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Heterotic effects of F_1 hybrids for grain yield and yield component traits in rice (*Oryza sativa* L.)

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Abstract
An investigation in rice was undertaken to study the nature and magnitude of heterosis for yield and yield component traits involving seven high yielding lines and three superior testers and twenty one hybrids were developed through line x tester mating design. Observations were recorded for traits *viz.,* days to 50 per cent flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, kernel L/B ratio, hundred grain weight and grain yield per plant. Significant heterosis for grain yield and yield component traits were observed in most of the hybrids. Nine hybrids exhibited positive and significant heterosis over standard parent but six crosses over better parent for grain yield per plant. Standard heterosis and heterobeltiosis for grain yield ranged from -38.71 to 32.96 % and -39.11 to 29.71%, respectively. A total of four hybrids *viz.,* MTU 1010 x IR 50, ADT 39 x TRY 2, ADT 39 x IR 50 and PKM 3 x IR 50 were recorded higher grain yield over both better parent and standard parent and were identified as best hybrids for exploiting hybrid vigor. Most of the heterotic crosses for grain yield per plant were accompanied by heterosis for two or more component traits.

Keywords: Rice, Line x Tester, heterosis, yield

Introduction

Rice is the staple food of more than 60% of Indian population. It accounts for about 43% of total food grain production and 46% of total cereal production in the country. The area under rice cultivation in India was 43.5 million hectares with a production of 104.32 million tonnes during 2016-2017 (Directorate of economics and statistics Report, 2016-17). The demand for rice is expected to be 125-130 million tons by 2025 and this demand can be met only by enhancing the productivity and production of rice in India (Mishra, 2002) [7]. Since the yield of high yielding varieties (HYVs) of rice is plateauing, it is rather difficult to achieve this target with the present day inbred varieties. Therefore, to sustain the self sufficiency in rice, additional production of 1.17 million tonnes is needed every year, which is possible through heterosis breeding and other innovative breeding approaches (Pandey *et al.*, 2010) [12]. Therefore, the major focus of rice research in the next decade must be the development of high-yielding and early maturing varieties in order to ensure food scarcity and efficient use of natural resources (swain, 2005) [18].

Heterosis in rice was first reported by Jones (1926) [6] who observed a marked increase in culm number and grain yield in some F1 hybrids in comparison to their parents. Both positive and negative heterosis is useful in crop improvement, depending on the breeding objectives. In general, positive heterosis is desired for yield and negative heterosis for early maturity (Nuruzzaman *et al.*, 2002) [10]. Heterosis is expressed in three ways, depending on the criteria used to compare the performance of a hybrid (Gupta, 2000) [5]. These three ways are mid-parents heterosis, better parent heterosis or heterobeltiosis and standard heterosis. From a practical point of view, standard heterosis is the most important of the two levels of heterosis because it is aimed at developing desirable hybrids superior to the existing high yielding commercial varieties (Chaudhary, 1984) [4]. Parental combination giving high heterosis to produce transgressive segregants along with higher magnitude of exploitable hybrid vigor is the pre-requisite for making breakthrough in grain yield. Hence, the present study was undertaken to assess the nature and magnitude of heterosis and to identify superior hybrid combination for yield, yield contributing and grain quality traits.

Materials and Methods

The experimental material consisted of ten parents *viz.*, ADT 45, ADT 39, JGL 1798, KNM 118, PKM 3, CO 51 and MTU 1010 as lines (females) and TRY 2, ASD l6 and IR 50 as testers (males) were generated following line x tester mating design (Kempthorne, 1957) [7].

The crosses (21 F_1s) along with their parents (10) and standard parent were evaluated in a randomized block design with three replications during July, 2017 at Plant Breeding farm of Department of Genetics and Plant Breeding, Annamalai University, Chidambaram, Tamil Nadu. Single row of each parent and hybrid was 3 m measured with 30 x 20 cm, row to row and plant to plant spacing, respectively. Single seedling was planted in each hill. Recommended package of practices and plant protection measures were followed to obtain a good harvest. Observations were recorded on randomly selected ten plants excluding border plants in each entry in each replication for plant height (cm), number of tillers per plant, number of productive tillers per plant and grain yield per plant. Days to 50 percent flowering was recorded on plot basis. For panicle traits like panicle length (cm) and number of grains per panicle, observations were recorded from 10 randomly selected panicles. For kernel traits like kernel length, kernel length and kernel L/B ratio, values were recorded from 10 randomly selected kernels. To estimate significant differences among hybrids and parents, the mean data of each character were subjected to Analysis of Variance (ANOVA) as suggested by Steel and Torrie (1980) [21]. The characters showing significant differences were subjected to heterosis calculation. Deviation of F_1 from its either of the parental values was interpreted by depicting type of gene action operating for controlling the trait. Heterosis was estimated as the per cent change in F_1 over better parent (Heterobeltiosis) and standard parent (Standard heterosis) by method suggested by Turner (1953) [22]. The significance of different types of heterosis was carried out by adopting 't test' as suggested by Nadarajan and Gunasekaran (2005). The mean of parents and F_1 hybrids were utilized for the estimation of heterosis. Heterobeltiosis (d_{ii}) and standard heterosis (d_{iii}) were estimated as follows:

$$\text{Heterobeltiosis } (d_{ii}) = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} X100$$

$$\text{Standard heterosis } (d_{iii}) = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} X100$$

Results and Discussion

The analysis of variance (Table 1) indicated that variances due to treatments (parents+ crosses), parents and hybrids were highly significant for all the characters. The variance due to parent vs. hybrids was also found highly significant for almost all the characters (Rahimi *et al.*, 2010) [15]. The significant differences between lines x testers interaction indicated that SCA attributed heavily in the expression of these traits and demonstrates the importance of dominance or non-additive variances for all the traits. (Sanghera and Hussain, 2012) [17]. Commercial exploitation of hybrid vigor is feasible only if the vigor is in excess of prevailing better parent and standard parent.

Heterosis was computed as per cent increase or decrease in F_1 value over better parent (heterobeltiosis) and over standard parent (standard heterosis) are accessible in (Table 2). The relative magnitude of heterosis over better parent and standard parent were studied for 11 characters *viz.*, days to 50 per cent flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, kernel L/B ratio, hundred grain weight and grain yield per plant. The salient results obtained on different aspects and conclusions drawn from the experiment are discussed below.

Table 1: Analysis of variance for line x tester analysis in rice for yield and yield contributing traits.

Source of variation	Df	MSS										
		Days to 50 per cent flowering (days)	Plant height (cm)	Number of tillers per plant	Number of productive tillers per plant	Panicle length (cm)	Number of grains per panicle	Kernel Length (mm)	Kernel Breadth (mm)	Kernel L/B ratio	Hundred grain weight (g)	Grain yield per plant (g)
Replication	2	0.11	5.44	2.87	2.49	1.33	0.20	0.0163	0.00	0.035	0.008	1.61
Genotype	30	80.02**	307.78**	53.19**	64.62**	80.79**	1210.06**	0.2546**	0.0041**	0.0244**	0.15**	80.98**
Cross	20	61.53**	181.75**	56.38**	71.49**	88.70**	443.02**	0.3077**	0.0052**	0.0291**	0.12**	99.17**
Line	6	90.58**	100.21**	119.08**	159.84**	184.47**	801.06**	0.2263**	0.0056**	0.0162**	0.33*	195.71**
Tester	2	177.25**	515.34**	65.20**	52.42**	52.76**	315.87**	0.6827**	0.0102**	0.0610**	0.09**	172.95**
L×T	12	27.71**	166.92**	23.55**	30.49**	46.81**	285.18**	0.2860**	0.0042**	0.0303**	0.03**	38.60**
Error	60	3.52	3.16	0.98	1.5	1.2	1.80	0.0173	0.0001	0.0001	0.005	0.4

*,** Significant at 5 and 1 per cent respectively

Table 2: Estimation of Heterosis over Better Parent (BP) and Standard parent (SP) for yield and yield contributing traits in rice

crosses		50% F		PH		NTP		NPTP		PL		GP	
		BP	SP	BP	SP	BP	SP	BP	SP	BP	SP	BP	SP
1	$L_1×T_1$	-2.13	-18.58**	3.64*	-6.23**	0.00	-2.74	-3.03	-0.00	10.39**	16.44**	1.09*	12.05**
2	$L_1×T_2$	17.99 **	-1.33	-4.03 **	21.98 **	-33.33 **	-36.99 **	-42.86 **	-43.75 **	-26.67 **	-24.66 **	0.00	6.02 **
3	$L_1×T_3$	-15.93 **	-15.93 **	-7.33 **	-7.33 **	-0.00	-0.00	4.69	4.69	14.67 **	17.81 **	2.84 **	9.04 **
4	$L_2×T_1$	-16.37 **	-16.37 **	-14.05 **	-3.66 *	9.59 **	9.59 **	10.45 *	15.62 **	16.88 **	23.29 **	7.43 **	19.08 **
5	$L_2×T_2$	-5.75 **	-5.75 **	-10.37 **	13.92 **	-6.85	-6.85	-7.46	-3.13	-10.81 **	-9.59 *	-0.73	8.63 **
6	$L_2×T_3$	-17.70 **	-17.70 **	-4.25 **	7.33 **	8.22 *	8.22 *	7.46	12.50 **	20.27 **	21.92 **	7.89 **	18.07 **
7	$L_3×T_1$	-1.79	-3.10	-14.33 **	5.13 **	-28.17 **	-30.14 **	-39.39 **	-37.50 **	-16.88 **	-12.33 **	-7.43 **	2.61 **
8	$L_3×T_2$	-2.69	-3.98 *	-24.21 **	-3.66 *	17.02 **	-24.66 **	9.76	-29.69 **	95.74 **	26.03 **	26.96 **	4.02 **
9	$L_3×T_3$	-2.21	-2.21	-8.66 **	12.09 **	-28.77 **	-28.77 **	-39.06 **	-39.06 **	-15.07 **	-15.07 **	6.02 **	6.02 **
10	$L_4×T_1$	-6.02 **	-10.18 **	-24.93 **	-5.13 **	-33.80 **	-35.62 **	-48.48 **	-46.88 **	-35.06 **	-31.51 **	-0.91	9.84 **
11	$L_4×T_2$	2.78	-1.77	-14.70 **	8.42 **	-5.36	-27.40 **	0.00	-29.69 **	-2.04	-34.25 **	31.16 **	9.04 **
12	$L_4×T_3$	-6.64 **	-6.64 **	-20.87 **	0.00	-35.62 **	-35.62 **	-39.06 **	-39.06 **	-31.51 **	-31.51 **	-1.81 **	-1.81 **
13	$L_5×T_1$	-1.60	-18.14 **	-1.15	-5.49 **	8.45 *	5.48	1.52	4.69	-2.60	2.74	3.80 **	15.06 **
14	$L_5×T_2$	7.94 **	-9.73 **	-14.70 **	8.42 **	-26.47 **	-31.51 **	-30.65 **	-32.81 **	-22.08 **	-17.81 **	-10.35 **	-2.61 **

15	$L_5 \times T_3$	-17.26 **	-17.26 **	-6.96 **	-6.96 **	6.85	6.85	12.50 **	12.50 **	14.29 **	20.55 **	9.61 **	19.08 **
16	$L_6 \times T_1$	-1.86	-6.64 **	14.29 **	8.42 **	-11.27 **	-13.70 **	-16.67 **	-14.06 **	-22.08 **	-17.81 **	-11.05 **	-1.41 *
17	$L_6 \times T_2$	-5.12 *	-9.73 **	-18.73 **	3.30 *	10.00	-24.66 **	11.36	-23.44 **	1.92	-27.40 **	37.80 **	5.42 **
18	$L_6 \times T_3$	-7.08 **	-7.08 **	8.42 **	8.42 **	-32.88 **	-32.88 **	-39.06 **	-39.06 **	-26.03 **	-26.03 **	-0.40	-0.40
19	$L_7 \times T_1$	5.85 *	-11.95 **	-1.97	-8.79 **	4.17	2.74	4.55	7.81	11.69 **	17.81 **	4.12 **	16.67 **
20	$L_7 \times T_2$	14.29 **	-4.42 *	-16.43 **	6.23 **	-1.39	-2.74	0.00	3.12	15.07 **	15.07 **	1.08 *	13.25 **
21	$L_7 \times T_3$	-15.04 **	-15.04 **	-6.59 **	-6.59 **	12.33 **	12.33 **	15.15 **	18.75 **	24.66 **	24.66 **	6.99**	19.88**

(i) Days to 50 per cent flowering

Early maturing hybrids are desirable as they produce more yields per day and fit in multiple cropping systems. Out of twenty one hybrids studied For heterobeltiosis, nine hybrids showed negative significant values ranged from -17.70 to -5.12 per cent. The maximum significant and negative value was recorded in cross ADT 39 × IR 50 (-17.70 per cent) followed by PKM 3 × IR 50 (-17.26 per cent). For standard heterosis, sixteen crosses showed negative as well as significant values ranged from -18.14 to -3.98. The crosses PKM 3 × ADT 45, ADT 39 × JGL 1798, PKM3 × JGL 1798 recorded significant and negative values in higher order with the values of -18.14, -17.70 and -17.26 per cent respectively. Early flowering in hybrids had been reported by Prem kumar *et al.* (2017) [14] and Vikas sahu, *et al.* (2013) [23].

(ii) Plant height

Shorter plant type is an important character of a hybrid to withstand lodging. For heterobeltiosis, values ranged from -24.93 to -4.03 per cent. The maximum significant and negative value was recorded by the cross KNM 118 × TRY2 (-24.93 per cent) followed by JGL 1798 × ASD 16 (-24.21 per cent). Nine crosses were recorded negative and significant standard heterosis which ranged from -8.79 to –3.30 per cent. The highly significant and negative value was recorded by the cross MTU 1010 × TRY 2 (-8.79 per cent) followed by ADT 45×IR 50 (-7.33 per cent) and PKM 3 × IR 50 (-6.96 per cent) for plant height. The negative heterosis for plant height was observed by Archana Devi *et al*. (2017) [3] and Nainu *et al.* (2016) [9].

(iii) Number of tillers per plant

For number of tillers per plant, the heterobeltiosis was positive and significant for five hybrid, and ranged from 8.22 to 17.02 per cent. The highest significant and positive heterobeltiosis was observed in cross JGL 1798 × ASD 16 (17.02 per cent) followed by MTU 1010 × IR 50 (12.33 per cent). Three hybrids recorded significantly positive standard heterosis which ranged from 8.22 to 12.33 per cent. The maximum significantly positive standard heterosis was noticed in MTU 1010 × IR 50 (12.33 per cent) followed by ADT 39 × TRY2 (9.59 per cent). The positive heterosis for number of tillers per plant was observed by Abdel-Moneam *et al.* (2016) [1] and Vikas sahu *et al*. (2013) [23].

(iv) Number of productive tillers per plant

Number of productive tillers per plant is known to directly contribute towards grain yield. In heterobeltiosis, the hybrid MTU 1010 × IR 50 (15.15 per cent) showed the maximum significant and positive value followed by PKM 3 × IR 50 (12.50 per cent). Four hybrids recorded significantly positive standard heterosis ranged from 12.50 to 18.75 per cent. The maximum significantly positive standard heterosis was observed in MTU 1010 × IR 50 (18.75 per cent) followed by ADT 39 × TRY2 (15.62 per cent) for this trait. This result was in accordance with the findings of Archana Devi *et al*. (2017) [3] and Ammar Gholizadeh *et al*. (2014) [2].

(v) Panicle length

A hybrid with greater panicle length is desirable since the spikelets attached to its primary and secondary branches would increase proportionally with the enhancement of panicle length. For heterobeltiosis, JGL 1798 × ASD 16 recorded the maximum positive significant value (95.74 per cent) followed by MTU 1010 × IR 50 (24.66 per cent). For panicle length, nine hybrids were recorded positively significant standard heterosis. Among them, JGL1798 × ASD16 (26.03 per cent) recorded the maximum significant positive value followed by MTU1010 × IR50 (24.66 per cent) for this trait. This result was in accordance with the findings of Veeresha *et al*. (2015) [24] and Ammar Gholizadeh *et al*. (2014) [2].

(vi) Number of grains per panicle

The number of grains per panicle directly contributes to the seed yield hence positive heterotic effect would be highly desirable. Thirteen hybrids exhibited positively significant heterobeltiosis for number of grains per panicle which ranged from 1.08 to 37.80 per cent. CO 51 x ASD 16 (37.80 per cent) recorded the maximum significant positive value followed by KNM 118 x IR 50 (31.16 per cent). For standard heterosis, seventeen hybrids were showed significantly positive values. MTU 1010 × IR 50 (19.33 per cent) followed by ADT 39 × TRY2 (19.88 per cent) recorded the maximum positive significant values. The positive heterosis for number of grains per panicle was observed by Abdel Moneam *et al.* (2016) [1] and palaniraja, *et al*. (2010) [12].

(vii) Kernel length

Kernel length helps in increasing the quality of rice as well as yield. Out of twenty one hybrids studied nine hybrids showed significant and positive heterobeltiosis and ranged from 2.88 to 8.57 per cent. The maximum heterobeltiosis was recorded by ADT 45 × IR 50 (8.57 per cent)**.** The standard heterosis for this trait was positive and significant for twelve hybrids and its ranged from 5.39 to 13.47 per cent. Cross MTU 1010 × IR 50 (13.47 per cent) showed the maximum standard heterosis value. This was followed by ADT 39 × TRY2 (13.12 per cent). This result was in accordance with the findings of Archana Devi *et al*. (2017) [3].

(viii) Kernel breadth

Kernel breadth also helps in increasing the quality as well as yield. Eight hybrids recorded significant and positive heterobeltiosis for this trait. The maximum value was recorded by PKM 3 x IR 50 (2.67 per cent) followed by ADT 45 x TRY 2 (2.23 per cent). Out of twenty one hybrids studied, eleven hybrids registered significant and positive standard heterosis and it ranged from 0.60 to 3.90 per cent. The maximum positive and significant value recorded by MTU 1010 × IR 50, PKM 3 x IR 50 (3.90 per cent) followed by ADT 39 × TRY2 (3.45 per cent). This result was in accordance with the findings of Rithesh Balan *et al*. (2005) [16] and Saravanan *et al*. (2004) [18].

(ix) Kernel L/B ratio

For this trait, five hybrid recorded significant and positive heterobeltiosis. Out of twenty one hybrids maximum value was recorded by ADT 45 x TRY 2 (5.62 per cent) followed by ADT 39 × TRY2 (3.61 per cent). Out of twenty one hybrids studied, thirteen hybrids recorded significant and positive standard heterosis. Cross ADT 39 x IR 50 (9.82 per cent) followed by ADT 39 × TRY2 (9.44 per cent) showed maximum positive and significant value for this trait. This result was in accordance with the findings of Venkatesan *et al*. (2007) [25].

(x) Hundred grain weight

The hundred grain weight is one of the important common traits which influence the yield. The heterobeltiosis was significantly positive for nine crosses. The maximum significant and positive heterobeltiosis was observed in MTU 1010 × IR 50 (13.17 per cent) followed by ADT 39 × IR 50 (10.22 per cent). Standard heterosis was observed to be significant and positive in seven crosses which was ranged from 5.75 to 13.90 per cent. The maximum positive and significant value was noticed in the cross MTU 1010 × IR 50 (13.90 per cent) followed by PKM 3 x IR50 (11.98 per cent) for this trait. This result was in accordance with the findings of Padmavathi *et al*. (2013) [11] and Tiwari *et al*. (2011) [20].

(xi) Grain yield per plant

The grain yield is a very complex trait. It is the multiplicative end product of several basic components of yield. A total of nine hybrids exhibited significantly positive heterobeltiosis where, the maximum significant and positive value was noticed in the cross MTU 1010 × IR 50 (29.71 per cent) followed by ADT 39 x TRY 2 (14.48 per cent). In case of standard heterosis, nine hybrids are recorded the positively significant values. The maximum positive significant was observed in MTU 1010 × IR 50 (32.96 per cent) and this was followed by ADT 39 x TRY 2 (24.73 per cent). This result was in accordance with the findings of Prem kumar *et al.*, (2017) [14], Padmavathi *et al*. (2013) [11] and Chaitali Sen and Singh (2011) [3].

Conclusion

Thus the findings from the present study on heterosis revealed that the higher and desirable magnitude of all yield and yield attributing traits were not expressed in a single cross combinations, which was varied from cross to cross due to diverse genetic background of their parents. On the basis of overall performance four hybrids, MTU 1010 x IR 50, ADT 39 x TRY 2, ADT 39 x IR 50 and PKM 3 x IR 50 were identified as top rankers and that could be used for exploitation of heterosis for yield and its components traits in rice.

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