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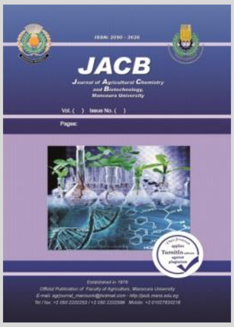
Improving Parental Lines for Hybrid Rice Development in Indica / Japonica Rice Crosses

Cross Mark

Awad-Allah, M. M. A.*

Rice Res. Dept. Field Crops Res. Inst., ARC, Egypt



ABSTRACT

The present study was done at the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, during 2016 and 2017 seasons to study combining ability, gene action and heterosis for grain yield and some agronomic traits in some lines to be utilized in hybrid rice development. The experiment comprised 30 crosses derived from six varieties/lines namely; Dular, Jip 5, O2428, Nekken 1, Giza 181 and Giza 182. A complete diallel cross set was done among these six rice parents including reciprocals. General combining ability and specific combining ability were found to be highly significant for all studied traits. This indicated the importance of both additive and non-additive genetic variances in determining inheritance of grain yield and related traits. While, highly significant reciprocal effects were detected for most studied traits indicating presence of the maternal effects in controlling of studied traits except panicle length and panicle weight for these rice crosses. The ratio of GCA/SCA was more than unity for all studied traits, indicated the preponderance of additive gene effects in the expression of these traits. Rice varieties; Dular, O2428 and Nekken 1 showed highly spikelets fertility (> 70%) when they crossed with both japonica and indica cultivars indicated that these lines can be identified as wide compatible genotypes. Moreover, the three crosses of Nekken 1 X Giza 182, Giza 181 X Giza 182 and Nekken 1 X Giza 181 were the best specific combiner for grain yield.

Keywords: complete diallel, grain yield, yield related traits, heterosis, combining Ability, wide compatibility, Rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population and has the second largest cereal production, Singh *et al*. (2015). The genetic improvement of rice is more important to meet the increasing demand for rice due to the increasing world population and ensuring sustainable agricultural development. It is obvious that the increase of the world population is main factor for reduction of the available arable land. Therefore, researchers have tried to find a genetic method that can increase yields. Heterosis exploitation is one of the main ways to reach this goal.

Heterosis is described as a prominent genetic tool that played an important role in various breeding programs to increase yields of cereal crops. Exploitation of heterosis in rice has resulted in release of many hybrids for commercial cultivation. One of the current aspects of hybrid rice breeding is exploitation of higher degree of heterosis in intervarietal crosses (indica / japonica) more than the intravarietal crosses (indica / indica, japonica / japonica and javanica / javanica). Generally crosses between japonica and indica rice show variable degrees of sterility. Previous studies indicated that the wide compatibility among when crossed between the indica and japonica type giving higher fertility in F_1 crosses. Wide compatibility (WC) is one of the majority important traits in rice which can conquer the sterility barrier in the indica / japonica crosses, Revathi *et al.* (2016). Ikehashi and Araki (1984) discovered a genetic tool, designated as wide compatibility gene (s), to conquer this hybrid sterility problem. The key to this way is to introduce widely compatible genes into the maintainer and CMS lines for improvement the widely compatible CMS lines. Additional strategies need to be deployed to breed widely compatible restorer (WCR) lines which show high heterosis and high restoration ability, and compatibility to both indica cytoplasmic male sterility (CMS) lines (WA cytoplasm) and japonica CMS lines (BT cytoplasm). Their use would enable exploiting indica / japonica heterosis and to overcome indica / japonica sterility barrier in breeding populations developed to breed rice and hybrid rice. The combining ability analysis has been the effective tool in choosing the enviable parents for hybridization programs and obtainable to appreciate the gene action effects, help in selecting the enviable parents and crosses for the exploitation of heterosis, Bhadru *et al.* (2013).

The main aim of the present study was to identify the best widely compatible (WC) lines which show high heterosis and cross combinations for high yielding ability under Egyptian conditions to utilize these genotypes for breeding new widely compatible restorer and maintainer lines. Furthermore, these lines were used in developing new parental lines of new hybrids of rice.

MATERIALS AND METHODS

The present study was done at the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, during 2016 and 2017 rice growing seasons. The experiment involved 30 crosses progenies derived from six varieties/lines. Names/origin and utilization of these genotypes studied are shown in Table 1 :

* **Corresponding author.**
E-mail address: momduhm@yahoo.com
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Table 1. Name, origin and utilization of the materials of the present study

No.	Genotype	Origin	Utilization
1	Dular	India	Indica variety, wide compatible
2	Jip 5	IRRI	Japonica variety, wide compatible
3	O2428	Japan	Japonica variety, wide compatible
4	Nekken 1	Japan	Japonica variety, wide compatible
5	Giza 181	Egypt	Indica restorer line
6	Giza 182	Egypt	Indica restorer line

At flowering time, in 2016 rice growing season, hybridization program including of possible combinations between the six parents was carried out, through a complete diallel cross set (with reciprocals) was done and 30 new crosses were resulted. The F_1 cross combinations beside their respective parents were cultivated in the nursery during the second week of May 2017. Seedlings at 30-days old for all 36 genotypes were transplanted individually in a randomized complete block design (RCBD) with three replications. Each replicate consisted of 36 genotypes, each genotype grown in one row, five meter length with 20 x 20 cm between rows/plants. The package of agronomic treatments were applied as recommended by RRTC (2011).

The data were recorded on pollen and spikelets fertility percentage. The rice genotypes showing more than 70% fertility in crosses to the indica (female) and japonica (female) were identified as WC varieties Araki *et al.* (1988) and Ikehashi (1991).

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

The studied traits were; no. of days to 50% of heading, plant height (cm), no. of panicles per plant, panicle length (cm), no. of spikelets per panicle, pollen fertility percentage, spikelets fertility percentage, no. of filled grains per panicle, panicle weight (g) and grain yield per plant (g).

Statistical analysis: The data were analyzed by using analysis of variances for RCBD as suggested by Panse and Sukhatme (1954) to test the significance of differences amid the genotypes. The genetic analysis was performed by Griffing analysis (1956) (method-1, Model-1) as a fixed model. Moreover, The steps mentioned by Singh and Chaudhary (1977) were used to estimate general combining Ability (GCA) effects for parents and Specific Combining Ability (SCA) effects as well as reciprocal effects for cross combinations.

Estimation of heterosis: Generally, the heterosis was determined as the percentage for increase or reduce in the performance of the cross over better parent (BP) and over mid-parent (MP), Mather (1949) and Mather and Jinks (1982). Suitable L.S.D. values were estimated to test the significance of the heterosis effects for better parent and mid-parent heterosis, according to Wyanne *et al.* (1970).

RESULTS AND DISCUSSION

The mean performances of the grain yield and agronomic traits of the genotypes under study are presented in Table 2. For no. of days to 50% of heading the data showed that Dular and Jip 5 were early, and number of days to 50% heading were 83.09 and 79.67 days, respectively. The three crosses; Dular X Jip 5, Jip 5 X Dular and Jip 5 X Nekken 1 were early, and number of days to 50% of heading were 83.60, 84.70 and 86.60 days, respectively. Concerning plant height, the two parents O2428 and Nekken 1 resulted the shortest plant height and showed the lowest mean values of plant height (69.77 and 71.58 cm). However, the two F_1 crosses; O2428 X Nekken 1 and Nekken 1 X O2428 gave values of 67.20 and 66.03 cm, respectively. The genotypes Giza 181 and Giza 182 showed the highest mean values of number of panicles per plant (23.98 and 21.04 respectively). While, the three crosses; Giza 182 X Giza 181, Giza 181 X Giza 182 and Giza 181 X Nekken 1 gave the highest mean values (28.80, 28.60 and 23.14, respectively). At no. of panicle per plant which is believed to be closely associated with high grain yield per plant. So, the genotypes with higher number of panicle per plant to is identified, Bhuiyan *et al.* (2014). Concerning genotypes Dular and Giza 181 gave the highest mean values of panicle length (25.76 and 24.89 cm, respectively), while the three crosses O2428 X Jip 5 , Giza 181 X Dular and Dular X Giza 181 gave the highest mean values (30.10, 30.00 and 29.53 cm, respectively). Concerning number of spikelets per panicle, the highest mean value was recorded for the parent O2428 (227.78). Meantime, the four crosses i.e., of Giza 181 X Jip 5, Jip 5 X Giza 181, Giza 182 X Jip 5 and Giza 181 X Nekken 1, gave the highest mean values of number of spikelets per panicle, with mean values of 257.90, 253.20, 249.60 and 247.73, respectively.

The mean performances of the grain yield and agronomic traits of the genotypes studied are presented in Table 2. For pollen fertility percentage, the genotypes; Giza 182 and Dular gave the highest mean values. The values were 95.63 and 95.53%, respectively. The crosses O2428 X Jip 5 (J/J), Giza 182 X O2428 (I/J), Dular X Giza 182 (I/I), Giza 182 X Dular (I/I), O2428 X Nekken 1 (J/J) and Nekken 1 X O2428 (J/J) gave the highest mean values. The values were 97.87, 96.93, 96.60, 96.50, 95.83 and 95.53%, respectively. These results agreed with those obtained by Awad-Allah (2006), Vaithiyalingan and Nadarajan (2010), Najeeb *et al.* (2013) and Awad-Allah (2016).

For spikelets fertility, the rice varieties, Dular (Indica), O2428 (Japonica), Nekken 1 (Japonica), Giza 181 (Indica) and Giza 182 (Indica) which showed highly spikelets fertility more than 70% when they were crossed with Japonica and Indica. Indicated that one of the parents of the crosses between these lines can be identified as wide compatibility these results similar with those obtained by Vaithiyalingan and Nadarajan (2010), Najeeb *et al.* (2013) and Awad-Allah (2016). Furthermore, Jip 5 (Japonica) showed highly spikelets fertility more than 70% when crossed with Japonica tester. While, some crosses showed spikelets fertility less than 70%, like Giza 182 X Jip 5 (24.53±2.66), Giza 181 X Jip 5 (25.50±2.66), Jip 5 X Giza 181 (27.63±2.66) and Jip 5 X Giza 182 (28.37±2.66) when crossed with Indica tester, this result agreed with the findings of Vaithiyalingan and Nadarajan (2010), Najeeb *et al.* (2013) and Awad-Allah (2016). Guiquen *et al.* (1994) reported that the sterility in the inter-varietal crosses of cultivated rice is caused by the allelic interaction at the F_1 pollen sterility loci.

Regarding to the mean values of spikelets fertility percentage, the genotypes; Giza 182, Dular and Jip 5 gave the highest mean values (92.60, 91.73 and 91.68%, respectively), while the crosses of O2428 X Jip 5 (J/J), Giza 182 X O2428 (I/J), Giza 182 X Dular (I/I) and Dular X Giza 182 (I/I) gave the highest mean values of the spikelet fertility (96.24, 93.56, 93.35 and 93.15%, respectively), these results agreed with those reported by Awad-Allah (2006).

Most of the crosses gave low spikelets fertility rate recorded for crosses between Indica and Japonica parents. This can be attributed to weak fertility inducing or wide compatibility genes in the parental lines. The spikelets fertility in Indica / Japonica hybrids has been explained by Ikehashi and Araki (1984) due to gamete abortion by an allelic interaction at a locus caused the hybrid sterility, which can overcome by incorporation of neutral allele Wide Compatibility Gene (WCG) into one of the parents. Two Japonica parents namely; Nekken 1 and O2428, and one Indica parent Dular included in the present study are reported to posses neutral allele $S\text{-}5^n$ normal fertile F_1 generation in combination with most of indica or Indica Japonica restorer cultivars. Hybrids between Japonica WC parent O2428 and each of Indica parents; Giza 181 and Giza 182 showed high fertility percentage. Further, the results revealed that the Indica and Indica / Japonica restorer cultivars posses gene(s) which enhance the sterility neutralizing effect of the WC gene possessing. The hybrids between each of Indica parents Giza 181 and Giza 182 and Japonica wide compatibility parent Nekken 1 which showed medium fertility of spikelets, possibly due to weak sterility neutralizing effect.

Concerning number of filled grains per panicle, O2428 cv. showed the highest mean value (192.71). The crosses Giza 181 X Dular (I/I), Dular X Giza 181 (I/I), Giza 182 X Dular (I/I) and O2428 X Jip 5 (J/J) gave the highest mean values (183.35, 181.27, 177.27 and 166.88, respectively). In addition, Giza 181, Giza 182 and Dular gave the highest mean values of panicle weight (3.63, 3.37 and 3.12, g, respectively) of the panicle weight. The crosses Dular X Giza 181 (I/I), Giza 181 X Dular (I/I), Nekken 1 X Dular (J/I), Giza 181 X Nekken 1 (I/J), O2428 X Giza 182 (J/I), Giza 182 X O2428 (I/J), Giza 181 X Giza 182 (I/I) and Giza 182 X Nekken 1 (I/J) gave the highest means of panicle weight with mean values of 4.96, 4.95, 4.77, 4.66, 4.57, 4.47, 4.44 and 4.43 g, respectively. Further, the results revealed that the genotypes; Giza 181 and Giza 182 showed the highest mean values (44.5 and 41.65, g, respectively) for grain yield/plant. Moreover, the crosses of Giza 182 X Giza 181 (I/I), Giza 181 X Giza 182 (I/I), Giza 182 X Nekken 1 (I/J), Nekken 1 X Giza 181 (J/I), Nekken 1 X Giza 182 (J/I) and Giza 181 X Nekken 1 (I/J) gave the highest mean values of the grain yield per plant. These values were 48.82, 48.64, 48.03, 44.30, 43.43 and 43.20 g, respectively.

Table 2. Mean performances for rice grain yield and agronomic traits of the studied genotypes during 2017 growing season.

Traits Genotypes	Type	Days to heading	Plant height (cm)	No. of panicles /plant	Panicle Length (cm)	No. of spikelets/ panicle
Dular	Indica	83.09	142.80	15.79	25.76	162.20
Jip 5	Japonica	79.67	117.10	10.03	19.57	110.17
O2428	Japonica	100.80	69.77	19.47	22.40	227.78
Nekken 1	Japonica	89.78	71.58	14.96	18.82	108.87
Giza 181	Indica	114.75	98.31	23.98	24.89	187.25
Giza 182	Indica	94.76	83.30	21.04	23.11	156.53
Dular X Jip 5	I/J*	83.60	140.27	10.90	23.17	163.10
Jip 5 X Dular	J/I**	84.70	107.08	18.10	22.77	199.00
Dular X O2428	I/J	94.00	122.27	10.90	26.98	175.57
O2428 X Dular	J/I	94.70	152.80	14.67	27.16	176.14
Dular X Nekken 1	I/J	87.66	131.44	22.16	26.20	160.24
Nekken 1 X Dular	J/I	87.79	128.07	21.55	25.77	163.21
Dular X Giza 181	I/I***	103.90	130.13	20.84	29.53	197.67
Giza 181 X Dular	I/I	103.83	127.74	20.02	30.00	200.79
Dular X Giza 182	I/I	89.19	125.24	20.68	26.87	175.84
Giza 182 X Dular	I/I	89.34	125.15	21.04	27.14	189.89
Jip 5 X O2428	J/J****	95.33	115.30	19.23	28.20	165.40
O2428 X Jip 5	J/J	96.80	113.75	21.27	30.10	173.40
Jip 5 X Nekken 1	J/J	86.60	118.17	19.40	20.33	106.43
Nekken 1 X Jip 5	J/J	88.10	117.33	19.83	21.13	109.20
Jip 5 X Giza 181	J/I	98.93	119.77	18.07	22.90	253.20
Giza 181 X Jip 5	I/J	100.53	118.53	19.23	22.00	257.90
Jip 5 X Giza 182	J/I	89.97	125.93	21.73	23.03	240.23
Giza 182 X Jip 5	I/J	91.57	124.17	22.00	22.67	249.60
O2428 X Nekken 1	J/J	96.17	67.20	15.70	23.37	92.64
Nekken 1 X O2428	J/J	94.80	66.03	16.00	23.60	90.87
O2428 X Giza 181	J/I	109.63	107.60	16.53	26.90	206.99
Giza 181 X O2428	I/J	108.37	109.27	17.07	25.93	200.20
O2428 X Giza 182	J/I	102.17	82.17	19.50	28.70	131.14
Giza 182 X O2428	I/J	100.70	80.00	20.37	27.80	139.83
Nekken 1 X Giza 181	J/I	113.38	115.60	22.21	23.87	231.38
Giza 181 X Nekken 1	I/J	113.00	115.14	23.14	24.05	247.73
Nekken 1 X Giza 182	J/I	96.82	98.77	21.75	20.90	190.87
Giza 182 X Nekken 1	I/J	97.33	98.65	21.22	19.56	201.24
Giza 181 X Giza 182	I/I	99.27	99.97	28.60	23.69	175.64
Giza 182 X Giza 181	I/I	98.18	99.26	28.80	23.42	172.37
L.S.D 5%		0.70	2.34	1.40	1.06	9.29
L.S.D 1%		0.93	3.11	1.85	1.41	12.33

*** I/J : Indica/Japonica, ** J/I : Japonica/Indica, ***I/I: Indica/Indica and ****J/J: Japonica/Japonica**

Table 2. Continued.

Traits Genotypes	Pollen fertility (%)	Spikelets fertility (%)	No. of filled Grains /panicle	Panicle weight (g)	Grain yield /plant (g)
Dular	95.53	91.73	148.76	3.12	27.81
Jip 5	95.10	91.68	100.99	2.40	27.52
O2428	87.47	84.60	192.71	2.83	33.53
Nekken 1	94.70	90.97	99.02	2.50	20.75
Giza 181	92.40	89.06	166.89	3.63	44.50
Giza 182	95.63	92.60	144.95	3.37	41.65
Dular X Jip 5	66.27	61.98	101.13	3.41	19.83
Jip 5 X Dular	76.30	72.56	144.44	3.43	24.40
Dular X O2428	86.17	82.24	144.43	3.58	32.93
O2428 X Dular	85.70	81.42	143.43	4.28	14.60
Dular X Nekken 1	94.23	90.64	145.27	4.07	27.14
Nekken 1 X Dular	94.53	90.86	148.22	4.77	27.81
Dular X Giza 181	94.87	91.71	181.27	4.96	40.77
Giza 181 X Dular	95.03	91.32	183.35	4.95	41.24
Dular X Giza 182	96.60	93.15	163.72	4.23	36.90
Giza 182 X Dular	96.50	93.35	177.27	4.29	37.59
Jip 5 X O2428	75.00	71.00	117.51	3.30	21.27
O2428 X Jip 5	97.87	96.24	166.88	4.02	26.81
Jip 5 X Nekken 1	75.73	71.63	76.25	2.63	22.23
Nekken 1 X Jip 5	86.20	82.20	89.77	2.93	26.83
Jip 5 X Giza 181	27.63	23.50	59.55	1.37	8.27
Giza 181 X Jip 5	25.50	21.17	54.64	1.10	8.93
Jip 5 X Giza 182	28.37	24.31	58.46	1.43	6.03
Giza 182 X Jip 5	24.53	20.27	50.66	1.80	6.46
O2428 X Nekken 1	95.83	92.10	85.32	3.57	26.37
Nekken 1 X O2428	95.53	91.89	83.50	3.87	29.18
O2428 X Giza 181	78.67	74.47	154.13	3.73	27.74
Giza 181 X O2428	79.33	74.73	149.69	3.63	32.30
O2428 X Giza 182	94.70	92.47	121.31	4.57	34.07
Giza 182 X O2428	96.93	93.56	130.87	4.47	37.31
Nekken 1 X Giza 181	73.20	69.00	159.67	4.34	44.30
Giza 181 X Nekken 1	73.00	66.20	164.01	4.66	43.20
Nekken 1 X Giza 182	75.40	71.35	136.13	4.25	43.43
Giza 182 X Nekken 1	71.67	67.79	136.57	4.43	48.03
Giza 181 X Giza 182	94.63	90.62	159.01	4.44	48.64
Giza 182 X Giza 181	94.23	89.38	153.82	4.33	48.82
L.S.D 5%	2.00	1.95	8.50	0.50	3.29
L.S.D 1%	2.66	2.59	11.29	0.66	4.37

The crosses between different subspecies (I/J and J/I) which contain one of parent as wide compatible lines showed the highest values more than the crosses of the same species (J/J and I/I), these results were agreed with those recorded by Awad-Allah (2016).

With regarded to grain yield and agronomic traits, the genotypes; Giza 182, Giza 181, O2428, Giza 182 X Giza 181, Giza 181 X Giza 182 and Giza 182 X Nekken 1, gave good desirable traits such as earliness, dwarfness, greatest number of panicles per plant, panicle length, number of spikelets per panicle, number of filled grains per panicle, panicle weight and grain yield per plant. So, some of these genotypes can be used as a source for developing new hybrid combinations as widely compatible in rice breeding programs. Yogameenakshi and Vivekanandan (2015), reported that the selection of parents is a crucial step in breeding programmes for improving new lines.

Parents with high mean values and general combining ability for yield and yield contributing characters are ideal for getting desirable segregates. Dwivedi and Pandey (2012) showed that, some crosses, specifically also exhibited high mean performance and were suggested for exploitation in the breeding program to create high-yielding pure lines by pedigree selection and/or directly for hybrid breeding. Another cross, which involves one good and other a poor combiner for grain yield, is recommended for exploitation in hybrid breeding only.

The analysis of variance for grain yield and agronomic traits, are presented in Table 3. The results revealed that the mean squares of the genotypes for all grain yield and agronomic traits showed highly significant values. These finding indicated the presence of large variations among them. Also, the results indicated that, the mean squares of the parents, parents *Vs* crosses, crosses, are showed highly significant differences. Parents *Vs*. crosses mean squares is an indication to average heterosis overall crosses. Similar results were obtained by Najeeb *et al*. (2011), Yogameenakshi and Vivekanandan (2015), Kumar *et al.* (2018) and Akanksha and Jaiswal (2019), they found that the mean squares of the genotypes for grain yield and agronomic traits showed highly significant values and the presence of large variations among them, the mean squares of the parents, parents *Vs* crosses and crosses.

Table 3. Analysis of variance and combining ability for rice grain yield and some agronomic traits for the studied genotypes during 2017 growing season.

Source of variance (SOV)	d.f	Days to heading	Plant height (cm)	No. of panicles/ plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)	Spikelets fertility (%)	No. of filled grains /panicle	Panicle weight (g)	Grain yield /plant (g)
Replications	2	0.52 ^{ns}	2.5 ^{ns}	0.8 ^{ns}	0.4^{ns}	27.8 ^{ns}	4.7 ^{ns}	0.8 ^{ns}	15.1 ^{ns}	0.2 ^{ns}	14.3 ^{ns}
Genotypes	35	234.3 **	1431.8**	50.8**	27.6**	6368.3**	1392.8**	1434.9**	4741.4**	3.2**	435**
Parents	5	491.7 **	2447.3**	74.1**	23.3**	6266.0**	30.2**	26.1**	4064.3**	0.7**	248.1**
P. *vs.* Crosses	1	112.5 **	3658.4**	73.0**	93.7**	7564.5**	3435.3**	3683.0**	3029.9**	7.8**	121.4**
Crosses	29	194.1 **	1179.9**	46.1**	26.0**	6344.7**	1557.3**	1600.3**	4917.2**	3.4**	478**
Error	70	0.25	2.8	1.0	0.6	43.4	2.0	1.9	36.3	0.1	5.4
G.C.A	5	472.2**	2153**	59.3**	35**	4495.5**	1062.2**	1079.9**	5611.1**	3.4**	478.6**
S.C.A	15	24.2**	327**	17.3**	9.4**	3381.4**	703.5**	725.9**	1652.8**	1.3**	163**
Reciprocal	15	0.6**	68.9**	2.5**	0.3 ns	73.2**	25.7**	30.2**	164.6**	0.1 ^{ns}	15.7**
Error	70	0.1	0.9	0.3	0.2	14.5	0.7	0.6	12.1	0.04	1.8
GCA / SCA		19.5	6.6	3.4	3.7	1.3	1.5	1.5	3.4	2.7	2.9

**** : Highly significant at 1%, * : Significant at 5% and ns : Non significant.**

General combining ability and specific combining ability were found to be highly significant for all traits under study. This indicated the importance of both additive and non-additive genetic variance in determining the inheritance of grain yield and agronomic traits studied. On the other side, significant reciprocal effects were detected for studied traits except panicle length and panicle weight, indicating the maternal or cytoplasmic effects in controlling grain yield and agronomic traits studied except panicle length and panicle weight in the present rice crosses, Dwivedi and Pandey (2012), Yogameenakshi and Vivekanandan (2015) and Kumar *et al.* (2018), they reported that the importance of both additive and non-additive genetic variance in determining the inheritance of grain yield and agronomic traits with dominated additive gene action.

The ratio of GCA/SCA variances were found to be greater than unity for grain yield and agronomic traits studied. This indicated importance of additive genetic variance in the inheritance of all studied characters. It could be conclude that selection procedures based on the accumulation of additive effect would be successful in improving these traits with wide compatibility and restoring ability gene's transfer. The importance of additive genetic variances have been reported by Najeeb *et al.* (2011), Kumar *et al.* (2018) and Akanksha and Jaiswal (2019).

Therefore, the selection procedures based on the accumulation of additive effect would be successful in improving grain yield and agronomic traits, Najeeb *et al.* (2011) and Awad-Allah (2016).

General combining ability (GCA) analysis is presented in Table 4. Concerning days to heading data revealed that the parents; Jip 5 (-6.5) and Dular (-5.7) gave highly significant negative values. These results indicated that these parents are believed as good combiners to develop early wide compatibility lines, widely compatible restorer lines, maintainer and restorer lines. Thus GCA estimate could help in identifying the parents which would give crosses and improve parental lines for desirable traits. These results were agreed with those obtained by Dwivedi and Pandey (2012) and Awad-Allah (2016). For plant height, the parents O2428 (-13.8), Nekken 1 (-10.2) and Giza 182 (-8.0) showed highly significant negative values of general combining ability (GCA) effects. The negative (desirable) values are indicators of reduce plant height. Therefore, those parents could be used to breed for short stature rice cultivars, widely compatible lines and maintainer lines. While, Dular gave highly significant positive value (21.2) GCA effects. The positive values are indicator of increased plant height; therefore it could be useful to breed widely compatible restorer lines. These results agreed with the results obtained by Dwivedi and Pandey (2012) and Awad-Allah (2016). For the number of panicles per plant, data indicated that the parents Giza 182 (2.9) and Giza 181 (2.5) showed highly significant positive value of GCA effects.

Concerning panicle length data revealed that the values of general combining ability effects were highly significant positive (desirable) values for the parents; Dular (1.9), O2428 (1.6) and Giza 181 (0.7), this means that these parents could help to improve of maintainer, restorer, widely compatible restorer lines in hybrid rice breeding, also identified by Awad-Allah (2006) and Awad-Allah (2016). Obviously for number of spikelets per panicle the data revealed that the highly significant positive value of GCA effects for the parents; Giza 181 (32.3) and Giza 182 (4.1). It means that these genotypes could be used as good parental lines in rice crosses. These results were agreed with the results obtained by Dwivedi and Pandey (2012).

Concerning pollen fertility percentage, data revealed that the three parents; Dular (8.9), O2428 (7.5) and Nekken 1 (4.5) recorded highly significant positive values of general combining ability (GCA) effects. It means that these genotypes could be useful as parents for breeding genotype with more fertile pollen grains per panicle for developing maintainer lines, restorer lines, widely compatible lines and widely compatible restorer lines. These results were agreed with the results recorded by Awad-Allah (2006) and Awad-Allah (2016). Regarding the spikelets fertility percentage, data revealed that the parental lines; Dular (9.0), O2428 (7.9) and Nekken 1 (4.3) showed highly significant positive values of general combining ability (GCA) effects. This means that these genotypes can be used as parents for breeding and developed promising lines with more fertile grains per panicle for developing maintainer lines, restorer lines, widely compatible lines and widely compatible restorer lines. These findings were agreed with that recorded by Dwivedi and Pandey (2012) and Awad-Allah (2016). Concerning the number of filled grains per panicles data indicated that the parents; Dular (22.1), Giza 181 (15.7) and O2428 (9.8) were identified as the best general combiners, since their estimates of general combining ability effects were highly significant positive values. These results were agreed with the results obtained by Dwivedi and Pandey (2012) and Awad-Allah (2016). For panicle weight, the data revealed that the parents Dular (0.4) and Giza 182 (0.2) showed highly significant positive values of general combining ability (GCA) effects (desirable) for panicle weight. Therefore, the former genotypes can be used in the hybrid rice breeding program and the rice breeding program as good combiners and donor for heavier panicle weight. These findings were agreed with those obtained by Awad-Allah (2016). For grain yield per plant data revealed that the parental varieties Giza 181 (5.8), Giza 182 (5.6) and Nekken 1 (1.4) showed positive highly significant and significant (desirable) values of general combining ability (GCA) effects. These genotypes appeared to be good combiners to improve yield and its attributes traits, these findings were agreed with those reported by Dwivedi and Pandey (2012).

The data showed that mean performance of the parents and their GCA effects (Table 2 and 4) revealed that none of the parents surpass for all the studied traits, this indicates that the values of multiple crosses alone lead to a significant improvement in the grain yield. Better general combiners for grain yield per plant were found to be good general combiners for some of the yield contributing traits as well. On the basis of mean performance and GCA effect, Giza 181 and Giza 182, Dular and O2428 were identified as the best parental lines for use in a hybridization to improve most of studied traits. Data indicated that the parents having higher mean performance for grain yield and some components to give higher GCA effects for the respective traits. Parental mean performance has been suggested as a useful index in rice for selecting parents for hybridization Dwivedi and Pandey (2012).

While, Verma *et al*. (2003) and Dwivedi and Pandey (2012) observed some similarities and the link between average performance and the GCA effects of quantitative traits in rice. High GCA effects mostly contributed to additive gene effects and represented a fixable portion of genetic variation. It would be useful to use these Indica and Japonica parents to develop improved lines or varieties in two rice groups. Moreover, the parents having high gene effects for particular components such as Jip 5 and Dular for earliness; O2428, Nekken 1 and Giza 182 for dwarfness; Giza 182 and Giza 181 for panicle number / plant; Dular, O2428 and Giza 181 for panicle length; Giza 181 and Giza 182 for spikelets number; Dular, O2428 and Nekken 1 for pollen fertility percentage; Dular, O2428 and Nekken 1 for spikelets fertility percentage; Dular, Giza 181 and O2428 for number of filled grains/panicles; Dular and Giza 182 for panicle weight and Giza 181, Giza 182 and Nekken 1 for grain yield/plant, may be utilized in breeding programs to improve and develop the yield and its components.

Table 4. General combining ability effects for rice grain yield and some agronomic traits during 2017 growing season.

Traits Parents	Days to heading (day)	Plant height (cm)	No. of Panicles/ plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)	Spikelet fertility \(%)	No. of filled grains/ panicle	Panicle weight (g)	Grain yield /plant (g)
Dular	-5.7**	21.2**	-1.7**	1.9**	-0.4 ^{ns}	8.9**	9.0**	22.1**	0.4**	-0.4 ^{ns}
Jip 5	-6.5**	9.4**	-1.9**	-1.6**	0.6 ^{ns}	-16.4**	-16.4**	-36.9**	-1.1**	-11.4**
O2428	3.4**	-13.8**	-1.9**	1.6**	-10.2**	7.5**	7.9**	9.8**	0.1 ^{ns}	-1.1*
Nekken 1	-1.0**	-10.2**	0.02 ^{ns}	-2.3**	-26.6**	4.5**	4.3**	-11.8**	0.1 ^{ns}	1.4*
Giza 181	10.5**	1.5**	2.5**	0.7**	32.3**	-4.1**	-4.5**	15.7**	0.2 ^{ns}	5.8**
Giza 182	-0.8**	-8.0**	2.9**	-0.3 ^{ns}	4.1**	-0.5 ^{ns}	-0.3 ^{ns}	1.1 ^{ns}	0.2*	5.6**
L.S.D 5%	0.2	0.8	0.5	0.4	3.1	0.7	0.6	2.8	0.2	1.1
1%	0.3	1.0	0.6	0.5	4.1	0.9	0.9	3.8	0.2	1.5

**** : Highly significant at 1%, * : Significant at 5% and ns : Non significant**

Specific combining ability (SCA) effects:

Specific combining ability effects for the grain yield and agronomic traits of the crosses are shown in Table 5. For no. of days to heading, data revealed that five cross combinations showed highly significant negative values of SCA effects. The highest significant negative values were shown in the cross combinations; Giza 181 X Giza 182 (-7.1), O2428 X Nekken 1 (-3.1) and Dular X Nekken 1 (-1.7), these results were agreed with those obtained by Dwivedi and Pandey (2012) and Awad-Allah (2016). As for plant height, the results showed that five crosses showed highly significant and negative values of SCA effects. The highest significant negative values were shown in the crosses; O2428 X Nekken 1 (-19.5), Dular X Jip 5 (-17.0) and O2428 X Giza 182 (-7.2). Negative values for SCA effects means reduced plant height and could be utilize to breed short stature rice lines. Whilst, the positive values of SCA effects indicated to increased plant height and could be utilize to breed restorer lines and widely compatible restorer. These findings were agreed with those obtained by Awad-Allah (2016). Concerning number of panicles per plant data indicated that five crosses gave highly significant and significant positive values. The highest significant positive values were shown in the cross combinations; Jip 5 X O2428 (4.6), Dular X Nekken 1 (4.1) and Giza 181 X Giza 182 (3.9). These results were agreed with those reported by Dwivedi and Pandey (2012) and Awad-Allah (2016). Regarding panicle length, data revealed that five crosses showed highly significant and significant positive (desirable) values of specific combining ability (SCA) effects. The highest significant positive values were shown in the crosses; Jip 5 X O2428 (4.6), Dular X Giza 181 (2.7) and O2428 X Giza 182 (2.5), these findings were in agreement with those obtained by Dwivedi and Pandey (2012) and Ali *et al.* (2014). Concerning number of spikelets per panicle, six crosses showed highly significant and significant positive values of specific combining ability (SCA) effects. The highest values were shown in the crosses; Jip 5 X Giza 182 (62.6), Nekken 1 X Giza 181 (56.2), Jip 5 X Giza 181

(45.1) and Nekken 1 X Giza 182 (41.0), These results are similar to the results obtained by Dwivedi and Pandey (2012) and Ali *et al*. (2014). Regarding pollen fertility percentage data revealed that seven crosses showed highly significant positive (desirable) values of specific combining ability effects. The highest significant positive values were shown in the cross combinations; Giza 181 X Giza 182 (18.2), Jip 5 X O2428 (14.4) and Jip 5 X Nekken 1 (12.0), these results were agreed with those obtained by Awad-Allah (2016). For spikelets fertility percentage data revealed that seven crosses combinations showed highly significant positive values of specific combining ability effects. The highest significant positive values were shown in the cross combinations; Giza 181 X Giza 182 (17.7), Jip 5 X O2428 (15.0), and Jip 5 X Nekken 1 (12.0). These genotypes appeared to be good combiners to improve rice lines and cultivars for grain yield per plant, these findings were agreed with obtained by Latha *et al*. (2013) and Awad-Allah (2016). For number of filled grains per panicle, data in Table 5 showed that six crosses recorded (desirable) highly significant or significant positive values of SCA effects. The highest significant positive values were shown in the crosses Jip 5 X O2428 (38.9), Nekken 1 X Giza 181 (27.6), Dular X Giza 182 (16.9) and Nekken 1 X Giza 182 (16.7). These positive values indicated that desirable types of non-additive effects could be present in these crosses for number of filled grains per panicle, these findings were agreed with those reported by Dwivedi and Pandey (2012), Ali *et al*. (2014) and Awad-Allah (2016).

Regarding panicle weight, five crosses showed highly significant and significant positive values of specific combining ability (SCA) effects. The highest significant positive values were shown in the crosses; Jip 5 X O2428 (0.99), Dular X Giza 181 (0.78) and Nekken 1 X Giza 181 (0.63), these results were agreed with those recorded by Hasan *et al*. (2015) and Awad-Allah (2016). As for grain yield per plant, seven crosses showed highly significant and significant positive values of specific combining ability (SCA) effects. The highest significant positive values were shown in the crosses; Nekken 1 X Giza 182 (8.4), Giza 181 X Giza 182 (7.0), Jip 5 X O2428 (6.3), Nekken 1 X Giza 181 (6.2), Dular X Giza 181 (5.3) and Jip 5 X Nekken 1 (4.3), these results were agreed with those reported by Dwivedi and Pandey (2012), Ali *et al*. (2014), Hasan *et al*. (2015) and Awad-Allah (2016). These findings indicated that the non-additive gene effects were superior in these set rice crosses for grain yield and could be attributed to the wide differences in grain yield between the included parents in these crosses. Therefore, it could be suggested that one or more of these crosses could be used in improving grain yield in rice and hybrid rice breeding program. 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 program Singh *et al.* (2007) and Shanthi *et al.* (2011). It is concluded from these results, that there is the possibility to breed good lines 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.

Table 5. Specific combining ability effects for the grain yield and some agronomic traits of the rice crosses during 2017 growing season.

Traits crosses	Days to heading (day)	Plant Height (cm)	No. of panicles/ plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)	Spikelets fertility (%)	No. of filled grains/ panicle	Panicle weight (g)	Grain yield /plant (g)
Dular X Jip 5	0.2 ^{ns}	-17.0**	-1.3 ^{ns}	-1.9**	3.3 ^{ns}	-2.1*	-2.4*	7.2 ^{ns}	0.46 ^{ns}	3.6*
Dular X O2428	0.5 ^{ns}	20.0**	-3.1**	-1.0 ^{ns}	8.9*	-11.4**	-12.1**	-18.4**	-0.24 ^{ns}	-5.0**
Dular X Nekken 1	-1.7**	8.6**	4.1**	1.9**	11.1*	0.1 ^{ns}	0.4 ns	6.1 ^{ns}	0.27 ^{ns}	-3.8*
Dular X Giza 181	3.0**	-3.9**	0.2 ^{ns}	2.7**	-10.3*	9.3**	10.0**	14.1**	0.78**	5.3**
Dular X Giza 182	-0.4 ^{ns}	1.9 ^{ns}	0.2 ^{ns}	0.9 ^{ns}	1.6 ^{ns}	7.2**	7.5**	16.9**	0.07 ^{ns}	1.7 ^{ns}
Jip 5 X O2428	3.0**	8.8**	4.6**	4.6**	1.5 ^{ns}	14.4**	15.0**	38.9**	0.99**	6.3**
Jip 5 X Nekken 1	-1.3**	8.4**	2.1**	0.1 ^{ns}	-43.8**	12.0**	12.0**	1.4 ^{ns}	0.13 ^{ns}	4.3**
Jip 5 X Giza 181	-0.3 ^{ns}	-1.9 ^{ns}	-1.3*	-1.2*	45.1**	-33.8**	-33.8**	-52.0**	-1.44**	-16.1**
Jip 5 X Giza 182	1.9**	13.5**	1.4*	0.2 ^{ns}	62.6**	-37.6**	-38.1**	-40.0**	-1.07**	-18.2**
O2428 X Nekken 1	-3.1**	-19.5**	-1.7*	-0.3 ^{ns}	-49.0**	2.8**	2.8**	-44.0**	-0.14 ^{ns}	-2.8 ^{ns}
O2428 X Giza 181	-1.0**	10.6**	-3.2**	-0.4 ^{ns}	3.9 ^{ns}	-5.3**	-5.8**	-4.0 ^{ns}	-0.20 ^{ns}	-5.0**
O2428 X Giza 182	2.7**	-7.2**	-0.5 ^{ns}	2.5**	-36.0**	7.9**	8.3**	-15.2**	0.626*	0.9 ^{ns}
Nekken 1 X Giza 181	7.6**	13.9**	0.8 ^{ns}	1.1*	56.2**	-8.2**	-9.2**	27.6**	0.631**	6.2**
Nekken 1 X Giza 182	2.7**	6.7**	-0.9 ^{ns}	-1.6**	41.0**	-11.4**	-11.5**	16.7**	0.46 ^{ns}	8.4**
Giza 181 X Giza 182	-7.1**	-4.0**	3.9**	-1.3*	-40.0**	18.2**	17.7**	9.2*	0.48*	7.0**
L.S.D 5%	0.7	2.2	1.3	1.0	8.8	1.9	1.8	8.0	0.47	3.1
L.S.D 1%	0.9	2.9	1.7	1.3	11.6	2.5	2.4	10.6	0.63	4.1

**** : Highly significant at 1%, * : Significant at 5% and ns : Non significant**

The specific combining ability effects revealed that top six crosses (Table 5) having the highest SCA effects for yield and yield contributing traits were; good x average: Nekken 1 X Giza 182 (8.4), good x good: Giza 181 X Giza 182 (7.0), poor x poor: Jip 5 X O2428 (6.3), average x good: Nekken 1 X Giza 181 (6.2), good x poor: Dular X Giza 181 (5.3), poor x average: Jip 5 X Nekken 1 (4.3). The SCA effects represent dominance, epistasis gene actions and can be used as an index to determine the interest of a specific cross combination in the exploitation of hybrids. These results were agreed with those reported by Ram *et al*. (1994) and Dwivedi and Pandey (2012). However, in self-pollinated crops, the additive x additive type of interaction component is also fixable in later generations if the crosses showing high SCA effects involved parents which are good general combiners. Such crosses are expected to through some useful transgressive segregates in the breeding program for pedigree method of selection. Moreover, if the crosses showing high SCA effects involved good x poor parents, the high potential was attributed to the interaction between positive alleles from the good combiners and negative alleles from the poor combiners. The high yield from such crosses would be non-fixable in later generations, Verma *et al*. (2003), Dwivedi and Pandey (2012). Combining ability studies indicated that crosses with significant and positive SCA effects involved parents with good x good and good x poor in F_1 diallel. Thus, it was evident from the SCA effects of crosses for grain yield / plant were attributed almost equally due to dominance and epistasis gene interaction or due to additive x additive interaction. These findings were agreed with those reported by Dwivedi and Pandey (2012).

While, Young (1987) indicated that, in majority of the crosses, the high SCA effects for grain yield were attributed to dominance and epistasis effects.

Reciprocal (maternal) effects:

Yogameenakshi and Vivekanandan (2015), reported that the bi-parental mating design or reciprocal recurrent selection can be followed which allows further recombination of alleles to produce desirable segregates. These methods can be well adopted in order to harness the epistatic interactions by way of breaking the undesirable linkages. Diallel selective mating system proposed by Jensen (1970) could be followed to break such undesirable linkages between two or more genes and to produce desirable recombinants. The reciprocal or maternal effects for grain yield and agronomic traits of F_1 crosses are shown Table 6 . For days to heading, data in Table 6 revealed that four cross combinations showed highly significant and significant negative values of reciprocal effects. The cross combinations were; Giza 181 X Jip 5 (-0.8), Giza 182 X Jip 5 (-0.8), Nekken 1 X Jip 5 (-0.75) and O2428 X Jip 5 (-0.7), these findings were agreed with those reported by Awad-Allah (2006). Concerning the reciprocal effects for another all studied traits the data reveled that all crosses showed no significant positive and negative desirable values except two cross combinations; Giza 182 X Jip 5 (1.9) and Giza 182 X Nekken 1 (1.9) for pollen fertility percentage, as well as two cross combinations; Giza 182 X Jip 5 (1.9) and Giza 182 X Nekken 1 (1.8). While, for grain yield per plant, data showed that the cross combination O2428 X Dular (9.2) gave highly significant value, these findings were agreed with those obtained by Awad-Allah (2006).

Table 6. Reciprocal effects of grain yield and some agronomic traits of the rice crosses during 2017 growing season

Traits crosses	Days to heading (day)	Plant Height (cm)	No. of panicles/ plant	Panicle length (cm)	No. of spikelets/ panicle	Pollen fertility (%)	Spikelets fertility (%)	No. of filled grains/ panicle	Panicle weight (g)	Grain yield /plant (g)
Jip 5 X Dular	-0.6 ns	16.6	-3.6**	0.2 ns	-18.0**	-5.0**	-5.3**	-21.7**	-0.01 ns	-2.3 ns
O2428 X Dular	-0.4 ns	-15.3	-1.9**	-0.1 ns	-0.3 ns	0.2 ns	0.4 ns	0.5 ns	-0.35 ns	9.2**
Nekken 1 X Dular	-0.1 ns	1.7 ns	0.3 ns	0.2 ns	-1.5 ns	-0.2 ns	-0.1 ns	-1.5 ns	-0.35 ns	-0.3 ns
Giza 181 X Dular	0.04 ns	1.2 ns	0.4 ns	-0.2 ns	-1.6 ns	-0.1 ns	0.2 ns	-1.0 ns	0.002 ns	-0.2 ns
Giza 182 X Dular	-0.1 ns	0.05 ns	-0.2 ns	-0.1 ns	-7.0 ns	0.1 ns	-0.1 ns	-6.8 ns	-0.03 ns	-0.3 ns
O2428 X Jip 5	-0.7*	0.8 ns	-1.0 ns	-0.9*	-4.0 ns	-11.4**	-12.6**	-24.7**	-0.36 ns	-2.8*
Nekken 1 X Jip 5	-0.75*	0.4 ns	-0.2 ns	-0.4 ns	-1.4 ns	-5.2**	-5.3**	-6.8 ns	-0.15 ns	-2.3 ns
Giza 181 X Jip 5	-0.8**	0.6 ns	-0.6 ns	0.5 ns	-2.4 ns	1.1 ns	1.2 ns	2.5 ns	0.13 ns	-0.3 ns
Giza 182 X Jip 5	-0.8**	0.9 ns	-0.1 ns	0.2 ns	-4.7 ns	1.9*	2.0*	3.9 ns	-0.19 ns	-0.2 ns
Nekken 1 X O2428	0.7*	0.6 ns	-0.1 ns	-0.1 ns	0.9 ns	0.1 ns	0.1 ns	0.9 ns	-0.15 ns	-1.4 ns
Giza 181 X O2428	0.6*	-0.8 ns	-0.3 ns	0.5 ns	3.4 ns	-0.3 ns	-0.1 ns	2.2 ns	0.05 ns	-2.3 ns
Giza 182 X O2428	0.7*	1.1 ns	-0.4 ns	0.4 ns	-4.3 ns	-1.1 ns	-0.5 ns	-4.8 ns	0.05 ns	-1.6 ns
Giza 181 X Nekken 1	0.2 ns	0.2 ns	-0.5 ns	-0.1 ns	-8.2*	0.1 ns	1.4 ns	-2.2 ns	-0.16 ns	0.5 ns
Giza 182 X Nekken 1	-0.3 ns	0.1 ns	0.3 ns	0.7 ns	-5.2 ns	1.9*	1.8*	-0.2 ns	-0.09 ns	-2.3 ns
Giza 182 X Giza 181	0.5 ns	0.4 ns	-0.1 ns	0.1 ns	1.6 ns	0.2 ns	0.6 ns	2.6 ns	0.06 ns	-0.1 ns
L.S.D 5%	0.6	1.9	1.1	0.9	7.6	1.6	1.6	6.9	0.41	2.7
L.S.D 1%	0.8	2.5	1.5	1.1	10.1	2.2	2.1	9.2	0.54	3.6

**** : Highly significant at 1%, * : Significant at 5% and ns : Non significant**

Estimation of heterosis effects:

Better parent heterosis (BP) and mid-parent (MP) heterosis for grain yield and agronomic traits are shown in Tables 7 and 8. For no. of days to heading, the data showed that the better parent heterosis (HB.P%) were not shown highly significant and significant negative (desirable) values. While, data confirmed that mid-parent heterosis (HM.P%), were highly significant negative for the crosses; Giza 182 X Giza 181 (-6.3%) and Giza 181 X Giza 182 (-5.2%). Significant desirable heterosis for this trait, also, was found by Awad-Allah (2016) and Yuga *et al.* (2018).

Regarding plant height, data showed that heterosis as deviation of better-parent (HBP%), were highly significant negative for the crosses Jip 5 X Dular (-8.6%) and Nekken 1 X O2428 (-5.4%). However, for HM.P% the crosses Jip 5 X Dular (-17.6%), Nekken 1 X O2428 (-6.6%) and O2428 X Nekken 1 (-4.9%) showed highly significant negaitive heterosis, respectively. On the other hand 27 and 27 crosses were highly significant positive (desirable) in HB.P% and HM.P% heterosis, respectively. These crosses may be useful to breed good restorer lines and widely compatible restorer lines. The crosses 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 and Awad-Allah (2016).

Concerning number of panicles/plant, data in Tables 7 and 8 showed that highly significant and significant positive values in HB.P% heterosis for the seven and one crosses. Furthermore, for mid-parent heterosis (HM.P%), 18 crosses showed highly significant positive values. The highest values were recorded in the crosses Dular X Nekken 1 (40.3%) and Nekken 1 X Jip 5 (58.7%) for HB.P% and HM.P% heterosis, respectively. Number of panicles per plant are an important yield component in rice. The number of panicles per plant is think to be closely associated with high grain yield per plant. So, the cross with highest number of panicles per plant may be identified, Bhuiyan *et al.* (2014). Similar results were reported by Awad-Allah (2016) and Yuga *et al.* (2018).

Table 7 . Estimates of percentage of heterosis over better parent (HB.P%) for grain yield and some agronomic traits of studied crosses.

Traits crosses	Days to heading (day)	Plant Height (cm)	No. Of panicles /plant	Panicle length (cm)	No. of spikelets/ panicle
Dular X Jip 5	4.9**	19.8**	-31**	-10.1**	0.6 ns
Jip 5 X Dular	6.3**	-8.6**	14.6**	-11.6**	22.7**
Dular X O2428	13.1**	75.3**	-44**	4.7 ns	-22.9**
O2428 X Dular	14.0**	119.0**	-24.7**	5.4*	-22.7**
Dular X Nekken 1	5.5**	83.6**	40.3**	1.7 ns	-1.2 ns
Nekken 1 X Dular	5.7**	78.9**	36.4**	0.01 ns	0.6 ns
Dular X Giza 181	25.0**	32.4**	-13.1**	14.6**	5.6 ns
Giza 181 X Dular	25.0**	29.9**	-16.5**	16.4**	7.2*
Dular X Giza 182	7.3**	50.3**	-1.7 ns	4.3 ns	8.4*
Giza 182 X Dular	7.5**	50.2**	0.02 ns	5.4*	17.1**
Jip 5 X O2428	19.7**	65.3**	-1.2 ns	25.9**	-27.4**
O2428 X Jip 5	21.5**	63**	9.2*	34.4**	-23.9**
Jip 5 X Nekken 1	8.7**	65.1**	29.7**	3.9 ns	-3.4 ns
Nekken 1 X Jip 5	10.6**	63.9**	32.6**	8.0*	-0.9 ns
Jip 5 X Giza 181	24.2**	21.8**	-24.7**	-8.0**	35.2**
Giza 181 X Jip 5	26.2**	20.6**	-19.8**	-11.6**	37.7**
Jip 5 X Giza 182	12.9**	51.2**	3.3 ns	-0.3 ns	53.5**
Giza 182 X Jip 5	14.9**	49.1**	4.6 ns	-1.9 ns	59.5**
O2428 X Nekken 1	7.1**	-3.7ns	-19.3**	4.3 ns	-59.3**
Nekken 1 X O2428	5.6**	-5.4**	-17.8**	5.4 ns	-60.1**
O2428 X Giza 181	8.8**	54.2**	-31.1**	8.1**	-9.1**
Giza 181 X O2428	7.5**	56.6**	-28.8**	4.2 ns	-12.1**
O2428 X Giza 182	7.8**	17.8**	-7.3 ns	24.2**	-42.4**
Giza 182 X O2428	6.3**	14.7**	-3.2 ns	20.3**	-38.6**
Nekken 1 X Giza 181	26.3**	61.5**	-7.4*	-4.1 ns	23.6**
Giza 181 X Nekken 1	25.9**	60.9**	-3.5 ns	-3.4 ns	32.3**
Nekken 1 X Giza 182	7.8**	38.0**	3.4 ns	-9.5**	21.9**
Giza 182 X Nekken 1	8.4**	37.8**	0.9 ns	-15.4**	28.6**
Giza 181 X Giza 182	4.8**	20.0**	19.3**	-4.8 ns	-6.2*
Giza 182 X Giza 181	3.6**	19.2**	20.1**	-5.9*	-7.9**
L.S.D 5%	0.8	2.7	1.6	1.2	10.7
L.S.D 1%	1.1	3.6	2.1	1.6	14.2

Table 7. Continued

Traits crosses	Pollen fertility (%)	Spikelets fertility (%)	No. of filled grains / panicle	Panicle weight (g)	Grain Yield /plant (g)
Dular X Jip 5	-30.6**	-32.4**	-32.0**	9.4 ns	-28.7**
Jip 5 X Dular	-20.1**	-20.9**	-2.9	10.2 ns	-12.3ns
Dular X O2428	-9.8**	-10.3**	-25.1**	14.9 ns	-1.8ns
O2428 X Dular	-10.3**	-11.2**	-25.6**	37.2**	-56.5**
Dular X Nekken 1	-1.4ns	-1.2 ns	-2.3	30.7**	-2.4ns
Nekken 1 X Dular	-1.0ns	-1.0 ns	-0.4	53.0**	0.0 ns
Dular X Giza 181	-0.7ns	-0.02 ns	8.6**	36.4**	-8.4ns
Giza 181 X Dular	-0.5ns	-0.5 ns	9.9**	36.3**	-7.3ns
Dular X Giza 182	1.0ns	0.6 ns	10.1**	25.7**	-11.4*
Giza 182 X Dular	0.9ns	0.8 ns	19.2**	27.3**	-9.7*
Jip 5 X O2428	-21.1**	-22.6**	-39.0**	16.5 ns	-36.6**
O2428 X Jip 5	2.9*	5.0**	-13.4**	41.8**	-20.0**
Jip 5 X Nekken 1	-20.4**	-21.9**	-24.5**	5.2 ns	-19.2**
Nekken 1 X Jip 5	-9.4**	-10.3**	-11.1*	17.2 ns	-2.5ns
Jip 5 X Giza 181	-70.9**	-74.4**	-64.3**	-62.4**	-81.4**
Giza 181 X Jip 5	-73.2**	-76.9**	-67.3**	-69.7**	-79.9**
Jip 5 X Giza 182	-70.3**	-73.7**	-59.7**	-57.4**	-85.5**
Giza 182 X Jip 5	-74.3**	-78.1**	-65.1**	-46.4**	-84.5**
O2428 X Nekken 1	1.2ns	1.2 ns	-55.7**	25.9*	-21.4**
Nekken 1 X O2428	0.9ns	1.0 ns	-56.7**	36.5**	-13.0*
O2428 X Giza 181	-14.9**	-16.4**	-20.0**	2.8 ns	-37.7**
Giza 181 X O2428	-14.1**	-16.1**	-22.3**	0.0 ns	-27.4**
O2428 X Giza 182	-1.0ns	-0.1 ns	-37**	35.8**	-18.2**
Giza 182 X O2428	1.4ns	1.0 ns	-32.1**	32.9**	-10.4*
Nekken 1 X Giza 181	-22.7**	-24.1**	-4.3	19.4*	-0.5ns
Giza 181 X Nekken 1	-22.9**	-27.2**	-1.7	28.3**	-2.9ns
Nekken 1 X Giza 182	-21.2**	-23.0**	-6.1	26.1**	4.3ns
Giza 182 X Nekken 1	-25.1**	-26.8**	-5.8	31.7**	15.3**
Giza 181 X Giza 182	-1.0ns	-2.1 ns	-4.7	22.3**	9.3*
Giza 182 X Giza 181	-1.5ns	-3.5**	-7.8**	19.2*	9.7*
L.S.D 5%	2.3	2.3	9.8	0.6	3.8
L.S.D 1%	3.1	3.0	13.0	0.8	5.0

**** : Highly significant at 1%, * : Significant at 5% and ns : Non significant**

A genotype with longer panicle length is favorite, since the lengthy panicles are generally associated with higher number of spikelets per panicle resulting in higher productivity. Data in Tables 7 and 8 indicated that highly significant and significant positive heterosis over HB.P% in seven and three crosses. While, for HM.P%, 20 and two crosses showed highly significant and significant positive heterosis. The highest values were recorded in the crosses O2428 X Jip 5 (34.4 and 43.4%) for HB.P% and HM.P% heterosis. This data suggested that the panicle length is one of the mainly important traits contributing to heterosis and breeders can use it to best advantage in rice promising lines, hybrid rice varieties and its parental lines. These results were agreed with those reported by Awad-Allah (2016) and Yuga *et al.* (2018).

For spikelets per panicle, heterosis over better parent (HB.P%) and mid-parent heterosis (HM.P%) shown in Tables 7 and 8 revealed that 12 and 16 crosses showed highly significant and significant positive values in HB.P% and HM.P%, respectively. The highest values (59.5 and 87.2%) were recorded in the crosses Giza 182 X Jip 5 for HB.P% and HM.P%, respectively. The previous data agreed with the data reported by Ali *et al.* (2014) and Awad-Allah (2016).

Concerning pollen fertility the data indicated that the better parent heterosis (HB.P%) were shown significant positive values (desirable) in cross O2428 X Jip 5 (2.9%). While, the mid-parent heterosis data shown highly significant positive values in five crosses. The highest values were recorded in the crosses O2428 X Jip 5 (7.2%) and Giza 182 X O2428 (5.9%). Similar results were reported by Awad-Allah (2006) and Awad-Allah (2016).

Spikelets fertility percentage is one of the main important traits which directly influences grain yield potentiality in rice varieties and hybrids, as well as based on pollen and spikelets fertility we can identified wide compatible lines, restorer lines, maintainer lines and widely compatible restorer lines. Better parent heterosis (HB.P%) and mid-parent heterosis (HM.P%) for spikelets fertility percentage are presented in Tables 7 and 8. The data revealed that the better parent heterosis (HB.P%) and mid-parent heterosis (HM.P%) were shown highly significant positive values in one and five crosses, respectively. The highest values (5.0 and 9.2%) were recorded in the crosses O2428 X Jip 5 for BP heterosis and MP heterosis respectively. Similar results were reported by Awad-Allah (2006), Ali *et al.* (2014) and Awad-Allah (2016).

Number of filled grains per panicle: is one of the main important traits which directly influences grain yield potentiality in rice varieties and hybrids. With respect to the HB.P% and HM.P% heterosis of the hybrid combinations studied for number of filled grains per panicle are presented in Tables 7 and 8. The data indicated that highly significant positive values in HB.P% and HM.P% for four and 12 crosses, respectively. The cross Giza 182 X Dular (19.2%) and Giza 181 X Nekken 1 (23.4%) showed highest values for HB.P% and HM.P%, respectively. Similar results were reported by Yuga *et al.* (2018).

Table 8. Estimates of percentage of heterosis over mid-parent (HM.P%) for grain yield and some agronomic traits of studied crosses.

Traits crosses	Days to heading (day)	Plant Height (cm)	No. of panicles/ plant	Panicle length (cm)	No. of spikelets / panicle
Dular X Jip 5	2.7**	7.9**	-15.6**	2.2 ns	19.8**
Jip 5 X Dular	4.1**	-17.6**	40.2**	0.4 ns	46.1**
Dular X O2428	2.2**	15.0**	-38.2**	12.0**	-10.0**
O2428 X Dular	3.0**	43.8**	-16.8**	12.8**	-9.7**
Dular X Nekken 1	1.4**	22.6**	44.1**	17.5**	18.2**
Nekken 1 X Dular	1.6**	19.5**	40.2**	15.6**	20.4**
Dular X Giza 181	5.0**	7.9**	4.8 ns	16.6**	13.1**
Giza 181 X Dular	5.0**	6.0**	0.7 ns	18.4**	14.9**
Dular X Giza 182	0.3ns	10.8**	12.3**	10.0**	10.3**
Giza 182 X Dular	0.5ns	10.7**	14.3**	11.1**	19.2**
Jip 5 X O2428	5.7**	23.4**	30.4**	34.4**	-2.1 ns
O2428 X Jip 5	7.3**	21.7**	44.2**	43.4**	2.6 ns
Jip 5 X Nekken 1	2.2**	25.3**	55.3**	5.9*	-2.8 ns
Nekken 1 X Jip 5	4.0**	24.4**	58.7**	10.1**	-0.3 ns
Jip 5 X Giza 181	1.8**	11.2**	6.2 ns	3.0 ns	70.3**
Giza 181 X Jip 5	3.4**	10.1**	13.1**	-1.0 ns	73.4**
Jip 5 X Giza 182	3.2**	25.7**	39.9**	7.9**	80.1**
Giza 182 X Jip 5	5.0**	23.9**	41.6**	6.2*	87.2**
O2428 X Nekken 1	0.9*	-4.9**	-8.8*	13.4**	-45.0**
Nekken 1 X O2428	-0.5ns	-6.6**	-7.0 ns	14.5**	-46.0**
O2428 X Giza 181	1.7**	28.0**	-23.9**	13.8**	-0.3 ns
Giza 181 X O2428	0.5ns	30.0**	-21.4**	9.7**	-3.5 ns
O2428 X Giza 182	4.5**	7.4**	-3.7 ns	26.1**	-31.8**
Giza 182 X O2428	3.0**	4.5**	0.6 ns	22.2**	-27.2**
Nekken 1 X Giza 181	10.9**	36.1**	14.1**	9.2**	56.3**
Giza 181 X Nekken 1	10.5**	35.6**	18.8**	10.1**	67.3**
Nekken 1 X Giza 182	4.9**	27.5**	20.9**	-0.3 ns	43.8**
Giza 182 X Nekken 1	5.5**	27.4**	17.9**	-6.7**	51.6**
Giza 181 X Giza 182	-5.2**	10.1**	27.1**	-1.3 ns	2.2 ns
Giza 182 X Giza 181	-6.3**	9.3**	28.0**	-2.4 ns	0.3 ns
L.S.D 5%	0.7	2.3	1.4	1.1	9.3
L.S.D 1%	0.9	3.1	1.9	1.4	12.3

Table 8 . Continued

Traits crosses	Pollen fertility (%)	Spikelets fertility (%)	No. of filled Grains / panicle	Panicle weight (g)	Grain Yield /plant (g)
Dular X Jip 5	-30.5**	-32.4**	-19.0**	23.6*	-28.3**
Jip 5 X Dular	-20.0**	-20.9**	15.7**	24.5**	-11.8ns
Dular X O2428	-5.8**	-6.7**	-15.4**	20.3*	7.4ns
O2428 X Dular	-6.3**	-7.7**	-16.0**	43.8**	-52.4**
Dular X Nekken 1	-0.9ns	-0.8 ns	17.3**	45.0**	11.8ns
Nekken 1 X Dular	-0.6ns	-0.5 ns	19.6**	69.8**	14.5*
Dular X Giza 181	1.0 ns	1.5 ns	14.9**	46.9**	12.8**
Giza 181 X Dular	1.1ns	1.0 ns	16.2**	46.8**	14.1**
Dular X Giza 182	1.1ns	1.1 ns	11.5**	30.6**	6.2ns
Giza 182 X Dular	1.0 ns	1.3 ns	20.7**	32.2**	8.2ns
Jip 5 X O2428	-17.8**	-19.4**	-20.0**	26.1**	-30.3**
O2428 X Jip 5	7.2**	9.2**	13.6**	53.5**	-12.2*
Jip 5 X Nekken 1	-20.2**	-21.6**	-23.8**	7.4 ns	-7.9ns
Nekken 1 X Jip 5	-9.2**	-10.0**	-10.2*	19.6 ns	11.2ns
Jip 5 X Giza 181	-70.5**	-74.0**	-55.5**	-54.7**	-77.0**
Giza 181 X Jip 5	-72.8**	-76.6**	-59.2**	-63.5**	-75.2**
Jip 5 X Giza 182	-70.3**	-73.6**	-52.5**	-50.3**	-82.6**
Giza 182 X Jip 5	-74.3**	-78.0**	-58.8**	-37.5**	-81.3**
O2428 X Nekken 1	5.2**	4.9**	-41.5**	33.7**	-2.9ns
Nekken 1 X O2428	4.9**	4.7**	-42.8**	44.9**	7.5ns
O2428 X Giza 181	-12.5**	-14.2**	-14.3**	15.5 ns	-28.9**
Giza 181 X O2428	-11.8**	-13.9**	-16.7**	12.4 ns	-17.2**
O2428 X Giza 182	3.4**	4.4**	-28.1**	47.5**	-9.4*
Giza 182 X O2428	5.9**	5.6**	-22.5**	44.3**	-0.7ns
Nekken 1 X Giza 181	-21.8**	-23.3**	20.1**	41.3**	35.8**
Giza 181 X Nekken 1	-22.0**	-26.5**	23.4**	51.9**	32.4**
Nekken 1 X Giza 182	-20.8**	-22.3**	11.6**	44.7**	39.2**
Giza 182 X Nekken 1	-24.7**	-26.1**	12.0**	51.1**	53.9**
Giza 181 X Giza 182	0.7ns	-0.2 ns	2.0 ns	27.0**	12.9**
Giza 182 X Giza 181	0.2ns	-1.6 ns	-1.3 ns	23.7**	13.3**
L.S.D 5%	2	1.9	8.5	0.5	3.3
L.S.D 1%	2.7	2.6	11.3	0.7	4.4

**** : Highly significant at 1%, * : Significant at 5% and ns : Non significant**

Better parent heterosis and mid-parent heterosis for panicle weight are cited in Table 7 and 8. Data showed that, 18 and 22 crosses gave highly significant and significant positive values in HB.P% and HM.P%, respectively. The highest values were showed in cross Nekken 1 X Dular (53%) for HB.P% and Nekken 1 X Dular for HM.P% (69.8%). The previous data agreed with the data obtained by Awad-Allah (2006) and Awad-Allah (2016).

Heterosis over better parent (HB.P%) and mid-parent heterosis (HM.P%) for grain yield are shown in Tables 7 and 8. Data revealed that three crosses showed highly significant and significant positive values in HB.P%. Moreover, mid-parent heterosis data revealed, highly significant and significant positive values for nine crosses combinations. Out of these crosses Giza 182 X Nekken 1 showed highest values for HB.P% (15.3%) and HM.P% (53.9%). The previous results agreed with the results reported by Yuga *et al.* (2018).

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تحسين السلالات الأبوية لإنتاج الأرز الهجين باستخدام هجن الأرز اليابانية / الهندية

ممدوح محمد أحمد إبراهيم عوض الله
قسم بحوث الأرز- معهد بحوث المحاصيل الحقلية - مركز البحوث الزراعية

أجريت هذه الدراسة لإجراء التحليل الوراثي وكذلك تقدير القدرة على الائتلاف وطبيعة الفعل الجيني وقوة الهجين بنوعيها (بالنسبة لمتوسط الآباء ولأفضل الآباء) لصفة محصول الحبوب وبعض الصفات المرتبطة به في الأرز في ٣٠ هجين ناتجة من ستة أصناف من الأرز وهى دولار وجب ٥ و أو٢٤٢٨ و نيكين ١ و جيزة ١٨١ وجيزة ١٨٢ كآباء وتم التهجين الدوري الكامل بينها شاملة الهجن العكسية وذلك في تجربة قطاعات كاملة العشوائية في ثلاثة مكررات في مزرعة محطة البحوث الزراعية بسخا في موسمي زراعة ٢٠١٦ و ٢٠١٧ وأظهرت نتائج تحليل التباين وجود اختلافات عالية المعنوية داخل التراكيب الوراثية والآباء مقابل الهجن والآباء والهجن لكل الصفات. على الجانب الآخر أظهر التأثير العكسي (الأموي) للهجن وجود اختلافات عالية المعنوية مما يدل على تأثير الوراثة الأمية في توارث هذه الصفات في الهجن تحت الدراسة ما عدا صفتي طول الدالية ووزن الدالية. و كانت النسبة بين القدرة العامة على الائتلاف إلى القدرة الخاصة على الائتلاف أكبر من الواحد لكل الصفات المدروسة وهى عدد الأيام حتى طرد الداليات, طول النبات, عدد الداليات في النبات, طول الدالية, عدد السنيبلات في الدالية، النسبة المئوية لخصوبة حبوب اللقاح, النسبة المئوية لخصوبة السنيبلات, عدد الحبوب الممتلئة في الدالية, وزن الدالية ، محصول الحبوب للنبات مما يدل على تفوق تأثير الفعل الجيني المضيف في توارث هذه الصفات. أظهرت الدراسة أن أصناف الأرز دولار و أو ٢٤٢٨ و نيكين ١ عند تهجينها مع الأصناف اليابانية أو الهندية تعطى نسبة خصوبة أعلى من أصناف الأرز العادية التي لا تحتوى على هذه الصفة على أن تكون هذه النسبة أكثر من ٧٠ فى المائة وبهذا نستطيع تعريفها أنها تحتوى على صفة التوافق العام بينما الصنف جيب ٥ لم يمكن تعريفه لصفة التوافق العام نظرا لأنه أعطى نسبة خصوبة بالسنيبلات أقل من ٧٠ % . علاوة على ذلك أظهرت الدراسة أن الهجن الثلاثة نيكين ١ X جيزة ١٨٢ و جيزة ١٨١ X جيزة ١٨٢ و نيكين ١ X جيزة ١٨١ كانت أفضل الهجن من حيث القدرة الخاصة على الائتلاف لصفة محصول الحبوب مما يعنى إمكانية استخدام هذه الهجن في تحسين وتربية سلالات جديدة من الأرز تعطى قوة هجين أكبر ومحصول حبوب أعلي.