly significant negative values of GCA effects. The negative values are indicators of decreased plant height; therefore it could be useful to breed short stature rice cultivars, widely compatible lines or hybrid combinations. Concerning the **number of panicles/plant**, data showed that the line Giza 182 (0.7) showed highly significant positive value and testers TNAU 6464 (6.4), Improved Sabramati (3.2), TNAU 831399 (2) and Giza 178 (1.3) showed highly significant positive values of GCA effects. That means these genotypes seemed to be good parental combiners in rice crosses.

Table 5: General combining ability effects of the lines for the morphological traits during 2013 season

Traits / Lines	Days to heading	Plant height (cm)	No. of Panicles/ plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)
Giza 177	-0.6**	2.5**	-0.7**	-0.6**	-3.3**	6.5**
Giza 182	0.6**	-2.5**	0.7**	0.6**	3.2**	-6.5**
L.S.D 5%	0.16	0.5	0.2	0.2	1.4	0.3
1%	0.23	0.7	0.3	0.3	1.9	0.4

Table 5: Continued

Traits / Lines	Spikelet fertility (%)	No. of filled grains / panicle	Panicle weight (g)	1000 grain weight (g)	Grain yield /plant (g)
Giza 177	6.6**	7.6**	0.2**	0.03 ns	0.9**
Giza 182	-6.6**	-7.6**	-0.2**	-0.03 ns	-0.9**
L.S.D 5%	0.4	1.3	0.05	0.1	0.5
1%	0.5	1.9	0.08	0.1	0.7

** : Highly significant at 1% * : significant at 5% ns : Non significant

Table 6: General combining ability effects of the tester lines for the morphological traits during 2013 season

Traits / Tester	Days to heading	Plant height (cm)	No. of Panicles/ plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)
85040-TR 853-4-1	2.5**	13.4**	-1.3**	-3.1**	24**	-14.3**
Giza 178	-1.5**	-22.1**	1.3**	-0.1 ns	-27.6**	14.3**
Improved Sabramati	-0.5*	-3.1**	3.2**	1**	31.3**	-8.4**
IR47686-18-6-1	0.05 ns	22.3**	-4.5**	3.0**	19.8**	11.4**
Millie	1**	12.4**	-1.6**	1.8**	18.4**	1.1**
Pecos	-11.5**	-6.3**	-2.7**	-2.9**	-18.9**	6.2**
TNAU 6464	0.5**	-19.5**	6.4**	-0.7**	-46.7**	-12.6**
TNAU 831358	2.5**	-8.5**	-1.4**	-0.5*	-24.8**	7**
TNAU 831399	0.5**	6.5**	2**	0.6*	-19.5**	-13.4**
Yabni M55	4.5**	-8.3**	-0.1 ns	-0.5*	-24.7**	14.2**
Yen Geng 135	1.5**	13**	-1.1**	1.5**	69.1**	-5.6**
L.S.D 5%	0.4	1.2	0.5	0.4	3.2	0.7
1%	0.5	1.8	0.8	0.6	4.5	1.0

Table 6: Continued

Traits / Tester	Spikelet fertility (%)	No. of filled grains/panicle	Panicle weight (g)	1000 grain weight (g)	Grain yield /plant (g)
85040-TR 853-4-1	-15.4**	-7.5**	0.3**	1.8**	3.8**
Giza 178	14.2**	-2 ns	-0.4**	-2.2**	15.8**
Improved Sabramati	-8.5**	9.5**	-0.2**	-2.9**	3.1**
IR47686-18-6-1	11.7**	37**	1.8**	3.9**	2.6**
Millie	0.9*	17.9**	0.5**	1.3**	-2.6**
Pecos	6.6**	-5.3**	-0.5**	-1**	-11**
TNAU 6464	-12.9**	-51.3**	-1.3**	-0.7**	-5**
TNAU 831358	7.7**	-8.2**	-0.1 ns	-0.8**	1.9**
TNAU 831399	-13.5**	-31.3**	-1.1**	-2.3**	-10.9**
Yabni M55	15.0**	1.5 ns	-0.2**	-0.2 ns	-0.2 ns
Yen Geng 135	-5.8**	39.6**	1.2**	3**	2.6**
L.S.D 5%	0.9	3.2	0.1	0.2	1.1
1%	1.2	4.5	0.2	0.4	1.5

** : Highly significant at 1% * : significant at 5% ns : Non significant

For **panicle length** data revealed that the values of general combining ability effects were highly significant and significant positive for the line Giza 182 (0.6). While the testers IR47686-18-6-1 (3), Millie (1.8), Yen Geng 135 (1.5), Improved Sabramati (1) and TNAU 831399 (0.6) gave the highly significant positive values, this means that these genotypes could help to improvement of maintainer, restorer, widely compatible restorer lines and hybrids rice. Obviously for **number of spikelets/panicle** the data illustrated highly significant positive value of GCA effects for the line Giza 182 (3.2). While the tester Yen Geng 135 (69.1), Improved Sabramati (31.3), 85040-TR 853-4-1 (24), IR47686-18-6-1 (19.8) and Millie (18.4) showed highly significant positive value of general combining ability effects. This means that these genotypes could be good parental combiners in rice crosses. For **pollen fertility percentage**, data indicated that the line Giza 177 (6.5) and six testers Giza 178 (14.3), Yabni M55 (14.2), IR47686-18-6-1 (11.4), TNAU 831358 (7), pecos (6.2) and Millie (1.1) showed highly significant positive values of GCA effects. It means that these genotypes could be utilized as parents for breeding genotype with more fertile pollen grains per panicle for developing maintainer, restorer lines and hybrids. Concerning the **spikelets fertility percentage**, data indicated that the line Giza 177 (6.6) and six testers Yabni M55 (15), Giza 178 (14.2), IR47686-18-6-1 (11.7), TNAU 831358 (7.7), Pecos (6.6) and Millie (0.9) showed highly significant positive values of GCA effects. It means that these genotypes could be utilized as parents for breeding genotype with more fertile grains per panicle for developing maintainer, restorer lines and hybrids. Concerning the **number of filled grains/panicles** data revealed that the lines Giza 177 (7.6) and the testers Yen Geng 135 (39.6), IR47686-18-6-1 (37), Millie (17.9) and Improved Sabramati (9.5) were identified as the best combiners, since their estimates of general combining ability effects were highly significant positive values. Concerning **panicle weight**, the data indicated that the line Giza 177 (0.2) and the tester IR47686-18-6-1 (1.8), Yen Geng 135 (1.2), Millie (0.5) and 85040-TR 853-4-1 (0.3) showed highly significant positive values of GCA effects for panicle weight. Consequently, the former genotypes can be used in the hybrid rice program as good combiners for heavier panicle weight. Furthermore, the values of GCA effects for **1000-grain weight**, were non significant positive for the lines. While, the testers IR47686-18-6-1 (3.9), Yen Geng 135 (3), 85040-TR853-4-1 (1.8) and Millie (1.3). It means that these genotypes could be considered as good combiners for heavy grain weight. The **grain yield/plant** data revealed that the lines Giza 177 (0.9) showed highly significant positive values of general combining ability effects. On the other hand, the testers Giza 178 (15.8), 85040-TR 853-4-1 (3.8), Improved Sabramati (3.1), IR47686-18-6-1 (2.6), Yen Geng 135 (2.6) and TNAU 831358 (1.9) showed highly significant positive values of general combining ability effects. These genotypes appeared to be good combiners to improve yield components.

Specific combining ability (SCA) effects:

Specific combining ability effects for the grain yield and contributing traits of the crosses are shown in Table 6. For **days to heading**, data in Table 6 revealed that ten cross combinations recorded highly significant negative values of specific combining ability effects. The highest significant negative values were shown in the cross combinations Giza 182 X Giza 178 (-5.4), Giza 177 X Yen Geng 135 (-5.1) and G 177 X 85040-TR 853-4-1 (-4.9). Concerning **plant height**, results are shown in Table (6), the results showed that ten cross combinations recorded highly significant and significant negative values of specific combining ability effects. The highest significant negative values were shown in the cross combinations Giza 182 X TNAU 6464 (-17.1), Giza 177 X Yabni M55 (-13.1) and Giza 182 X Giza 178 (-11.1). The negative values of SCA effects means decreased plant height and could be useful to breed short stature rice cultivars. While the positive values of SCA effects means increased plant height and could be useful to breed restorer lines and widely compatible restorer. Regarding **number of panicles/plant** data in Table 6 showed that six cross combinations recorded highly significant positive values. The highest significant positive values were shown in the cross combinations Giza 182 X 85040-TR 853-4-1 (4.9), Giza 182 X TNAU 831358 (2.9). For **panicle length**, data in Table 6 showed that 8 cross combination recorded highly significant positive values of SCA effects. The highest significant positive values were shown in the cross combination Giza 182 X Yen Geng 135 (2), Giza 177 X Giza 178 (1.9) and Giza 182 X IR47686-18-6-1 (1.4). For **number of spikelets/panicle**, ten cross combinations showed highly significant and significant positive values of SCA effects. The highest values were shown in the cross combinations Giza 177 X Giza 178 (36), Giza 182 X Yen Geng 135 (21.4) and Giza 182 X 85040-TR 853-4-1 (16). For **pollen fertility percentage** data showed that 11 cross combinations recorded highly significant positive value of specific combining ability effects. The highest significant positive values were shown in the cross combinations Giza 177 X Millie (12.2), Giza 177 X Yabni M55 (11.3) and Giza 177 X IR47686-18-6-1 (10.7). The conclusion of high estimates of SCA effects, in any crosses, might be not necessarily to be dependent upon the general combining ability effects. Concerning **spikelet fertility percentage** data showed that 11 cross combinations recorded highly significant positive value of specific combining ability effects. The highest significant positive value were shown in the cross combinations Giza 177 X Yabni M55 (12.2), Giza 177 X Millie (12.1),

Table 7: Specific combining ability effects for the morphological traits of the crosses during 2013 season

Traits / crosses	Days to heading	Plant height	No. of Panicles/ plant	Panicle length	No. of spikelets/ panicle	Pollen fertility (%)
Giza 177 X 85040-TR 853-4-1	-4.9**	-10.4**	-1.2**	-0.2 ns	-7.2**	2.9**
Giza 182 X 85040-TR 853-4-1	1.1**	-3.5**	4.9**	0.9**	16**	-5.6**
Giza 177 X Giza 178	1.1**	17.1**	2.0**	1.9**	36**	-10.4**
Giza 182 X Giza 178	-5.4**	-11.1**	-0.4 ns	-1.0**	-14.7**	-5.1**
Giza 177 X Improved Sabramati	1.6**	-3.8**	-2.9**	-0.2 ns	5.4*	2.0**
Giza 182 X Improved Sabramati	-3.9**	-6.5**	0.6 ns	-1.3**	-6.5**	3.2**
Giza 177 X IR47686-18-6-1	0.1 ns	-1.1 ns	-0.3 ns	0.4 ns	-14**	10.7**
Giza 182 X IR47686-18-6-1	2.1**	13.1**	-0.7 ns	1.4**	12.2**	-11.3**
Giza 177 X Millie	1.1**	10.9**	0.5 ns	1.2**	3.1 ns	12.2**
Giza 182 X Millie	5.1**	2.3*	-1.4**	-1.2**	-8.8**	-6.2**
Giza 177 X Pecos	2.1**	-7.0**	-1.2**	-2.0**	-21.4**	7.8**
Giza 182 X Pecos	4.9**	10.4**	1.2**	0.2 ns	7.3**	-2.9**
Giza 177 X TNAU 6464	-1.1**	3.5**	-4.9**	-0.9**	-16**	5.6**
Giza 182 X TNAU 6464	-1.1**	-17.1**	-2.0**	-1.9**	-36**	10.4**
Giza 177 X TNAU 831358	5.4**	11.1**	0.4 ns	1.0**	14.7**	5.1**
Giza 182 X TNAU 831358	-1.6**	3.8**	2.9**	0.2 ns	-5.3*	-2.0**
Giza 177 X TNAU 831399	3.9**	6.5**	-0.6 ns	1.3**	6.6**	-3.2**
Giza 182 X TNAU 831399	-0.1 ns	1.1 ns	0.3 ns	-0.4 ns	14**	-10.7**
Giza 177 X Yabni M55	-2.1**	-13.1**	0.7 ns	-1.4**	-12.1**	11.3**
Giza 182 X Yabni M55	-1.1**	-10.9**	-0.5 ns	-1.2**	-3 ns	-12.2**
Giza 177 X Yen Geng 135	-5.1**	-2.3*	1.4**	1.2**	8.8**	6.2**
Giza 182 X Yen Geng 135	-2.1**	7.0**	1.2**	2.0**	21.4**	-7.8**
L.S.D 5%	0.5	1.8	0.8	0.6	4.5	1.0
1%	0.8	2.5	1.1	0.8	6.4	1.4

Table 7: Continued

Traits / crosses	Spikelet fertility (%)	No. of filled grains/ panicle	Panicle weight	1000 grain weight	Grain yield /plant
Giza 177 X 85040-TR 853-4-1	3.2**	3.0 ns	0.3**	-0.8**	-10.8**
Giza 182 X 85040-TR 853-4-1	-5.7**	5.3*	0.2*	-0.6**	21.3**
Giza 177 X Giza 178	-10.3**	8.6**	0.3**	1.3**	6.0**
Giza 182 X Giza 178	-4.8**	-20.5**	-1.0**	-1.0**	-10.5**
Giza 177 X Improved Sabramati	1.8**	8.5**	0.0 ns	-1.36**	-11.0**
Giza 182 X Improved Sabramati	3.7**	-2.2 ns	-0.1 ns	0.1 ns	0.8 ns
Giza 177 X IR47686-18-6-1	10.5**	-0.8 ns	-0.4**	1.3**	-0.4 ns
Giza 182 X IR47686-18-6-1	-12.2**	-7.0**	0.3**	0.2 ns	1.5*
Giza 177 X Millie	12.1**	17.0**	0.3**	0.1 ns	5.6**
Giza 182 X Millie	-6.0**	-17.9**	-0.6**	-0.9**	-7.5**
Giza 177 X Pecos	7.6**	5.9*	0.7**	1.39**	5.0**
Giza 182 X Pecos	-3.2**	-3.0 ns	-0.3**	0.8**	10.8**
Giza 177 X TNAU 6464	5.7**	-5.3*	-0.2*	0.6**	-21.3**
Giza 182 X TNAU 6464	10.3**	-8.6**	-0.3**	-1.4**	-6.0**
Giza 177 X TNAU 831358	4.8**	20.5**	1.0**	1.0**	10.5**
Giza 182 X TNAU 831358	-1.8**	-8.5**	-0.03 ns	1.1**	11.0**
Giza 177 X TNAU 831399	-3.7**	2.2 ns	0.1 ns	-0.1 ns	-0.8 ns
Giza 182 X TNAU 831399	-10.5**	0.8 ns	0.4**	-1.3**	0.4 ns
Giza 177 X Yabni M55	12.2**	7.0**	-0.3**	-0.2 ns	-1.5*
Giza 182 X Yabni M55	-12.1**	-17.0**	-0.3**	-0.1 ns	-5.6**
Giza 177 X Yen Geng 135	6.0**	17.9**	0.6**	0.9**	7.5**
Giza 182 X Yen Geng 135	-7.6**	-5.9*	-0.7**	-1.4**	-5.0**
L.S.D 5%	1.2	4.5	0.2	0.4	1.5
1%	1.7	6.3	0.3	0.5	2.2

** : Highly significant at 1% * : significant at 5% ns : Non significant

Giza 177 X IR47686-18-6-1 (10.5) and Giza 182 X TNAU 6464 (10.3). These genotypes appeared to be good combiners to improve rice cultivars and hybrids for grain yield/plant. For **number of filled grains/panicle**, data in Table (6) showed that 8 cross combinations recorded highly significant or significant positive values of SCA effects. The highest significant positive values were shown in the crosses Giza 177 X TNAU 831358 (20.5), Giza 177 X Yen Geng 135 (17.9) and Giza 177 X Millie (17). These positive values indicated that desirable types of non-additive effects could be present in these cross combinations for number of filled grains/panicle. Concerning **panicle weight**, 9 cross combinations recorded highly significant or significant positive values of SCA effects. The highest significant positive values were shown in the cross combinations Giza 177 X TNAU 831358 (1), Giza 177 X Pecos (0.7) and Giza 177 X Yen Geng 135 (0.6). For **1000-grain weight** data revealed that 8 cross combinations had highly significant positive values of SCA effects. The highest significant positive values were shown in the cross combinations Giza 177 X Giza 178 (1.4), Giza 177 X Pecos (1.4) and Giza 177 X IR47686-18-6-1 (1.3). So, it could be suggested that one or more of the former cross combinations may be used in improving 1000-grain weight in rice cultivars. Concerning **grain yield/plant**, 9 cross combinations gave highly significant and significant positive values of SCA effects. The highest significant positive values were shown in the cross combinations Giza 182 X 85040-TR 853-4-1 (21.3), Giza 182 X TNAU 831358 (11), Giza 182 X Pecos (10.8) and Giza 177 X TNAU 831358 (10.5). These results indicated that the non-additive gene effects were predominant in these particular rice cross combinations for grain yield/plant and could be attributed to the wide differences in grain yield/plant between the involved parents in these cross combinations. Accordingly, it could be suggested that one or more of these cross combinations could be used in improving grain yield in hybrid rice breeding programe. The crosses showing high SCA effects involving low/low general combiners indicate the non-additive genetic effects and these crosses could be exploited for heterosis breeding programme **(Singh *et al.,* 2007 and Shanthi *et al.* 2011)**. It is concluded from the present results, that there is the possibility to breed good hybrids and rice cultivars with desirable traits and high yielding rice lines than the existing lines either through heterosis breeding or through recombinant breeding with selection in later generations to develop traits adaptable high yielding parental lines of hybrid.

The proportional contribution of lines, testers and line × tester interaction for the expression of traits is presented in Table 7. It is evident that testers was more important for pollen fertility percentage (52.82%), spikelet fertility percentage (53.77%), days to heading (60.19%), plant height (67.61%), no. of panicles/plant (65.78%), panicle length (62.56%) no. of spikelets/ panicle (80.55%), no. of filled grains/ panicle (78.64%), panicle weight (74.51%) and 1000 grain weight (83.89%) These results are similar to those obtained by **Awad-Allah *et al.,* (2015), Waza *et al.,* (2015)** for days to heading**,** plant height and 1000 grain weight **Sanghera and Hussain (2012)** for no. of panicles/plant. It revealed preponderance testers influence for these traits.

Table 8: Percent contribution of different components (lines, testers and lines x testers) towards the crosses sum of squares for various traits in rice

Characters	Contribution of line %	Contribution Of tester %	Contribution of line x tester %
Days to heading	1.35	60.19	38.46
Plant height (cm)	2.18	67.61	30.21
No. of panicles/plant	4.13	65.78	30.10
Panicle length (cm)	8.08	62.56	29.36
No. of spikelets/ panicle	0.78	80.55	18.67
Pollen fertility (%)	19.11	52.82	28.06
Spikelet fertility (%)	19.07	53.77	27.16
No. of filled grains/ panicle	6.98	78.64	14.38
Panicle weight (g)	3.01	74.51	22.47
1000 grain weight (g)	0.01	83.89	16.10
Grain yield/plant (g)	0.58	36.88	62.53

The contribution of maternal and paternal interaction (line x tester) was more important for grain yield/plant (62.53%). These results are agreed with the results obtained by **Waza *et al.,* (2015) and Rahaman (2016)** they found the contribution of maternal and paternal interaction (line x tester) was more important for grain yield/plant.

Estimation of heterosis effects:

Better-parent heterosis (BP), mid parent (MP) heterosis and standard heterosis (SH) for grain yield and its components are shown in Tables 8, 9 and 10. For **Days to heading,** the data revealed that the hybrid Giza 177 X Pecos (-8%) showed highly significant negative value of better parent heterosis. Regarding data emphasized that the heterosis as deviation of mid-parent (MP), were highly significant negative for the hybrids Giza 177 X Pecos (-8.8%) and Giza 177 X IR47686-18-6-1 (-5%). Moreover, the data revealed that the standard heterosis, were highly significant and significant negative for four hybrids. The hybrids Giza 177 X Pecos (-14.7%) and

Table 9: Estimates of percentage of heterosis over better-parent (BP) for grain yield and its contributing traits of studied crosses

Traits / crosses	Days to heading	Plant height	No. of Panicles/ plant	Panicle length	No. of spikelets/ panicle	Pollen fertility (%)
Giza 177 X 85040-TR 853-4-1	4.2**	52.7**	-18.0*	-1.4 ns	32.6**	-21.0**
Giza 182 X 85040-TR 853-4-1	14.6**	64.9**	4.8 ns	6.8 ns	49.5**	-37.3**
Giza 177 X Giza 178	6.3**	14.6**	42.9**	1.7 ns	-17.2**	-0.4 ns
Giza 182 X Giza 178	4.2**	11.3**	-19.6*	-0.4 ns	-32.5**	-1.5 ns
Giza 177 X Improved Sabramati	7.4**	67.2**	-3.9 ns	12.3**	37.7**	-28.6**

Giza 182 X Improved Sabramati	5.2**	9.2**	-17.0**	0.9 ns	-4.1 ns	-19.3**
Giza 177 X IR47686-18-6-1	1.1 ns	63.6**	-27.6**	4.8 ns	-8.9*	-2.8 ns
Giza 182 X IR47686-18-6-1	12.5**	77.0**	-23.4**	18.3**	12.4**	-1.3 ns
Giza 177 X Millie	9.5**	60.1**	-24.1*	21.5**	42.3**	-6.2**
Giza 182 X Millie	6.3**	55.3**	15.1 ns	30.0**	38.8**	-19.9**
Giza 177 X Pecos	-8.0**	31.5**	-3.4 ns	-5.9 ns	-1.5 ns	0.3 ns
Giza 182 X Pecos	1.6 ns	35.0**	-18.2*	13.7**	14.2**	-18.6**
Giza 177 X TNAU 6464	7.4**	21.2**	16.9*	-0.1 ns	-35.6**	-11.3**
Giza 182 X TNAU 6464	7.3**	11.5**	28.9**	1.7 ns	-10.3*	-44.9**
Giza 177 X TNAU 831358	11.6**	54.8**	-34.4**	0.1 ns	8.6 ns	-13.7**
Giza 182 X TNAU 831358	7.3**	7.5*	-17.8**	-6.6 ns	-5.7 ns	-3.8*
Giza 177 X TNAU 831399	8.4**	71.8**	19.7*	5.7 ns	26.2**	-10.6**
Giza 182 X TNAU 831399	6.3**	29.2**	16.3*	1.2 ns	28.2**	-48.3**
Giza 177 X Yabni M55	16.8**	40.7**	-20.3**	6.8 ns	9.9 ns	-1.1 ns
Giza 182 X Yabni M55	6.6**	21.4**	8.1 ns	25.4**	35.0**	0.9 ns
Giza 177 X Yen Geng 135	10.5**	56.5**	-5.2 ns	-4.5 ns	3.3 ns	-7.2**
Giza 182 X Yen Geng 135	6.3**	60.1**	6.2 ns	17.9**	29.2**	-33.4**
L.S.D 5%	1.5	5.0	2.2	1.7	12.8	2.9
L.S.D 1%	2.0	6.6	2.9	2.2	16.9	3.8

Table 9: Continued

Traits / crosses	Spikelet fertility (%)	No. of filled grains / panicle	Panicle weight	1000 grain weight	Grain yield /plant
Giza 177 X 85040-TR 853-4-1	-22.7**	22.1**	38.6**	-3.1 ns	24.5*
Giza 182 X 85040-TR 853-4-1	-40.5**	1.6 ns	7.8 ns	2.0 ns	56.0**
Giza 177 X Giza 178	-1.4 ns	-18.1**	-6.7 ns	-12.0**	154.5**
Giza 182 X Giza 178	-3.3 ns	-34.7**	-26.4**	13.9**	-14.7 ns
Giza 177 X Improved Sabramati	-29.9**	-3.3 ns	14.0 ns	-7.5**	9.1 ns
Giza 182 X Improved Sabramati	-22.1**	-25.2**	-12 ns	-1.4 ns	-28.2**
Giza 177 X IR47686-18-6-1	-2.3 ns	1.5 ns	3.2 ns	-7.5**	21.6 ns
Giza 182 X IR47686-18-6-1	-1.3 ns	20.0**	41.0**	-1.4 ns	51.0**
Giza 177 X Millie	-6.8**	41.6**	22.7**	-1.5 ns	-8.0 ns
Giza 182 X Millie	-20.8**	11.5 ns	11.4 ns	10.1**	34.2**
Giza 177 X Pecos	1.2 ns	-0.2 ns	0.0 ns	-5.5**	-0.2 ns
Giza 182 X Pecos	-20.8**	-9.5 ns	-4.2 ns	9.0**	-37.0**
Giza 177 X TNAU 6464	-12.3**	-42.5**	-28.8**	-0.3 ns	-19.9**

Giza 182 X TNAU 6464	-48.0**	-53.3**	-13 ns	12.3**	-23.0**
Giza 177 X TNAU 831358	-16.0**	-8.8 ns	33.7**	-4.4*	10.4 ns
Giza 182 X TNAU 831358	-4.4*	-9.7 ns	1.3 ns	13.4**	-5.0 ns
Giza 177 X TNAU 831399	-11.4**	7.3 ns	-6.0 ns	-9.9**	-7.6 ns
Giza 182 X TNAU 831399	-51.1**	-40.6**	-34.2**	6.5**	-53.8**
Giza 177 X Yabni M55	-0.1 ns	10.0 ns	0.0 ns	-5.9**	11.6 ns
Giza 182 X Yabni M55	2.5 ns	38.3**	69.8**	24.1**	30.7**
Giza 177 X Yen Geng 135	-7.8**	12.3**	8.4 ns	-3.8*	61.9**
Giza 182 X Yen Geng 135	-34.7**	-5.5 ns	-24.0**	-12.2**	-3.6 ns
L.S.D 5%	3.5	12.6	0.5	1.0	4.3
L.S.D 1%	4.6	16.7	0.7	1.3	5.7

** : Highly significant at 1% * : significant at 5% ns : Non significant

Table 10: Estimates of percentage of heterosis over mid-parents (MP) for grain yield and its contributing traits of studied crosses

Traits / crosses	Days to heading	Plant height	No. of panicles/plant	Panicle length	No. of spikelets/ panicle	Pollen fertility (%)
Giza 177 X 85040-TR 853-4-1	-1.0 ns	22.5**	-12.8 ns	7.6 ns	44.2**	-16.2**
Giza 182 X 85040-TR 853-4-1	9.5**	36.4**	7.7 ns	16.6**	66.8**	-34.9**
Giza 177 X Giza 178	3.2**	-4.1 ns	54.5**	9.9**	1.4 ns	-0.05 ns
Giza 182 X Giza 178	1.6*	-4.1 ns	-18.8**	7.5*	-15.6**	0.4 ns
Giza 177 X Improved Sabramati	3.7**	46.4**	19.9**	20.6**	65.2**	-28.1**
Giza 182 X Improved Sabramati	2.2**	-1.5 ns	-3.6 ns	8.2*	17.7**	-18.1**
Giza 177 X IR47686-18-6-1	-5.0**	25.3**	-24.0**	14.2**	12.5**	2.3 ns
Giza 182 X IR47686-18-6-1	6.4**	40.0**	-12.7 ns	28.9**	41.7**	1.6 ns
Giza 177 X Millie	5.6**	30.0**	-23.9**	22.5**	52.7**	-4.0**
Giza 182 X Millie	3.0**	30.0**	25.9**	31.0**	52.9**	-19.9**
Giza 177 X Pecos	-8.8**	22.0**	6.2 ns	1.8 ns	7.2 ns	0.8 ns
Giza 182 X Pecos	0.3 ns	28.8**	-2.7 ns	23.1**	27.6**	-17.2**
Giza 177 X TNAU 6464	1.2 ns	0.7 ns	37.6**	6.4 ns	-27.1**	-10.1**
Giza 182 X TNAU 6464	1.6*	-4.5 ns	40.2**	8.3*	4.0 ns	-44.4**
Giza 177 X TNAU 831358	4.6**	28.8**	-21.9**	9.2**	18.3**	-13.7**
Giza 182 X TNAU 831358	1.1 ns	-7.9**	-9.5 ns	1.7 ns	5.5 ns	-1.7 ns
Giza 177 X TNAU 831399	2.7**	38.6**	27.4**	14.1**	27.0**	-10.2**

Giza 182 X TNAU 831399	1.2 ns	7.5**	19.4**	9.2**	31.1**	-47.4**
Giza 177 X Yabni M55	16.4**	18.5**	-10.6 ns	8.2*	10.8*	0.2 ns
Giza 182 X Yabni M55	6.4**	5.4*	11.4 ns	27.1**	37.8**	1.9 ns
Giza 177 X Yen Geng 135	7.1**	18.6**	5.1 ns	3.5 ns	33.3**	-0.7 ns
Giza 182 X Yen Geng 135	3.6**	25.2**	27.2**	27.7**	70.1**	-30.2**
L.S.D 5%	1.3	4.3	1.9	1.5	11.0	2.5
L.S.D 1%	1.8	5.7	2.5	1.9	14.7	3.3

Table 10: Continued

Traits / crosses	Spikelet fertility (%)	No. of filled grains/ panicle	Panicle weight	1000 grain weight	Grain Yield/plant
Giza 177 X 85040-TR 853-4-1	-15.6**	22.7**	43.6**	-0.8 ns	25.5*
Giza 182 X 85040-TR 853-4-1	-36.6**	6.6 ns	26.5**	15.2**	84.3**
Giza 177 X Giza 178	-1.0 ns	0.5 ns	5.1 ns	1.9 ns	196.3**
Giza 182 X Giza 178	-0.4 ns	-16.4**	-7.2 ns	19.9**	-12.6 ns
Giza 177 X Improved Sabramati	-29.8**	16.0**	21.6**	0.6 ns	43.5**
Giza 182 X Improved Sabramati	-20.0**	-6.4 ns	5.9 ns	0.5 ns	-18.5**
Giza 177 X IR47686-18-6-1	3.9*	18.9**	22.9**	-0.4 ns	41.0**
Giza 182 X IR47686-18-6-1	2.4 ns	46.9**	86.3**	16.6**	102.1**
Giza 177 X Millie	-3.9*	47.3**	33.3**	0.3 ns	-5.6 ns
Giza 182 X Millie	-20.4**	22.0**	36.2**	19.9**	63.0**
Giza 177 X Pecos	1.2 ns	8.6 ns	3.9 ns	1.5 ns	4.7 ns
Giza 182 X Pecos	-18.7**	3.4 ns	12.8 ns	12.6**	-28.1**
Giza 177 X TNAU 6464	-11.6**	-35.4**	-27.9**	10.8**	0.4 ns
Giza 182 X TNAU 6464	-47.1**	-45.0**	0.0 ns	12.7**	-17.7**
Giza 177 X TNAU 831358	-15.2**	0.2 ns	33.9**	4.6**	37.1**
Giza 182 X TNAU 831358	-1.0 ns	4.0 ns	15.5 ns	14.9**	0.2 ns
Giza 177 X TNAU 831399	-11.3**	9.7 ns	-2.8 ns	-1.9 ns	9.8 ns
Giza 182 X TNAU 831399	-49.8**	-36.0**	-22.9**	8.5**	-53.8**
Giza 177 X Yabni M55	1.9 ns	13.0*	15.0 ns	5.3**	16.8 ns
Giza 182 X Yabni M55	3.1 ns	42.1**	71.6	25.7**	49.3**
Giza 177 X Yen Geng 135	-0.3 ns	36.2**	38.2**	3.9**	79.7**
Giza 182 X Yen Geng 135	-31.1**	19.5**	6.3 ns	4.1**	4.2 ns
L.S.D 5%	3.0	10.9	0.4	0.9	3.7
L.S.D 1%	4.0	14.5	0.6	1.1	5.0

** : Highly significant at 1% * : significant at 5% ns : Non significant

Table 11: Estimates of percentage of heterosis over standard heterosis (SH) for grain yield and its contributing traits of studied crosses

Traits / crosses	Days to heading	Plant height	No. of Panicles/plant	Panicle length	No. of spikelets/panicle	Pollen fertility (%)
Giza 177 X 85040-TR 853-4-1	-1.8*	9.8**	-20.9*	-16.0**	0.03 ns	-20.5**
Giza 182 X 85040-TR 853-4-1	9.2**	25.0**	7.0 ns	-8.9*	12.7**	-39.7**
Giza 177 X Giza 178	0.2 ns	-17.6**	42.9**	1.7 ns	-17.2**	0.3 ns
Giza 182 X Giza 178	-0.8 ns	-15.7**	-17.9*	-0.4 ns	-32.5**	-1.5 ns
Giza 177 X Improved Sabramati	1.2 ns	20.3**	35.6**	10.8**	30.6**	-28.2**
Giza 182 X Improved Sabramati	0.2 ns	-17.2**	17.2*	-0.5 ns	-9.0*	-20.0**
Giza 177 X IR47686-18-6-1	-4.7**	17.7**	-38.5**	6.9 ns	-7.0 ns	-2.2 ns
Giza 182 X IR47686-18-6-1	7.2**	34.2**	-21.9**	20.8**	14.7**	-5.1**
Giza 177 X Millie	3.2**	15.2**	-35.5**	5.2 ns	4.3 ns	-5.6**
Giza 182 X Millie	1.2 ns	17.7**	17.5*	12.6**	1.7 ns	-23.0**
Giza 177 X Pecos	-14.7**	-5.4*	-17.9*	-19.9**	-25.5**	0.9 ns
Giza 182 X Pecos	-5.7**	2.4 ns	-16.5*	-3.0 ns	-13.7**	-19.0**
Giza 177 X TNAU 6464	1.2 ns	-12.8**	42.1**	-3.0 ns	-46.8**	-10.7**
Giza 182 X TNAU 6464	2.2**	-15.5**	56.8**	-1.3 ns	-26.0**	-46.0**
Giza 177 X TNAU 831358	5.2**	11.4**	-17.9*	2.2 ns	-17.8**	-13.2**
Giza 182 X TNAU 831358	2.2**	-18.5**	2.8 ns	-4.8 ns	-28.5**	-3.2*
Giza 177 X TNAU 831399	2.2**	23.6**	15.8 ns	5.6 ns	-20.1**	-10.0**
Giza 182 X TNAU 831399	1.2 ns	-2.0 ns	18.7*	1.2 ns	-19.8**	-48.4**
Giza 177 X Yabni M55	10.2**	1.2 ns	-13.6 ns	-9.1*	-30.4**	-0.5 ns
Giza 182 X Yabni M55	1.2 ns	-8.0**	17.2*	6.9 ns	-15.8**	-1.0 ns
Giza 177 X Yen Geng 135	4.2**	12.6**	-19.4*	-3.9 ns	18.8**	-6.6**
Giza 182 X Yen Geng 135	1.2 ns	21.3**	8.4 ns	18.7**	48.6**	-35.9**
L.S.D 5%	1.5	5.0	2.2	1.7	12.8	2.9
L.S.D 1%	2.0	6.6	2.9	2.2	16.9	3.8

Table 11: Continued

Traits / crosses	Spikelet fertility (%)	No. of filled grains / panicle	Panicle weight	1000 grain weight	Grain yield/plant
Giza 177 X 85040-TR 853-4-1	-23.3**	-23.1**	15.6*	39.8**	-9.2 ns
Giza 182 X 85040-TR 853-4-1	-43.9**	-36.7**	-10.1 ns	47.0**	64.1**
Giza 177 X Giza 178	-1.4 ns	-18.1**	-6.7 ns	21.2**	154.5**
Giza 182 X Giza 178	-3.3 ns	-34.7**	-26.4**	26.6**	-10.3 ns
Giza 177 X Improved Sabramati	-30.2**	-8.7*	1.2 ns	27.3**	50.5**
Giza 182 X Improved Sabramati	-22.5**	-29.4**	-21.9**	13.9**	-1 ns
Giza 177 X IR47686-18-6-1	-3.0 ns	-9.7*	17.8**	48.6**	-12.7 ns
Giza 182 X IR47686-18-6-1	-6.9**	6.8 ns	61.0**	58.3**	58.8**
Giza 177 X Millie	-7.5**	-3.4 ns	13.3*	35.6**	-34.0**
Giza 182 X Millie	-25.3**	-24.0**	2.8 ns	46.2**	41.2**
Giza 177 X Pecos	0.5 ns	-25.1**	-16.1*	30.1**	-21.0*
Giza 182 X Pecos	-21.3**	-32.0**	-19.6**	29.3**	-33.8**
Giza 177 X TNAU 6464	-12.9**	-53.6**	-43.3**	37.4**	-3.4 ns
Giza 182 X TNAU 6464	-49.2**	-62.3**	-30.9**	24.7**	-7.1 ns
Giza 177 X TNAU 831358	-15.0**	-30.0**	4.1 ns	31.7**	29.7**
Giza 182 X TNAU 831358	-3.3 ns	-30.8**	-21.1**	29.4**	11.6 ns
Giza 177 X TNAU 831399	-11.8**	-29.4**	-21.9**	24.1**	-2.9 ns
Giza 182 X TNAU 831399	-51.3**	-60.9**	-45.3**	22.9**	-51.4**

Giza 177 X Yabni M55	-0.8 ns	-30.8**	-22.4**	29.6**	-12.0 ns
Giza 182 X Yabni M55	-2.2 ns	-17.6**	-0.4 ns	38.0**	37.5**
Giza 177 X Yen Geng 135	-8.4**	8.9*	47.8**	55.6**	44.9**
Giza 182 X Yen Geng 135	-38.4**	-8.4*	3.6 ns	42.0**	1.4 ns
L.S.D 5%	3.5	12.6	0.5	1.0	4.3
L.S.D 1%	4.6	16.7	0.7	1.3	5.7

** : Highly significant at 1%   * : significant at 5%   ns : Non significant

Giza 182 X Pecos (-5.7%) recorded highest values. Significant desirable heterosis for this trait, also, was found by **Elixon *et al.,* (2015)** and **Nayak *et al.,* (2015)**. Concerning the **plant height**, the better-parent heterosis (BP) were not showen highly significant and significant negative values. However, for MP the hybrid Giza 182 X TNAU 831358 (-7.9%) showed highly significant negaitive heterosis. For standard heterosis data revealed that eight hybrids showed highly significant and significant negative heterosis. The highest desirable values were observed in the hybrids Giza 182 X TNAU 831358 (-18.5%) and Giza 177 X Giza 178 (-17.6%), respectively. On the other hand 22, 16 and 11 hybrids were highly significant and significant positive in BP, MP and SH heterosis respectively. These hybrids may be to useful to breed good restorer lines and widely compatible restorer lines. The hybrids showed negative values may be useful to breed good rice cultivars, maintainer lines, widely compatible CMS lines and widely compatible maintainer lines. Similar results were found by **Awad-Allah *et al.*, (2015) and Elixon *et al.,* (2015)**. Obviously more **number of productive tillers** give high grain yield. Evidently, data presented in Tables 8, 9 and 10 showed that highly significant and significant positive values in BP heterosis for the two and three hybrids. Moreover, for mid-parent heterosis, the eight hybrids showed highly significant positive values. While, for SH heterosis four and four hybrids showed highly significant and significant positive heterosis. The highest values were recorded in the hybrids Giza 177 X Giza 178 (42.9%), Giza 177 X Giza 178 (54.5%) and Giza 182 X TNAU 6464 (56.8%) for BP, MP and SH heterosis, respectively. Number of Productive tillers are an important yield component in rice. The number of panicle bearing tillers/ plant is believed to be closely associated with high grain yield/plant so, the hybrids with more number of panicle bearing tillers/plant may be identified. The variety or hybrid with low tillering capacity is not wanted in transplanted rice culture **Bhuiyan *et al.,* (2014).** Similar results were reported by **Ali *et al.,* (2014) and Elixon *et al.,* (2015).** A hybrid with longer **panicle length** is desirable, since the lengthy panicles are generally associated with higher number of spikelets per panicle resulting in higher productivity. Data in Tables 8, 9 and 10 revealed that highly significant positive heterosis over BP in seven hybrids.

However, for MP 13 and three hybrids showed highly significant and significant positive heterosis. While, for SH four hybrids showed highly significant positive heterosis. The highest values were recorded in the hybrid Giza 182 X Millie (30%, 31% and 18.47%) for BP and MP, as well as the hybrid Giza 182 X IR47686-18-6-1 (20.8%) for SH heterosis. This data suggested that the panicle length is one of the most important traits contributing to heterosis and breeders can exploit it to best advantage in hybrid rice varieties and its parental lines. These results were in agreement with those reported by **Nayak *et al.,* (2015)**. For **spikelets/panicle**, heterosis over better-parent (BP), mid-parent heterosis (MP) and standard heterosis (SH) shown in Tables 8, 9 and 10 revealed that 11, 16 and 5 hybrids showed highly significant and significant positive values in BP, MP and SH heterosis respectively. The highest values (49.5%, 70.1% and 48.6%) were recorded in the hybrids Giza 182 X 85040-TR 853-4-1, Giza 182 X Yen Geng 135 and Giza 182 X Yen Geng 135 for BP heterosis, MP heterosis and SH heterosis. The previous data agreed with the data reported by **Sanghera and Hussain (2012), Ali *et al.,* (2014)** and **Awad-Allah *et al.*, (2015)**. For **pollen fertility** the data revealed that the Better-parent heterosis (BP), mid parent heterosis and standard heterosis (SH) were not showen highly significant and significant positive values. Similar results were reported by **Awad-Allah (2011). Spikelets fertility** is one of the most important characters which directly influences grain yield potentiality in rice varieties and hybrids, as well as based on pollen and spikelet fertility we can identified restorer lines, wide compatible lines, maintainer lines and hybrids. Better-parent heterosis (BP), mid-parent heterosis (MP) and standard heterosis (SH) for spikelets fertility are presented in Tables 8, 9 and 10. The data revealed that the better-parent heterosis (BP) and standard heterosis (SH) were not showen significant positive values. While, mid parent heterosis the hybrid Giza 177 X IR47686-18-6-1 (3.9%) showed significant positive value. Similar results were reported by **Sanghera and Hussain (2012), Ali *et al.,* (2014) and Awad-Allah *et al.*, (2015). Number of filled grains/panicle** is one of the most important characters which directly influences grain yield potentiality in rice varieties and hybrids. With respect to the BP, MP and SH heterosis of the hybrids studied for number of filled grains/panicle are presented in Tables 8, 9 and 10. The data revealed highly significant and significant positive values in BP, MP and SH for five, ten and one hybrids respectively. The hybrid Giza 177 X Millie showed highest values (41.6% and 47.3%) for BP and MP, while the hybrid G 177 X Yen Geng 135 (8.9%) showed significant positive value for SH heterosis. Similar results were reported by **Ali *et al.,* (2014)** and **Elixon *et al.,* (2015).** Better-parent heterosis, mid parent heterosis and standard heterosis for **panicle weight** are shown in Table 8, 9 and 10. Data revealed that, five, ten and five hybrids showed highly significant and significant positive values in BP, MP and SH heterosis respectively. The highest values were showed in hybrids G46A X Giza 178 (69.8%) for BP, G 182 X IR47686-18-6-1 for MP (86.3%) and SH heterosis (61%). The previous data agreed with the data reported by **Awad-Allah *et al.*, (2015)**. Tables 8, 9 and 10 revealed the better-parent heterosis, mid-parent heterosis and standard heterosis for **1000-grain weight**. Data revealed that seven and 14 hybrids exhibited highly significant positive values in BP and MP heterosis, respectively. The highest values were detected in hybrid Giza 182 X Yabni M55 (24.1% and 25.7%) for BP and MP heterosis, respectively. While, the data revealed that the all hybrids showed highly significant positive standard heterosis. The highest values were observed for the hybrids Giza 182 X IR47686-18-6-1 (58.3%) and Giza 177 X Yen Geng 135 (55.6%). Moreover, 1000-grain weight is one of the most important characters which directly influences grain yield potentiality in rice varieties and hybrids. These results agreed with the results reported by **Elixon *et al.,* (2015)** and **Nayak *et al.,* (2015).** Heterosis over better-parent (BP), mid-parent heterosis (MP) and standard heterosis (SH) for **grain yield** are cited in Tables 8, 9 and 10. Data indicated that seven hybrid combinations showed highly significant and significant positive values in BP heterosis. Moreover, mid-parent heterosis data revealed, highly significant and significant positive values for ten hybrids. While, standard heterosis data revealed, highly significant positive values for eight hybrids. Out of these hybrids Giza 177 X Giza 178 showed highest values for BP (154.5%), MP (196.3%) and SH heterosis (154.5%). The previous data agreed with the data reported by **Sanghera and Hussain (2012), Elixon *et al.,* (2015)** and **Nayak *et al.,* (2015).**

REFERENCES

Ali M., M. A. K. Mian, M. A. Hossain, M. Z. Islam and M. M. Hossain (2014). Combining ability And Heterosis In Quasi Aromatic Rice (*Oryza sativa* L.). Bangladesh J. Pl. Breed. Genet., 27(1): 01-08.

Araki H., Toya K., and H. Ikehashi (1988). Role of wide compatibility genes in hybrid rice breeding. P 79-83 in Hybrid rice. Int. Rice Res. Inst., Manila, Philippines.

Awad-Allah, M.M.A. (2011). Integrated Restorer Fertility and Wide Compatibility genes for producing promising restorer lines in Rice. Ph.D. Thesis, Fac. Agric., Al-Azhar Univ., Cairo, Egypt.

Awad-Allah, M.M.A., Kotb A. Attia, A.A. El.Gohary and B. B. Mikhael (2015). Combining Ability and Gene Action of Grain Yield and Its Components for Some Parental Lines used in Hybrid Rice Production. Egypt. J. Agric. Res., 93, 2 (A):187-216.

Bhadru D., D. Lokanadha Reddy and M.S. Ramesha (2013). The Effect of Environment on Combining Ability and Heterosis in Hybrid Rice. Greener Journal of Agricultural Sciences, 3 (9) : 669-686.

Bhuiyan M. S. H.; Zahan A., H. Khatun, M. Iqbal, F. Alam, and M. R. Manir (2014). Yield performance of newly developed test crossed hybrid rice variety. Inter., J. of Agronomy and Agric., Res., (IJAAR), 5(4) : 48-54, 201 4.

Brandle, J. E., and P.B.E. McVetty (1990). Geographic diversity, parental selection, and heterosis in oilseed rape. Canadian J. of Plant Sci. 70, 935- 940.

Elixon S., R. Asfaliza, O. Othman and J. Mohd Solehin (2015). Performance and heterosis estimation on yield and yield components of several rice hybrid lines. J. Trop. Agric. and Fd. Sc. 43(1): 11 – 20.

EL-Rouby, M.M., (2009). Statistical Genetics for Plant Breeding Methods. University of Alexandria. 51-54. (Research Notes).

Guiquen, Z., L. Yonggen, Z. Hau, Y. Jinchang and L. Guifu. (1994). Genetic studies on the hybrid sterility in cultivated rice (*Oryza sativa*) IV. Genotypes for F_1 pollen sterility. *Chinese J. Genet. 21:*35-42.

Hasan M. J., M.U. Kulsum, Emran Hossain, M. Manzur Hossain, M. Mustafizur Rahman and Niaz M. Farhat Rahmat (2015). Combining ability analysis for identifying elite parents for heterotic rice hybrids. Academia Journal of Agricultural Research 3(5): 070-075.

Ikehashi H. (1991). Genetics of hybrid sterility in wide hybridization in rice (*Oryza sativa* L.). Pages 113-127 in Biotechnology in agriculture and forestry. 14. Rice. Y. S. P. Bajaj, ed. Springer-Verlag, Berlin.

Ikehashi, H. and H. Araki, (1984). Varietal screening of compatibility types revealed in F_1 fertility of distant crosses in rice. Japan J. Breed 34: 304–318

Kempthorne, O. (1957). An Introduction to Genetic Statistics. John Wiley and Sons Inc., New York, 458-471.

Koli, N. R., Chandra Prakash, S. S.Punia and B. L.Kumhar (2013). L line x tester analysis for grain yield and its contributing traits in aromatic rice (*Oryza Sativa* L.). International J. of Integrative scie. Innovation and Technology, 2 (2): 1-4.

Marathi, B., Guleria S., Mohapatra T., Parsad R., Mariappan N., Kurungara V.K., Atwal S. S., Prabhu K. V., Singh N.K., and A. K. Singh (2012). QTL analysis of novel genomic regions associated with yield and yield related traits in new plant type based recombinant inbred lines of rice (*Oryza sativa* L.). BMC Plant Biolology 12, 137.

Mather, K. and J. L. Jinks (1982). Biometrical genetics. 3rd ed. Cambridge Univ. Press, London, N.Y.

Mather, K. (1949). Biometrical Genetics. 3rd ed. Cambridge Univ. Press, London, N.Y., 158 p.

Nayak G. P., Sreedhar. M, S. Ch. Raju, and S. Vanisree (2015). Heterosis Studies Of Aromatic Lines For Yield and Grain Quality Traits In Rice. International Journal of Applied Biology and Pharmaceutical Technology, 6 (1) : 232 – 239.

Nevame, A. Y. M., R. M. Emon, T. Y. Nassirou, G. Mamadou, A. D. Samoura (2014). The more knowledge about heterotic loci is a pre-requisite for enhancing grain yield potential in distant crosses. Inter. J. of Agronomy and Agric. Res., 5 (5) : 200-215.

Panse, V. G. and P. V. Sukhatme (1954). Statistical methods for agricultural workers. ICAR, New Delhi, 227 p.

Rafii, M.Y.; M.Z. Zakiah; R. Asfaliza, M.D. Iffahhaifaa, M.A. Latif and M.A. Malek (2014). Grain Quality Performance and Heritability Estimation in Selected F_1 Rice Genotypes. Sains Malaysiana 43(1): 1–7.

Rahaman Md. A. (2016). Study of nature and magnitude of gene action in hybrid rice (Oryza sativa L.) through experiment of line x tester mating design. International Journal of Applied Research; 2(2): 405-410.

Sanghera G.S. and W. Hussain (2012). Heterosis and Combining Ability Estimates using Line x Tester Analysis to Develop Rice Hybrids for Temperate Conditions. Notulae Sci., Biol, 4(3):131-142.

Shanthi P., S.Jebaraj and S.Geetha (2011). Study on gene action for sodic tolerance traits in rice (*Oryza sativa* L.). Electronic J. of Plant Breeding, 2(1):24-30.

Shinde, D. A. and P. B. Patel (2014). Study of heterosis for improvement in aerobic rice (*Oryza sativa* L.). the bioscan 9(2): 739-743.

Singh, N. K., S. Singh, A. K. Singh, C. L Sharma., P. K Singh and O. N. Singh, (2007). Study of heterosis in rice (*Oryza sativa* L.) using line x tester mating system. Oryza, 44 (3): 260-263.

Singh, R. K. and B. D. Chaudhary (1977). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, Ludhiana, India, pp. 300.

Waza S. A., H. K. Jaiswal, T. Sravan, K. Priyanka, D. A. Bano and V. P. Rai (2015). Combining ability analysis for various yield and quality traits in rice (*Oryza sativa* L.). J. of Applied and Natural Science 7 (2): 865 – 873.

Wyanne, J. C.; D. A. Emery and P. W. Rice (1970). Combining ability estimates in (*Arachis hypogae* L.). II. Field performance of F_1 hybrids. Crop Sci. 10(6): 713-715.

التحليل الوراثي واكتشاف صفة التوافق العام في بعض التراكيب الوراثية في الأرز في مصر

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أجريت هذه الدراسة لإجراء التحليل الوراثي واكتشاف بعض السلالات لصفة التوافق العام واستخدامها في إنتاج الأرز الهجين وكذلك تقدير القدرة على الائتلاف والفعل الجيني وقوة الهجين بأنواعها الثلاثة (بالنسبة لمتوسط الآباء ولأفضل الآباء وللصنف القياسى) لصفة محصول الحبوب وبعض الصفات المرتبطة به في الأرز فى 22 هجين ناتجة من الصنف جيزة 177 وجيزة 182 وكذا إحدى عشر سلالة كملقح والآباء المكونة لها فى تجربة قطاعات كاملة العشوائية فى ثلاثة مكررات فى مزرعة مركز البحوث والتدريب فى الأرز بسخا موسمى 2012 و 2013وأظهرت نتائج تحليل التباين وجود اختلافات عالية المعنوية ومعنوية داخل مجموعات الآباء (السلالات وسلالات الكشافات) والهجن وتفاعل السلالات مع الآباء لكل الصفات. و كانت النسبة بين القدرة العامة على الائتلاف إلى القدرة الخاصة على الائتلاف أكبر من الواحد لصفات عدد الأيام حتى طرد السنابل, طول النبات, عدد الداليات فى النبات, طول الدالية, عدد السنيبلات فى الدالية، النسبة المئوية لخصوبة حبوب اللقاح, النسبة المئوية لخصوبة السنيبلات, عدد الحبوب الممتلئة فى الدالية, وزن الألف حبة، محصول الحبوب مما يدل على تفوق تأثير الفعل الجينى المضيف في توارث هذه الصفات. على العكس تماما كانت النسبة بين القدرة العامة على الائتلاف إلى القدرة الخاصة على الائتلاف أقل من الواحد لصفة وزن الدالية (السنبلة). وأظهرت الدراسة استكشاف وتعريف صفة التآلف العام والتى ترجع أهميتها إلى انه عند تهجينها مع الأصناف اليابانية أو الهندية تعطى نسبة خصوبة أعلى من أصناف الأرز العادية التى لا تحتوى على هذه الصفة على أن تكون هذه النسبة أكثر من 70 فى المائة. وأظهرت الدراسة أفضل السلالات و الكشافات ذات القدرة العامة على الائتلاف. علاوة على ذلك أظهرت النتائج أن الهجينين جيزة 177 / جيزة 178 و جيزة 177 / بيكوس كانا أفضل التراكيب الهجينة في القدرة الخاصة على الائتلاف لصفات محصول الحبوب ووزن الألف حبة وأظهرت التراكيب الهجينية قيم عالية المعنوية ومعنوية فى الثلاثة أنواع من قوة الهجين لكل الصفات تحت الدراسة فيما عدا صفتى النسبة المئوية لخصوبة حبوب اللقاح, النسبة المئوية لخصوبة السنيبلات.