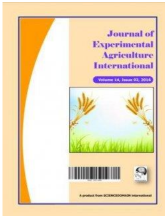

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Hybrid Vigor Expression for Some Important Agronomic Traits in Rice Using Diallel Method

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Authors' contributions

This work was carried out in collaboration between all authors. Authors HFEM and GBA designed the study, wrote the protocol, collected the data and wrote the first draft of the manuscript. Authors GBA, AES and CB prepared the manuscript and did proofreading. All authors read and approved the final manuscript.

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ABSTRACT

Hybrid vigor expression in rice was studied for some agronomic traits in 15 hybrids involving six parents using half diallel mating design. Analysis of variance showed significant differences in parent's vs crosses for all studied traits. The high manifestation of heterosis for grain yield per plant is evident by significant superiority of hybrids over mid parent was ranging from 16.37 to 65.35% in most of hybrid combinations. The high better parent heterosis (heterobeltiosis) for yield per plant was observed in the cross Giza 177 x Chinese2 with value of 63.09%. Similarly, the cross Chinese 2 x GZ 8479-6-2-3-1 showed superiority over mid-parent heterosis with 65.35% for grain yield and also showed significant heterosis for some traits. The development of pure lines from segregating population is very important for evolving high yielding varieties. The crosses exhibiting good heterotic expression in F1 are likely to give better segregants in later generations were additive gene effects were high.

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is an important crop which supplies staple food for nearly 50% of the global [1,2]. Among the most cultivated cereals in theworld, rice ranks as second to wheat [3]. Rice is the most important food crop among other crops all around the world, even more than 3.5 billion people count on rice for more than 20% of their calories. International rice demand is predestined to rise from 676 million tons in 2010 to 763 million tons in 2020 and to more increase to 852 million tons in 2035 [4]. This is a generally increase of 176 million tons in the following 25 years. Rice crop plays a significant role in Egypt, as strategic crop for sustaining the food self-sufficiency and for increasing the export. The total rice production in Egypt reached 5.91 million tons with a national average yield of 9.52 tons/ha in 2012 growing season (FAO2016 This year, the average rice yield of Egypt is the first among the rice producing countries in the world [1].

Heterosis is the hybridization between unrelated strains in self-pollinated crops that generally leads to an increased vigor and fertility. This aspect is of great significance in breeding. Most of the improved varieties hybrids utilize this phenomenon of hybrid vigour [5]. Estimation of heterosis over mid and better parents may be useful in identifying the heterotic cross combinations. The success of hybrid rice programme depends upon the magnitude of heterosis which also helps in the identification of potential cross combinations to be used in the conventional breeding programmes to create wide array of variability in the segregating generations. Good hybrids should manifest high heterosis for commercial exploitation [6]. Considering the above facts the present research work is designed to assess the extent of exploitable heterosis using six diverse genotypes of rice crossed in diallel mating design.

2. MATERIALS AND METHODS

The experimental materials consists of six parents viz. Giza 177, Sakha 101, Chinese2, IR67701B, GZ8479-6-2-3-1 and Sakha 106 for crossing programme in diallel mating design. All the 15 F1 and 6 parents were raised in randomized block design with three replications at Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt in 2012 and 2013 growing seasons. The six parental varieties in this study were sown in the summer season of 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, seedlings of the parents were transplanted to the experimental field in three rows, of 5 meters long and 20 cm x 20 cm apart between plants and rows.

The observations were recorded six characteristics viz., days to maturing (days), plant height (cm), flag leaf area, panicle length (cm), spikelets panicle-1, panicles plant-1, panicle weight (g), 1000-grain weight (g), spikelets fertility % and grain yield plant-1(g). All the recommended agronomic practices were followed. Relative mid and better parent heterosis was worked out utilizing the overall mean of each hybrid for each trait. Significance of heterosis was tested using the formula given by Snedecor and Cochran [7].

3. RESULTS AND DISCUSSION

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. Genetically, heterosis is thought mainly to be the result of adding dominant or partially dominant alleles in repulsion at loci [8]. As such one parent contributes useful alleles at some of the loci, which other parent compliments by providing desirable alleles at the remaining loci. A second type of heterosis can also be visualized, that is crossing two plants with different morphologies. If the loci controlling the morphologies are partially to completely dominant and each affects yield positively, then the morphologically different contribution of each parent in the hybrid may create higher yield progeny by combining morphologies. Heterosis was observed among the hybrids over mid-parent and high-parent for various traits studied. The negative estimates of heterosis for days to heading are preferred to develop short duration rice variety(s). Results in Table 1 revealed highly significant negative heterosis over better parent for all hybrids except Giza 177 x Sakha 106 (2.43%). Maximum estimates were estimated for the hybrids, Sakha 101 x Sakha 106 (-17.30%), Chinese2 x IR67701B (-16.76%) and Giza 177 x Chinese2 (-16.47%). Moreover, highly significant negative heterosis effects were found as deviation from the mid-parents values for eleven hybrid combinations. The highest values were estimated for the hybrids Sakha 101 x Gz8479-6-2-3-1 (-12.56%) followed by Sakha 101 x Sakha 106 (-10.33%) and Chinese2 x IR67701B (-10.14%). Young and Virmani [9] reported negative values of heterosis and heterobeltiosis while Li [10], Bhuiyan [11] and Anis [12] reported negative value of heterobeltiosis for days to flowering. Heterosis values were estimated for plant height trait over the better parent and the results are presented in Table 1. Significant negative heterosis for plant height is preferred to develop short stature rice varieties and hybrids. The results illustrated that the estimates of heterosis as a deviation from the better parent were found to be significant and highly significant negative for eight crosses ranging from -3.09% for the cross Giza 177 x Sakha 106 to -21.00% for the cross Chinese2 x IR67701B. Concerning the heterosis over the mid-parents in Table 1, four hybrid combinations out of fifteen showed highly significant negative. Such estimates ranged from -5.28% in the hybrid combination Sakha 101 x Sakha 106 to -17.53% in the hybrid Chinese2 x IR67701B. In general, the estimated values of heterosis over better parent and mid-parents which showed highly significant and positive values (undesirable) towards tallness. Janardhanam [13]; Li [13], Shanthala [14] and Anis [15] noted significant desirable heterosis for plant height. For flag leaf area, results in Table 1 emphasized that the estimates of heterosis as deviation of better-parent were highly significant and negative for ten hybrid combinations and one hybrid showed highly significant and positive values. The highest negative estimates were determined for the hybrids Chinese2 x IR67701B (-30.13%) followed by Sakha 101 x Chinese2 (-23.80%) and Sakha 101 x Sakha 106 (-21.79%). The positive value was determined for the hybrid combination Gz8479-6-2-3-1 x Sakha 106 (28.44%). With regard to heterosis effects as deviation estimates from the mid-parents, results indicate that two hybrid combinations showed highly significant and positive. These estimates were 31.85% in hybrid Gz8479-6-2-3-1 x Sakha 106 and 10.80% in hybrid IR67701B x Sakha 106. On the other hand, eight hybrid combinations showed highly significant and negative. These estimates ranged from -8.43% in hybrid Chinese2 x Gz8479-6-2-3-1 to -28.24 in hybrid Chinese2 x IR67701B. These results are in general agreement with those reported by Verma [16], Shanthala [14], Bhuiyan [11] and Anis [15].

Concerning panicle length, results indicated that six hybrids showed significant and highly significant positive heterosis over better-parent (Table 2). The highest values were recorded in the hybrids Sakha 101 x Gz8479-6-2-3-1 (11.26%) which was followed by Chinese2 x IR67701B (10.53%) and IR67701B x Gz8479-6-2-3-1 (9.92%). The mid-parent heterosis was highly significant positive in eight hybrid combinations. The highest heterotic effects over mid-parent were (15.69, 15.59, 13.56, 9.92 and 8.70%) in the hybrids Sakha 101 x Gz8479-6-2-3-1, Chinese2 x IR67701B, IR67701B x Sakha 106, IR67701B x Gz8479-6-2-3-1 and Giza 177 x Chinese2, respectively. These findings suggest that panicle length is one of the most important traits contributing to heterosis and breeders can exploit it to best advantage in hybrid breeding. These results are in general agreement with those reported by El-Mowafi [17], Sahu [18], Shanthala [14] and Anis [19].

With respect to spikelets panicle^{-1}, the estimates of better-parent heterosis were highly significant and positive in seven hybrid rice combinations (Table 2). Maximum estimates were recorded for the hybrids Sakha 101 x Gz8479-6-2-3-1 (58.88%), IR67701B x Sakha 106 (28.83%), Gz8479-6-2-3-1 x Sakha 106 (25.32%) and Giza 177 x Gz8479-6-2-3-1 (24.95%). Significant and positive values of heterosis over mid parents were obtained for nine hybrids with, the highest heterotic effects of (79.50, 47.77, 37.47, 36.08 and 36.07%) for the hybrid rice combinations, Sakha 101 x Gz8479-6-2-3-1, Chinese2 x IR67701B, IR67701B x Gz8479-6-2-3-1, Gz8479-6-2-3-1 x Sakha 106 and Giza 177 x Gz8479-6-2-3-1 in respective order. Pronounced heterosis was also obtained by El-Mowafi [17], Liakat [20], Bhuiyan [11], Zaazaa and Anis [21] and Anis [15]. For panicle weight, results in Table (2) showed that eight hybrid rice combinations exhibited highly significant and positive heterosis over better-parent. Maximum estimates were detected for the hybrids Giza 177 x IR67701B, Giza 177 x Sakha 101, Giza 177 x Gz8479-6-2-3-1, Sakha 101 x IR67701B and IR67701B x Gz8479-6-2-3-1 with values 56.95, 36.15, 31.09, 30.15 and 29.26%, respectively. With respect to mid-parents heterosis, highly significant and positive effects were found in all hybrid rice combinations except Chinese2 x Sakha 106. The highest heterosis over mid-parents was (62.27%), followed (47.75%), (40.16%), (37.19%) and (36.84%) for the hybrids, Giza 177 x IR67701B, Giza 177 x Sakha 101, Chinese2 x IR67701B, Giza 177 x Gz8479-6-2-3-1, Sakha

101 x IR67701B, respectively. Similar results were obtained by El-Mowafi [17] and Shanthala [14].

Results in Table 3 revealed significant and highly significant positive mean heterosis for 1000-grain weight measured as deviation from the better-parent for ten rice hybrids. These estimates ranged from 1.06% in Giza 177 x Sakha 106 to 12.35% in Chinese2 x Gz8479-6-2-3-1. Moreover, heterosis as deviation from mid-parent values was highly positive significant for all hybrid combinations except Giza 177 x IR67701B and Sakha 101 x IR67701B. The main values of 12.88, 10.67, 10.58 and 10.17% were recorded for the hybrids Chinese2 x Gz8479-6-2-3-1, Giza 177 x Gz8479-6-2-3-1, Gz8479-6-2-3-1 x Sakha 106 and Chinese2 x Sakha 106, respectively. The reports by El-Mowafi [17], Liakat [20] and Bhuiyan [11] also revealed peak

Table 1. Estimates of heterosis for mid-parent and better parent for studied characteristics

Hybrids	Days to heading		Plant height (cm)		Flag leaf area (cm^2)	
	Mp	Bp	Mp	Bp	Mp	Bp
Giza 177 x Sakha 101	-7.18**	-14.66**	2.94*	-9.93**	-9.93**	-11.28**
Giza 177 x Chinese 2	-8.54**	-16.47**	3.52**	-17.13**	-17.13**	-19.99**
Giza 177 x IR 67701 B	-2.24**	-3.73**	8.00**	-0.81	-0.81	-1.66
Giza 177 x GZ 8479-6-2-3-1	0.34	-2.63**	6.76**	-1.37	-1.37	-7.76**
Giza 177 x Sakha 106	2.79**	2.43**	0.48	1.36	1.36	-2.80
Sakha 101 x Chinese 2	-6.55**	-7.23**	6.53**	-22.23**	-22.23**	-23.80**
Sakha 101 x IR 67701 B	4.09**	-2.93**	1.75	-20.54**	-20.54**	-21.05**
Sakha 101 x GZ 8479-6-2-3-1	-12.56**	-17.30**	27.08**	3.47	3.47	-4.58
Sakha 101 x Sakha 106	-10.33**	-17.30**	-5.98**	-17.27**	-17.27**	-21.79**
Chinese 2 x IR 67701 B	-10.14**	-16.76**	-17.53**	-28.24**	-28.24**	-30.13**
Chinese 2 x GZ 8479-6-2-3-1	-9.85**	-15.32**	-7.76**	-8.43**	-8.43**	-17.12**
Chinese 2 x Sakha 106	-5.68**	-13.58**	-9.50**	-10.01**	-10.01**	-16.55**
IR 67701 B x GZ 8479-6-2-3-1	-6.51**	-7.89**	16.48**	-2.72	-2.72	-9.75**
IR 67701 B x Sakha 106	-3.26**	-4.41**	17.09**	10.80**	10.80**	5.39
GZ 8479-6-2-3-1 x Sakha 106	-1.01	-3.62**	12.67**	31.85**	31.85**	28.44**
L.S.D. at 0.05%	1.07	1.23	2.45	1.79	1.79	2.06
at 0.01%	1.43	1.65	3.28	2.39	2.39	2.76

*MP: Heterosis over mid-parents; BP: Heterosis over better parent and *, ** significant at 0.05 and 0.01 levels, respectively*

Table 2. Estimates of heterosis for mid-parent and better parent for studied characteristics

Hybrids	Panicle length (cm)		Spikelets $panicle^{-1}$		Panicle weight (gm)	
	Mp	Bp	Mp	Bp	Mp	Bp
Giza 177 x Sakha 101	-4.98**	-5.41**	10.35**	5.98	47.75**	36.15**
Giza 177 x Chinese 2	8.70**	7.57**	-6.83**	-23.90**	25.17**	8.50**
Giza 177 x IR 67701 B	4.31**	0.76	23.88**	20.68**	62.27**	56.95**
Giza 177 x GZ 8479-6-2-3-1	0.24	-3.18*	36.07**	24.95**	37.19**	31.09**
Giza 177 x Sakha 106	-8.44**	-10.43**	-2.42	-2.73	19.69**	1.20
Sakha 101 x Chinese 2	4.48**	3.86*	12.35**	-5.18*	5.58**	-1.27
Sakha 101 x IR 67701 B	5.85**	1.80	1.27	-0.19	36.84**	30.15**
Sakha 101 x GZ 8479-6-2-3-1	15.69**	11.26**	79.50**	58.88**	16.74**	12.38**
Sakha 101 x Sakha 106	-7.52**	-9.13**	-15.73**	-19.31**	8.87**	-0.95
Chinese 2 x IR 67701 B	15.59**	10.53**	47.77**	23.24**	40.16**	25.10**
Chinese 2 x GZ 8479-6-2-3-1	-17.77**	-21.36**	-13.54**	-33.86**	13.83**	2.74
Chinese 2 x Sakha 106	-17.45**	-18.41**	-8.72**	-25.63**	0.58	-2.33
IR 67701 B x GZ 8479-6-2-3-1	9.92**	9.92**	37.47**	23.26**	30.89**	29.26**
IR 67701 B x Sakha 106	13.56**	7.39**	32.65**	28.83**	4.75*	-8.89**
GZ 8479-6-2-3-1 x Sakha 106	-4.52**	-9.71**	36.08**	25.32**	12.37**	-1.20
L.S.D. at 0.05%	0.57	0.66	9.57	11.05	0.19	0.22
at 0.01%	0.77	0.89	12.80	14.78	0.26	0.30

*MP: Heterosis over mid-parents; BP: Heterosis over better parent and *, ** significant at 0.05 and 0.01 levels, respectively*

Table 3. Estimates of heterosis for mid-parent and better parent for studied characteristics

Hybrids	1000-grain weight (gm)		Spikelet fertility%		Grain yield plant^{-1} (gm)	
	Mp	Bp	Mp	Bp	Mp	Bp
Giza 177 x Sakha 101	2.14**	0.68	2.01	1.90	38.54**	23.48**
Giza 177 x Chinese 2	3.35**	-0.37	-13.77**	-16.60**	63.60**	63.09**
Giza 177 x IR 67701 B	0.77	-0.02	-0.49	-0.71	17.92**	6.98*
Giza 177 x GZ 8479-6-2-3-1	10.67**	7.17**	-0.81	-1.79	22.11**	10.72**
Giza 177 x Sakha 106	2.28**	1.06*	2.12	2.10	61.77**	59.25**
Sakha 101 x Chinese 2	4.91**	2.56**	0.51	-2.68	17.80**	4.71
Sakha 101 x IR 67701 B	-0.93	-1.58**	-4.65**	-4.97**	41.37**	38.59**
Sakha 101 x GZ 8479-6-2-3-1	5.90**	4.01**	-2.19	-3.26	24.59**	22.23**
Sakha 101 x Sakha 106	5.92**	5.66**	0.52	0.39	16.37**	5.18
Chinese 2 x IR 67701 B	5.81**	2.78**	-18.55**	-21.39**	35.80**	22.87**
Chinese 2 x GZ 8479-6-2-3-1	12.88**	12.35**	4.85**	0.45	65.35**	49.49**
Chinese 2 x Sakha 106	10.17**	7.45**	4.44**	1.01	38.61**	36.03**
IR 67701 B x GZ 8479-6-2-3-1	2.84**	0.36	-16.13**	-16.78**	26.67**	26.58**
IR 67701 B x Sakha 106	7.97**	7.52**	-1.15	-1.35	41.08**	29.84**
GZ 8479-6-2-3-1 x Sakha 106	10.58**	8.35**	-1.02	-1.98	38.93**	27.77**
L.S.D. at 0.05%	0.28	0.30	3.02	3.49	2.35	2.71
at 0.01%	0.35	0.41	4.04	4.67	3.14	3.62

*MP: Heterosis over mid-parents; BP: Heterosis over better parent and *, ** significant at 0.05 and 0.01 levels, respectively*

levels of heterosis for 1000-grain weight. Regarding spikelets fertility (%) data showed that four crosses exhibited highly significant negative heterosis over better-parent ranging from -4.97% in hybrid Sakha 101 x IR67701B to -21.39% for hybrid Chinese2 x IR67701B (Table 3). With respect to mid-parent heterosis, highly significant positive were detected for two crosses Chinese2 x Gz8479-6-2-3-1 and Chinese2 x Sakha 106 with values 4.85 and 4.44%, respectively. Similar results were obtained by Gnanasekaran [22] and Anis [15]. For grain yield plant^{-1}, the calculated values of heterosis for the better parent revealed significantly positive heterosis for all hybrid rice combinations except Sakha 101 x Chinese2 and Sakha 101 x Sakha 106 (Table 3). The highest values were 63.09% for the hybrid Giza 177 x Chinese2 followed by the hybrid, Giza 177 x Sakha 106, Chinese2 x Gz8479-6-2-3-1 and Sakha 101 x IR67701B with respective values of 59.25, 49.49 and 38.59%. On the other hand, all hybrid rice combinations revealed highly significant and positive heterosis over mid-parent. The utmost estimates of 65.35, 63.60, 61.77, 41.37 and 41.08% were obtained for the hybrid rice combinations of Chinese2 x Gz8479-6-2-3-1, Giza 177 x Chinese2, Giza 177 x Sakha 106, Sakha 101 x IR67701B and IR67701B x Gz8479-6-2-3-1, respectively. Significant heterosis effects for grain yield have been reported by El Mowafi [17], Liakat [20], Bhuiyan [11], Abdel-Moneam [23] and Anis [12].

4. CONCLUSION

The results of the present study suggested that the hybrid combinations viz., Giza 177 x Chinese2 followed by the hybrid, Giza 177 x Sakha 106, Chinese2 x Gz8479-6-2-3-1 and Sakha 101 x IR67701B were existing rice hybrids due to good heterosis values for grain yield trait. Thus these genotypes with higher magnitude of this trait could be either evolved by breeding program for genetic improvement of yield in rice.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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