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Assessment of Combining ability for some Grain Yield and Quality Traits in Rice *(Oryza sativa L.)* by using Griffing Method and Biplot Analysis

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ABSTRACT

During 2017 growing season, half diallel crosses were made among six genotypes of rice. The obtained 15 F_1 and their parents were evaluated during 2018 growing season to analyze the general combining ability (GCA) and specific combining ability (SCA). For all studied characters, the mean squares due to GCA and SCA were highly significant, indicating the importance of the behaviour of both additive and dominance gene in the heredity of these characters. Variances due to GCA were greater than these due to SCA for all studied traits, except milling and grain elongation. Giza 178 and Giza179 possessed highly significant GCA effects for earliness, panicle length, number of filled grains panicle^{-1}, grain yield plant^{-1} and hulling. IET1444 was good combiner for cooking traits, beside panicle length and number of tillers plant^{-1}. Seven crosses viz., Giza178xIET1444, Sakha 106x Giza 179, Sakha 105x Giza 179, IET1444x WAB880-SG, Giza178xGiza179, Sakha105xSakha106, and Sakha105xGiza178 evidence positive and significant SCA effects for grain yield plant^{-1}. The cross, Sakha 105xGiza179 recorded significant SCA effect in favourable direction for seven traits viz., days to 50%heading, panicle length, number of filled grains/panicles, grain yield plant^{-1}, milling, grain elongation, and amylose content. Sakha105x Sakha106 rice hybrid showed desirable either negative or positive directions and significant SCA effects for days to 50%heading, plant height, grain yield plant^{-1}, gelatinization temperature and grain elongation. Concerning results obtained by biplot analysis, found agreement between two methods of griffing and biplot for analyzing the half-diallel in determining the best parents and hybrids.

Keywords: Rice, heterosis, half diallel analysis, Biplot, grain yield and quality traits.

INTRODUCTION

Rice *(Oryza sativa* L.*)* is one of the most important food for all stages of human life and more than one-half of the world's population is relies on rice (Bouman, 2007). Rice is the second major field crop after wheat in Egypt. It plays an important role in sustaining the food self-sufficiency and for export development. The area cultivated annually by rice in Egypt is about 0.6 million ha^{-1} until 2017 and decreased to 0.32 million ha^{-1} in 2018, all under irrigation ecosystem. by 2030, the world population is expected to reach 8 billion and rice production must be increased by 50 percent to meet rising world demand (Khush and Brar 2002and Fageria, 2007).

Next to yield, breeding rice genotypes with preferred grain quality characteristics has become the second most important goal. In order to enhance high yield potential genotypes of better or good quality, knowledge about the type of parents to be used for crossing purpose is needed (Allahgolipour *et al*., 2015).

Combining ability analysis provides an important method for selecting of preferred parents and providing the request information concerning the nature of gene action regulating desired trait (Sprague and Tatum,1942; Sarker *et al*., 2002 and Rashid *et al*., 2007). Plant breeders Generally use Griffin's (Griffing1956) half diallel model to gain knowledge of genetic effects, general combining ability estimates (GCA), specific combining ability (SCA) and variance components (Yadav and Srivastava, 2002 and Goral *et al.* 2006). It also provides information on the inheritance of important traits, identification of promising heterotic combinations, and heterotic trends based on the total variance partitioning into GCA and SCA (Bertoia *et al.*, 2006).

GCA is correlated with the parents in half diallel evaluation and SCA with the hybrids. A new GGE biplot model was developed by Yan and Hunt (2002) to analyze the diallel data to obtain a combination of parent ability and interrelationships based on graphical presentation using PC1 and PC2 obtained from PC analysis of environment-centred yield data.

The main objective of this study was to assess combining ability for agronomic, yield, yield components and rice grain quality traits to recognize the most desirable genotypes for rice breeding program and analyze diallel data using GGE biplot model to collect information about genetic interrelationships among parents and correspondence of heterotic combinations for high grain yield.

MATERIALS AND METHODS

This investigation was conducted at the experimental farm of Rice Research Department, Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during the two rice growing seasons; 2017 and 2018. Six diverse rice genotypes were used as parents in this study (Table 1). These genotypes prove a wide range of their characters due to their different genetic background, origin, pedigree and types.

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Table 1. Characterization of the six rice genotypes used in the present study.

No.	Parents	Origin	Pedigree	Type
1	Sakha 105	Egypt	(GZ 5581-46-3/GZ 4316-7-1-1)	Japonica
2	Sakha 106	Egypt	Giza 177/Hexi 30	Japonica
3	Giza 178	Egypt	Giza175/ Milyang 49	Indica/ Japonica
4	Giza 179	Egypt	(GZ 6296-12/GZ1368-5-S-4)	Indica/ Japonica
5	IET 1444	India	(TN 1 X CO 29)	Indica
6	WAB880_SG	Africa Rice	(WAB 56-50/CG 14)	Indica/ Japonica

In the summer season of 2017, the six parental genotypes in this research were shown in three sowing dates, at 15 days intervals to overcome the difference of heading date among the parental genotypes. Three rows, five meters long and 20 x 20 cm apart between plants and rows were transplanted to the experimental field after 30 days of the seedling by the parents. Among the six parents, a half diallel cross was carried out in the growing season of 2017 to produce 15 crosses. The hybridization method of Jodon (1938) and modified by Butany (1961), the emasculation method of hot water, was used. In a Randomized Complete Block Design (RCBD) experiment with three replications in the 2018 growing season, the six parental genotypes and the resulting 15 crosses were estimated. For each genotype used, 25 individual plants were included in each replication contained. The data was obtained as follows:

Agronomic traits; Days to 50% heading(day), as an average between number of days for the first flowering plant to the 50% flowering, plant height (cm), panicle length (cm) and number of tillers/plants, were measured at complete heading stage.

Grain yield and its component characters: The plants were individually harvested and threshed separately to determine; number of panicles plant-1, number of filled grains/panicles, 100-grain weight (g) and grain yield plant-1(g).

Milling recovery and cooking quality characters: Hulling (%), milling (%), head rice (%), gelatinization temperature (G.T), grain elongation (%) and amylose content (%).

All this characters according to the standard evaluation system for rice, (RRTC, 2016). All required cultural practices were followed in order to obtain normal crop growth.

Statistical analysis

To (Griffing, 1956), method-2, model-1 data was analyzed. This is a fixed model which was found most acceptable as its all requirements were met by the experiment. Variances due to general and specific combining ability were evaluated.

Bi plot analysis

The average data was presented using Yan's GGE biplot program for graphical analysis. Mean and stability of genotypes referred to GCA and SCA of parents, respectively in GGE biplot (Yan and Hunt 2002). The results obtained from GGE biplot analysis were showed ATC polygon view to test GCA, SCA, and heterotic combinations. The findings were seen in the ATC polygon view according to the average tester position, which is a virtual tester (i.e., PC1 and PC2 scores = average PC1 and PC2 scores) for all the testers. The ATC was evaluated by passing through the origin with its abscissa. GCA effects of the entries are approximated by the ATC abscissa projections. Parallel lines perpendicular to the abscissa participate in the GCA classification of entries. SCA effects that indicate the tendency of the entries to produce superior crosses were subjected to the projections of the entries on the ATC coordinate. The biplot polygon view is drawn by connecting the entries. The biplot is divided into several sectors by perpendicular line to each side drawn from the plot's roots, and each tester falls into one sector. The best mating partner shares the tester falling in a sector with another entry present at the vertex of the polygon in that sector. Entries located near the biplot origin of the biplot are less sensitive to the change of the testers.

As a rule, each genotype was considered both as an entry (with normal letters) and a tester with half diallel data in biplot analysis (bold capital letters). Heterosis over better parents(heterobeltiosis) were also determined using the following formula to assay the authenticity of GGE biplot in the presentation of heterotic crosses:

$$\textbf{Heterosis at BP [\%]} = \frac{\mathbf{F1 - BP}}{\mathbf{BP}} \times \mathbf{100}$$

Where,

F_1 = mean value of the F_1s of the cross BP = mean value of the better parent in the cross.

RESULTS AND DISCUSSION

The analysis of variance showed significant or highly significant differences among parents (P) for all studied characters, except head rice and grain elongation percentage (Table 2).

The analysis of variance showed significant differences among crosses (C) for all characters, and parents versus crosses were also significant for all the characters except days to 50% heading and gelatinization temperature. These results have shown that the genetic material used in this study included a wide range of genetic variations. These results were in line with the results of Allahgolipour et al., (2015) and Okaz et al (2016).

For most characters that mention that significant heterosis occurred in the crosses. Crosses had a higher mean sum of square (MSS) than parents (Table 2).

Combining ability analysis has been divided into two groups by Sprague and Tatum (1942), as an important method for identifying superior parents for crosses i.e., general combining ability and specific combining ability. The average performance of the lines in the hybrid combinations and the specific combining ability (SCA) are indicated by the general combining ability (GCA) as the deviation from GCA based expectation. The analysis of variance for combining ability for 14 characters in this study is summarized in Table 3.

A critical perusal of analysis of variance for combining ability appeard that the general combining ability (GCA) and specific combining ability (SCA) variances were significant for all traits under study except (SCA)of gelatinization temperature. (Table 3) this indicates the importance of both the additive and nonadditive genetic effects in the expression of these characters. These findings are in close agreements with those of Kumar and Thania (2007), Naseer et al. (2016) and El-Malky and Al-Daej (2018).

Table 2. **Analysis of variance for different traits in rice genotypes.**

S. O. V	d.f	Days to 50% heading	Plant height(cm)	Panicle length (cm)	Number of tillers plant^{-1}	Number of panicles plant-1	Number of filled grains/panicle	100-grain weight (g)
Replication (Rep)	2	11.29	10.43	3.69	10.92	1.86	33.44	0.64
Treatments (T)	20	65.82**	1933.73**	21.98**	73.43**	72.51**	789.74**	0.23**
Parents (P)	5	67.33**	748.22**	10.47**	64.76**	55.16**	515.79**	0.19**
Crosses (C)	14	69.94**	2323.17**	23.02**	74.34**	74.21**	813.95**	0.25**
P vs. C	1	0.51	2409.24**	65.03**	104.03**	135.34**	1820.7**	0.17**
Error	40	0.57	11.21	1	3.09	4.69	7.09	0.015
Total	62	21.96	631.36	7.86	26.03	26.47	260.41	0.105

Table 2. **Cont.**

S. O. V	d.f	Grain yield plant-1	Hulling (%)	Milling (%)	Head Rice (%)	Gelatinization Temperature (G.T)	Grain elongation (%)	Amylose Content (%)
Replication (Rep)	2	6.938	0.104	0.004	0.513	0.048	6.478	0.255
Treatments (T)	20	187.82**	7.79**	17.90**	30.44**	1.87**	328.79**	9.34**
Parents (P)	5	110.43**	9.63**	4.74**	6.39*	2.32**	26.38	9.61**
Crosses (C)	14	221.35**	5.80**	13.48**	23.80**	1.83**	274.73**	9.81**
P vs. C	1	105.37**	26.5**	145.72**	243.55**	0.08	2597.55**	1.36*
Error	40	4.08	0.76	1.01	2.58	0.36	15.65	0.24
Total	62	63.44	3.01	6.43	11.50	0.84	116.36	3.17

∗P < 0.05 and ∗∗P < 0.01.

Table 3. Mean squares of general combining ability (GCA) and specific combining ability (SCA)

S. O. V	d.f	Days to 50% heading	Plant height (cm)	Panicle length (cm)	Number of tillers plant^{-1}	Panicles plant^{-1}	Number of filled grains panicle^{-1}	100-grain weight (g)
G.C.A	5	51.99**	1561.56**	14.59**	44.65**	46.84**	662.11**	0.11**
S.C.A	15	11.92**	338.92**	4.91**	17.75**	16.61**	130.29**	0.07**
Error	40	0.19	3.74	0.33	1.03	1.56	2.37	0.01
G.C.A/ S.C.A		4.36	4.61	2.98	2.52	2.82	5.08	1.73
S. O. V	d.f	Grain yield plant-1	Hulling (%)	Milling (%)	Head Rice (%)	Gelatinization Temperature	Grain elongation (%)	Amylose Content (%)
G.C.A	5	190.20**	4.05**	4.50**	10.77**	1.79**	65.11**	7.87**
S.C.A	15	20.08**	2.11**	6.46**	9.94**	0.23	124.42**	1.53**
Error	40	1.36	0.25	0.34	0.86	0.12	5.22	0.08
G.C.A/ S.C. A		9.47	1.92	0.70	1.08	7.67	0.52	5.16

∗P < 0.05 and ∗∗P < 0.01.

The GCA variances values greater than SCA variances values for all studied characters except milling (%) and grain elongation (%). These results showed that, the additive genes effects were more important in inheritance of these traits. Therefore, the selection will be effective using pedigree method. The highest estimated values for SCA compared to their GCA for milling (%) grain elongation (%) indicated that the non-additive genetic variance in the inheritance of these traits played comparatively bigger role. This shows that the selection of bulk method is efficient. Rahaman (2016) reported a high level of estimated SCA variance i.e., non-additive gene action for 1000 grain weight, days to flowering and grain yield per hill. The SCA variances recorded by Montazeri *et al.* (2014) were higher than the GCA variances for panicle length and 1000-grain weight, suggesting that inheritance of these characters indicated predominance of non-additive gene action in the. Rahimi *et al*. (2010), El-Refaee *et al*. (2016), Rahaman (2016) and Satheeshkumar *et al*. (2016) mentioned that, the analysis of variance for combining ability due to GCA and SCA were highly significant for days to heading, yield and its components characters indicated that both additive and non-additive gene effects contributed to the inheritance of the characters.

Mean performances:

The mean performances of the 6 parents and their 15 F_1 crosses for all studied traits are illustrated in Table (4). Among the parents, Giza 179 was the earliest and the shortest parent (97 day) and (95.67 cm), respectively. It is the favourite type for rice breeder. For panicle length, Giza 179 and IET1444 have a longest panicle (25, 23.5cm.), respectively. With respect to number of tillers plant^{-1}, number of panicles plant $^{-1}$, Giza 179 and Giza 178 were detected the highest mean values for these traits, in addition number of filled grains panicle^{-1}(152.33 and 147 grains) and grain yield (47.36 and 46.22 g.), respectively. While, Wab880-SG and Sakha 106 gave the highest mean values for 100-grain weight (2.9-2.7 g), respectively.

Concerning hulling (%) and milling (%), Sakha 105 has the highest mean performance value (82% and 73.33%), respectively. While Wab880-SG has the highest head rice percentage (63.34%). The highest mean values of grain elongation % was recorded by Sakha 106. The parents; Giza 179 and Giza 178 had the lowest amylose content % (17.79 and 18.07%), respectively, that acceptable for rice breeder. These results agree with (Abd-El Salam *et al.*, 2016).

With respect to the mean performance of the 15 F1 crosses, data in Table 4 showed that, the cross Sakha 105x Giza 178 was the earliest hybrid, this hybrid could be favourable for earliness. Plant height of three rice crosses were ranged between (90.67-100.33cm) this suitable for the target of rice breeders for selecting ideal short plant height for lodging resistance and suitable for mechanical harvesting. Most of the crosses have longer panicle than the longest panicle parent, their estimated were values ranged from 26 cm for (Sakha106 x Giza 178, Sakha 106x

WAB880- SG and Giza 178x WAB880- SG) and 28.43 cm for (Giza 178x IET1444). Four crosses Sakha 106x IET1444, Giza178x Giza 179, Giza 178x WAB880-SG and Giza 179 x WAB880-SG have the highest mean values for number of tillers plant^{-1} and number of panicles/plants. For number of filled grains /panicles, the cross Giza178x Giza 179 gave the highest mean values than the highest parent.

Concerning 100-grain weight, the crosses Sakha 105x Sakha 106, Sakha106 x Giza 179, Giza 178x WAB880-SG and Giza 179x WAB880- SG had the highest values of 100-grain weight. For grain yield/plant was found to be higher than the highest parent for seven rice crosses, indicating that over-dominance played a remarkable role in the heritance of these characters in these mentioned crosses.

Table 4. Mean performances of parental varieties and their 15 F_1's crosses for fourteen studied characters in rice.

	Days to 50% heading	Plant height (cm)	Panicle length (cm)	Number of tillers plant^{-1}	Number of panicles plant-1	Number of filled grains/panicle	100-grain weight (g)
Sakha 105	103	102.67	22.43	23.67	21	132.67	2.63
Sakha 106	98	111	22.87	28	24.67	123	2.7
Giza 178	100	105.67	23	31.33	29	147	2.5
Giza 179	97	95.67	25	34.67	30	152.33	2.4
IET1444	98.33	115.33	23.5	29.33	26.67	141	2.17
WAB880- SG	109.67	141	19.33	22.33	19.33	119.67	2.9
Sakha 105x Sakha 106	96	90.67	21.4	29	26	117.33	2.9
Sakha 105x Giza 178	94	115	23.33	32.67	29.67	120.33	2.4
Sakha 105xGiza179	97	110.67	26.3	27.33	25.33	142.33	2.3
Sakha 105x IET1444	98	127.67	23	31.67	28.67	102.67	2.73
Sakha 105x WAB880- SG	110	124	18	19.67	17	107.67	2.8
Sakha 106xGiza 178	98	114.33	26	30	27.67	123.33	2.57
Sakha 106x Giza 179	97	100.33	27	29	25.33	126	3.13
Sakha 106x IET1444	105	108	27.5	39	35	119	2.53
Sakha 106x WAB880- SG	111	174	26	23.67	21	113	2.4
Giza 178x Giza 179	100	98.67	27	35.33	34.67	164.67	2.43
Giza 178x IET1444	100	101	28.43	33	30.67	133.33	2.3
Giza 178x WAB880- SG	102	156	26	37	34	123	3.03
Giza 179x IET1444	100	127.33	26.5	31.33	28.33	145.33	2.53
Giza 179x WAB880- SG	102	170	25	34.67	32	114	3.13
IET1444x WAB880- SG	102	166	22.6	32.67	30	108.67	2.77
LSD at 0.05	1.245	5.526	1.651	2.9	3.574	4.395	0.203
LSD at 0.01	1.665	7.39	1.208	3.879	4.78	5.88	0.27

Table 4.Cont.

	Grain yield plant^{-1}(g)	Hulling (%)	Milling (%)	Head Rice (%)	Gelatinization Temperature	Grain elongation (%)	Amylose Content (%)
Sakha 105	43.22	82	73.33	62	6	37.23	18.58
Sakha 106	41.33	81.67	73.33	63.11	5.33	42.14	18.2
Giza 178	46.22	81.89	72.22	62.56	5.33	36.05	18.07
Giza 179	47.36	81.78	71	61.56	5.67	37.56	17.79
IET1444	40.4	77.89	70.22	59.33	7	34.96	20.72
WAB880- SG	30.4	78.98	72.44	63.34	4.33	33.51	22.21
Sakha 105x Sakha 106	47.1	76.89	65.6	58.78	6.33	56.57	20.17
Sakha 105x Giza 178	50	78.97	70.63	58.25	4.33	48.28	19.21
Sakha 105xGiza179	52.83	80	72.22	60	5.67	63.63	17.49
Sakha 105x IET1444	42.53	79	70	55.44	6.67	50.06	21.91
Sakha 105x WAB880- SG	28.77	80.2	69.63	56.78	5.67	32.28	20.72
Sakha 106xGiza 178	49.27	81.78	70	58.33	5	55.91	19.09
Sakha 106x Giza 179	53.53	80	70.78	56.67	5.67	54.3	18.25
Sakha 106x IET1444	38.43	79.67	67	55	6.67	53.71	19.56
Sakha 106x WAB880- SG	33.63	78.33	68.44	60.22	4.33	29.29	18.32
Giza 178x Giza 179	55.57	81.67	71.67	61.22	5	46.85	16.98
Giza 178x IET1444	52.27	78.11	66.78	53	6.33	57.18	20.72
Giza 178x WAB880- SG	33.47	80.04	68.12	61.89	5.33	47.11	18.29
Giza 179x IET1444	50.8	78.34	66.22	52.89	6.67	58.73	22.08
Giza 179x WAB880- SG	39.17	77.67	66.67	56	5.67	52.65	17.94
IET1444x WAB880- SG	37.9	78.33	67.11	59.99	6	60.28	23.04
LSD at 0.05	3.334	1.437	1.658	2.652	0.996	6.527	0.8053
LSD at 0.01	4.460	1.922	2.219	3.548	1.332	8.734	1.077

All crosses had high mean values for grain elongation % except the two crosses (Sakha 105 x WAB880-SG and Sakha 106 x WAB880-SG). The crosses Sakha 105x Giza 179 and Giza 178x Giza 179 showed the lowest mean values for amylose content. Amylose and amylopectin in kernels determine the texture of cooked rice and consumers prefer rice with intermediate amylose content, (Rafii *et al*., 2014.)

In general, the results in this study indicated that, the superiority of some F_1 crosses, were relayed on their corresponding parents. When selecting these single crosses as diverse F_1 base populations to initiate reciprocal selection for combining ability, these estimates were kept in mind.

Consequently, in order to enhance the yield and yield components, the parents involved in the previous combinations should be used and the best crosses in the initiated breeding programme should be used.

General combining ability (GCA):

The selection of suitable parents for hybridization is one of the most important steps for the best combination in F_1 hybrids or in segregating generations in a breeding programme. The GCA is controlled by additive genes which is fixable (Simmonds, 1979.) In terms of expected performance of their progenies, it provides information on the preferance of parents. Regarding the six evaluated parents, highly significant negative values of GCA for days to 50% heading and plant height would be of interest from the plant breeder point of view. For days to 50% heading, all parent, exceptWAB880-SG showed highly significant and negative GCA effects. The parents; Sakha 105, Sakha 106, Giza 178 and Giza 79 exhibited highly significant desirable negative estimates of GCA effects for plant height. Parents; Sakha 106, Giza 178, Giza 79 and IET1444 gave highly significant GCA for panicle length. El- Hity *et al.* 2016 and El- Refaee *et al.* (2016).

Concerning number of tillers plant^{-1} and number of panicles/plant, Giza 178, Giza179 and IET1444 proved to be good combiners for improving these traits. Favourable highly significant GCA effects were showed by Giza178 and Giza179 parents for number of filled grains/panicle. WAB880-SG for 100-grains weigh and Giza178 and Giza 179 for grain yield plant $^{-1}$ and hulling%.

Meanwhile, the parents; Sakha 105 and Giza178 for milling, Giza178 and WAB880-SG for head rice, IET1444 for gelatinization temperature, Giza179 and IET1444 for grain elongation % and Giza 179 for amylose content, were the best general combiners for improving these traits. (Table 5). These results consistent with Vange *et al.* 2020

Table 5. General combining ability effects of parents.

Parents	Days to 50% heading	Plant height (cm)	Panicle length (cm)	Number of tillers plant^{-1}	Number of panicles plant^{-1}	Number of filled grains/panicle	100-grain weight (g)
Sakha 105	-0.63**	-9.79**	-1.65**	-3.01**	-2.92**	-4.56**	-0.003
Sakha 106	-0.38*	-5.29**	0.45*	-0.64	-0.96*	-5.93**	0.06**
Giza 178	-1.5**	-6.92**	0.84**	2.36**	2.83**	8.32**	-0.09**
Giza 179	-2**	-6.67**	1.47**	1.90**	1.71**	13.11**	-0.01
IET1444	-0.54**	1.13	0.62**	1.82**	1.75**	-0.14	-0.15**
WAB880- SG	5.04**	27.54**	-1.73**	-2.43**	-2.42**	-10.81**	0.19**
L.S.D.05 (gi)	0.28	1.26	0.38	0.66	0.82	1.00	0.05
L.S.D.01 (gi)	0.38	1.69	0.50	0.89	1.09	1.34	0.06

Parents	Grain yield plant-1	Hulling (%)	Milling (%)	Head Rice (%)	Gelatinization Temperature	Grain elongation (%)	Amylose Content(%)
Sakha 105	0.37	0.17	0.87**	0.14	0.13	-0.52	0.03
Sakha 106	-0.01	0.28	0.09	0.39	-0.13	0.58	-0.58**
Giza 178	3.54**	0.83**	0.48*	0.71*	-0.38**	-0.25	-0.75**
Giza 179	5.24**	0.44*	0.22	-0.28	0.04	2.73**	-1.02**
IET1444	-0.25	-1.06**	-1.28**	-2.14**	0.83**	2.56**	1.54**
WAB880- SG	-8.88**	-0.65**	-0.37	1.18**	-0.5**	-5.1**	0.79**
L.S.D.05 (gi)	0.76	0.33	0.38	0.61	0.23	1.49	0.18
L.S.D.01 (gi)	1.02	0.44	0.51	0.81	0.30	1.99	0.25

***P < 0.05 and **P < 0.01.**

Specific combining ability

In Table 6. The specific combining ability is the differences from the expected results based on general combining ability (Allard,1960). Data revealed that, nine crosses of Sakha 105 x Giza 178, Sakha 105 x Sakha 106, IET1444 x WAB880-SG, Giza 178x WAB880-SG, Giza 179x WAB880-SG, Sakha 105x IET1444, Sakha 106x Giza 179, Sakha 105x Giza 179, and Sakha 106x Giza 178 had highly significant and negative SCA for days to 50% heading. These crosses could be used in rice breeding program for improving earliness.

Regarding plant height, six combinations showed negative significant estimates SCA. The best crosses were Sakha 105x Sakha 106, Sakha 105 x WAB880- SG, Giza 178x IET1444, Sakha 106x IET1444, Giza 178x Giza 179 and Sakha 106x Giza 179 These superior crosses would be considered as the desirable combinations to improve short stature plants in rice breeding program, similar results were reported by El- Hity *et al.* 2016 and El-Malky and Al-Daej (2018).

Concerning panicle length, five crosses; Sakha106xWAB880-SG, Giza178x IET1444, Giza 178x WAB880-SG, Sakha105x Giza179and Sakha106x IET1444 displayed desirable positive and highly significant SCA effects values and ranged from 2.138 to 2.984.

Crosses; Sakha 106 x IET1444, Giza 178x WAB880-SG, Giza 179x WAB880-SG and IET1444 x WAB880-SG recorded significant SCA effect in desirable direction for both of number of tillers plant^{-1} and number of panicles plant^{-1} beside cross Sakha105x Giza178 and Sakha 105x IET1444 for number of tillers plant^{-1}.

Three crosses; Giza 178x Giza 179, Sakha105x Giza179 and Giza 179x IET1444 showed positive and significant SCA effect for number of filled grains/panicle.

Regarding to 100-grain weight, five combinations Sakha106x Giza179, Giza 179x WAB880-SG, Giza 178x WAB880-SG, Sakha 105x IET1444 and Sakha 105x Sakha 106 gave the highest positive and significant SCA effects.

Seven crosses viz., Giza 178x IET1444, Sakha 106x Giza 179, Sakha 105x Giza 179, IET1444 x WAB880- SG, Giza 178 x Giza 179, Sakha 105x Sakha 106, and Sakha 105 x Giza 178 exhibited positive and significant SCA effect for grain yield plant^{-1} indicating that these crosses would be used in breeding program to improve this trait.

The crosses (Sakha 105 x WAB880- SG and Sakha 106x Giza 178) registered the highest SCA for hulling%, and crosses (Sakha 105x Giza 179 and Giza 178x Giza 179) for milling%, meanwhile (Giza 178x Giza 179 and IET1444x WAB880- SG) for head rice%.

Belong to cooking quality traits, the positive estimations of SCA in desirable and the good specific cross combinations for gelatinization temperature was Sakha 105x Sakha 106, meanwhile, seven crosses gave the highest significant for grain elongation%, these crosses were (IET1444 x WAB880- SG, Sakha 105x Giza 179, Sakha 105x Sakha 106, Sakha 106x Giza 178, Giza 179 x WAB880- SG, Giza 178x IET1444and Giza 179x IET1444). Regarding to amylose content %, negative amounts of SCA are good, the crosses gave highest negative SCA were (Sakha 106x WAB880- SG, Giza 179 x WAB880- SG, Giza 178 x WAB880- SG, Sakha 105x Giza 179, Sakha 106x IET1444 and Giza 178 x Giza 179).

Table 6. Specific combining ability effects of hybrids.

Crosses	Days to 50% Heading	Plant height (cm)	Panicle length (cm)	Number of tillers plant^{-1}	Number of panicles plant^{-1}	Number of filled grains/panicle	100-grain weight (g)
Sakha 105x Sakha 106	-3.86**	-15.92**	-1.69**	2.40*	2.45*	0.38	0.21**
Sakha 105x Giza178	-4.73**	10.04**	-0.15	3.07**	2.32*	-10.88**	-0.14*
Sakha 105xGiza179	-1.23**	5.46**	2.18**	-1.81	-0.89	6.33**	-0.32**
Sakha 105x IET1444	-1.69**	14.67**	-0.27	2.61**	2.41*	-20.08**	0.26**
Sakha 105x WAB880- SG	4.73**	-15.42**	-2.92**	-5.14**	-5.09**	-4.42**	-0.02
Sakha 106xGiza 178	-0.98*	4.88**	0.42	-1.98*	-1.64	-6.5**	-0.04
Sakha 106x Giza 179	-1.48**	-9.38**	0.79	-2.52**	-2.85*	-8.63**	0.449**
Sakha 106x IET1444	5.06**	-9.5**	2.14**	7.57**	6.78**	-2.38	-0.01
Sakha 106x WAB880- SG	5.48**	30.08**	2.98**	-3.52**	-3.05**	2.29	-0.49**
Giza 178x Giza 179	2.64**	-9.42**	0.40	0.82	2.696*	15.79**	-0.10
Giza 178x IET1444	1.19**	-14.88**	2.68**	-1.44	-1.35	-2.29	-0.09
Giza 178x WAB880- SG	-2.40**	13.71**	2.59**	6.82**	6.16**	-1.96	0.299**
Giza 179x IET1444	1.69**	11.21**	0.12	-2.64**	-2.55*	4.92**	0.065
Giza 179x WAB880- SG	-1.90**	27.46**	0.96	4.94**	5.28**	-15.75**	0.32**
IET1444x WAB880- SG	-3.36**	15.67**	-0.59	3.02**	3.24**	-7.83**	0.099
L.S.D.05(sij)	0.78	3.46	1.03	1.82	2.24	2.76	0.13
L.S.D.01(sij)	1.04	4.63	1.38	2.43	2.997	3.69	0.17

Table 6. **Cont.**

Crosses	Grain yield/plant	Hulling (%)	Milling (%)	Head Rice (%)	Gelatinization Temperature	Grain elongation (%)	Amylose Content (%)
Sakha 105x Sakha 106	3.21**	-3.24**	-5.04**	-0.63	0.67*	9.45**	1.24**
Sakha 105x Giza 178	2.57*	-1.70**	-0.4	-1.48	-1.08**	1.99	0.45
Sakha 105xGiza179	3.70**	-0.28	1.45**	1.26	-0.17	14.36**	-1.01**
Sakha 105x IET1444	-1.12	0.22	0.73	-1.43	0.04	0.96	0.85**
Sakha 105x WAB880- SG	-6.26**	1.01*	-0.55	-3.42**	0.38	-9.17**	0.42
Sakha 106xGiza 178	2.21*	0.99*	-0.25	-1.64	-0.17	8.52**	0.94**
Sakha 106x Giza 179	4.78**	-0.40	0.79	-2.32**	0.08	3.93	0.36
Sakha 106x IET1444	-4.84**	0.77	-1.49**	-2.12*	0.29	3.51	-0.89**
Sakha 106x WAB880- SG	-1.01	-0.98*	-0.96	-0.22	-0.71*	-13.25**	-1.37**
Giza 178x Giza 179	3.26**	0.73	1.28*	1.92*	-0.33	-2.69	-0.75**
Giza 178x IET1444	5.45**	-1.33**	-2.11**	-4.45**	0.21	7.81**	0.44
Giza 178x WAB880- SG	-4.73**	0.19	-1.68**	1.12	0.54	5.4*	-1.24**
Giza 179x IET1444	2.28*	-0.71	-2.40**	-3.57**	0.13	6.38**	2.06**
Giza 179x WAB880- SG	-0.73	-1.80**	-2.87**	-3.78**	0.46	7.95**	-1.32**
IET1444x WAB880- SG	3.49**	0.37	-0.92	2.08*	0	15.77**	1.22**
L.S.D.05(sij)	2.09	0.90	1.04	1.66	0.62	4.09	0.51
L.S.D.01(sij)	2.80	1.21	1.39	2.22	0.84	5.47	0.68

$*P < 0.05$ and $**P < 0.01$.

Heterosis relative to better parent:

Under this research, a large number of crosses showed high estimates of heterosis in a desirable direction for various characters. Table 7 presented the assessment of better parent heterosis (BH) for different traits. Negative heterosis for days to 50% heading is desirable for breed short stature hybrids and varieties, eight crosses had negative significant high parent heterosis ranged between (-6.99 to -2), moreover, the crosses; Giza 179 x WAB880-SG, IET1444 x WAB880- SG and Giza 178 x WAB880-SG were recorded the highest negative heterosis. For plant hight, five crosses recorded significant better parent heterosis in a desirable negative direction. Sakha 105x Sakha 106 recorded the highest negative heterosis.

For panicle length, nine crosses Giza 178 x IET1444, followed by Sakha 106 x WAB880- SG, Giza 178 x WAB880- SG, Sakha 106 x Giza 178, Sakha 106 x Giza 179, Giza 178 x Giza 179, Giza 179 x IET1444, Sakha 105 x Giza 179 and Sakha 106 x IET1444 showed significant and positive best parent heterosis.

The result on estimates of heterosis (Ht) revealed that best parent heterosis for number of tillers plant^{-1} recorded in seven crosses ranged between (32.95 to 3.57) these crosses were Sakha 106 x IET1444, Giza 178 x WAB880- SG, IET1444 x WAB880-SG, Sakha 105x IET1444, Sakha 105 x Giza 178, Sakha 105x Sakha 106 and Giza 178 x Giza 179. These crosses were important based on highly significant heterosis. Over-dominant type of gene action was suggested for cross Giza 178 x IET1444 indicated significant heterosis displaying epistasis type of gene action. These results were in agreement with earlier findings (Vanaja and Babu, 2004). For number of panicles plant^{-1}, heterosis varied from -19.05** to 31.25** where eight crosses showed significant positive heterosis but the rest of crosses are negative. Positive heterosis is expected for number of filled grains/panicle.

For 100-grain weight (g), six hybrids manifested significantly positive desirable heterosis. On the contrary, nine hybrids had significantly negative heterosis. For grain yield, eight hybrids had positive significant heterosis Similar results were obtained by Sarker *et al*., 2002; Gnansekaran *et al.* (2006) and Vange *et al.* (2020)

Concerning milling recovery characters, only one cross showed significant and positive best-parent heterosis for hulling% and head rice% (Giza 178 x IET1444 and Sakha 105x Giza 178), respectively. Meanwhile, Sakha 105x Sakha 106 gave positive best-parent heterosis for gelatinization temperature.

Regarding to grain elongation had Highly significant positive heterosis was identified in all crosses except Sakha 105 x WAB880-SG and Sakha 106 x WAB880-SG.

Heterosis in Table 7. The percent of heterosis in F_1 hybrids varied from trait to another or from cross to cross. Negative heterosis is expected for amylose content%, heterosis for amylose content% was ranged from -19.21to 8.60, eight hybrids Giza 179 x WAB880-SG, Giza 178 x WAB880-SG, Sakha 106 x WAB880-SG, Sakha 105 x WAB880-SG, Giza 179 x IET1444, Giza 178 x Giza 179, Sakha 105x Giza 179 and Sakha 106 x IET1444 exhibited significant negative heterosis their estimated values were -19.21**, -17.65**, -17.50**, -6.69**, -6.53** -6.01**, -5.83** and -5.60** respectively.

Table7. Estimate of heterosis over better parent for different characters in rice.

Crosses	Days to 50% heading	Plant height	Panicle Length	Number of tillers plant^{-1}	Number of Panicles/plant	Number of filled grains/panicle	100-grain weight(g)
Sakha 105x Sakha 106	-6.80**	-18.32**	-6.41**	3.57*	5.41*	-11.56**	7.41**
Sakha 105xGiza 178	-6.00**	8.83**	1.45	4.26**	14.10**	-18.14**	-8.86**
Sakha 105xGiza179	-5.83**	7.79**	5.20**	-21.15**	-15.56**	-6.56**	-12.66**
Sakha 105x IET1444	-4.85**	10.69**	-2.13*	7.95**	7.50**	27.19**	3.80**
Sakha 105x WAB880- SG	0.3	-12.06**	-19.76**	-16.90**	-19.05**	-18.84**	-3.45**
Sakha 106xGiza 178	-2.00**	3	13.04**	-4.26**	-4.60*	-16.10**	-4.94**
Sakha 106x Giza 179	-1.02	-9.61**	8.00**	-16.35**	-15.56**	-17.29**	16.05**
Sakha 106x IET1444	6.78**	-6.36*	4.00**	32.95**	31.25**	-15.60**	-6.17**
Sakha 106x WAB880- SG	1.22	23.40**	13.70**	-15.48	-14.86**	-8.13**	-17.24**
Giza 178x Giza 179	0	-6.62*	8.00**	1.92**	15.56**	8.10**	-2.67**
Giza 178x IET1444	0	-12.4**	20.99**	5.32	5.75**	-9.30**	-8.00**
Giza 178x WAB880- SG	-6.99**	10.64**	13.04**	18.09**	17.24**	-16.33**	4.60**
Giza 179x IET1444	1.69**	10.40**	6.00**	-9.62**	-5.56*	-4.60*	5.56**
Giza 179x WAB880- SG	-6.99**	20.57**	0	0	-6.67**	-25.16**	8.05**
IET1444x WAB880- SG	-6.99**	17.73**	-3.83**	11.36**	12.50**	-21.23**	-4.60**

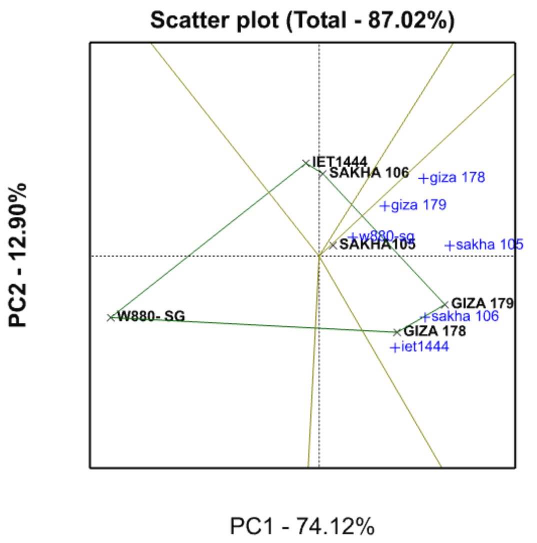
Table 7. Cont.

Crosses	Grain yield plant^{-1}	Hulling (%)	Milling (%)	Head rice (%)	Gelatinization temperature	Grain elongation (%)	Amylose content (%)
Sakha 105x Sakha 106	8.99**	-6.23**	-10.54**	-6.87**	5.56**	34.25**	8.60**
Sakha 105x Giza 178	8.17**	-3.70**	-3.68**	6.88**	-27.78**	29.66**	3.43**
Sakha 105xGiza179	11.56**	-2.44**	-1.51	-3.23*	-5.56**	69.42**	-5.83**
Sakha 105x IET1444	-1.58	-3.66**	-4.54**	-10.58**	-4.76**	34.44**	5.73**
Sakha 105x WAB880- SG	-33.44**	-2.20**	-5.04**	-10.35**	-5.56**	-13.31**	-6.69**
Sakha 106xGiza 178	6.58**	-0.14	-4.55**	-7.57**	-6.25**	32.68**	4.93**
Sakha 106x Giza 179	13.03**	-2.18**	-3.49**	-10.21**	0	28.87**	0.29
Sakha 106x IET1444	-7.01**	-2.44**	-8.64**	-12.86**	-4.76**	27.46**	-5.60**
Sakha 106x WAB880- SG	-18.62**	-4.08**	-6.67**	-4.92**	-18.75**	-30.49**	-17.50**
Giza 178x Giza 179	17.33**	-0.27	-0.77	-2.14	-11.76**	24.74**	-6.01**
Giza 178x IET1444	13.07**	4.62**	-7.54**	-15.28**	-9.52**	58.63**	-0.03
Giza 178x WAB880- SG	-27.60**	-2.26**	-5.97**	-2.29	0	30.69**	-17.65**
Giza 179x IET1444	7.26**	-4.21**	-6.73**	-14.08**	-4.76**	56.37**	-6.53**
Giza 179x WAB880- SG	-17.30**	-5.03**	-7.97**	-11.59**	0	15.09**	-19.21**
IET1444x WAB880- SG	-6.19**	-0.82	-7.36**	-5.28**	-14.29**	72.42**	3.74**

Bi plot analysis:

The principal components together explained 87.02% (74.12% and 12.9% by PC1 and PC2, resp.) of the total variation (Figure 1). The remaining proportion of the total variation was not accounted by biplot analysis due to much complexity in genetics involved in this trait among the six parents.

The parents Giza 178 and Giza 179 had positive GCA, whereas IET1444 and WAB880- SG had negative GCA effects. Parents Giza 178 and Giza 179 had the greatest GCA based on the distance between entry and ATC abscissa. Parent Giza 178 had the highest SCA based on the abscissa's largest projections. Three well determined sectors were clearly regarded by the biplot, that is, IET1444, (Giza 178, Giza 179) and WAB880- SG. The two heterotic groups [IET1444, Sakha 106, Giza 179] and [Giza 178, WAB880-SG] were shown to indicate that heterosis should be shown in the hybrids between these groups, which can also be confirmed by polygon data. The crosses Giza 179 × Sakha 106 and Giza 178 × iet1444 in sector Giza 178 and Giza 179 crosses would be heterotic due to the presence of parents as testers in their respective sectors (**Anu *et al.*,2011**). It is important to note that all the heterotic crosses obtained through biplot analysis showed similar heterotic effects for same crosses analyzed manually following standard formula, confirming the authenticity of the biplot when displaying the heterotic combinations. These heterotic crosses can be easily exploited by heterosis breeding, while the transgressive segregants can be exploited by recurrent breeding and biparental mating in segregating generation, finally from the results obtained, we find agreement between two methods of griffing for analyzing the half-diallel and bi plot analyzing in determining the best parents and hybrids for the traits under study.



Average tester coordination

Figure 1. Polygon view for grain/yield among testers (bold capital letters) and entries (normal letters).

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تقييم القدره على التآلف لبعض صفات محصول الحبوب والجودة فى الأرز بإستخدام طريقتى جرفينج والمحاور الثنائية الإتجاه

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تم زراعة ستة تراكيب وراثيه أبويه من الأرز، تم التهجين بطريقة التزاوج التبادلى النصف دائرى فى موسم 2017 في مزرعة قسم بحوث الأرز- محطة البحوث الزراعيه بسخا- كفرالشيخ للحصول على تقاوي 15 هجين فردى. وفى موسم 2018 تم زراعة 6 آباء و15 هجين فردى، وتم إستخدام تصميم القطاعات الكامله العشوائيه بهدف تقدير تاثيرات القدره العامه على التآلف للأباء والقدره الخاصه على التآلف للهجن لجميع الصفات المدروسه. وكانت أهم النتائج المتحصل عليها: حيث كان متوسط مجموع المربعات للقدره العامه والخاصه على التآلف عالى المعنويه لكل الصفات المدروسه مما يشير إلى أهمية التباين الإضافى والسيادى في توريث هذه الصفات. و أظهرت النتائج أن قيم تباينات القدره العامه على التآلف كانت أكبر من قيم تباينات القدره الخاصه على التآلف لجميع الصفات تحت الدراسه ما عدا تصافي التبييض و إستطالة الحبوب٪، وهذا يوضح تفوق الفعل المضيف للجين في التعبير عن هذه الصفات. الأباء جيزه 178 و جيزه 179 أظهرا تأثيراً إيجابياً عالي المعنويه للقدره العامه على التآلف وذلك لصفات التبكير، طول النوره الداليه، عدد الحبوب الممتلئه، محصول الحبوب للنبات الفردي وتصافي التقشير٪. بينما بالنسبة لصفة وزن ال100حبه (جم)، نسبة الحبوب السليمه كان الأب WAB880-SG أفضل أب لتحسين هاتين الصفتين. والأبIET1444 كان جيد لصفات الطهي بالإضافه إلي طول النوره الداليه و عدد الفروع للنبات. وقد أوضحت النتائج أن هناك سبع هجن جيزة 178 × IET1444، سخا 106 × جيزة 179، سخا 105 × جيزة 179، IET1444 x WAB880-SG، جيزة 178 × جيزة 179، سخا 105 × 106، سخا 105 × جيزة 178 لهم تأثير إيجابى ومعنوى فى القدره الخاصه على التآلف لمحصول الحبوب. وقد سجل الهجين سخا 105× جيزه 179 تأثيراً معنوياً مرغوب فيه للقدره الخاصه على التآلف لسبع صفات وهي عدد الأيام حتى 50%تزهير، طول النوره الداليه، عدد الحبوب الممتلئه للنوره، محصول الحبوب للنبات الفردي، تصافي التبييض، إستطالة الحبوب٪ و محتوي الأميلوز٪. و أيضا الهجين سخا 105 × سخا 106 أظهر تأثيراً معنوياً فى القدره الخاصه على التآلف لعدد الأيام حتى 50% تزهير، طول النبات، محصول الحبوب للنبات الفردي، درجة حرارة الجلتنه و إستطالة الحبوب٪.فيما يتعلق بتحليل المحاور ثنائية الإتجاه لتحديد قوة الهجين، والأباء المتشابهين وراثياً ويوفرشكل المضلع طريقة لتجميع الأباء المختبرة إستنادًا إلى أفضل شركاء التزاوج فقد عرضت طريقة المحاور الثنائيه بوضوح ثلاثة قطاعات محدده جيدًا، وهي IET1444 و W880 SG و Giza 178. وقد لوحظت مجموعتان لقوة الهجين IET1444، سخا 106، جيزه 179 وجيزه 178، WAB880-SG وتظهر قوة الهجين من خلال الهجن جيزه 179 × سخا 106 و جيزه 179× IET1444 في قطاع جيزه 179و جيزه 178× IET144 و جيزه 179× IET144 في قطاع IET144 و يمكن إستغلال هذه الهجن بسهوله فى التربيه لقوة الهجين. ومن النتائج المتحصل عليها نجد إتفاقاً بين طريقتى جرفينج لتحليل التزاوج التبادلى النصف دائرى وتحليل المحاور الثنائية فى تحديد أفضل الأباء والهجن للصفات محل الدراسه.