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Utilization of Combining Ability and Genetic Components for Yield and its Contributing Traits of some Rice (*Oryza sativa* L.) Genotypes

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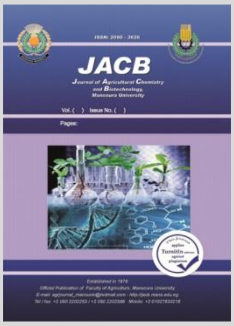

ABSTRACT

Twenty-one hybrids developed from crossing seven lines and three testers were assessed for the extent of combining ability effects, heterosis and genetic parameters for yield and related contributing traits. The analysis of variance uncovered that there were highly significant differences for all the studied traits except panicle weight among parents and parents *vs.* crosses. The two promising lines GZ 9461-4-2-3-1 and GZ 1368-S-5-4 were seen as a good general combiner among lines for most of the traits, while among the testers, the parental variety Sakha S 300 was superior. Two crosses out of hybrids, GZ 9461-4-2-3-1 / Milyang 349 and GZ 1368-S-5-4 / IR14K642 exhibited positive and highly significant SCA effects for grain yield plant^{-1}, respectively. The maximum positive and highly significant mid-parent heterosis and heterobeltiosis for grain yield plant^{-1} were observed. The five crosses GZ 1368-S-5-4 / Sakha S 300, GZ 1368-S-5-4 / IR14K642, GZ 9461-4-2-3-1 / Milyang 349, GZ 9461-4-2-3-1 / Sakha S 300 and GZ 9461-4-2-3-1 / IR14K642 recorded the highest values and maybe extensively used in rice programs by adopting a heterosis breeding strategy. The additive gene action was noticed for days to 50% flowering, plant height, flag leaf area, number of panicles plant^{-1}, panicle length, panicle weight, panicle density index, spikelets fertility, 1000-grain weight, and grain yield plant^{-1}. Grain yield plant^{-1} was highly significantly and positively correlated with plant height, flag leaf area, number of panicles plant^{-1}, panicle weight and panicle density index indicating the significance of these traits as determination criteria in yield enhancement.

Keywords: rice, combining ability, heterosis, genetic components and line x tester.

INTRODUCTON

Rice (*Oryza sativa* L.) is one of the world's significant food crops and is the staple food for the greater part of the world's population. Amazing advancement has been accomplished in rice productivity during the previous 50 years. Food security is among the greatest difficulties of the 21st century. Worldwide rice request is evaluated to ascend from 676 million tons in 2010 to 763 million tons in 2020 and further increment to 852 million tons in 2035 (Khush, 2013). Rice productivity saw an enormous increment during the green revolution stage (the late 1960s to 1970s); in any case, the gain yield slowly reached a plateau. The world rice necessity by 2050 will be 943.6 million tons, which requires a yearly increment of about 5.8 million tons from the present degree of creation (FAO, 2017). The significant objectives of agricultural research are to augment the grain quality, yield potential and stress resistance of rice developed in changing climate (Zhang, 2007 and Ghidan *et al.*, 2016). In this way, innovations should be created to accelerate the breeding process through further developed phenotyping and genotyping strategies (Mark and Peter, 2010).

As of now, there are many some high-throughput phenotyping stages to measure plant development and morphology (Sun *et al.*, 2017). These stages can be partitioned into three categories depending upon the environment: for field-based measurements, greenhouse and laboratory (Pratap *et al.*, 2015). Jones (1926) watched a checked increment in culm number and grain yield in some F_1 crosses in contrast with their parents, first reported heterosis in rice. In crop improvement, both positive and negative heterosis is helpful depending on the breeding goals. Overall, positive heterosis and negative heterosis are desired to the yield and duration (Nuruzzaman *et al.*, 2002). Among the every conceivable other option, heterosis is a significant methodology for expanding rice productivity (Duvick, 1999). Heterosis has been economically abused in rice with a yield advantage of 20-25% over the best lines (Rather *et al.*, 2001).

Heterosis is communicated in three different ways, contingent upon the criteria used to compare the performance of a hybrid (Gupta, 2000). These three different ways are mid-parent heterosis, better parent heterosis (heterobeltiosis) and standard heterosis. From a practical point of view, standard heterosis is a higher priority than the other two degrees of heterosis because it is planned for creating desirable hybrids superior to the existing better yielding commercial varieties (Chaudhary, 1984). Heterosis breeding is a significant genetic tool that can encourage yield upgrade from between 30 to 400% and improves numerous other desirable qualitative traits in crops (Srivastava, 2000). Breeding methodologies based on hybrid production require an elevated level of heterosis as well as the specific combining ability of crosses. One of the fundamental issues of plant breeders for improving

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high yielding varieties is to choose acceptable good parents and crosses. Understanding the gene action for yield and yield-related characters are essential for high yielding adjusted upland rice varieties (Dar *et al.*, 2014).

Different biometrical systems intended to analyze the genetic variability for yield traits have been created (Comstock *et al.*, 1948; Griffing, 1956; Kempthrone, 1957 and Kempthrone *et al.*, 1961). These mating designs give solid data about general combining ability and specific combining ability of the parents and hybrids. The differences in general combining ability are mainly due to additive gene action, while the differences in the specific combining ability are attributed to non-additive gene effects. Estimation of general combining ability helps the breeder to identify parents with the superior combining ability that maybe crossed to utilize heterosis (Fasahat *et al.,* 2016). In this way, the information on combining ability gives data on the nature and extent of gene effects that organize grain yield and yield traits, hence enabling the breeder to design an effective breeding method for genetic upgrading of yield and its components (Dar *et al.*, 2014). Past investigations revealed an expansion in grain yield because of ideal heterosis for traits such as number of spikelets per plant, flag leaf area and number of filling grains per panicle (Vanaja and Babu 2004).

Line x tester is helpful in choosing the proportional ability of female and male lines to deliver desirable hybrid combinations. It additionally gives data on genetic components and enables the breeder to choose appropriate strategies for development breeding programs. Data on general and specific combining ability for characters will demonstrate valuable in the determination of appropriate parents for the improvement of superior hybrids. The information on heritability and genetic advance might be useful in some promising material selection from the current population, which would be of most significance (Kempthrone, 1957). The present research work was done with the targets to evaluate combining ability dependent on mean performance, genetic components, heterosis and heterobeltiosis for some yield traits in rice. Broad and narrow-sense heritability and phenotypic correlation coefficient were estimated for all studied traits. The data got in this way will be utilized in the selection of suitable parents and choice of appropriate breeding tools to upgrade high yielding rice genotypes.

MATERIALS AND METHODS

Experimental design and parental lines:

The present investigation was conducted at the research farm of Rice Research Department, Sakha, Kafr El-Sheikh, Egypt. The experimental material consisted of ten parental lines and their twenty-one F_1 crosses according to the line x tester mating design during the 2018 and 2019 rice growing seasons. Seven Egyptian genotypes i.e., the five commercial varieties; Giza 177, Giza 178, Giza 179, Sakha 101 and Sakha 108, and the two promising lines; GZ 1368-S-5-4 and GZ 9461-4-2-3-1 used as females (lines) were crossed with three diverse genotypes i.e., Milyang 349, Sakha S 300 and IR14K642 used as males (testers). Thus, the resultant twenty-one crosses along with their parents were evaluated in a randomized block design with three replications. All the recommended package of practices was followed.

Data Collection:

Observations on vegetative and yield traits were recorded based on twenty-five plants in every genotype in every replication. Every genotype was raised in 2.5 m long single row plot, keeping 20 x 15 cm dividing. The information was recorded on randomly selected plants from every replication for different quantitative characters studied were *viz.,* days to 50% flowering (day), plant height (cm), flag leaf area (cm^2), number of panicles plant^{-1}, panicle length (cm), panicle weight (g), panicle density index, spikelets fertility (%), 1000-grain weight (g) and grain yield plant^{-1} (g). The general reference for information collection was a standard assessment system for rice (Virmani *et al.*, 1997 and Anonymous, 2002)

Statistical analysis:

The mean data of each trait was exposed to analysis of variance (ANOVA), to estimate significant differences among crosses and parents as proposed by Steel and Torrie (1980). The general combining ability (GCA) effects of the parents and the specific combining ability (SCA) effects of the hybrids were dictated by the utilization of the line x tester mating design (Kempthrone, 1957). The estimation of heterosis of an individual cross for every characteristic was resolved as the increase of the F_1 hybrid mean over either mid-parent and better parent, the deviation of F_1 from its both of the parental values was deciphered by Mather (1949) and Mather and Jink (1977) portraying a type of gene action operating for the trait control. Heterotic and combining ability effects were tested by the least significant differences (LSD) test at the 0.05 and 0.01 levels using the t-test. Correlation coefficients (r) among every considered traits were registered to utilize the SPSS statistical package according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Analysis of variance:

The presence of genetic variability is pre-essential for the selection of predominant genotypes during crop improvement programs. Therefore, the assessment of the extent of variation present in the genetic material is important to estimate the magnitude of improvement that can be achieved in breeding material for various characters. The analysis of variance uncovered highly significant differences among genotypes, crosses, lines, testers, and line x tester were observed in all studied characters. Variation among parents and parent *vs.* crosses were highly significant for most of the studied traits except panicle weight, which was non-significant as present in Table 1. The significance of line x tester for all the traits gave an immediate test, showing that non-additive variances were significant for most of these traits. The significant mean square of lines and testers showed a prevalence of additive variance for the yield and yield components (Jayasudha and Sharma, 2006). This reveals high variability among the genotypes providing abundant scope of selection for different quantitative traits. A significant variation for various quantitative traits was also reported (Bekele *et al.*, 2013; Sandhya *et al.,* 2014 and Ghidan *et al.,* 2018).

Table 1. Analysis of variance for lines, testers involving the parents of the investigated traits.

Source of variation	df	Days to 50% flowering (day)	Plant height (cm)	Flag leaf area (cm^2)	Panicles plant^{-1}	Panicle length (cm)	Panicle weight (g)	Panicle density (%)	Spikelets fertility (%)	1000-grain weight (g)	Grain yield plant^{-1} (g)
Replications	2	1.688	18.591**	0.610	2.452	1.187	0.050	0.154	5.259**	0.207	0.072
Genotype	30	343.190**	1098.252**	527.469**	278.128**	20.556**	3.588**	14.151**	1089.27**	67.049**	4821.130**
Parents	9	134.019**	144.004**	93.384**	4.848**	5.961**	0.878	2.552**	25.133**	68.755**	69.538**
Parents *vs.* Crosses	1	115.977**	11716.648**	3901.269**	3204.502**	94.149**	1.617	69.184**	8427.643**	17.118**	25272.147**
Crosses	20	448.678**	996.744**	554.118**	254.786**	23.444**	4.906**	16.618**	1201.227**	68.778**	5936.795**
Lines	6	715.889**	1261.037**	262.514**	539.545**	42.745**	3.545**	8.337**	2253.529**	65.425**	12927.569**
Testers	2	1012.206**	2416.016**	2297.019**	176.714**	43.655**	25.182**	76.803**	1199.082**	121.307**	3711.567**
Line x Tester	12	221.151**	628.053**	409.436**	125.418**	10.425**	2.208**	10.728**	675.433**	61.700**	2812.280**
Error	60	2.144	3.580	0.901	19.763	0.843	0.197	0.148	7.215	0.783	0.547

***,** Significant at 5% and 1% probability levels, respectively.**

Mean performance:

The mean performance of lines, testers, and their 21 F_1 crosses for different traits are shown in Table 2. For days to 50% flowering and plant height traits the lowest mean values are desirable. The two varieties Giza 179 and Giza 177 were recorded the lowest mean values of 91.00 and 92.33 day for 50% flowering among lines and testers. While, the most F_1 crosses desirable mean values towards the earliness were obtained from Giza 178 / Milyang 349, Giza 179 / IR14K642 and GZ 9461-4-2-3-1 / Milyang 349 which gave the lowest mean values of 90.00, 90.33 and 90.67 for 50% flowering, respectively. Regarding plant height, the three parents Milyang 349, Giza 177 and Sakha 101 recorded the lowest mean values among testers and lines with values of 85.67, 90.00 and 90.67 cm, respectively.

While, all F_1 generation had the highest mean values compared with parental lines indicated that over dominance for this trait occurred.

Concerning the flag leaf area, the parental varieties Sakha S 300, IR14K642, Giza 178 and GZ 9461-4-2-3-1 recorded the highest mean values of 41.99, 36.38, 35.71 and 32.09 cm^2, respectively. While, Sakha101 scored the lowest mean values of 24.50 cm^2. On the other side, the three crosses GZ 1368-S-5-4 / Sakha S 300, GZ 9461-4-2-3-1 / Sakha S 300 and Giza 178 / Sakha S 300 exhibited the highest mean values of 82.58, 64.71 and 59.75 cm^2, respectively. Nevertheless, the three crosses Giza 178 / Milyang 349, Giza 177 / Milyang 349 and GZ 1368-S-5-4 / Milyang 349 gave the lowest mean values of 28.09, 28.52 and 31.87 cm^2, respectively. The highest mean values for number of panicles plant^{-1} were obtained from the parents Giza177 and Milyang 349 (16.33 and 15.33 panicle), but Sakha 101 gave the lowest mean value of 11.33 panicles plant^{-1}. In the meantime, the three crosses GZ 1368-S-5-4 / IR14K642, GZ 9461-4-2-3-1 / IR14K642 and Giza 179 / Milyang 349 exhibited the highest mean values of 42.33, 41.67 and 39.00 panicles plant^{-1}, respectively. Among the parental lines, the genotypes IR14K642 and Sakha S 300 exhibited the highest mean values of 24.63 and 23.7 cm for the panicle length trait. While, Sakha 101 and Giza 177 gave the lowest mean values 19.93 and 20.43 cm for the lines. The two hybrid combinations GZ 9461-4-2-3-1 / IR14K642 and Giza 177 / IR14K642 gave the highest panicle length mean values of 29.20 and 28.37 cm, respectively.

Regarding panicle weight, the two parental varieties, Sakha S 300 and Sakha 108 recorded the highest mean values of 4.69 and 3.81g, respectively. In the meantime, the four crosses Giza 177 / Sakha S 300, Giza 179 / Sakha S 300, Sakha 108 / Sakha S 300 and Giza 178 / Sakha S 300 recorded the highest mean values of 5.50, 5.36, 5.34 and 5.08g, respectively. As for panicle density index, the parental genotypes Milyang 349 and GZ 9461-4-2-3-1exhibited the highest mean values of 7.28 and 6.91%, respectively. While, Sakha 108 exhibited the lowest mean values of 4.77%. In this concern, the three hybrid combinations Sakha 108 / Sakha S 300, GZ 1368-S-5-4 / Sakha S 300 and Giza 178 / Sakha S 300 had the highest mean values of 12.49, 11.50 and 11.33%, respectively. However, Sakha 101 / IR14K642 and Giza 178 / IR14K642 recorded lowest mean values of 4.31 and 4.60%, respectively. Regarding the spikelets fertility percentage, the two parental varieties, Giza 179 and Sakha 108 recorded the highest mean values of 95.59 and 94.97%, respectively. While, the two rice genotypes IR14K642 and Giza 177 recorded the lowest mean values of 86.75 and 87.86%, respectively. In this concern, the three crosses Giza 177 / IR14K642, Sakha 108 / Sakha S 300 and Sakha 108 / IR14K642 recorded the highest mean values of 97.09, 95.71 and 93.16%, respectively. Nevertheless, the lowest values were found in two crosses; Giza 179 / Milyang 349 and Sakha 108 / Milyang 349 with mean values of 17.89 and 43.85%.

For 1000-grain weight traits, the mean values of the parental genotypes among lines and testers showed that IR14K642, Giza 177 and Sakha S 300 exhibited the highest 1000-grain weight with the mean values of 36.80, 28.40 and 28.07g, respectively. While, the two parental varieties Sakha 101 and Sakha 108 gave the lowest mean value of 20.43 and 21.07g. In the meantime, the hybrid combination GZ 1368-S-5-4 / Milyang 349 gave the highest 1000-grain weight (36.23g), but the cross Sakha 101 / Milyang 349 gave the lowest mean value (14.27g) for the same traits. For grain yield plant^{-1}, among lines and testers, the two parents GZ 9461-4-2-3-1 and Sakha S 300 recorded the highest mean values of 51.82 and 51.09g, respectively. While, the highest mean values were observed in the six crosses GZ 9461-4-2-3-1 / Sakha S 300, Sakha 108 / Sakha S 300, GZ 1368-S-5-4 / Sakha S 300, GZ 9461-4-2-3-1 / IR14K642, GZ 1368-S-5-4 / IR14K642 and GZ 9461-4-2-3-1 / Milyang 349 with mean values ranged from 110.00 to 190.45g. Nevertheless, the crosses Giza 177 / Milyang 349 and Sakha 101 / IR14K642 gave the lowest mean values for grain yield plant^{-1}, which were 35.04, and 35.12g, respectively.

Table 2. The mean performances of lines, testers and their F_1 crosses concerning studied traits.

Genotypes	Days to 50% flowering (day)	Plant height (cm)	Flag leaf area (cm^2)	Panicles $plant^{-1}$	Panicle length (cm)	Panicle weight (g)	Panicle density (%)	Spikelets fertility (%)	1000-grain weight (g)	Grain yield $plant^{-1}$ (g)
Lines										
Giza 177	92.33	90.00	28.38	16.33	20.43	3.21	4.80	87.86	28.40	42.51
Giza 178	102.67	97.67	35.71	14.67	22.70	3.66	4.89	92.16	22.37	42.55
Giza 179	91.00	93.00	29.00	14.33	21.67	3.10	4.86	95.59	24.40	46.54
Sakha 101	111.33	90.67	24.50	11.33	19.93	2.83	5.77	92.51	20.43	44.99
Sakha 108	106.00	92.67	29.10	14.00	21.73	3.81	4.77	94.97	21.07	39.19
GZ 1368-S-5-4	104.00	103.33	26.59	14.67	21.80	2.89	5.25	93.56	24.20	40.39
GZ 9461-4-2-3-1	99.33	92.33	32.09	14.00	22.63	3.60	6.91	89.75	23.73	51.82
Testers										
Milyang 349	103.67	85.67	25.43	15.33	21.70	3.62	7.28	92.38	27.13	41.23
Sakha S 300	110.33	100.67	41.99	14.00	23.77	4.69	5.86	90.36	28.07	51.09
IR14K642	101.00	108.33	36.38	14.33	24.63	3.42	4.85	86.75	36.80	37.51
Crosses										
Giza 177 / Milyang 349	91.00	91.67	28.52	13.00	23.27	3.21	5.24	86.64	27.67	35.04
Giza 177 / Sakha S 300	106.00	116.67	54.19	18.00	26.83	5.50	9.16	80.46	31.57	73.83
Giza 177 / IR14K642	91.00	112.00	33.91	18.00	28.37	2.99	5.62	97.09	27.33	51.05
Giza 178 / Milyang 349	90.00	99.33	28.09	23.33	25.00	2.02	5.59	60.12	26.27	42.41
Giza 178 / Sakha S 300	115.00	127.33	59.75	18.00	17.67	5.08	11.33	73.27	31.60	91.37
Giza 178 / IR14K642	95.67	120.67	41.62	32.67	23.50	3.02	4.60	60.97	24.83	39.94
Giza 179 / Milyang 349	87.67	92.67	33.88	39.00	23.87	2.09	8.54	17.89	27.27	45.48
Giza 179 / Sakha S 300	117.00	140.00	46.79	23.67	20.80	5.36	8.35	60.75	30.30	96.93
Giza 179 / IR14K642	90.33	114.33	36.66	32.33	25.67	2.09	5.54	51.60	27.50	45.99
Sakha 101 / Milyang 349	121.33	124.00	39.13	25.67	24.50	1.22	6.25	52.63	14.27	43.42
Sakha 101 / Sakha S 300	115.00	117.33	36.90	23.00	25.33	4.49	7.36	66.44	28.57	65.34
Sakha 101 / IR14K642	122.67	94.67	49.96	27.33	26.73	2.95	4.31	64.17	22.77	35.12
Sakha 108 / Milyang 349	119.67	128.00	56.33	22.67	24.73	4.50	8.31	43.85	21.63	54.04
Sakha 108 / Sakha S 300	109.00	110.67	51.66	21.00	23.87	5.34	12.49	95.71	31.23	110.40
Sakha 108 / IR14K642	115.00	107.33	34.01	17.00	25.93	2.59	6.33	93.16	18.90	38.51
GZ 1368-S-5-4 / Milyang 349	96.33	127.33	31.87	16.33	21.77	3.90	5.48	83.81	36.23	78.09
GZ 1368-S-5-4 / Sakha S 300	108.33	152.67	82.58	31.67	20.37	4.77	11.50	83.20	23.57	112.14
GZ 1368-S-5-4 / IR14K642	99.00	144.67	37.50	42.33	20.70	4.21	6.70	91.12	26.67	154.55
GZ 9461-4-2-3-1 / Milyang 349	90.67	103.00	40.83	38.33	26.13	4.63	9.60	92.69	24.07	190.45
GZ 9461-4-2-3-1 / Sakha S 300	117.00	150.67	64.71	39.00	25.07	4.66	5.87	65.96	28.60	110.00
GZ 9461-4-2-3-1 / IR14K642	98.00	133.33	51.36	41.67	29.20	4.45	6.56	74.22	27.30	145.86
LSD 0.05	2.38	3.07	1.54	7.22	1.49	0.72	0.63	4.36	1.44	1.20
LSD 0.01	3.14	4.06	2.04	9.55	1.97	0.95	0.83	5.77	1.90	1.59

General Combining Ability (GCA) Effects of Parents:

The general combining ability recognizes predominant parents while specific combining ability helps in the distinguishing of good hybrid combinations that may at last lead to the improvement of hybrids (Shiva *et al.*, 2013). The general combining ability effects of some agronomic and yield traits are exhibited in Table 3. The three parental varieties Sakha 101, Sakha 108 and Sakha S 300 seems to be longer to reach days to 50% flowering while, the seven genotypes Giza 177, Giza 179, Milyang 349, Giza 178, GZ 1368-S-5-4, IR14K642 and GZ 9461-4-2-3-1 had shorter days in 50% flowering due to their negative GCA effects. The genotypes GZ 1386-S-5-4, Sakha S 300 and GZ 9461-4-2-3-1 were tall plants because they showed positive and significant GCA effects for plant height while, Giza 177, Milyang 349, Sakha 101, Sakha 108, Giza 179, Giza 178 and IR14K642 had negative GCA effects and they were short-statured plants. The four parental genotypes Sakha S 300, GZ 9461-4-2-3-1, GZ 1368-S-5-4 and Sakha 108 had a long flag leaf area while Milyang 349, Giza 177, Giza 179, IR14K642, Sakha 101 and Giza 178 with negative GCA effect exhibited short flag leaf area. The three parents GZ 9461-4-2-3-1, Giza 179, IR14K642 and GZ 1368-S-5-4 had more number of panicles $plant^{-1}$ while Giza 177, Sakha 108 and Sakha S 300 had fewer number of panicles $plant^{-1}$.

The three parental lines GZ 9461-4-2-3-1, Giza 177 and Sakha 101 exhibited the positive and significant GCA effects for panicle length among lines and by IR14K642 among testers. GZ 9461-4-2-3-1, GZ 1368-S-5-4 and Sakha 108 exhibited the significant and positive GCA effects for panicle weight among lines and Sakha S 300 among testers. The positive and significant GCA effects for the panicle density index among lines and testers were exhibited by Sakha S 300, Sakha 108 and GZ 1368-S-5-4 while, IR14K642, Sakha 101, Giza 177 and Milyang 349 had negative GCA effects. Giza 177, GZ 1368-S-5-4, GZ 9461-4-2-3-1, Sakha 108, IR14K642 and Sakha S 300 had a significant and positive GCA effect for spikelets fertility percentage while, Giza 179, Sakha 101, Milyang 349 and Giza 178 exhibited negative GCA effects. Giza 177, GZ 1368-S-5-4, Giza 179 and Giza 178 among lines and Sakha S 300 among testers exhibited the significant and positive GCA effects for 1000-grain weight. While, Sakha 101 and Sakha 108 among lines, IR14K642 and Milyang 349 among testers exhibited the significant and negative GCA effects. The significant and positive GCA effects for grain yield $plant^{-1}$ were exhibited by GZ 9461-4-2-3-1 and GZ 1368-S-5-4 among lines and by Sakha S 300 among testers.

The line GZ 9461-4-2-3-1 had the highest GCA effects for grain yield plant-^{1}, also showed significant and desirable GCA effects for spikelets fertility percentage, panicle weight, panicle length, number of panicle plant^{-1}, flag leaf area and days to 50% flowering. The line GZ 1368-S-5-4 had the highest GCA effects for grain yield plant^{-1}, also exhibited significant and desirable GCA effects for 1000-grain weight, spikelets fertility percentage, panicle density index, panicle weight, number of panicles plant^{-1}, flag leaf area and days to 50% flowering. The tester Sakha S 300 had the highest GCA effects for grain yield plant^{-1}, also revealed significant and desirable GCA effects for 1000-grain weight, spikelets fertility percentage, panicle density index, panicle weight, and flag leaf area. Previous studies also announced good general combiners for yield and its components characters in rice genotypes (Raju et al., 2014; Sathya and Jebaraj, 2015 and Devi et al., 2017).

Table 3. General combining ability (GCA) effects for related traits in rice.

Parents	Days to 50% flowering (day)	Plant height (cm)	Flag leaf area (cm^{2})	Panicles plant^{-1}	Panicle length (cm)	Panicle weight (g)	Panicle density (%)	Spikelets fertility (%)	1000-grain weight (g)	Grain yield plant^{-1} (g)
Lines										
Giza 177	-8.56**	-12.67**	-5.90**	-10.52**	1.90**	0.13	-0.70**	16.84**	2.28**	-25.74**
Giza 178	-4.33**	-3.67**	-1.62**	-2.19	-2.20**	-0.39**	-0.19	-6.44**	0.99**	-21.14**
Giza 179	-6.22**	-3.78**	-5.66**	4.81**	-0.81**	-0.58**	0.11	-27.81**	1.78**	-16.25**
Sakha 101	15.11**	-7.44**	-2.78**	-1.52	1.27**	-0.88**	-1.39**	-10.15**	-4.71**	-31.09**
Sakha 108	10.00**	-4.11**	2.56**	-6.63**	0.59	0.38*	1.68**	6.35**	-2.66**	-11.39**
GZ 1368-S-5-4	-3.33**	22.11**	5.88**	3.25*	-3.31**	0.53**	0.52**	14.82**	2.24**	35.88**
GZ 9461-4-2-3-1	-2.67**	9.56**	7.53**	12.81**	2.55**	0.81**	-0.03	6.40**	0.08	69.73**
LSD 0.05	0.97	1.26	0.63	2.95	0.61	0.29	0.26	1.78	0.59	0.49
LSD 0.01	1.28	1.66	0.83	3.90	0.81	0.39	0.34	2.35	0.78	0.65
Testers										
Milyang 349	-5.03**	-10.02**	-7.82**	-1.38	-0.07	-0.68**	-0.37**	-8.71**	-1.23**	-9.20**
Sakha S 300	7.92**	11.32**	11.88**	-1.95*	-1.40**	1.26**	2.07**	3.89**	2.77**	15.24**
IR14K642	-2.89**	-1.30**	-4.06**	3.33**	1.48**	-0.58**	-1.70**	4.82**	-1.53**	-6.04**
LSD 0.05	0.64	0.82	0.41	1.93	0.40	0.19	0.17	1.17	0.38	0.32
LSD 0.01	0.84	1.09	0.54	2.55	0.53	0.25	0.22	1.54	0.51	0.42

***,** Significant at 5% and 1% probability levels, respectively.**

Specific Combining Ability (SCA) Effects of F_1 Hybrids:

The estimates of specific combining ability effects of twenty-one rice hybrids for the studied traits are presented in Table 4. Seven crosses exhibited negative and high significant desirable SCA effects to 50% flowering. In addition, nine crosses were found to be negative and highly significant desirable SCA effects in plant height, while flag leaf area ten crosses gave highly significant and positive SCA effects. Two hybrids exhibited positive and highly significant SCA effects for a number of panicles plant^{-1}.

Table 4. Specific combining ability (SCA) effects of crosses for different studied traits in rice.

Crosses	Days to 50% flowering (day)	Plant height (cm)	Flag leaf area (cm^{2})	Panicles plant^{-1}	Panicle length (cm)	Panicle weight (g)	Panicle density (%)	Spikelets fertility (%)	1000-grain weight (g)	Grain yield plant^{-1} (g)
Giza 177 / Milyang 349	0.03	-5.10**	-2.53**	-1.95	-2.82**	-0.01	-1.07**	7.29**	0.05	-9.07**
Giza 177 / Sakha S 300	2.08*	-1.43	3.44**	3.62	2.08**	0.34	0.42	-11.49**	-0.06	5.28**
Giza 177 / IR14K642	-2.11*	6.52**	-0.91	-1.67	0.73	-0.33	0.65**	4.21**	0.01	3.79**
Giza 178 / Milyang 349	-5.19**	-6.43**	-7.24**	0.05	3.02**	-0.67**	-1.22**	4.04*	-0.07	-6.30**
Giza 178 / Sakha S 300	6.86**	0.24	4.72**	-4.71	-2.98**	0.45	2.09**	4.60**	1.26**	18.22**
Giza 178 / IR14K642	-1.67	6.19**	2.53**	4.67	-0.03	0.22	-0.87**	-8.64**	-1.20**	-11.92**
Giza 179 / Milyang 349	-5.63**	-12.98**	2.59**	8.71**	0.49^{ns}	-0.40	1.43**	-16.82**	0.15	-8.12**
Giza 179 / Sakha S 300	10.75**	13.02**	-4.20**	-6.05*	-1.24*	0.92**	-1.19**	13.45**	-0.83	18.89**
Giza 179 / IR14K642	-5.11**	-0.03	1.61**	-2.67	0.75	-0.52*	-0.24	3.37*	0.68	-10.77**
Sakha 101 / Milyang 349	6.70**	22.02**	4.96**	1.71	-0.95	-0.98**	0.64**	0.26	-6.37**	4.66**
Sakha 101 / Sakha S 300	-12.59	-5.98**	-16.97**	-0.38	1.22*	0.34	-0.68**	1.48	3.93**	2.14*
Sakha 101 / IR14K642	5.89**	-16.03**	12.02**	-1.33	-0.27	0.64*	0.04	-1.73	2.43**	-6.80**
Sakha 108 / Milyang 349	10.14**	22.68**	16.82**	3.83	-0.04	1.04**	-0.36	-25.01**	-1.05*	-4.41**
Sakha 108 / Sakha S 300	-13.48**	-15.98**	-7.55**	2.73	0.43	-0.07	1.38**	14.25**	4.54**	27.51**
Sakha 108 / IR14K642	3.33**	-6.70**	-9.27**	-6.56*	-0.39	-0.98**	-1.01**	10.77**	-3.49**	-23.10**
GZ 1368-S-5-4 / Milyang 349	0.14	-4.21**	-10.95**	-12.40**	0.89	0.29	-2.05**	6.47**	8.65**	-27.64**
GZ 1368-S-5-4 / Sakha S 300	-0.81	-0.21	20.04**	3.51	0.83	-0.79**	1.54**	-6.73**	-8.03**	-18.03**
GZ 1368-S-5-4 / IR14K642	0.67	4.41**	-9.09**	8.89**	-1.72**	0.50	0.51*	0.26	-0.62	45.66**
GZ 9461-4-2-3-1 / Milyang 349	-6.19**	-15.98**	-3.64**	0.05	-0.60	0.73**	2.63**	23.77**	-1.35**	50.88**
GZ 9461-4-2-3-1 / Sakha S 300	7.19**	10.35**	0.53	1.29	-0.33	-1.19**	-3.54**	-15.55**	-0.83	-54.01**
GZ 9461-4-2-3-1 / IR14K642	-1.00	5.63**	3.11**	-1.33	0.92	0.45	0.92**	-8.23**	2.18**	3.13**
LSD 0.05	1.68	2.17	1.09	5.11	1.06	0.51	0.44	3.09	1.02	0.85
LSD 0.01	2.22	2.87	1.44	6.75	1.39	0.67	0.58	4.08	1.34	1.12

***,** Significant at 5% and 1% probability levels, respectively.**

For panicle length, three hybrid combinations showed positive significant and highly significant SCA effects while the panicle weight trait exhibited positive and highly significant SCA effects by three hybrids. Nine crosses were found to be positive significant and highly significant SCA effects for panicle density index while, for spikelets fertility percentage, ten crosses recorded positive significant and highly significant SCA effects. For 1000-grain weight, six hybrids showed positive and highly significant SCA effects, timely, ten crosses exhibited significant and highly significant positive SCA effects in grain yield plant^{-1}.

The hybrid combination, GZ 9461-4-2-3-1 / Milyang 349 recorded the highest significant SCA effects for grain yield plant^{-1} also showed desirable and highly significant SCA effects for spikelets fertility percentage, panicle density index, panicle weight, plant height and days to 50% flowering. In addition, the four hybrids GZ 1368-S-5-4 / IR14K642, Sakha 108 / Sakha S 300, Giza 179 / Sakha S 300 and Giza 178 / Sakha S 300 were identified as specific combiners for grain yield plant^{-1} and could be utilized for breeding to exploit hybrid vigor. The high yield potential noticed in the crosses with high x low general combining ability combinations could be attributed to an interaction among positive alleles in the great combiner and negative alleles in the poor combiner (Hasan *et al.,* 2015). High SCA effects of hybrids that started from high x low general combining ability combining parents would be unfixable in subsequent generations and thus cannot be abused by pedigree selection strategy (Sathya and Jebaraj, 2015). However, these crosses would deliver desirable transgressive segregates in later generations on change of the conventional breeding methodology approaches to understand both additive and non-additive genetic effects (Chakraborty *et al.*, 2009).

Heterosis:

Heterosis is the reason for the development of harvest yield and heterozygosity, which is because of superior gene content possible in a contributed hybrid by both the parents (Mather, 1955). The heterotic responses of hybrids over mid-parent (average) and better parent (heterobeltiosis) for the ten studied traits are presented in Table 5.

For days to 50% flowering and plant height, negative heterosis were desirable, but for the rest of the studied traits, positive heterosis was desirable. It was seen that a significant positive and negative heterosis in the studied traits. None of the hybrids in this investigation had demonstrated the most extreme heterosis for all the traits. In any case, a desirable level and a significant of heterosis over mid-parent and better parent were gotten in several crosses. The negative and highly significant mid-parent heterosis and heterobeltiosis for the days of 50% flowering were found in hybrid Giza 178 / Milyang 349 (-12.76 and -12.34%, respectively). Therefore, earlier maturing crosses proposed the possibility of growing early developing lines. Comparable discoveries were additionally revealed by Rahimi *et al.,* (2010).

It had also positive significant mid-parent heterosis and heterobeltiosis for different related characters, such as plant height, all hybrid combinations were found to be positive and highly significant heterotic effects which in detected that there is not any negative heterotic for the same trait. Therefore, the dominance plays an important role in the inheritance of this trait. Similar findings were also suggested by Borah *et al.,* (2017). For the flag leaf area, the maximum significant and positive mid-parent heterosis and heterobeltiosis were exhibited in hybrid GZ 1368-S-5-4 / Sakha S 300 (140.83 and 96.67 cm^2, respectively).

In addition, 18 hybrid combinations gave positive significant and highly significant heterotic effects that varied from 4.72 to 106.59% over the respectively mid-parent. While, the better parent was found to be highly significant and positive heterotic effects in 14 hybrids varied from 3.09 to 93.57% for the same trait.

Table 5. Estimation of heterosis over mid (Mp) and better (Bp) parents for the investigated traits.

Crosses	Days to 50% flowering (day)		Plant height (cm)		Flag leaf area (cm^2)		Panicles plant^{-1}		Panicle Length (cm)	
	MP %	BP %	MP %	BP %	MP %	BP %	MP %	BP %	MP %	BP %
Giza 177 / Milyang 349	-7.14*	-1.44	4.36	7.00**	5.98**	0.47	-17.89	-20.41**	10.44**	7.22**
Giza 177 / Sakha S 300	4.61	14.80**	22.38**	29.63**	54.00**	29.05**	18.68*	10.20**	21.42**	12.90**
Giza 177 / IR14K642	-5.86	-1.44	12.94**	24.44**	4.72*	-6.79**	17.39	10.20**	25.89**	15.16**
Giza 178 / Milyang 349	-12.76**	-12.34**	8.36*	15.95**	-8.13**	-21.36**	55.56**	52.17**	12.61**	10.13**
Giza 178 / Sakha S 300	7.98*	12.01**	28.40**	30.38**	53.80**	42.31**	25.58**	22.73**	-23.96**	-25.67**
Giza 178 / IR14K642	-6.06	-5.28**	17.15**	23.55**	15.47**	14.41**	125.29**	122.73**	-0.70	-4.60**
Giza 179 / Milyang 349	-9.93**	-3.66**	3.73	8.17**	24.49**	16.84**	162.92**	154.35**	10.07**	9.98**
Giza 179 / Sakha S 300	16.23**	28.57**	44.58**	50.54**	31.82**	11.43**	67.06**	65.12**	-8.44**	-12.48**
Giza 179 / IR14K642	-5.90	-0.73	13.58**	22.94**	12.16**	0.77	125.58**	125.58**	10.87**	4.19**
Sakha 101 / Milyang 349	12.87**	17.04**	40.64**	44.75**	56.72**	53.84**	92.50**	67.39**	17.69**	12.90**
Sakha 101 / Sakha S 300	3.76	4.23**	22.65**	29.41**	11.00**	-12.11**	81.58**	64.29**	15.94**	6.59**
Sakha 101 / IR14K642	15.54**	21.45**	-4.86	4.41**	64.11**	37.31**	112.99**	90.70**	19.97**	8.53**
Sakha 108 / Milyang 349	14.15**	15.43**	43.55**	49.42**	106.59**	93.57**	54.55**	47.83**	13.89**	13.80**
Sakha 108 / Sakha S 300	0.77	2.83*	14.48**	19.42**	45.33**	23.03**	50.00**	50.00**	4.91*	0.42
Sakha 108 / IR14K642	11.11**	13.86**	6.80	15.83**	3.87	-6.52**	20.00*	18.60**	11.86**	5.28**
GZ 1368-S-5-4 / Milyang 349	-7.22*	-7.07**	34.74**	48.64**	22.54**	19.87**	8.89	6.52	0.08	-0.15
GZ 1368-S-5-4 / Sakha S 300	1.09	4.17**	49.67**	51.66**	140.83**	96.67**	120.93**	115.91**	-10.61**	-14.31**
GZ 1368-S-5-4 / IR14K642	-3.41	-1.98	36.69**	40.00**	19.11**	3.09**	191.95**	188.64**	-10.84**	-15.97**
GZ 9461-4-2-3-1 / Milyang 349	-10.67**	-8.72**	15.73**	20.23**	41.96**	27.23**	161.36**	150.00**	17.89**	15.46**
GZ 9461-4-2-3-1 / Sakha S 300	11.61**	17.79**	56.13**	63.18**	74.70**	54.12**	178.57**	178.57**	8.05**	5.47**
GZ 9461-4-2-3-1 / IR14K642	-2.16	-1.34	32.89**	44.40	50.00**	41.17**	194.12**	190.70**	23.55**	18.54**
LSD 0.05	6.18	2.38	7.99	3.07	4.01	1.54	18.77	7.22	3.88	1.49
LSD 0.01	8.17	3.14	10.56	4.06	5.29	2.04	24.80	9.55	5.12	1.97

Table 5. Continued….

Crosses	Panicle weight (g)		Panicle density (%)		Spikelets fertility (%)		1000-grain weight (g)		Grain yield plant^{-1} (g)	
	MP %	BP %	MP %	BP %	MP %	BP %	MP %	BP %	MP %	BP %
Giza 177 / Milyang 349	-6.15**	-11.42**	-13.28**	-28.07**	-3.86	-6.21**	-0.36	-2.58**	-16.32**	-17.58**
Giza 177 / Sakha S 300	39.04**	17.12**	71.77**	56.18**	-9.71	-10.96**	11.81**	11.15**	57.76**	44.52**
Giza 177 / IR14K642	-9.85**	-12.57**	16.54**	15.92**	11.21	10.51**	-16.16**	-25.72**	27.61**	20.10**
Giza 178 / Milyang 349	-44.48**	-44.76**	-8.13**	-23.25**	-34.85**	-34.92**	6.13**	-3.19**	1.23	-0.33
Giza 178 / Sakha S 300	21.76**	8.31**	110.84**	93.28**	-19.71**	-20.50**	25.31**	12.59**	95.16**	78.84**
Giza 178 / IR14K642	-14.74**	-17.50**	-5.46**	-5.81**	-31.84**	-33.85**	-16.06**	-32.52**	-0.22	-6.13**
Giza 179 / Milyang 349	-37.70**	-42.17**	40.64**	17.22**	-80.97**	-81.29**	5.82**	0.49	3.63	-2.28
Giza 179 / Sakha S 300	37.64**	14.28**	55.81**	42.45**	-34.66**	-36.45**	15.50**	7.96**	98.57**	89.73**
Giza 179 / IR14K642	-35.99**	-38.99**	14.09**	14.00**	-43.40**	-46.02**	-10.13**	-25.27**	9.44**	-1.18
Sakha 101 / Milyang 349	-62.07**	-66.21**	-4.19**	-14.17**	-43.08**	-43.12**	-40.01**	-47.42**	0.70	-3.50*
Sakha 101 / Sakha S 300	19.36**	-4.33**	26.64**	25.59**	-27.33**	-28.18**	17.80**	1.78*	36.01**	27.89**
Sakha 101 / IR14K642	-5.49**	-13.65**	-18.76**	-25.21**	-28.41**	-30.64**	-20.44**	-38.13**	-14.86**	-21.94**
Sakha 108 / Milyang 349	21.22**	18.20**	37.97**	14.15**	-53.19**	-53.83**	-10.24**	-20.27**	34.39**	31.06**
Sakha 108 / Sakha S 300	25.52**	13.71**	134.95**	113.01**	3.28	0.78	27.14**	11.28**	144.56**	116.09**
Sakha 108 / IR14K642	-28.45**	-32.11**	31.67**	30.55**	2.53	-1.91	-34.68**	-48.64**	0.42	-1.74
GZ 1368-S-5-4 / Milyang 349	19.71**	7.64**	-12.61**	-24.80**	-9.85	-10.42	41.17**	33.54**	91.34**	89.38**
GZ 1368-S-5-4 / Sakha S 300	25.80**	1.63**	106.94**	96.14**	-9.53	-11.07	-9.82**	-16.03**	145.17**	119.50**
GZ 1368-S-5-4 / IR14K642	33.54**	23.20**	32.57**	27.51**	1.07	-2.61	-12.57**	-27.54**	296.80**	282.64**
GZ 9461-4-2-3-1 / Milyang 349	28.22**	27.81**	35.35**	31.84**	1.78	0.33	-5.37**	-11.30**	309.35**	267.55**
GZ 9461-4-2-3-1 / Sakha S 300	12.34**	-0.78*	-8.12**	-15.06**	-26.75**	-27.00**	10.42**	1.90**	113.79**	112.29**
GZ 9461-4-2-3-1 / IR14K642	26.94**	23.82**	11.50**	-5.10**	-15.90**	-17.30**	-9.80**	-25.82**	226.59**	181.50**
LSD 0.05	1.87	0.72	1.63	0.63	11.34	4.36	3.74	1.44	7.08	2.72
LSD 0.01	2.47	0.95	2.15	0.83	14.99	5.77	4.94	1.90	9.35	3.60

***,** Significant at 5% and 1% probability levels, respectively.**

The hybrid GZ 9461-4-2-3-1 / IR14K642 had the positive and high significant mid-parent heterosis and heterobeltiosis effect for both number of panicles plant^{-1} (194.12 - 190.70%) and panicle length (23.55 -18.54%) traits, respectively. Highly significant and positive mid-parent heterosis and heterobeltiosis effect of panicle weight (39.04 and 27.81%) were observed in the two crosses of Giza 177 / Sakha S 300 and GZ 9461-4-2-3-1 / Milyang 349, respectively. These results are in corroborating with the findings of Tiwari *et al.,* (2011) and Bhati *et al.,* (2015).

The maximum highly significant and positive mid-parent heterosis and heterobeltiosis for the panicle density index were found in hybrid Sakha 108 / Sakha S 300 (134.95 and 113.01%, respectively). For spikelets fertility percentage, all hybrid combinations were found to be negative and highly significant for mid parent heterosis and heterobeltiosis effect which in detecting that there is not any negative heterotic for the same trait, except the cross Giza 177 / IR14K642 was found to be highly significant positive heterobeltiosis effect. Positive significant and highly significant heterosis over mid-parent and heterobeltiosis effect was observed in 1000-grain weight in seven crosses. On the contrast, 11 crosses showed negative and highly significant heterosis over mid and better parents for 1000- grain weight. These results are in agreement with the findings of Stalin *et al.,* (1999).

Heterosis for grain yield and yield components is a very important consideration in breeding programs. Yield is a complex character and ultimate aim of plant breeding. Highly significant and maximum positive heterosis as a deviation from the mid and better parents was observed in grain yield plant^{-1} in the most crosses under study. The crosses GZ 1368-S-5-4 / Sakha S 300, GZ 1368-S-5-4 / IR14K642, GZ 9461-4-2-3-1 / Milyang 349, GZ 9461-4-2-3-1 / Sakha S 300 and GZ 9461-4-2-3-1 / IR14K642 recorded the highest heterosis values over mid and better parents. Thus, at least one of these crosses may be utilized in breeding programs (Parihar and Pathak, 2008 and Reddy *et al.,* 2012).

Genetic components for studying traits:

The phenotypic and genotypic coefficients of variance can be utilized for evaluating and contrasting the nature and magnitude of variability contained for different traits in the breeding materials. Heritability in a broad sense measures the extent of heritable genetic variance to total phenotypic change, while heritability in a narrow sense represents the fixable additive genetic variance ratio to total phenotypic change. Estimates of heritability help in assessing anticipated advancement through selection (Devi *et al.,* 2017). The estimates of genetic parameters were computed for ten traits of 21 crosses and their ten parents in Table 6. Expectedly, phenotypic variance (PCV) was somewhat higher than the genotypic variance (GCV) for all the considered traits, uncovering the extremely least impact of environment on the expression of these traits and selection through phenotype alone could be effective. High estimates of the PCV and GCV were recorded for grain yield plant^{-1}, spikelets fertility, plant height, and flag leaf area showing the huge extent of selection for these traits. While, different characteristics had moderate or low PCV and GCV values demonstrating less variability and requirement for the creation of variation through a breeding program. Limbani et *al.,* (2017) and Prasad *et al.,* (2017) additionally watched close estimates of GCV and PCV for various characteristics in rice and values of PCV were marginally higher than GCV.

The non-additive (σ^2D) gene effect due to lines × testers interactions was found to be highly significant for all the traits representing the importance of specific combining ability (SCA) and non-additive gene action, the above outcomes proposed the significance of both additive and non-additive gene effects for agronomic traits.

Heritability is a valuable quantitative parameter, which finds the role of heredity and the environment, determining the expression of a trait (Allard, 1960). In the present study, high estimates of heritability in a broad sense were observed for almost traits except panicles plant^{-1}, which exhibited moderate heritability. The high estimates of direct selection parameters watched for the above characters are extensively in concurrence with prior reports in rice (Padmaja *et al.,* 2008 and Sumanth *et al.,* 2017).

The low to high estimates of direct selection parameters for the previously mentioned traits demonstrated that perfect traits with high estimates are perfect for improvement through selection in the context of materials assessed because of the presence of high genetic variability represented by high coefficients of variation and high transmissibility indicated by high heritability for them. Traits with low estimates of choice parameters showed that improving through selection in the context of present material would be difficult because of an absence of genetic variability for these characters. The most noteworthy appraisals of direct selection parameters watched for the above characters are comprehensively in concurrence with Basavaraja *et al.,* (2013).

Table 6. Genetic parameters estimates of parents and their F_1 crosses concerning studied traits.

Genetic Parameter	Days to 50% flowering (day)	Plant height (cm)	Flag leaf area (cm^2)	Panicles plant^{-1}	Panicle length (cm)	Panicle weight (g)	Panicle density (%)	Spikelets fertility (%)	1000-grain weight (g)	Grain yield plant^{-1} (g)
Phenotypic coefficient of variation (PCV)	81.07	221.34	140.85	58.35	4.38	0.94	3.83	243.65	21.27	1020.67
Genotypic coefficient of variation (GCV)	78.93	217.76	139.95	38.59	3.53	0.74	3.68	236.43	20.49	1017.86
Additive variance (σ^2 A)	5.93	9.60	3.77	3.37	0.34	0.07	0.15	13.69	0.18	81.37
Dominant variance (σ^2 D)	73.00	208.16	136.18	35.22	3.19	0.67	3.53	222.74	20.31	937.24
Broad sense heritability (h^2b.s) %	97.36	98.38	99.36	66.13	80.73	79.01	96.13	97.04	96.32	99.95
Narrow sense heritability (h^2n.s) %	7.31	4.34	2.68	5.77	7.75	7.50	4.01	5.62	0.89	7.98

Contribution of parental line and their interaction:

The corresponding contribution of lines, testers, and line × tester interaction for ten traits were displayed in Table 7. The maximum contribution of lines was recorded in grain yield plant^{-1} (65.33%) followed by a number of panicles plant^{-1} (63.53%), spikelets fertility percentage (56.28%), panicle length (54.70%), days to 50% flowering (47.87%), plant height (37.95%), 1000-grain weight (28.54%), panicle weight (21.68%), panicle density index (15.05%) and flag leaf area (14.21%). For testers, the maximum contribution was recorded for panicle weight (51.33%) followed by a panicle density index (46.22%), flag leaf area (41.45%), plant height (24.24%), days to 50% flowering (22.56%), panicle length (18.62%), 1000-grain weight (17.64%), spikelets fertility percentage (9.98%), number of panicles plant^{-1} (6.94%) and grain yield plant^{-1} (6.25%). The proportional contribution on line × tester was found maximum for 1000-grain weight (53.83%) followed by the flag leaf area (44.33%), panicle density index (38.73%), plant height (37.81%), spikelets fertility percentage (33.74%), days to 50% flowering (29.57%), number of panicles plant^{-1} (29.53%), grain yield plant^{-1} (28.42%), panicle weight (27.00%) and panicle length (26.68%).

Table 7. Contribution of lines, testers and their interaction to total variance in rice genotypes.

Contribution of genotypes	Days to 50% flowering (day)	Plant height (cm)	Flag leaf area (cm^2)	Panicles plant^{-1}	Panicle length (cm)	Panicle weight (g)	Panicle density (%)	Spikelets fertility (%)	1000-grain weight (g)	Grain yield plant^{-1} (g)
Lines	47.87	37.95	14.21	63.53	54.70	21.68	15.05	56.28	28.54	65.33
Testers	22.56	24.24	41.45	6.94	18.62	51.33	46.22	9.98	17.64	6.25
Line x Tester	29.57	37.81	44.33	29.53	26.68	27.00	38.73	33.74	53.83	28.42

Phenotypic correlation coefficient:

Complete information of the interrelationship of plant traits like grain yield with different characters is of fundamental significance to the plant breeder for improving in complex quantitative traits like grain yield for which direct choice is not a lot of compelling. Hence, investigation was attempted to decide the direction of selection and number of traits to be considered in developing grain yield. The phenotypic correlation coefficient among the ten studied traits was assessed and presented in Table 8.

Grain yield plant^{-1} was highly significantly and positively correlated with plant height, flag leaf area, number of panicles plant^{-1}, panicle weight and panicle density index indicating the importance of these traits as selection criteria in yield enhancement programs. 1000-grain weight exhibited a highly significant and positive phenotypic correlation with the panicle weight trait, also panicle density showed a significant and highly significant positive correlation with plant height, flag leaf area and panicle weight. Panicle weight and number of panicles plant-^{1} were positive significant and highly significant correlated with plant height and flag leaf area. At last, the phenotypic correlation coefficient was positive and highly significant between the flag leaf area and both days to 50% flowering and plant height. These findings were in full compatible with the past announced by Keshava *et al.,* (2011); Hammoud *et al.,* (2012) and Lakshmi *et al.,* (2014).

Table 8. Estimates of phenotypic correlation coefficients among each pair of studied traits.

Traits	Days to 50% flowering (day)	Plant height (cm)	Flag leaf area (cm^2)	Panicles $plant^{-1}$	Panicle length (cm)	Panicle weight (g)	Panicle density (%)	Spikelets fertility (%)	1000-grain weight (g)	Grain yield $plant^{-1}$ (g)
Days to 50% flowering (day)	1.00	0.340	0.461**	-0.096	-0.077	0.298	0.220	-0.106	-0.265	-0.021
Plant height (cm)		1.00	0.732**	0.560**	0.012	0.446*	0.370*	-0.235	0.180	0.580**
Flag leaf area (cm^2)			1.00	0.445*	0.071	0.588**	0.611**	-0.231	0.105	0.484**
Panicles $plant^{-1}$				1.00	0.321	0.063	0.227	-0.504	-0.038	0.640**
Panicle length (cm)					1.00	-0.126	-0.156	-0.195	-0.045	0.064
Panicle weight (g)						1.00	0.591**	0.259	0.465**	0.604**
Panicle density (%)							1.00	-0.091	0.176	0.552**
Spikelets fertility (%)								1.00	0.057	0.117
1000-grain weight (g)									1.00	0.196
Grain yield $plant^{-1}$ (g)										1.00

***,** Significant at 5% and 1% probability levels, respectively.**

CONCLUSION

From the entire study, it can be concluded that based on performance and combining ability effects three genotypes *viz*., GZ 9461-4-2-3-1, GZ 1368-S-5-4 and Sakha S 300 among the parental lines were identified as a good combiners for most of the studied traits. On the other hand, the crosses Sakha 108 / Sakha S 300, GZ 1368-S-5-4 / Sakha S 300, GZ 1368-S-5-4 / IR14K642, GZ 9461-4-2-3-1 / Milyang 349, GZ 9461-4-2-3-1 / Sakha S 300, GZ 9461-4-2-3-1 / IR14K642 exhibited positive and highly significant heterosis and heterobeltiosis effects for grain yield $plant^{-1}$ and some other studied traits. Hence, they may be extensively used in developing superior genotypes in future breeding programs.

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الإستفادة من القدرة علي الخلط والمكونات الوراثية للمحصول والصفات المساهمة لبعض التراكيب الوراثية في الأرز

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تم تقييم 21 هجين ناتج من تهجين 7 سلالات مع 3 كشافات لدراسة القدرة علي الائتلاف ، قوة الهجين و المكونات الوراثية للمحصول وبعض الصفات المتعلقة به. أظهر تحليل التباين وجود معنوية عالية لمعظم الصفات تحت الدراسة ماعدا صفة طول السنبلة بين الأباء والأباء × الهجين. أظهرت السلالتين GZ 9461-4-2-3-1 وGZ 1368-S-5-4 قدرة عامة جيدة للائتلاف بين السلالات بينما تفوق الصنف Sakha S300 بين الكشافات. كما أظهر إثنين من الهجن Milyang 349 / GZ 9461-4-2-3-1 و GZ 1368-S-5-4 / IR14K642 معنوية عالية وموجبة للقدرة الخاصة علي الائتلاف لصفة محصول النبات الفردي. كما سجلت أعلي قيمة موجبة وعالية المعنوية لقوة الهجين لمتوسط وأفضل الأبوين لصفة محصول النبات الفردي للهجن التاليه GZ 1368-S-5-4 / Sakha S 300، GZ 1368-S-5-4 / IR14K642، GZ 9461-4-2-3-1 / Milyang 349، GZ 9461-4-2-3-1 / Sakha S 300 و GZ 9461-4-2-3-1 / IR14K642 لذا يمكن إستخدام تلك التراكيب الوراثية علي نطاق واسع في برامج تربية وتحسين الأرز من خلال إعتماد إستراتيجية التربية بالتهجين. تم أيضا ملاحظة تأثير فعل الجين المضيف لكل من صفات عدد الأيام حتي 50% تزهير ، طول النبات ، مساحة الورقة العلم ، عدد السنابل لكل نبات ، طول السنبلة ، دليل كثافة السنبلة ، نسبة الخصوبة ، وزن الـ 1000 حبة ومحصول النبات الفردي بالجرام. أظهرت النتائج ايضا ان محصول النبات الفردي مرتبط بشكل إيجابي وعالي المعنوية مع صفات طول النبات ، مساحة الورقة العلم ، عدد السنابل لكل نبات ، وزن السنبلة وكثافة السنبلة والتى أشارت الي أهمية تلك الصفات المرتبطة كمعايير إنتخاب للمحصول العالي في الأرز