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Research Article

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Genetic Components and Correlation Coefficient for Earliness and Grain Yield in Rice

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Abstract

The present research was conducted to study earliness and their correlations with grain yield in rice breeding. It was carried out during 2012 and 2013 growing seasons at RRTC Farm, Sakha, Kafr El-Sheikh, Egypt. F_1 were evaluated along with their parents for genotypic variation. ANOVA revealed significant differences at the 0.01 level among crosses and parents as well as between parents and crosses. These results indicated a wide range of variations among parental groups. The mean squares of parents vs. crosses were found to be significant for all grain yield and its component characters. Variance among crosses indicated significant SCA effects at the 0.01 level for all its component traits. Concerning GCA effects four entries; Sakha 101, Novator, Anait and Large Stigma exhibited positive significant estimates at 0.01 levels for grain yield /plant. The desirable hybrid combinations Giza 179 X Large Stigma and Sakha 105 X VNIRB 572 exhibited significant values of SCA effects at 0.01 and 0.05 levels for grain yield. Heritability estimates in narrow sense ranged from low to moderate. Sakha 101 X Novator, Sakha 106 X Novator and Giza 179 X Large Stigma were the promising hybrid combinations for improving yield character according to results for mid and better parent heterosis. Positive significant correlation coefficient at 0.01 level was recorded between 1000-grain weight and grain yield/plant. The four earliness component traits understudy contributed directly to the earliness character. Also, the earliness component traits; days to heading, days to maturity and elongation of panicle initiation had a direct contribution to yield component.

Keywords

Line X tester analysis; Combining ability; Genetic parameters; Heterosis

Introduction

Rice is the most important staple food for about one-half of the human race [1]. It is one of the major field crops in Egypt, grown on nearly 500, 000 feddans (1 feddan = 0.42 ha) [2]. Also, it is considered the second most popular and important field crop in Egypt for several reasons; (1) it is a staple food after wheat, (2) is a second exporting crop after cotton, (3) is a land reclamation crop for improving the productivity of the saline soils widely spread in North Delta and coastal area regions, and (4) finally it is a social crop in which every person in the farmers' family could find work in rice fields and gain money during the growing season. Rice production in Egypt for the year 2016 was 4.0 million tons milled (5.8 million tons rough) [3]. This amount has to be increased by about 60% by the year 2025 to feed the additional rice consumers**.** Increasing rice production has been a problem due to limited land availability and water shortage. Egypt has only one main source of water supply, the Nile River. The available amount of irrigation water from River Nile is not only limited but also, liable to decrement year after year, due to the competition of other water usage in the country. Therefore, planting early mature varieties is one of the solutions to overcome this problem. In general, early maturing varieties yield better, use less water, reduce the likelihood of pest problems and give a better chance of producing a profitable ratoon crop than late mature varieties. In addition, early maturing varieties save 20-25% from irrigation water and allow the planting of the following crops (particularly clover) one month earlier than the traditional period. This will help increase the number of clover cuts and help reduce crop exposure to biotic and abiotic stresses [4].

The grouping criteria of rice maturity based on harvest time are (1) ultra-maturity, less than 85 days, (2) super maturity, 85-94 days, (3) early maturity, 95-104 days, (4) mature, 105-124 days, (5) intermediate maturity, 125-164 days and (6) late maturity, >165 days [5]. It is crucial to producing shorter duration varieties without sacrificing yield by selecting parental lines possessing desirable genes to produce superior F_1 progeny [6]. Mainly, selection of desirable parents is conducting based on combining abilities and heterosis estimates. Line X tester design is the best analysis for estimating general combining ability (GCA), specific combining ability (SCA), heterosis and various types of gene actions. Many researchers such as Roy and Mandal, Nuruzzaman et al, Faiz et al, Saleem et al. Estimated heterosis and SCA effects for yield and its components in rice using line X tester analysis [7-10]. Also, Heterosis for grain yield was determined in rice by Sarker et al. and Rashid et al. using same analysis. In addition, heterosis and combining the ability of hybrid rice were estimated by Zhang et al., Singh and Kumar [11-14]. Recently, another experiment of a line X tester mating design was conducted to study the nature and magnitude of gene action of yield and yield contributing characters [15]. A similar study was carried out through line X tester analysis to know the genetic architecture of various yields and yield attributing traits in rice under coastal saline condition [16]. Recently, another line X tester cross was carried out to estimate heterosis effects on yield at the Experimental Farm of Rice Research and Training Center, (RRTC), Sakha, Kafr EL-Sheikh, Egypt [17]. An added advantage of this method is that it gives an overall genetic picture of the materials under investigation in a single generation. Therefore, this study was undertaken to estimate genetic components of earliness and yield and its component traits and determines the combining ability of locally adaptable varieties for heterosis. In addition, it was conducted to determine the correlation coefficient among these traits.

Material and Methods

This experiment was conducted at Rice Research and Training Center, Sakha, Kafr El-Sheikh, Egypt, during the two successive growing seasons of 2012 and 2013 to study the magnitude of combining abilities and genetic parameters in some rice genotypes [4].

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Experimental material

The experimental materials used in this study consisted of 35 entries. These entries included five Egyptian commercial varieties, i.e., Sakha 101, Sakha 104, Sakha 105, Sakha 106 and Giza 179 which were used as parental lines. Also, they included five early maturing rice genotypes introduced from foreign countries, i.e., Novator, VNIRB 572, Anait, ZX788 and Large Stigma which were used as testers. Parentage and origin of these genotypes were presented in Table 1. In addition, crosses were made among those genotypes to produce 25 F_1 crosses which were included as experimental materials in this study.

Experimental procedure

In the growing season of the year, 2012 the ten parental varieties of this study were sown in the summer season of the year 2012 in three sowing date, at 15 days intervals to overcome the difference of heading date among the parental varieties. After 30 days from sowing, the seedlings of the parents were transplanted to the experimental field in three rows, of five meters long and 20 X 20 cm apart between plants and rows. A line X tester cross was conducted among the ten parents in the year 2012 to produce 25 crosses. The modified hybridization technique of Butany and hot water method of emasculation were utilized [18]. The parental varieties and the resulting twenty-five crosses obtained arranged in a randomized complete block design (RCBD) experiment with three replications in the year 2013. The studied traits were divided into two groups, the first one included four earliness traits; days to heading, days to maturing, panicle initiation and elongation of panicle initiation, the second group included yield traits; number of panicle/plant, spikelet fertility %, 1000-grain weight, and grain yield/plant. Each replication contained 25 individual plants. All agronomic practices such as fertilization, irrigation, and weed and pest control were done as recommended with rice crop during both seasons of the study.

Statistical analysis

The averages of data were statistically analyzed using two-way analysis of variance (ANOVA) for a randomized complete block design as suggested by Panse and Sukhatme and the analysis of variance for line X tester crossing followed the design of Kempthorne [19,20]. Significant values were determined according to p values ($p<0.05$ = significant and $p<0.001$ = highly significant). Also, GCA and SCA were in accordance with the procedure suggested by Kempthorne [20]. Also, correlation coefficients (r) among all studied traits were computed according to Gomez and Gomez [21]. Also, Heterosis was estimated according to Mather and Jinks [22]. Finally, Least Significant Difference (LSD) values were estimated according to the formula suggested by Wynne et al. [23].

Results

ANOVA

ANOVA (Tables 2 and 3) was performed to test the difference amongst parents and hybrids for all studied traits. Results revealed that mean squares due to genotypes were significant for all the traits. The mean squares due to genotypes were further partitioned 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 level. Parents vs. crosses mean squares further revealed highly significant differences in all crosses. Also, male testers exhibited highly significant differences for all traits. The highly significant mean squares of lines X testers for all traits indicated that they interacted and produced markedly different combining ability effects, and this might be due to the wide genetic diversity 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.

Table 1: Parentage and origin of ten genotypes under study.

No.	Genotypes	Parentage	Origin
1	Sakha 101	Giza 176/Milyang 79	Egypt
2	Sakha 104	GZ4096-8-1/GZ4100-9-1	Egypt
3	Sakha 105	GZ5581-46-3/GZ4316-7-1-1	Egypt
4	Sakha 106	Giza 177/Hexi 30	Egypt
5	Giza 179	GZ1368-5-5-4/GZ6296	Egypt
6	Novator	PRIKUBANSKY/ITALICA 10	Russia
7	VNIRB 572	VNIR 7718/VNIR 1418	Russia
8	Anait	(IZUMRUD/SERPANTIN)//(VNIIR 10006/SNEZHNKA)	Russia
9	ZX788	Unknown	China
10	Large Stigma	Unknown	China

Table 2: Analysis of variance and mean square from line x tester analysis for earliness studied traits.

Source	df	Days to heading	Days to maturing	Panicle initiation	Elongation of panicle initiation
Reps	2	1.23	0.47	046	0.60
Genotypes	(34)	748.27**	743.07**	380.01**	64.99**
Parents	(9)	890.833**	871.12**	340.67**	120.30**
Crosses	(24)	642.67**	644.18**	381.38**	35.77**
Lines	(4)	771.12**	767.09**	412.98**	59.22**
Testers	(4)	2768.52**	2796.62**	1682.28**	137.52**
Line x testers	(16)	79.10**	75.34**	48.26**	4.47**
P vs. C	(1)	1999.62**	1963.90**	701.11**	268.53**
Error	68	0.99	0.93	1.02	1.01

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

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Mean performance

Mean performance of parents, lines and their hybrids for studied earliness traits are presented in Table 4. Testers showed a considerable amount of earliness values and lines showed less amount of values than testers. Sakha 101 indicated the least values for earliness, while all testers showed high values for earliness. None of the hybrids indicated significant high values for earliness similar to testers. Sakha 106 X Anait hybrid indicated the best value for days to heading (78), Sakha 106 X Anait and Giza 179 X VNIRB 572 for days to maturing (108), Sakha 106 X Anait and Giza 179 X VNIRB 572 for panicle initiation (54) and Sakha 106 X VNIRB 572 for elongation of panicle initiation (24). Conversely, line X tester interaction was significant for all earliness traits. Data of yield traits for testers, lines, and hybrids are presented in Table 5. In general, lines demonstrated high values for a number of panicle/plant, spikelet fertility%, 1000-grain weight and grain yield/plant than testers. However, some hybrids indicated high values for yield traits; Giza 179 X Novator for number of panicle/plant (25), Sakha 106 X VNIRB 572 for spikelet fertility% (95.8), Sakha 101 X Anait for 1000-grain weight (37.6) and Sakha 101 X Novator for grain yield/plant (82.53).

GCA effects

Estimates of GCA effects of parent are presented in Table 6. Two genotypes Sakha 106 and Giza 179 scored the best values of -1.76 and -10.56 for days to heading, -1.71 and -10.64 for days to maturing, -0.92 and -8.12 for panicle initiation and (- 0.84) (- 2.44) for elongation of panicle initiation. On the other hand, the testers Novator , VNIRB 572 and Anait were the best combiners for earliness traits i.e., days to heading -8.76, -8.16, -12.36, days to maturing -8.91, -8.31 and -12.24, panicle initiation -6.92, -6.72 and -9.32 and elongation of panicle initiation -1.84, -1.44 and -3.04, respectively.

Estimates of GCA for yield and its components traits are presented in Table 7. Grain yield/plant is the most important component of rice yield. Sakha 101 showed the best value for this trait, however, the rest of lines gave unwanted GCA effects values. Among testers, Novator and ZX788 and Large Stigma indicated the best rice verities for GCA effects and recorded 1.44 and 1.24 values, respectively. Therefore, the four entries; Sakha 101, Novator, Anait and Large Stigma could be good combiners for this trait. In case of spikelet fertility percent the parents Sakha 101, Sakha 105, Sakha 106, Novator, VNIRB 572, Anait and ZX788 showed highly significant and positive estimates of GCA effects with values 4.68, 7.16, 4.14, 8.92, 4.00, 11.90 and 3.59 respectively indicating that these entries could be considered as good donor for increase fertility percentage. For 1000-grain weight Sakha 101, Sakha 105 and Giza 179 lines and Anait, Large Stigma as testers showed highly significant and positive estimates of GCA indicating that these parents appeared to be good parental combiners in rice crosses for this trait. These results were similar with Dalvi andPateland Saidaiah et al. [24,25].

SCA effects

Estimates of SCA effects for F_1 crosses for studied traits are presented in Tables 8 and 9. For days to heading, out of 25 hybrids combinations, 11 hybrids showed highly significant negative estimates for SCA effects and ranged from -1.44 for Sakha 101 X Large Stigma to -8.84 for Large Stigma X Giza 179. On the other hand, 10 hybrids combinations showed undesirable estimates for SCA effects for this trait. The crosses Giza 179 X ZX788 and Giza 179 X large sigma were the best combinations and we can use them in rice breeding program to improve this trait. Concerning to days to maturing 11 crosses gave significant and highly significant negative estimates of SCA effects. The best combination of them was Giza 179 X Large Stigma which gave -8.76, while 10 hybrids combinations showed highly significant positive estimates of SCA effects. The crosses which gave negative significant values could be utilized in rice breeding program to develop new early duration rice varieties. Regarding panicle initiation 10 hybrid combinations recorded highly significant negative estimates of SCA effects. The best crosses were Giza 179 X ZX788 and Giza 179 X Large Stigma which gave -7.48 and -6.68 respectively. For elongation of panicle initiation, five crosses gave significant and highly significant negative estimated of SCA effects. The best crosses were Giza 179 X large Stigma and Giza 179 X ZX788 with -2.16 and -1.16, respectively.

Regarding a number of panicle/ plant, eight hybrid combinations exhibited significant and a highly significant positive values of SCA effects. The desirable hybrid combinations were Giza 179 X Novator and Sakha 101 X Anait which gave 3.76 and 1.96 respectively, indicating that they could be used in breeding program. In case of spikelet fertility %, 13 crosses gave the highest value of SCA effects. The best crosses were Giza 179 X Large Stigma and Giza 179 X ZX788 which gave 42.27 and 30.00 respectively. The crosses which showed the highest values of fertility % can be used in the breeding program to improve this trait. Concerning 1000-grain weight, 11 crosses showed highly significant and positive estimates of SCA effects ranging between 0.17 for Sakha 106 X Large Stigma and 2.27 for Sakha 105 X ZX788. For grain yield/plant 12 rice crosses exhibited significant and highly significant values of (SCA) effects. The desirable hybrid combinations were Giza 179 X Large Stigma and Sakha 105 X VNIRB 572 which gave 19.37 and 12.05 respectively. The present finding was also supported by Dalvi and Patel, Bagheri and Jelodar and Saidaiah

Table 3: Analysis of variance and mean square from line x tester analysis for yield studied traits.

Source	df	No. of panicles/plant	Spikelet fertility %	1000-grain weight (g)	Grain yield/plant
Reps	2	15.11	1.71	0.06	0.84
Genotypes	(34)	31.25**	1538.20**	53.43**	495.60**
Parents	(9)	42.70**	42.88**	83.17**	209.87**
Crosses	(24)	27.47**	1724.09**	38.33**	445.54**
Lines	(4)	91.02**	1146.97**	7.92**	1074.30**
Testers	(4)	30.42**	3966.51**	206.54**	103.52**
Line x testers	(16)	10.85**	1307.77**	3.88**	373.86**
P vs. C	(1)	18.93**	10534.87**	148.07**	4268.68**
Error	68	0.58	0.52	0.01	1.12

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

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Table 4: Mean performance of parents and their F_1 hybrid for studied earliness traits.

Genotypes	Days to heading	Days to maturing	Panicle initiation	Elongation of panicle initiation
Lines				
Sakha 101	113	143	80	33
Sakha 104	103	133	71	32
Sakha 105	95	125	65	30
Sakha 106	96	126	66	30
Giza 179	93	123	64	29
Testers				
Novator	69	99	51	19
VNIRB 572	70	100	51	19
Anait	68	98	50	18
ZX788	69	99	51	19
Large Stigma	69	99	51	19
Hybrids				
Sakha 101 x Novator	96	125	66	31
x VNIRB 572	97	126	66	28
x Anait	89	119	61	33
x ZX788	115	145	82	35
x Large Stigma	119	149	84	28
Sakha 104 x Novator	89	118	61	27
x VNIRB 572	87	117	60	25
x Anait	82	112	57	31
x ZX788	110	140	79	34
x Large Stigma	118	148	84	25
Sakha 105 x Novator	82	112	57	27
x VNIRB 572	87	117	60	25
x Anait	80	110	55	31
x ZX788	109	139	78	33
x Large Stigma	114	144	81	25
Sakha 106 x Novator	80	110	55	25
x VNIRB 572	80	110	55	24
x Anait	78	108	54	31
x ZX788	110	140	79	33
x Large Stigma	114	144	81	25
Giza 179 x Novator	80	110	55	25
x VNIRB 572	79	108	54	25
x Anait	80	110	55	27
x ZX788	87	117	60	28
x Large Stigma	92	122	64	30
L.S.D. 5%	1.35	1.35	1.37	1.37
1%	1.94	1.94	1.96	1.96

et al. [24-26].

Estimates of genetic parameters

Genetic components, additive, and dominance, as well as heritability values, were estimated for the four earliness traits and four yield and its component traits. The results are presented in Tables 10 and 11. Result revealed that the additive variance under study was higher than non-additive variance or dominance for all earliness traits and the character 1000 grain weight indicated that former characters largely governed by additive gene action. On the other hand, the estimates showed that the non-additive variance or dominance for number of panicles/plant, spikelet fertility, and grain yield/plant were higher than the additive variance (σ^2A) indicated that the importance of dominance gene action in the inheritance of these traits. Regarding heritability estimates for the eight traits under study, the result revealed that the heritability in broad sense was high for all characters with values of 98.24, 98.33, 97.03, 73.45, 88.01, 99.88, 99.68 and 99.13 for days to heading, days to maturing, panicle initiation, elongation of panicle initiation, number of panicle/plant, spikelet fertility, 1000-grain weight and grain yield/plant, respectively. While narrow sense ranged from low to moderate with a minimum of 2.92 for grain yield/plant and the maximum value of 58.23 for 1000 grain weight. The proportional contribution of lines, testers and their interaction to the total variance are presented in Tables 10 and 11. It is evident from the given data that testers played an important role towards days to heading, days to maturing, panicle initiation, spikelet fertility % and 1000 grain weight. This indicated predominance of testers influences for these traits. On the contrary, maternal lines contributed most for number of panicles/plant (55.22%) and grain yield/plant (40.18%). The large

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Table 5: Mean performance of parents and their F1 hybrids for studies yield traits.

Genotypes	No. of panicles/plant	Spikelet fertility %	1000-grain weight (g)	Grain yield/plant
Lines				
Sakha 101	23	91.83	27.20	56.20
Sakha 104	21	94.37	28.10	55.50
Sakha 105	19	93.03	27.70	42.13
Sakha 106	18	95.50	27.80	38.37
Giza 179	25	89.63	23.90	42.83
Testers				
Novator	15	92.53	29.30	33.67
VNIRB 572	17	83.10	25.30	36.50
Anait	13	94.13	41.80	38.57
ZX788	15	95.87	25.43	31.43
Large Stigma	17	94.70	34.10	38.43
Hybrids				
Sakha 101 x Novator	19	88.27	32.70	82.53
x VNIRB 572	18	71.40	27.40	59.47
x Anait	21	84.47	37.60	70.60
x ZX788	23	78.17	28.80	58.67
x Large Stigma	20	52.57	34.70	76.33
Sakha 104 x Novator	18	79.67	31.00	58.53
x VNIRB 572	15	88.57	28.40	54.50
x Anait	14	94.67	36.40	61.50
x ZX788	19	54.17	28.10	57.63
x Large Stigma	16	27.60	34.80	47.27
Sakha 105 x Novator	15	94.53	30.20	45.43
x VNIRB 572	14	81.33	26.30	60.37
x Anait	15	93.47	37.20	60.27
x ZX788	18	86.43	30.80	51.47
x Large Stigma	14	31.53	34.50	42.20
Sakha 106 x Novator	17	94.53	30.30	58.47
x VNIRB 572	14	95.80	27.90	52.43
x Anait	13	92.30	35.30	42.60
x ZX788	15	61.40	25.70	37.53
x Large Stigma	17	28.17	33.10	44.47
Giza 179 x Novator	25	39.10	31.70	43.63
x VNIRB 572	17	34.40	30.20	32.47
x Anait	18	46.10	36.80	52.47
x ZX788	18	89.27	28.70	62.50
x Large Stigma	21	69.53	33.70	73.60
L.S.D. 5%	1.04	0.98	0.13	1.44
1%	1.49	1.40	0.19	2.06

Table 6: General combining ability effects for parents for earliness traits.

Genotypes	Days to heading	Days to maturing	Panicle initiation	Elongation of panicle initiation
Lines				
Sakha 101	9.04**	8.89**	6.08**	2.96**
Sakha 104	3.04**	3.03**	2.48**	0.56**
Sakha 105	0.24	0.43*	0.48*	-0.24
Sakha 106	-1.76**	-1.71**	-0.92**	-0.84**
Giza 179	-10.56**	-10.64**	-8.12**	-2.44**
Tester				
Novator	-8.76**	-8.91**	-6.92**	-1.84**
VNIRB 572	-8.16**	-8.31**	-6.72**	-1.44**
Anait	-12.36**	-12.24**	-9.32**	-3.04**
ZX788	12.04**	12.09**	9.88**	2.16**
Large Stigma	17.24**	17.36**	13.08**	4.16**
L.S.D. 5%	0.42	0.40	0.43	0.41
1%	0.59	0.57	0.62	0.42

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

Table 7: Parents' general combining ability effects for yield traits.

Genotypes	No. of panicles/plant	Spikelet fertility %	1000-grain weight (g)	Grain yield/plant
Lines				
Sakha 101	2.84**	4.68**	0.55**	14.04**
Sakha 104	-0.96**	-1.36**	0.05*	0.41
Sakha 105	-2.16**	7.16**	0.11**	-3.53**
Sakha 106	-2.16**	4.14**	-1.23**	-8.38**
Giza 179	2.44**	-14.62**	0.53**	-2.54**
Tester				
Novator	1.44**	8.92**	-0.51**	2.24**
VNIRB 572	-1.76**	4.00**	-3.65**	-3.63**
Anait	-1.16**	11.90**	4.97**	2.01**
ZX788	1.24**	3.59**	-3.27**	-1.92**
Large Stigma	0.24	-28.42**	2.47**	1.30**
L.S.D. 5%	0.31	0.30	0.04	0.45
1%	0.45	0.43	0.05	0.64
*, ** Significant at 5% and 1% probability levels, respectively.				

Table 8: Estimates of specific combining ability (SCA) effects for earliness traits.

Hybrids	Days to heading	Days to maturing	Panicle initiation	Elongation of panicle initiation
Sakha 101 x Novator	1.56**	1.31*	1.12*	0.44
x VNIRB 572	1.96**	1.71**	0.92	1.04*
x Anait	-1.84**	-1.69**	-1.48**	-0.36
x ZX788	-0.24	-0.03	0.32	-0.56
x Large Stigma	-1.44**	-1.29*	-0.88	-0.56
Sakha 104 x Novator	0.56	0.17	-0.28	0.84
x VNIRB 572	-2.04**	-1.76**	-1.48**	-0.56
x Anait	-2.84**	-2.83**	-1.88**	-0.96*
x ZX788	0.76	0.84	0.92	-0.16
x Large Stigma	3.56**	3.57**	2.72**	0.84
Sakha 105 x Novator	-3.64**	-3.56**	-2.28**	-1.36*
x VNIRB 572	0.76	0.84	0.52	0.24
x Anait	-2.04**	-1.89**	-1.88**	-0.16
x ZX788	2.56**	2.44**	1.92**	0.64
x Large Stigma	2.36**	2.17**	1.72**	0.64
Sakha 106 x Novator	-3.64**	-3.43**	-2.88**	-0.76
x VNIRB 572	-4.24**	-4.03**	-3.08**	-1.16*
x Anait	-2.04**	-2.09**	-1.48**	-0.56
x ZX788	5.56**	5.24**	4.32**	1.24*
x Large Stigma	4.36**	4.31**	3.12**	1.24*
Giza 179 x Novator	5.16**	5.51**	4.32**	0.84
x VNIRB 572	3.56**	3.24**	3.12**	0.44
x Anait	8.76**	8.51**	6.72**	2.04**
x ZX788	-8.64**	-8.49**	-7.48**	-1.16*
x Large Stigma	-8.84**	-8.76**	-6.68**	-2.16**
L.S.D. 5%	*0.95*	*0.91*	*0.96*	*0.96*
1%	1.36	1.31	1.38	1.38
*, ** Significant at 5% and 1% probability levels, respectively.				

contribution of both maternal and paternal was found for spikelet fertility (50.56%) and grain yield/plant (55.94%).

Estimates of heterosis

Heterosis for mid-parents and a better parent for earliness traits are presented in Table 12. For panicle initiation trait, nine hybrids showed highly significant negative heterosis, eleven highly significantly positive, three non-significant positive and two hybrids showed non-significant negative over mid-parents heterosis. According to this data, the best promising hybrid combination was Sakha 101 X Anait with a value of -70.70. However, the result for elongation of panicle initiation trait showed that no single cross recorded significant or highly significant negative heterosis for mid or better parent heterosis for this trait. For days to heading, the result indicated that seven hybrid combinations recorded significant and highly significant negative heterosis over mid-parents. Sakha 106 X Anait was the most promising cross combination since it showed highly significant negative heterosis over mid-parents for this trait.

Table 9: Estimates of specific combining ability (SCA) effects for yield traits.

Hybrids	No. of panicles/plant	Spikelet fertility %	1000-grain weight (g)	Grain yield/plant
Sakha 101 x Novator	-2.64**	4.37**	0.97**	10.77**
x VNIRB 572	-0.44	-7.58**	-1.19**	-6.42**
x Anait	1.96**	-2.41**	0.39**	-0.93
x ZX788	1.56**	-0.40	-0.17**	-8.94**
x Large Stigma	-0.44	6.01**	-0.01	5.52**
Sakha 104 x Novator	0.16	1.81**	-0.23**	0.40
x VNIRB 572	0.36	15.63**	0.31**	2.24**
x Anait	-1.24**	13.83**	-0.31**	3.60**
x ZX788	1.36**	-18.36**	-0.37**	3.66**
x Large Stigma	-0.64	-12.92**	0.59**	-9.92**
Sakha 105 x Novator	-1.64**	8.15**	-1.09**	-8.76**
x VNIRB 572	0.56	-0.13	-1.85**	12.05**
x Anait	0.96*	4.10**	0.43**	6.31**
x ZX788	1.56**	5.38**	2.27**	1.44*
x Large Stigma	-1.44**	-17.51**	0.23**	-11.04**
Sakha 106 x Novator	0.36	11.17**	0.35**	9.12**
x VNIRB 572	0.56	17.36**	1.09**	8.96**
x Anait	-1.04*	5.96**	-0.13*	-6.51**
x ZX788	-1.44**	-16.63**	-1.49**	-7.65**
x Large Stigma	1.56**	-17.86**	0.17**	-3.93**
Giza 179 x Novator	3.76**	-25.50**	-0.01	-11.54**
x VNIRB 572	-1.04*	-25.28**	1.63**	-16.84**
x Anait	-0.64	-21.48**	-0.39**	-2.48**
x ZX788	-3.04**	30.00**	-0.25**	11.48**
x Large Stigma	0.96*	42.27**	-0.99**	19.37**
L.S.D. 5%	0.73	0.68	0.09	1.01
1%	1.05	0.97	0.13	1.45

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

Table 10: Estimates of genetic parameters for earliness traits.

Genetic parameter	Days to heading	Days to maturing	Panicle initiation	Elongation of panicle initiation
Additive variance (σ^2 A)	29.65	29.93	17.52	1.64
Dominant variance (σ^2 D)	26.03	24.80	15.74	1.15
Broad sense heritability ($h^2 b$) %	98.24	98.33	97.03	73.45
Narrow sense heritability ($h^2 n$) %	52.31	53.77	51.11	43.21
Contribution of lines	19.99	19.84	18.04	27.59
Contribution of testers	71.79	72.35	73.51	64.07
Contribution of line x tester	8.20	7.79	8.43	8.33

Table 11: Estimates of genetic parameters for yield traits.

Genetic parameter	No. of panicles/plant	Spikelet fertility %	1000-grain weight (g)	Grain yield/plant
Additive variance (σ^2 A)	0.87	21.90	1.81	3.77
Dominant variance (σ^2 D)	3.42	435.74	1.29	124.24
Broad sense heritability ($h^2 b$) %	88.01	99.88	99.68	99.13
Narrow sense heritability ($h^2 n$) %	17.92	4.78	58.23	2.92
Contribution of lines	55.22	11.08	3.44	40.18
Contribution of testers	18.45	88.34	89.80	3.87
Contribution of line x tester	26.31	50.56	6.74	55.94

For days to mature, the same hybrid Sakha 106 X Anait was the best cross and recorded highly significant negative relative heterosis over mid-parents from seven promising hybrid combinations.

On the other hand, heterosis for yield and its components traits is presented in Table 13. For a number of panicles/plant, only one hybrid combination Giza 179 X Novator scored highly significant positive heterosis over mid parents with the value of 25.0. Fourteen hybrids expressed high significant negative, seven non-significant positive and three hybrids indicated non-significant negative heterosis over mid parents for a number of panicles/plant. Spikelet's fertility is an important character for rice yield improvement. For this trait, data showed two hybrids possessed highly significant positive, nineteen highly significant negatives, two non-significant positives, and two

Table 12: Mid-parent and better parent heterosis for earliness traits.

Hybrids	Days to heading		Days to maturing		Panicle initiation		Elongation of panicle initiation	
	MP	BP	MP	BP	MP	BP	MP	BP
Sakha 101 x Novator	5.49**	39.13**	3.30**	26.62**	0.76	29.41**	15.38**	57.89**
x VNIRB 572	6.01**	38.57**	3.70**	26.00**	0.76	29.41**	19.23**	63.15**
x Anait	-1.65*	30.88**	-1.24*	21.42**	-70.7**	22.00**	11.11**	55.55**
x ZX788	26.76**	66.66**	19.83**	46.46**	25.19**	60.78**	26.92**	73.68**
x Large Stigma	30.76**	72.46**	23.14**	50.50**	28.24**	64.70**	34.61**	84.21**
Sakha 104 x Novator	3.48**	28.98**	1.72**	19.19**	0.00	19.60**	9.80**	47.36**
x VNIRB 572	0.57	24.28**	0.42	17.00**	-1.63	17.64**	5.88*	42.10**
x Anait	-4.09**	20.58**	-3.03*	14.28**	-5.78**	14.00**	0.00	38.88**
x ZX788	27.90**	59.42**	20.68**	41.41**	29.50**	54.90**	21.56**	63.15**
x Large Stigma	37.20**	71.01**	27.58**	49.49**	37.70**	64.70**	33.33**	78.89**
Sakha 105 x Novator	0.00	18.84**	0.00	13.13**	-1.72	11.76**	2.04	31.57**
x VNIRB 572	5.45**	24.28**	0.04	17.00**	3.44**	17.64**	10.20**	42.10**
x Anait	-1.84**	17.64**	-1.34*	12.24**	-4.34**	10.00**	4.16	38.88**
x ZX788	32.92**	57.97**	24.10**	40.40**	34.48**	52.94**	26.53**	63.68**
x Large Stigma	39.02**	65.21**	28.57**	45.45**	39.65**	58.82**	34.69**	73.68**
Sakha 106 x Novator	-3.03**	15.94**	-2.22**	11.11**	-5.98**	7.84**	2.04	31.57**
x VNIRB 572	-3.61**	14.28**	-2.65**	10.00**	-5.98**	7.84**	2.04	31.57**
x Anait	-4.87**	14.70**	-3.57**	10.20**	-6.89**	8.00**	0.00	33.33**
x ZX788	33.33**	59.42**	24.44**	41.41**	35.04**	54.90**	26.53**	63.15**
x Large Stigma	38.18**	65.21**	28**	45.45**	38.46**	58.82**	34.69**	73.68**
Giza 179 x Novator	-1.23	15.94**	-0.90	11.11**	-4.34**	7.84**	4.16	31.57**
x VNIRB 572	-3.06**	12.85**	-3.13**	8.00**	-6.08**	5.88**	4.16	31.57**
x Anait	-0.62	17.64**	-0.45	12.24**	-3.50**	10.00**	6.38**	38.88**
x ZX788	7.40**	26.08**	5.40**	18.18**	4.34**	17.64**	12.50**	42.10**
x Large Stigma	13.58**	33.33**	9.90**	23.23**	11.30**	25.49**	16.66**	47.63**
L.S.D. 5%	1.4	1.62	1.36	1.57	1.42	1.64	1.42	1.64
1%	1.87	2.16	1.81	2.09	1.89	2.19	1.88	2.18

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

hybrids had non-significant negative mid-parent heterosis estimates. The best promising hybrids for improving this trait were Sakha 105 X Novator and Sakha 106 X VNIRB 572 with values of 1.88% and 7.27%, respectively. In case of better-parent heterosis, only one hybrid Sakha 105 X Novator had significant positive with a value of 1.61%. These results in agreement with Latha et al. and Anis et al. [27,28].

The manifestation of heterosis effects for 1000-grain weight was variable. Twenty-three hybrids showed highly significant positive and two highly significant negative heterosis over mid-parent for this trait. The best three hybrid combinations were Giza 179 X VNIRB 572, Giza 179 X ZX788 and Giza 179 X Large Stigma with values of 22.76%, 16.62% and 16.20%, respectively [29]. For better parent estimates, thirteen hybrids disclosed highly significant positive, one significant positive, nine highly significant negative and two hybrids indicated non-significant positive heterosis over the better parent. The hybrid Giza 179 X VNIRB 572 gave the highest value 19.36% for 1000-grain weight. Evaluation of high-yielding hybrids along with significant positive heterosis over mid and better parent effects is very important for rice breeders. Most of the hybrids had highly significant positive mid-parent heterosis. Twenty-three hybrids possessed highly significant positive, one highly significant negative and one hybrid had non-significant positive mid-parent heterosis for this grain yield/plant [20,29]. On the other hand, nineteen hybrids had highly significant positive, two highly significant negatives, three non-significant positives and one had a non-significant negative for better-parent heterosis. The result showed that Sakha 101 X Novator, Sakha 106 X Novator and Giza 179 X Large Stigma were the promising hybrid combinations for improving yield character. Similar results were obtained by Kiani and Abdel-Moneam et al. [17,30].

Correlation coefficient

The study of relationships among earliness and grain yield and its components traits is of great importance. The estimates of correlation coefficient among all studied characters are presented in Table 14. Concerning days to heading, data showed that highly significant positive correlation with plant height and with other earliness characters (days to maturing, panicle initiation and elongation of panicle initiation) with values of 0.999, 0.991 and 0.539, respectively. While a significant positive correlation between days to heading and number of panicle/plant was noticed. On the other hand, it showed only highly significant and negative correlation with spikelet fertility percentage. As for days to mature, the result indicated highly significant positive correlation coefficient with panicle initiation 0.992, elongation of panicle initiation 0.350 and significant positive correlation with a number of panicles/ plant. At the same time, it showed significant negative correlation with spikelet fertility percentage -0.458. With regard to panicle initiation, positive and highly significant correlation coefficient was recorded between this trait and elongation of panicle initiation with a value of 0.497. On the other hand, the result showed significant negative correlation coefficient with spikelet fertility percentage -0.467. Highly significant and positive correlation coefficient was recorded between elongation of panicle initiation and a number of panicle/plant with value 0.433 and grain yield/plant 0.471. At the same time, a highly significant

Table 13: Estimates of mid-parent and better parent heterosis for yield traits.

Hybrids	No. of panicles/plant		Spikelet fertility %		1000-grain weight (g)		Grain yield/plant	
	MP	BP	MP	BP	MP	BP	MP	BP
Sakha 101 x Novator	0.00	-17.39**	-4.24**	-4.60**	15.75**	11.60**	83.68**	46.85**
x VNIRB 572	-10.0**	-21.73**	-18.36**	-22.24**	4.38**	0.73**	28.30**	5.81**
x Anait	-61.53**	-8.69**	-9.15**	-10.26**	8.98**	-10.04**	49.00**	25.62**
x ZX788	-21.05**	0.00	-16.70**	-18.46**	9.46**	5.88**	33.91**	4.39**
x Large Stigma	0.00	-13.04**	-43.63**	-44.48**	13.21**	1.75**	61.34**	35.81**
Sakha 104 x Novator	0.00	-14.28**	-14.74**	-15.57**	8.01**	5.80**	31.29**	5.45**
x VNIRB 572	-21.05**	-28.57**	-0.18	-6.14**	6.36**	1.06**	18.47**	-1.80
x Anait	-17.76**	-33.33**	0.44	0.31	4.14**	-12.91**	30.76**	10.81**
x ZX788	5.55	-9.52**	-43.05**	-43.49**	5.00**	0.00	32.60**	3.83**
x Large Stigma	-15.78**	-23.80**	-70.80**	-70.85**	11.89**	2.05**	0.66**	-14.82**
Sakha 105 x Novator	-11.76**	-21.05**	1.88**	1.61*	5.96**	3.07**	19.86**	7.35**
x VNIRB 572	-22.22**	-26.31**	-7.64**	-12.57**	-0.75**	-5.05**	53.57**	43.29**
x Anait	-6.25	-21.05**	-0.11	-0.70	7.05**	.11.00**	49.36**	34.05**
x ZX788	5.88	-5.26	-8.49**	-9.84**	15.96**	11.19**	40.67**	22.16**
x Large Stigma	-22.22**	-26.31**	-66.40**	-66.70**	11.65**	1.17**	4.76**	0.16
Sakha 106 x Novator	3.03	-5.55	0.55	-1.01	6.12**	3.41**	62.32**	52.38**
x VNIRB 572	-20.00**	-22.22**	7.27**	0.31	5.08**	0.35	40.07**	36.64**
x Anait	-16.12**	-27.77**	-2.64**	-3.35**	1.43**	-15.55**	10.73**	10.44**
x ZX788	-9.09**	-16.66**	-35.82**	-35.95**	-3.41**	-7.55**	7.53**	2.18**
x Large Stigma	-2.85	-5.55	-70.37**	-70.50**	6.94**	-2.93**	15.80**	15.71**
Giza 179 x Novator	25.00**	0.00	-57.07**	57.74**	19.17**	8.19**	14.06**	1.86
x VNIRB 572	-19.04**	-32.00**	-60.16**	-61.61**	22.76**	19.36**	-18.12**	-24.18**
x Anait	-5.26	-28.00**	-49.82**	-51.02**	12.02**	-11.96**	28.91**	22.50**
x ZX788	-10.00**	-.2800**	-3.75**	-6.88**	16.62**	12.85**	68.32**	45.92**
x Large Stigma	0.00	-16.00**	-24.55**	-26.57**	16.20**	-1.17**	81.14**	71.84**
L.S.D. 5%	1.07	1.24	1.01	1.17	0.14	0.16	1.49	1.72
1%	1.43	1.64	1.35	1.56	0.18	0.21	1.96	2.28

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

Table 14: Estimates of correlation coefficient for studied traits.

Traits	Days to heading	Days to maturing	Panicle initiation	Elongation of panicle initiation	No. of panicles/ plant	Spikelet fertility %	1000-grain weight	Grain yield/ plant
Days to heading	1.00	0.999**	0.991**	0.539**	0.351*	-0.461**	-0.108	0.329
Days to maturing	--	1.00	0.992**	0.539**	0.350*	-0.458**	0.107	0.325
Panicle initiation	--	--	1.00	0.497**	0.316	-0.467**	0.102	0.269
Elon. of panicle initiation	--	--	--	1.00	0.433**	0.079	-0.003	0.471**
No. of panicles/plant	--	--	--	--	1.00	-0.113	-0.236	-0.295
Spikelet fertility %	--	--	--	--	--	1.00	-0.195	0.705**
1000-grain weight	--	--	--	--	--	--	1.00	0.238
Grain yield/plant	--	--	--	--	--	--	--	1.00

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

positive correlation coefficient was recorded between 1000-grain weight and grain yield/plant. Mohammed et al., Babu et al. found that Grain yield was significantly and positively correlated with a number of panicles/plant and panicle weight in rice. Lakshmi et al. Sarker et al. reported that days to maturity had significant positive correlation with grain yield/plant [5,11,31,32]. Plant height exhibited significant and positive phenotypic correlation with a number of panicles/plant, panicle weight and 1000- grain weight. Lakshmi et al. reported that plant height exhibited significant positive correlation with 1000-grain weight [32].

Discussion

Breeding for earliness still remains one of the major objectives in rice breeding programs. Such varieties fit well into multiple cropping systems and have a natural advantage of drought avoidance in the later part of the crop cycle. Therefore, the present study was undertaken to obtain the information pertaining to the extent of heterosis and combining ability for earliness traits and their correlations with grain yield, through a line X tester crossing design involving five diverse female parents and five male parents. The chosen traits were the most important traits in breeding for rice earliness [33,34].

In the present study, ANOVA for combining ability revealed significant differences among all genotypes for studied traits and amongst the treatments. This result indicated a considerable amount of variability among genotypes for various traits and a substantial amount of heterosis among hybrids. Also, the performance of hybrids was different from that of parents thereby supporting the presence of heterosis for all studied traits. Selected lines were significantly different for all traits indicating a better representation and selection for this study. Also, it was evident from the result of the mean performance of earliness traits that the presence of a valuable amount of genetic variability for the improvement of these traits. Also, it showed highly significant line X tester interaction which might be due to wide genetic diversity among lines and testers [35-37]. At the same time, mean performance of yield traits showed different genetic system involved in controlling yield traits, which emphasized the importance of the study of these traits [17,28]. Further, the genotype with negative GCA values is preferred for earliness traits and considered as a good combiner for earliness traits. The estimates of general combining ability GCA effects among lines for earliness traits showed that the rice genotypes Sakha 106 and Giza 179 were the best combiners for early duration rice varieties. The result was similar with Dalvi and Patel; Saidaiah et al. [24,25]. At the same time, Giza 179 X ZX788 and Giza 179 X Large Stigma crosses gave the best negative significant specific combining ability effects values for earliness traits and best positive values in case of spikelet fertility % yield trait. These crosses could be utilized in rice breeding program to develop new early duration rice varieties. The present finding was also supported by Dalvi and Patel; Bagheri and Jelodar; Saidaiah et al. Genetic component estimates showed that non-additive variance or dominance governed earliness traits. Heritability estimates indicated a predominance of tester's influences for these traits [24,25].

Heterosis is the process by which the performance of an F_1 generated by crossing two genetically different individuals is superior to that of the mean of the parents. Negative heterosis is a desirable feature for the earliness characters as it is useful for developing new early mature rice varieties. The panicle initiation trait is related to elongation of panicle initiation trait and to maturity period for rice varieties. However, in this investigation, there were some different results which may be due to genetic diversity among studied rice genotypes. Abou-Youssef and Anis determined heterosis over mid and better parent heterosis for earliness traits in rice hybrids [38,39]. Negative heterosis for these traits was reported by Abou-Youssef; Anis; Reddy; Latha et al. The best promising hybrid combination was Sakha 101 X Anait and Sakha 106 X Anait [38-40]. These two hybrids showed the reasonable result for yield traits. Heterotic combinations that were obtained from crosses in which parents had low GCA effects indicated that prediction of heterosis on the basis of GCA may not always be accurate.

Finally, complete knowledge on the interrelationship of plant character like earliness with other characters is of paramount importance to the breeder for making improvement in complex quantitative character like earliness for which direct selection is not much effective. Hence, association analysis was undertaken to determine the direction of selection and number of characters to be considered in improving earliness. Correlation coefficient among the traits was assessed. The association amongst the traits indicated that significant positive correlation amongst earliness traits. This indicates that these component traits exhibited a positive significant association with important earliness attributes. Thus, these four traits contribute directly to the earliness character. Although a number of panicles per plant, spikelet fertility, thousand grain weight, and grain yield did not exhibit positive significant association, their role in contributing towards grain yield could not be overlooked as these component traits exhibited a positive significant association with important yield attributes [41]. Thus, these traits may be assumed to indirectly contribute via other traits in governing grain yield. In this regard, it is important to partition out the observed phenotypic association into direct and indirect effects of the component traits towards grain yield. A number of panicles per plant were associated with days to heading, days to maturity and elongation of panicle initiation. This indicates direct contributions of these traits with respect to yield components. Also, grain yield per plant was significantly associated with elongation of panicle initiation demonstrated the importance of this trait on yield.

Conclusion

The present study was undertaken to determine the number of characters to be considered in improving earliness and to obtain knowledge on the interrelationship of earliness character with yield characters. Results indicated that four traits namely; days to heading, days to maturing, panicle initiation and elongation of panicle initiation contributed directly to the earliness character. However, data showed that a number of panicles per plant, spikelet fertility, thousand grain weight, and grain yield traits indirectly contributed to grain yield. Also, grain yield per plant demonstrated great importance on yield. Finally, earliness component traits; days to heading, days to maturity and elongation of panicle initiation had the direct contribution of yield component.

Significance Statement

This study discovers the possible combined effect of days to heading, days to maturing, panicle initiation and elongation of panicle initiation traits on earliness character that can be beneficial for the production of early mature varieties. This study will help the researchers to uncover the critical area of the complex quantitative characters like earliness that many researchers were not able to explore. Thus a new theory on these combinations traits and possibly other combinations may arrive

Author Contributions

A. I. Fahmi and R. A. Eissa developed the concepts and also designed the experiments. M. M. El-Malky performed parent's cultivation and F_1 crosses. A. I. El-Sherif carried out F_1 data collection and statistical analysis.

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