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LINE X TESTER ANALYSIS FOR GRAIN YIELD AND QUALITY TRAITS IN RICE (*Oryza sativa* L.*)*

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ABSTRACT

Eight rice genotypes (five commercial varieties as lines and three exotic varieties as testers with differentt in yield, yield component and grain quality traits were provided from the genetic stock of the Rice Research and Training Center. These genotypes were planted during 2019 growing season. At heading the crosses among lines and testers were done. All the five lines, three testers and their fifteen crosses were grown during 2020. The experiment was carried out using arandomized completely block design with three replications. The data were recorded on plant height, number of panicles/hill, panicle weight, number of filled grains/panicle, sterility%, 1000-grain weight, grain yield/plant and quality characters. Heterosis was estimated and t-test was performed. Combining ability analysis was performed using line x tester method. The results showed significant variation for all characters among the lines and testers. The mean squares showed highly significant differences among parents and their crosses for studied traits. The tester Millyang 97 was good general combiner for yield, while Hexi 12 was good general combiner for head rice and amylose content%. The crosses Giza 179x Milyang 97, Sakha 104x Hexi 12 and E. Yasmine x Hexi 12 were observed as good specific combiners for yield/plant. The cross Giza 179x Milyang 97was good specific combiner for panicle weight, 1000-grains weight and grain yield but the crosses Giza 178 x Tongil and Giza 181x Milyang 97 were good specific combiners for head rice%, lines played important role towards panicle weight, number of filled grains/panicle, sterility%, grain yield, grain length, grain shape, hulling%, milling rice% and head rice% indicating predominant maternal influence for these traits. Line × tester interaction contributed to combinations of variances for number of panicles/plant and1000-grains weight. The genetic components of that characters exhibited a non additive variance. Significant and desirable heterosis was observed in twelve crosses over better parent but the maximum value was shown by Giza 178x Milyang 97 followed by Giza178x Hexi 12 .All crosses recorded significant and positive for mid parent heterosis for grain yield per plant. But only Giza 181x Milyang 97 cross recorded high heterobeltiosis (6.46%) and relative heterosis (4.82%) for head rice recovery.

Key words: ***Rice: Combining ability; Genetic parameters; Heterosis*.**

INTRODUCTION

Rice is the most important food crop in the world, it´s suitable food for all ages and also suitable for poor peoples (FAO, 2016). So, the demand for rice increases year after year due to the population increase. However, more than two billions of people in the globe depend on rice as a good source of proteins and calories (Ye *et al* 2000, Seck *et al* 2012; Futakuchi *et al* 2013 and Xu *et al* 2020).

In past few years, rice breeding programs focused mainly on improving yield and yield component characters through conventional breeding and biotechnology methods. But they found some obstacles in the production of rice such as attack of insects and diseases, shortage of water in addition to the challenging environments, which resulted in declining grain quality. This constrains will affect on grain quality and marketing of rice varieties (Adjah *et al* 2020).

Breeders of rice have focused on improving the quality of rice for various objectives and markets (Chen *et al* 2012). Anyway, the basic traits have been used to determine the quality of rice: milling characteristics and cooking quality (Yu *et al* 2008). Milling characteristics, included brown rice ratio, milled rice ratio and head rice ratio (Wang *et al* 2017). Meanwhile, the broken grains decreased the rice price by 50 percent (Oyedele and Adeoti, 2013). Also the consumer preference and market requirements so improvement of grain quality is an important target besides boosting yields (Sahu *et al* 2017). Therefore, the breeding of rice varieties that includes milling and quality becomes a major goal of rice breeders in worldwide (Wang *et al* 2017). In any case, breeding to improve the grain quality traits is depending on the good genetic component, which will be used to transfer grain quality traits to the new offspring through crosses or hybridization method (Zewdu 2020).

The knowledge of genetic parameters such as combining ability and heterosis gives conclusion about gene action, signals the suitable selection strategy to be used in the breeding program and the desirable parents to be identified (Sharma 2006 and Torres and Gealdi 2007). Combining ability analysis is a powerful tool to estimate the desirable parents and crosses for exploitation of heterosis. Estimates of the influence of an additive and non-additive genes action through this technique may be important in evaluation of the potential for commercial exploitation of heterosis (Ariful *et al* 2015). Information of available genetic materials will assist breeders to recognize suitable genotypes for crossing (Adjah *et al* 2020). The development of genotypes with high yield and proportion of milled grains will boost the market for local production.

Consequently, the main objective of this research was to study general combining ability, specific combining ability and heritability which can be used to investigate the genetic control of yield and grain quality of rice in crosses for selection of suitable parents.

MATERIALS AND METHODS

This study was conducted at the Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during the years 2019 and 2020. The plant materials used were eight genotypes of rice including five commercial varieties namely; Giza 178, Giza 179, Giza 181, Sakha 104 and Egyptian Yasmine were used as "Lines", while the genotypes Hexi 12, Milyang 97 and Tongil were used as "Testers"(Table 1).A hot water method for emasculation was used for the hybridization (Jodon, 1938 and Butany, 1961). In the 2020 season, F_1 seeds and their parents were grown in plots. Each plot contained three rows and each row contained 25 plants, grown at a spacing of 20 × 20 cm using a randomized complete block design (RCBD) with three replications. All the cultural practices and fertilizer were followed according to recommended of RRTC.

Table 1. Origin and parentage of the eight genotypes used as parents under study.

Group	No	Genotype	Parentage	Origin
(Lines)	1	Giza 178	Giza 175/Millyang 49	Egypt
	2	Giza 179	GZ6296-12-1-2-1-1/GZ1368-S-5-	Egypt
	3	Giza 181	IR1626-203/IR28//IR22	Egypt
	4	Sakha 104	GZ 4096/GZ 4100	Egypt
	5	Egyptian	IR262-43-8-11 / KDML105	Egypt
(Tester)	1	Hexi 12	Not available	China
	2	Milyang 97	Not available	Korea
	3	Tongil	IR-8/ (YukaraxTN-1)[12]	Korea

The studied traits were measured at harvest stage on ten random plants from each genotype harvested individually. These traits were divided into two groups, the first one included six yield traits viz, number of panicles/hill, panicle weight (g), number of filled grains/panicle, sterility%, 1000-grain weight (g) and grain yield/plant (g). While, the second group included physical and milling characters: grain length and shape were measured for paddy rice grain according to Khush *et al* (1979). On the other hand, hulling%, milling% and head rice% were determined according to Adair (1952) by using Satake testing machines. Amylose content was estimated for milled rice samples following Juliano (1971).

Statistical analysis: Data recorded were analyzed consistent with analysis of variance (ANOVA) technique as outlined by Steel *et al* (1997). Heterosis was estimated from mean values consistent with Fehr (1987) and t-test was performed. Combining ability analysis was done using line x tester method according to Kempthorne (1957).

The estimates of heterosis: Heterosis over the mid-parent = [(F_1 – MP)/MP x 100] and S.E. (F_1 – MP) = (3MS/2r) 1/2, Heterosis over the better-parent = [(F1 – BP)/BP x 100] and S.E. (F_1 – BP) = (2MS/r) 1/2.

RESULTS AND DISCUSSION

Analysis of variance: ANOVA (Table 2) was performed to test the differences amongst parents and hybrids for all studied traits.

Table 2. Mean squares for yield and yield components used in the study.

SOV	df	Ms					
		No, panicle/ plant	Panicle weight (g)	No. filled grains/panicle	Sterility%	1000-grains weight	Grain yield g/ plant
Rep	2	1.52	0.10	3.08	0.16	1.08	4.82
Genotype	22	52.86 **	1.49**	1684.47**	226.84**	201.88**	191.11**
Parents (P)	7	42.74**	0.66**	670.05**	81.15**	420.15**	64.77**
Crosses (c)	14	59.93**	1.68**	2023.95**	173.53**	31.98**	158.64**
P x C	1	24.71**	4.78**	4032.54**	1978.53**	1052.72**	1530.11**
Group I (lines)	4	75.47**	4.65**	6119.22**	477.68**	17.07**	407.11**
Group II (tester)	2	17.95**	0.18**	819.20**	162.63**	82.07**	152.09**
Line x tester	8	62.66**	0.57*	277.51**	24.18**	26.91**	36.04**
Error	44	2.36	0.04	5.10	1.92	0.87	3.05

Genotype	df	Ms					
		Grain length (mm)	Grain shape Length/width	Hulling%	Milling rice%	Head rice%	Amylose content%
Rep	2	2.12	0.03	1.54	0.11	1.09	0.41
Genotype	22	4.09**	1.06 **	57.20 **	30.50**	28.35**	14.99**
Parents (P)	7	1.58	1.06**	29.82 **	7.51**	42.70**	17.96**
Crosses (c)	14	5.64**	1.10**	71.42 **	39.58**	17.19**	14.13**
P x C	1	0.02	0.64**	49.72 **	64.48**	84.21**	6.23**
Group I (lines)	4	11.95*	2.50**	155.34**	52.69**	50.13**	18.64**
Group II (tester)	2	4.26*	1.73**	121.97 **	83.74**	8.51**	32.53**
Line x tester	8	2.82*	0.24**	16.83 *	21.98**	2.89**	7.27**
Error	44	1.01	0.06	6.49	0.23	0.67	0.25

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

Data showed that mean squares to genotypes were significant for all studied characteristics. The mean squares to genotypes were divided into parents, crosses and parents vs. crosses. The differences among parents were highly significant for all traits, indicating the presence of wide genetic variability among parents for almost all traits. The mean squares due to crosses for all traits were found to be significant at 0.01 levels. Parents vs. crosses mean squares further revealed highly significant differences in all crosses. Also, male testers exhibited highly significant differences for all traits. High significant mean squares of lines X testers for all traits showed that they interacted and produced markedly different combining ability effects, and this might be to the wide genetic variety of lines and testers. Also, mean squares due to lines vs testers were significant for all traits, which indicated that female and male parents differed significantly for these traits. Istipliler *et al* (2015).

Mean performance for the studied traits: Mean performance of parents, lines and their hybrids for studied traits are presented in Table (3). The results showed wide range for all characters for the eight parents under study. This showed that a high genetic variety among the cultivars under study. Variation provides evidence that selection is made possible for improvement and hybridization (Abebe *et al* 2017).For grain yield characters, data in (Table 3) pointed that the highest number of panicles/plant was found by Giza 179 (line) followed by Milyang 9٧(tester).

Moreover, the superior panicle weight (3.93g) was obtained for E. Yasmine (line) then Tongil gave (3.80 g). In addition, Giza 179 recorded the highest number of filled grains/panicle (169.16) followed by Tongil (164.00). The lowest sterility% was found in Tongil and Milyang 97 rice genotypes comparing with the other parents under study. Sakha 104 variety gave the heaviest 1000-grain weight (27.43). While, Giza 178 had the lowest mean values of 1000- grain weight (21.6g). Giza 179 surpassed the other rice cultivars under study in grain yield/plant followed by Millyang 97. So, rice breeders should use Giza 179 as donor entry to improve Hexi 12 for new rice variety in their breeding program.

Table 3. Means performance of the eight rice genotypes and their crosses for all the traits.

Group	Genotypes	Traits					
		No, panicles/ plant	Panicle weight (g)	No. filled grains /panicle	Sterility%	1000-grains weight (g)	Grain yield g/plant
Group I (lines)	Giza 178	23.26	2.76	124.40	10.41	21.6	42.10
	Giza 179	26.00	2.90	169.16	7.03	24.2	44.26
	Giza 181	22.34	3.10	145.30	19.08	26.37	41.96
	Sakha 104	23.20	3.78	134.34	10.56	27.43	39.71
	E. Yasmine	19.35	3.93	152.16	16.61	26.00	31.69
Group II tester	Hexi 12	17.26	3.15	158.5	9.41	25.00	34.30
	Milyang 97	23.90	3.70	150.83	5.88	26.67	42.35
	Tongil	14.80	3.80	164.00	3.87	23.367	34.70
Crosses							
Giza 178x Hexi 12		31.67	4.42	129.33	26.21	28.06	57.83
Giza 178x Milyang 97		29.13	3.5	129.33	23.52	20.06	58.53
Giza 178x Tongil		19.88	4.26	106.20	20.11	24.00	55.3
Giza 179x Hexi 12		23.47	2.47	168.00	20.1	18.56	45.16
Giza 179x Milyang 97		20.03	3.31	178.66	15.7	24.40	57.13
Giza 179x Tongil		25.07	2.23	175.33	12.64	29.80	46.86
Giza 181x Hexi 12		22.80	3.91	118.00	20.9	24.00	47.52
Giza 181x Milyang 97		25.86	4.21	148.50	27.86	23.70	55.3
Giza 181x Tongil		18.93	4.40	141.11	19.01	27.56	47.8
Sakha 104x Hexi 12		20.91	3.82	93.57	15.43	26.39	52.19
Sakha 104x Milyang 97		20.20	4.63	108.02	13.93	25.06	49.19
Sakha 104x Tongil		15.58	4.48	107.74	11.94	29.91	43.18
E. Yasmine x Hexi 12		18.28	4.43	121.93	37.98	23.05	41.65
E. Yasmine x Milyang 97		18.90	4.48	140.76	33.13	21.88	39.27
E .Yasmine x Tongil		27.06	4.38	140.39	25.21	26.11	34.46
LSD 0.05 LSD 0.01		2.734 3.688	0.171 0.230	2.33 3.14	0.95 1.28	0.081 0.109	3.95 5.33

Table 3. Cont.

Group	Genotypes	Traits					
		Grain length (mm)	Grain shape Length/ width	Hulling%	Milling rice%	Head rice%	Amylose content%
Group I (lines)	Giza 178	7.35	2.00	82.33	71.1	66.71	18.20
	Giza 179	7.60	2.19	84.56	72.65	56.70	17.03
	Giza 181	8.47	3.17	78.86	69.67	63,30	18.01
	Sakha 104	7.64	2.3	80.16	71.33	62.65	18.57
	E. Yasmine	9.19	3.54	74.36	67.33	61.54	17.90
Group II tester	Hexi 12	7.25	2.11	82.4	7343	69.5	14.96
	Milyang 97	7.50	1.90	83.00	70.01	65.50	22.90
	Tongil	7.53	2.26	81.00	72.10	64.30	19.34
	LSD 0.05 LSD 0.01	0.198 0.267	0.185 0.250	1.60 2.61	0.338 0.456	0.621 0.838	0.310 0.418
Crosses							
Giza 178x Hexi 12		7.06	1.56	78.20	71.42	69.66	15.65
Giza 178x Milyang 97		5.78	1.52	79.10	70.23	68.20	14.79
Giza 178x Tongil		7.70	2.55	74.03	72.46	69.50	18.00
Giza 179x Hexi 12		7.74	2.15	75.00	64.44	63.10	14.20
Giza 179x Milyang 97		7.58	2.21	83.07	75.00	62.50	17.78
Giza 179x Tongil		7.80	2.78	83.30	76.00	61.70	16.70
Giza 181x Hexi 12		7.54	1.67	81.50	75.6	67.01	16.00
Giza 181x Milyang 97		7.12	2.08	84.70	74.96	68.13	19.36
Giza 181x Tongil		8.16	1.68	83.30	76.42	64.02	17.02
Sakha 104x Hexi 12		7.29	1.76	76.849	70.77	67.10	16.83
Sakha 104x Milyang 97		6.45	1.81	82.49	73.40	66.97	19.18
Sakha 104x Tongil		8.52	2.40	78.77	75.99	65.70	23.07
E. Yasmine x Hexi 12		9.26	2.72	71.288	66.80	65.92	16.23
E. Yasmine x Milyang		9.48	2.87	76.52	69.29	65.78	18.47
E .Yasmine x Tongil		10.28	3.66	73.072	71.74	64.54	18.25
LSD 0.05 LSD 0.01		0.198 0.267	0.185 0.250	1.60 2.61	0.338 0.456	0.621 0.838	0.310 0.418

For grain quality characters, results in Table (3) showed that E. Yasmine and Giza 181 recorded the maximum grain length (9.19 and 8.47mm respectively) and grain shape (3.54 and 3.17, respectively), which indicated that varieties belonged to Indica type. These results were agreement with Sharma (2002).

Concerning amylose content, all cultivars under study revealed low amylose content that ranged from 14.96 to 19.34%, except Milyang 97 variety which was intermediate (22.90). However, low amylose and very low are good sources to use as donor to produce new rice variety of high grain quality characters in breeding program. While, number of panicles per plant of the F_1 mean values ranged between 15.58 for cross (Sakha 104x Tongil) to 31.67 for cross (Giza 178x Hexi 12). For panicle weight, the fifteen rice crosses ranged from 2.23 for the cross (Giza 179 x Tongil) to 4.63 for (Sakha 104 xMilling 97).On the other hand, the highest number of filled grains was found by cross (Giza 179xMilling 97), which gave 178.66 grain per panicle. As for sterility percentage, the cross (Sakha 104x Tongil) was found to be the lowest sterility%. For 1000 -grain weight, the crosses (Sakha 104x Tongil), (Giza 179x Tongil) and (Giza 178x Hexi 12) were higher than the highest parents showed that over-dominance acted an essential role in the inheritance of this trait in tease crosses. On the other hand, the cross (Giza 178x Milyang 9٧), (Giza 178x Hexi12) then (Giza 179 x Milyang 97) gave the highest grain yield/plant (58.53, 57.83and 57.13g/plant, respectively).

Concerning grain shape, all crosses were round and medium in grain shape except(E. Yasmine x Tongil) cross was slender. For head percentage, the cross (Giza 178 x Hexi 12) had the highest value. As for amylose content, all crosses gave the lowest value of amylose content, except the cross (Sakha 104 x Tongil), which gave 23.07.

General combining ability (GCA)

Estimates of GCA effects of parents are presented in Table (4). Two varieties (Giza 178 and Hexi 12) had significant and positive and scored the best GAA effects (4.37 and 0.91) for number of panicles/plant. These varieties were good donors for this trait. For panicle weight, E. Yasmine, Sakha 104, Giza 181and Giza 178 had highly significant and positive GCA effects for this trait, it means that these parents were good combiners and could be used in breeding program to improve this trait. Additionally for number of filled grains per panicle, a positive and significant GCA effects were found with the varieties Giza 179, Milyang 97 and Giza 181.

Table 4. General combining abilities (GCA) effects of traits under study.

Genotype			No, panicles/ plant	Panicle weight (g)	No. filled grains/ panicle	Sterilit%	1000-grains weight (g)	Grain yield (g)/ pant
Group I (lines)	1	Giza 178	4.37**	0.13*	-12.16**	2.12**	-0.80*	8.46**
	2	Giza 179	0.34	-1.26**	40.32**	-5.46**	-0.58	0.96
	3	Giza 181	0.01	0.24**	2.16**	0.99*	0.25	1.45*
	4	Sakha 104	-3.62**	0.38**	-30.67**	-8.16**	2.28**	-0.57
	5	E. Yasmine	-1.10*	0.50**	0.36	10.51**	-1.15**	-10.30**
	S.E (gi)		0.149	0.170	0.211	0.103	0.090	0.159
	S.E (gi-gj)		2.38	0.294	3.50	2.27	1. 55	2.713
Group II (testers)	1	Hexi 12	0.91*	-0.12*	-7.62**	2.66**	-0.82**	0.11
	2	Milyang 97	0.31	0.10	7.14**	1.03**	-1.82**	3.13**
	3	Tongil	-1.21**	0.02	0.48	-3.68**	2.64**	-3.24**
	S.E (gi)		1.06	0.131	1.57	1.01	0.693	1.214
	S.E (gi-gj)		2.38	0.291	2.14	1.317	0.947	1.65
Genotype			**Grain length (mm)**	**Grain shape (Length/ width)**	**Hulling%**	**Milling rice%**	**Head rice%**	**Amylose%**
Group I (lines)	1	Giza 178	-0.62	-0.35**	-2.05*	-1.20**	3.00**	-1.29**
	2	Giza 179	0.24	0.15	1.38	-0.42*	-3.52**	-1.21**
	3	Giza 181	-1.11**	-0.42**	5.78**	3.43**	0.42	0.02
	4	Sakha 104	-0.38	-0.24**	0.32	1.15**	0.64*	2.26**
	5	E. Yasmine	1.87**	0.86**	-5.42**	-2.96**	-0.54	0.22
	S.E (gi)		0.469	0.22	0.23	0.54	0.080	0.046
	S.E (gi-gj)		1.559	0.377	3.961	0.935	1.268	0.779
Group II (tester)	1	Hexi 12	-0.03	-0.25**	-2.53**	-2.43**	0.50*	-1.65**
	2	Milyang 97	-0.52	-0.13*	3.09**	0.14	0.36	0.48**
	3	Tongil	0.55*	0.39**	-0.56	2.29**	-0.87**	1.17**
	S.E (gi)		0.286	0.169	1.77	0.418	0.567	0.349
	S.E (gi-gj)		1.46	0.230	2.421	0.571	0.775	0.476

***, ** and NS indicate P < 0.05, P< 0.01 and not significant, respectively.**

These results indicated that these genotypes are good combiners in this trait and could be used as donors for breeding program. On the other hand, significant and negative value was found for sterility percentage with Sakha 104, Giza 179 and Tongil.This negative value is desirable and these genotypes can be used as donors or a good combiners for low sterility. As for the 1000-weight, two genotypes (Sakha 104 and Tongil) showed significant and positive .Concerning for grain yield per plant, three genotypes (Giza 178, Millyang 97 and Giza 181) had significant and positive GCA effects.The significant desirable values of GCA effect for grain length was recorded by E. Yasmine. Significant and negative value of GCA effects for grain shape was observed for Giza 181, Giza 178, Hexi 12 and Sakha 104. For milling characters, a significant and positive value of GCA effects among the parents was recorded by Giza 181 and Millyang 97 in hulling. While, Giza 181,Tongil and Sakha 104 were the best parents in milling% and the positive and significant GCA effects were recorded by Giza 178, Sakha 104 and Hexi 12 in head rice. Thakare *et al* (2013) reported both positive and negative significant GCA effects for milling recovery. Finally, for amylose content depends on consumer Egyptians who prefer the low amylose content so, that negative and significant (GCA) effects for the trait was estimated for Giza 178 and Giza 179 (as lines). However, the highest negative and significant GCA effects were recorded by Hexi 12 (as testers) for amylose content% only. These parents appeared to be good parental combiners in rice crosses for improving this trait.

These results clarified that none of the parents showed significant desirable GCA effects simultaneously in desired direction for all the traits under study. These results agreed with Waza *et al* (2015).

Specific combining ability (SCA)

The positive and significant SCA effects are desirable in all characters under study except sterility percentage, grain length, grain shape and amylose content. The results in Table (5) showed that the five crosses (E .Yasmine x Tongil), (Giza 178x Hexi 12), (Giza 179x Tongil), (Giza 181x Milyang 9٧) and (Giza 178x Milyang 97) had positive and significant SCA effects in number of panicles per plant. In panicle weight, the results revealed that two crosses (Giza 179x Milyang 97) and (Giza 178x Hexi 12) had positive SCA effects. While, the crosses (Giza 178x Hexi 12) followed by (E. Yasmine x Tongil), (Giza 181x Milyang 97), (Giza 181x Tongil) and (Sakha 10 x Tongil) were positive and significant SCA effects for number of filled grains/panicle.

Table 5. Estimates of specific combining ability (SCA) effects.

Cross	No, panicle/ plant	Panicle weight (g)	No.filled grains/ panicle	Sterilit%	1000-grains weight (g)	Grain yield weight g/ plant
Giza 178x Hexi 12	3.86**	0.48**	15.33**	0.16	4.85**	0.50
Giza 178x Milyang 97	1.93*	-0.66**	0.57	-0.90	-2.16**	-1.82
Giza 178x Tongil	-5.80**	0.18	-15.90**	0.74	-2.68**	1.32
Giza 179x Hexi 12	-0.29	-0.08	1.51	1.63*	-4.87**	-4.67**
Giza 179x Milyang 97	-3.13**	0.54**	-2.58	-1.48	1.96**	4.28**
Giza 179x Tongil	3.42**	-0.46**	1.08	-0.15	2.91**	0.38
Giza 181x Hexi 12	-0.64	-0.14	-10.33**	-4.35**	-0.27	-2.80**
Giza 181x Milyang 97	3.03**	-0.06	5.42**	3.58**	0.43	1.97
Giza 181x Tongil	-2.39*	0.20	4.91**	0.77	-0.16	0.83
Sakha 104x Hexi 12	1.10	-0.37**	-1.92	-0.66	0.09	3.89**
Sakha 104x Milyang 97	1.00	0.22	-2.23	-1.20	-0.24	-2.12*
Sakha 104x Tongil	-2.10*	0.15	4.15**	1.86*	0.15	-1.77
E. Yasmine x Hexi 12	-4.04**	0.12	-4.59**	3.22**	0.20	3.08**
E .Yasmine x Milyang 97	-2.82**	-0.04	-1.18	-0.01	0.01	-2.32*
E .Yasmine x Tongil	6.86**	-0.07	5.77**	-3.21**	-0.21	-0.76
S.E (sij)	1.311	0.222	2.62	1.68	1.16	2.03
S.E (sij-skl)	1.788	0.139	1.66	1.37	0.734	1.284
Cross	**Grain length (mm)**	**Grain shape Length/width**	**Hulling%**	**Milling rice%**	**Head rice%**	**Amylose content%**
Giza 178x Hexi 12	-0.09	-0.06	3.19*	2.81**	-0.29	1.16**
Giza 178x Milyang 97	-0.88	-0.23	-0.42	-1.95**	-1.12*	-1.84**
Giza 178x Tongil	0.18	0.29*	-2.77	-0.86**	1.41**	0.68*
Giza 179x Hexi 12	0.11	0.03	-3.24*	-4.94**	0.16	-0.37
Giza 179x Milyang 97	0.06	-0.04	0.14	3.05**	-0.30	1.07**
Giza 179x Tongil	0.22	0.01	3.10*	1.90**	0.13	-0.70*
Giza 181x Hexi 12	0.87	0.12	0.53	2.37**	0.12	0.19
Giza 181x Milyang 97	0.94	0.40**	-0.89	-0.84**	1.39**	1.42**
Giza 181x Tongil	-1.81**	-0.52**	0.36	-1.53**	-1.51**	-1.61**
Sakha 104x Hexi 12	-0.11	0.03	-0.33	-0.19	0.01	-1.21**
Sakha 104x Milyang 97	-0.45	-0.05	0.70	-0.13	0.01	-0.99**
Sakha 104x Tongil	0.56	0.02	-0.37	0.32	-0.02	2.20**
E .Yasmine x Hexi 12	-0.11	-0.11	-0.15	-0.04	0.01	0.23
E. Yasmine x Milyang 97	-0.45	-0.08	0.47	-0.13	0.01	0.34
E. Yasmine x Tongil	0.56	0.19	-0.32	0.17	-0.01	-0.57
S.E (sij)	0.351	0.282	0.699	0.699	0.949	0.583
S.E (sij-skl)	0.738	0.178	1.875	0.442	0.600	0.369

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

On the other hand, the cross combination (Giza 181x Hexi 12) followed by (E. Yasmine x Tongil) showed a highly significant and negative SCA effects for sterility percentage. For 1000-grain weight, the crosses combination (Giza 178 x Hexi 12), (Giza 179 x Tongil) and (Giza 179 x Milyang 97) had significant and positive SCA effects Table (5). While, the crosses (Giza 179 x Milyang 97), (Sakha 104 x Hexi 12) and (E. Yasmine x Hexi 12) gave positive and segnificant SCA effecys for grain yield per plant trait. Results indicated the preponderance of non-additive gene action in the inheritance of these traits. The predominance of non-additive gene action was noted for grain yield was clarified by the variance of SCA was higher than variance of GCA. This result matches with the findings of various scientists who declared the predominance of non-additive gene action (Zeinab *et al* (2014).

Only the cross combination (Giza 181 x Tongil) showed a significant and negative SCA effects for grain length and grain shape. The best crosses were (Giza 178 x Hexi 12) and (Giza 179 x Tongil) for hulling. However, highly significant and positive estimates of SCA effects were recorded for three crosses (Giza 178 x Hexi 12, Giza 179 x Milyang 97 and Giza 181 x Hexi 12) for milling%. Only two crosses gave high significant positive SCA effects for head rice% namely (Giza 181 x Milyang 97) and (Giza 178 x Tongil). Only five crosses gave high significant and negative SCA value for amylose content% (Giza 178 x Milyang 97), (Giza 181 x Tongil), (Giza 178 x Milyang 97**)**, (Sakha 104 x Milyang 97) and (Giza 179 x Tongil**).**

The contribution% of lines, testers and line x tester interaction

The proportional contribution of lines, testers and their interaction for twelve traits is presented in Table (6). The data indicated that lines played important role towards panicle weight (79.161%), number of filled grains/panicle (86. 38%), sterility% (78.64), grain yield (73.322%),grain length (60.568%),grain shape (65.067%), hulling% (62.142%), milling rice% (38.042%) head rice% (83.325%) indicating predominant maternal influence for these traits. Testers were not important for any character. Line × tester interaction contributed to combinations of variances for number of panicles/plant (59.741%), 1000-grain weight (48.086%) much more than lines and testers, individually.

Table 6. The contribution of lines, testers and line × tester interaction for hybrid generation (%).

Source	No. panicle/ plant	Panicle weight (g)	No. filled grains/ panicle	Sterility %	1000-grains weight (g)	Grain yield weight (g/plant)
Group I (L)	35.978	79.161	86.38	78.64	15.250	73.322
Group II (T)	4.279	1.541	5.78	13.38	36.662	13.69
L x T (I x II)	59.741	19.297	7.83	7.96	48.086	12.98
Source	**Grain length (mm)**	**Grain shape Length/ width**	**Hulling%**	**Milling rice%**	**Head rice %**	**Amylose content%**
Group I (L)	60.568	65.067	62.142	38.042	83.325	37.692
Group II (T)	10.807	22.475	24.395	30.226	7.077	32.894
L x T (I x II)	28.623	12.457	13.462	31.731	9.597	29.413

Accordingly, line × tester interactions supply much extra variation for the appearing of the traits wing of the traits. It is marked that hybrid combinations had higher values than their parents with respect to number of panicles/plant and 1000-grain weight. Marked that hybrid combinations had higher values than their parents with respect to number of panicles /plant, and1000-grain weight. These results are in agreement with Istipliler *et al* (2015).

Genetic components

Genetic variance components of variances are assessed through the estimates of GCA and SCA variances. The additive genetic variance is equal to GCA variance and dominance variance is equal to SCA variance Bano and Singh (2019). The estimates of GCA variance were lower than SCA variance for all characters under study (Table 7). Therefore, these characters exhibited non- additive variance. This result is in close agreement with (Shorifi and Naghi (2011) and Waza *et al* 2015).

Table 7. Genetic component estimates.

Component	No, panicle/ plant	Panicle weight (g)	No. filled grains/ panicle	Sterilit %	1000-grains weight	Grain yield (g/plant)
σ^2 GCA (Line)	1.423	0.453	649.07	50.38	-1.093	41.230
σ^2 GCA (Tester)	-2.980	-0.025	36.11	9.22	3.677	7.736
σ^2 GCA (Average)	-0.096	0.039	61.74	5.27	0.179	4.334
σ^2 SCA	20.098	0.176	206.25	5.27	8.679	10.997
σ^2A	-0.385	0.157	246.97	21.11	0.716	17.337
σ^2D	80.392	0.707	363.21	29.68	34.71	43.989
Component	**Grain length (mm)**	**Grain shape Length/width**	**Hulling%**	**Milling rice%**	**Head rice%**	**Amylose content%**
σ^2 GCA (Line)	1.014	0.251	15.390	3.413	5.248	1.262
σ^2 GCA (Tester)	0.096	0.099	7.009	4.117	0.375	1.683
σ^2 GCA (average)	0.099	0.030	1.930	0.622	0.505	0.242
σ^2 SCA	0.605	0.060	3.443	7.250	0.740	2.340
σ^2A	0.397	0.121	7.720	2.488	2.022	0.969
σ^2D	2.421	0.240	13.775	29.00	2.961	9.360

Estimates of heterosis

Heterosis related to mid-parent and better parent for studied traits are presented in Table (8). Heterosis over mid parent (relative heterosis), over better parent (heterobeltiosis) was estimated in crosses under study for fifteen characters to search out the best combination of parents giving a high degree of useful heterosis and characterization of parents for their prospects for future use in breeding programs. The degree of heterosis differed from cross to another and from character to another. Alam *et al* (2007) in upland rice observed the varying degree of heterosis for yield and grain quality traits. For sterility% negative heterosis was desirable but for rest of the characters positive heterosis was desirable. Gowayed *et al* (2020). Maximum and significant heterosis for number of panicles/plant was registered by (E. Yasmine x Tongil) then (Giza 178x Hexi 12) over better parent (58.50 and 56.25%) and over mid parent 39.86 and 36.10%), respectively. Chuwang *et al* (2019) reported highly significant and positive heterotic effects with respect to tiller number per plant which is in accordance with the present results.

Table 8. Heterosis as deviation from mid-parent(MP) and better patent(BP).

Cross	No, panicle/plant		Panicle weight (g)		No. filled grains/panicle		Sterility%		1000-grains weight		Grains yield weight (g/plant)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Giza 178x	56.25*	36.10*	52.12*	44.98*	-8.57**	-	167.74*	154.85	20.46*	12.27*	51.59**	37.70**
Giza 178x	23.53*	21.90*	8.35**	-5.32**	-6.02**	-	192.76*	129.06	-	-	38.78**	38.19**
Giza 178x	4.47**	-	29.75*	12.11*	-	-	190.76*	99.49*	6.75**	2.71**	44.20**	31.67**
Giza 179x	8.52**	-9.71**	-	-	2.54	-0.69	148.43*	117.07	-	-	14.98**	2.03
Giza 179x Mi	-19.7	-	0.40**	-	11.67*	5.62**	143.03*	123.12	-4.06**	-8.50**	31.91**	29.07**
Giza 179x	22.88*	-3.59**	-	-	5.45**	3.84*	125.66*	74.99*	25.30*	23.14*	18.70**	5.87**
Giza 181x	15.13*	2.06	27.19*	26.24*	-	-	46.67**	9.50**	-6.55**	-8.98**	24.62**	13.24**
Giza 181x	11.88*	8.23**	23.92*	13.87*	0.29	-1.55	117.86*	42.51*	-	-	31.16**	30.56**
Giza 181x	1.96	-	27.54*	15.79*	-8.61**	-	71.37**	3.09**	10.86*	4.55**	24.70**	13.90**
Sakha 104x	3.38**	-9.84**	11.85*	1.10**	-	-	54.53**	46.11*	0.66	-3.81**	41.04**	31.43**
Sakha 104x	-	-	23.86*	22.55*	-	-	61.37**	25.62*	-7.33**	-8.63**	19.90**	16.15**
Sakha 104x	-	-	18.37*	18.06*	-	-	60.81**	9.91**	17.77*	9.03**	16.06**	8.74**
E.Yasmine x	-0.11	-5.49**	26.94*	12.72*	-	-	191.85*	128.60	-9.58**	-	26.23**	21.44**
E.Yasmine x	-	-	17.61*	14.10*	-7.52**	-7.93**	194.54*	99.42*	-	-	6.08**	-7.27**
E.Yasmine x	58.50*	39.86*	13.33*	11.38*	-	-	146.13*	51.78*	5.79**	0.43	3.82**	-0.67
LSD 0.05 LSD 0.01	2.19 2.92	2.52 2.27	0.270 0.360	0.311 0.416	3.21 4.29	3.71 4.96	1.97 2.63	2.28 3.04	1.331 1.778	1.537 2.053	2.487 3.323	2.872 3.837

Crosses	Grain length (mm)		Grain shape (Length/ width)		Hulling%		Milling%		Head rice		Amylose content%	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Giza 178x	-	-3.90**	-	-	-5.30**	-5.34*	0.71	0.12	1.57**	-0.48	-5.61**	-14.01**
Giza 178x	-	-	-	-	-4.44*	-4.82*	-0.73	-1.08*	3.57**	2.25**	-28.03**	-35.41**
Giza 178x	3.43**	2.17**	20.05*	12.78*	-9.39**	-	3.16**	2.79**	6.35**	4.20**	-4.10**	-6.93**
Giza 179x	4.22**	1.84*	0.31	-1.41**	-	-	-9.26**	-9.66**	0.01	-9.21**	-11.18**	-16.58**
Giza 179x	0.44	-0.18	8.11**	0.92**	-0.93	-1.85	5.86**	5.63**	2.71**	-3.85**	-10.94**	-22.36**
Giza 179x	16.36*	15.88*	24.87*	22.74*	0.62	-1.50	8.04**	7.51**	2.24**	-3.59**	-8.17**	-13.65**
Giza 181x	-	-	-	-	1.07	-1.09	4.76**	3.56**	1.13	-3.60**	-4.76**	-14.16**
Giza 181x	-	-	-	-	4.65*	2.05	4.12**	2.69**	6.46**	4.82**	-6.79**	-15.46**
Giza 181x	1.92**	-3.74**	-	-	4.21*	2.84	6.89**	4.69**	0.79	0.01	-10.37**	-12.00**
Sakha 104x	-	-4.60**	-	-	-5.46**	-6.74**	-0.79	-0.79	1.56**	-3.44**	0.41	-9.36**
Sakha 104x	-	-	-	-	1.12	-0.61	3.15**	2.91**	4.93**	3.03**	-7.49**	-16.23**
Sakha 104x	12.33*	11.53*	5.24**	4.49**	-2.24	-2.74	7.55**	6.55**	3.76**	2.66**	21.70**	19.30**
E. Yasmine x	11.29*	-1.39	-3.67**	-	-9.05**	-	-3.65**	-6.35**	0.62	-5.14**	-1.21**	-9.34**
E. Yasmine x	12.22*	0.95	5.88**	-	-2.74	-7.80**	0.18	-2.40**	3.97**	1.21	-9.44**	-19.32**
E. Yasmine x	21.48*	9.48**	26.20*	3.52**	-5.92**	-9.78**	4.48**	2.49**	2.83**	0.86	-1.95**	-5.59**
LSD 0.05 LSD 0.01	1.43 1.910	1.651 2.206	0.346 0.462	0.399 0.534	3.63 4.85	4.19 5.60	0.676 0.904	0.781 1.043	1.116 1.553	1.342 1.793	0.714 0.954	0.825 1.102

The maximum and significant heterosis for panicle weight was recorded by (Giza 178x Hexi 12) (44.98%) over better and (52.12%) over mid parent. (Giza 179x Tongil) cross gave positive and significant heterobeltiosis (5.45%) for number of filled grains / panicle. Prasad *et al* (2019) who reported high heterotic effects for the number of grains per panicle. For the trait of sterility %, no cross recorded negative heterosis. Li *et al* (2019) reported that the trait1000- grain weight effects on yield in rice. In this study, maximum, significant and positive heterotic effect for 1000-grain weight over better parent was (23.14%) and mid parent was recorded (25.3%) in Giza 179x Tongil. For grain yield, out of the fifteen crosses under study, significant and desirable heterosis was observed in twelve crosses over better parent. The maximum value was recorded by Giza 178 x Milyang 97 followed by Giza178 x Hexi 12.All crosses recorded significant and positive mid parent heterosis for grain yield per plant (Table 8). The highest mid parent heterosis% was recorded in (Giza178 x Hexi 12) followed by (Giza 178 x Tongil).The cross (Giza 178x Hexi 12) exhibited the highest heterobeltiosis and relative heterosis% for grain yield per plant and was identified as the best cross. Significant and positive heterosis for grain yield per plant has been reported by Gowayed *et al* (2020). Giza 178x Milyang 97 cross recorded the highest negative heterobeltiosis (-22.96 %) and highest relative heterosis (-22.16%) for grain length. The data for grain shape showed that the maximum negative and significant heterotic effects over better parent was (-47.05%) and mid parent (-38.18%) was exhibited by the Giza 181 x Tongil cross. The cross Giza 181x Milyang 97 registered significant and positive heterobeltiosis and relative heterosis for hulling percentage. The highest heterosis of 7.51% (over better parent) and 8.04% (over mid parent) were exhibited in (Giza 179 x Tongil) for milling percentage.

One of the most important criteria for measuring the quality of milled rice is high head rice production.Giza181 x Milyang 9٧ cross recorded high heterobeltiosis (4.82%) and relative heterosis (6.46%) for head rice recovery. Parveen and Singh (2019) also reported significant and positive heterosis for hulling percentage, milling percentage and head rice recovery in their studies. Sakha 104 x Tongil recorded the highest heterobeltiosis and highest relative heterosis for amylose content. Ultimate goal of breeding is to obtain the heterotic yield associated with other heterotic characters. Yield is a complex character, so (Giza 178 x Hexi 12) for grain yield and (Giza 181x Milyang 9٧) cross for head rice may be considered for further study of combining ability. The exploitation of heterosis can increase yield (Begum *et al* 2020).

CONCLUSION

The tester Millyang 97 was a good general combiner for yield, while Hexi 12 was good general combiner for head rice and amylose content% under study .The crosses Giza 179 x Milyang 97, Sakha 104 x Hexi 12 and E. Yasmine x Hexi 12 were observed as good specific combiners for yield/plant, but the cross Giza 178 x Tongil and Giza 181 x Milyang 97 were good specific combiners for head rice. The genetic components revealed these characters under study exhibited non additive variance. Significant and desirable heterosis was observed in twelve crosses over better parent but the maximum value was recorded (Giza 178x Milyang 97) followed by (Giza178x Hexi12). All crosses recorded significant and positive mid parent heterosis for grain yield per plant. But only Giza 181x Milyang 97 cross recorded high heterobeltiosis and relative heterosis for head rice recovery**.**

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تحليل السلالة x الكشاف للمحصول وصفات جودة الحبوب في الأرز

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أقيمت هذه التجربة لدراسة القدرة علي التالف باستخدام تحليل السلالة x الكشاف وكذلك قوه الهجين في صفات المحصول وجوده الحبوب في الأرز عند قياسه كإنحراف عن متوسط الابوين أوعن متوسط الأب الأعلى .تم استخدام ثمانيه تراكيب وراثيه (خمسة أصناف أرز محليه وثلاثة اصناف مستورده تختلف في صفات المحصول وجوده الحبوب بالإضافة إلي الهجن الناتجة من هذه الأصناف(خمسه عشر) حيث تم زراعتها في مزرعة مركز بحوث الأرز والتدريب باستخدام تصميم القطاعات الكاملة العشوائية. وتم تقدير صفات المحصول ومكوناته وصفات جودة

الحبوب في كل من الأصناف والهجن الناتجة. أشارت النتائج إلي ما يلي: وجد اختلافات عالية المعنوية بين الأصناف وبين السلالات والكشافات والهجن الناتجة في جميع الصفات المدروسة. كما أظهرت فروق عالية المعنوية بين الابوين والهجين للصفات المدروسة. وقد لوحظ أن الصنف ميليانج ٩٧ هو أفضل الاصناف في القدرة العامة علي الائتلاف بالنسبة لصفه محصول الحبوب بينماالصنف هكسي ١٢ كان أفضل الاصناف في القدرة العامة علي الائتلاف بالنسبة لصفه نسبه الحبوب السليمة وكذلك نسبه محتوى الأميلوز. كما سجلت الهجن (جيزة ١٧٩x ميليانج ٩٧) و(سخا ١٠٤ × هيكسي ١٢) و(الياسمين المصري × هيكسي ١٢) نتائج معنويه وموجبه في القدرة الخاصة علي التالف لصفه محصول الحبوب/النبات. ولقد لوحظ ان الهجين جيزة ١٧٩x ميليانج ٩٧ أظهر نتائج معنويه وموجبه في القدرة الخاصة علي التالف لكلا من وزن السنبلة ، وزن ١٠٠٠ حبة ووزن محصول الحبوب ولكن كانت نتائج معنويه وموجبه في القدرة الخاصة علي التالف لصفه نسبه الحبوب السليمة لكلا من الهجين(جيزة ١٧٨ x تونجيل) و(جيزة ١٨١ x ميليانج ٩٧). أشارت البيانات إلى أن السلالات لعبت دورا مهما في وزن السنبلة، عدد الحبوب الممتلئة للسنبلة ونسبة العقم، محصول الحبوب، وشكل الحبوب، ونسبة التقشير، نسبه التبيض ونسبة الأرز السليمة، مما يشير إلى التأثير السائد للأم على هذه الصفات. لم يكن للأصناف التابعة للكشاف دور مهمالاي صفه .ساهم تفاعل السلالة × الكشاف دورا مهم لكل من عدد السنابل/النبات ووزن ١٠٠٠ حبة .أظهتر المكونات الوراثيه أن الصفات قيد الدراسة أظهرت تباينًا غير مضيف. ولقد أوضحت النتائج قوه هجين معنويه موجبه بالقياس لمتوسط الأبوين في ١٥ هجين و وفي ١٢ هجين عن متوسط الأب الأعلى ، ولكن القيمة القصوى لقوه الهجين ظهرت في (الجيزة ١٧٨ x ميليانج ٩٧) تليها (الجيزة ١٧٨ x هيكسي١٢) للمحصول/النبات،بينما كانت واضحه في هجين واحد (جيز١٨١ x ميليانج ٩٧) فقط بالنسبة لصفه الحبوب السليمة وذلك عند قياسها كإنحراف عن متوسط الأبوين وعن الاب الافضل.

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