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Heterosis analysis 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 ten high yielding lines and three superior grain quality testers and thirty hybrids were developed through line x tester mating design. Observations were recorded for days to 50% flowering, plant height, number of productive tillers per plant, panicle length, number of filled grains per panicle, hundred grain weight and single plant yield. 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 check but six crosses over better parent for single plant yield plant. Standard heterosis and heterobeltiosis for grain yield ranged from -15.64 to 20.04% and -23.75 to 15.50%, respectively. A total of four hybrids *viz*., ADT 39 x I.W.Ponni, ADT 43 x I.W. Ponni, ADT 49 x I.W. Ponni and CO (R) 50 x I.W. Ponni were recorded higher grain yield over both better parent and standard check 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, tester, heterosis, yield

Introduction

Rice has been one of the world's most important food crops, and staple food for 65% of the global population and forms the cheapest source of food, energy and protein (Khush, 1997) [6]. In India, rice is cultivated by different methods under diverse environmental conditions to meet the food demand of the growing population and to achieve food security in the country, the present production levels need to be increased by 2 million tones every year, which is possible through heterosis breeding and other innovative breeding approaches. The government of India has set a target of expanding the cultivation of hybrid rice to 25 % of the area occupied by the crop by 2015 thereby contributing significantly towards national food security (Spielman *et al*., 2013) [19]. Heterosis in rice was first reported by Jones (1926) [4] who observed a marked increase in culm number and grain yield in some F_1 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) [11].

Heterosis is expressed in three ways, depending on the criteria used to compare the performance of a hybrid (Gupta, 2000) [3]. These three ways are mid-parents heterosis (the performance of a hybrid compared with the average performance of its parents), better parent heterosis or heterobeltiosis (the performance of a hybrid compared with that of the best parent in the cross) and standard heterosis (the performance of a hybrid compared with high yielding variety in the region). 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) [2]. 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 thirteen parents including ten high yielding rice varieties *viz*., ADT 36, ADT 39, ADT 43, ADT 45, ADT 49, CO 43, CO (R) 49, CO (R) 50, ASD 16 and ASD 20 as lines (females) and three varieties with good grain quality *viz*., BPT 5204, Improved white ponni and JGL 3855 as testers (males) were generated following line x tester mating design (Kempthorne, 1957) [5]. The crosses (30 F_1s) along with their parents

(13) and standard check were evaluated in a randomized block design with three replications during January, 2012 at research farm of Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai, Tamil Nadu. Single row of each parent and hybrid was 3 m measured with 20 x 15 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 productive tillers per plant and single plant yield. Days to 50% flowering was recorded on plot basis. For panicle traits like panicle length (cm) and number of filled grains panicle, observations were recorded from 10 randomly selected panicles. Heterosis was estimated as the per cent change in F_1 over better parent (Heterobeltiosis) and standard check (Standard heterosis) by method suggested by Turner (1953) [20]. The significance of different types of heterosis was carried out by adopting 't test' as suggested by Nadarajan and Gunasekaran (2005) [10] as given below:

$$\text{Heterobeltiosis} = \frac{F_1 - BP}{BP} \times 100$$

$$\text{Standard Heterosis} = \frac{F_1 - SP}{SP} \times 100$$

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) [14]. The significant differences between lines x testers interaction indicates 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 commercial check.

One of the major objective in plant breeding is to get higher grain yield per plant, therefore, emphasis was given in the present study for heterosis over better parent and standard check. The hybrids recorded -23.75 to 15.50% heterobeltiosis and -15.64 to 20.04% economic heterosis for grain yield per plant. The cross combinations ADT 39 x I.W. Ponni, ADT 43 x I.W.Ponni and ADT 49 x I.W. Ponni recorded highest potential for this trait (Table 2). Aditya *et al*. (2012) [1], Kumar Babu *et al*. (2010) [8] and Mohammad Yussouf Saleem *et al.* (2010) [9] reported very high estimates of heterosis for grain yield in rice.

Early maturing hybrids are desirable as they produce more yields per day and fit in multiple cropping systems. Maximum desirable heterosis for days to 50% flowering was observed in the hybrid ASD 16 x JGL 3855 (-2.47 %) compared to standard check and -30.15% by the hybrid ADT 43 x I.W. Ponni on better parent along with yield and yield attributing traits. Out of 30 hybrids, only three hybrids *viz*., ADT 36 x JGL 3855, ADT 45 x BPT 5204 and ASD 16 x JGL 3855 registered significant negative heterobeltiosis and standard heterosis. Early flowering in hybrids had been reported by Patil *et al*. (2011) [13] and Sanjeev Kumar *et al.* (2010) [18].

Shorter plant type is an important character of a hybrid to withstand lodging. For plant height, the spectrum of variation was from -23.70 (ADT 45 x I.W. Ponni) to 4.34% (ADT 43 x JGL 3855) for heterobeltiosis. As many as 26 cross combination expressed significant heterobeltiosis in negative direction. Standard heterosis ranged from -4.09 (ADT 45 x JGL 3855) to 21.76% (CO 43 x I.W. Ponni) against check ADT 43. A total of five hybrids significantly excelled the standard check ADT 43. The negative heterosis for plant height was observed by Krishna *et al*. (2011) [7] and Rao *et al.* (1996) [15].

Number of productive tillers per plant is known to directly contribute towards grain yield. In case of productive tillers per plant, heterosis over better parent varied from -17.28 (ASD 20 x JGL 3855) to 24.79% (CO 43 x JGL 3855). Four hybrids out of 30, were registered positive significant values. With respect to standard heterosis, the range was from -7.31(ASD 16 x BPT 5204) to 22.09% (CO 43 x JGL 3855) and five hybrids recorded significantly positive values. This result was in accordance with the findings of Kumar Babu *et al*. (2010a) [8] and Sandhyakishore Neelam *et al*. (2009) [16].

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 panicle length, four hybrids registered significantly positive heterobeltiosis and five hybrids exhibited significantly positive standard heterosis for the above said trait. The hybrid CO 43 x JGL 3855 recorded the highest heterobeltiosis and standard heterosis in this regard. The similar result was also obtained by Sanjeev Kumar *et al.* (2010) [18].

In respect of filled grains per panicle, five crosses exhibited positive and significant heterobeltiosis and standard heterosis. Panwar and Mashiat Ali (2010) [12] and Patil *et al*. (2011) [13] observed significant positive heterosis for this trait. Out of 30 hybrids tested, five hybrids showed positively significant heterosis over their respective better parental values, while 18 crosses exhibited significant positive heterosis over standard check ADT 43 for hundred grain weight (Table 2). This was in accordance with earlier findings of Panwar and Mashiat Ali (2010) [12] and Sanjeev Kumar *et al.* (2010) [18].

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

Source of variation	Mean Squares							
	df	DFF	PH	NPT	PL	NFG	HGW	SPY
Replication	2	32.66	13.87	0.06	0.05	1.38	0.01	0.39
Genotypes	42	288.51**	83.94**	2.27**	3.10**	711.70**	0.06**	20.90**
Crosses	29	270.57**	65.96**	2.24**	2.36**	597.95**	0.06**	20.78**
Lines	9	821.14**	69.64**	1.87**	3.65**	1057.28**	0.12**	32.23**
Testers	2	30.95**	351.58**	2.68**	10.73**	74.79**	0.19**	62.72**
L x T interaction	18	21.91**	32.38**	2.38**	0.78**	426.42**	0.02**	10.39**
Error	84	0.78	2.02	0.06	0.05	2.93	0.01	0.42

DFF- days to 50% flowering, PH- plant height, NPT- number of productive tillers per plant, PL- panicle length, NFG- number of filled grains per panicle, HGW- hundred grain weight and SPY- Single plant yield

* & ** Significant at 5% and 1% level, respectively

Table 2: Estimate of Heterosis over Better Parent (BP) and Standard Check (SC) for yield and yield contributing traits in rice

Crosses	DFF		PH		NPT		PL		NFG		HGW		SPY	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
L_1xT_1	-15.11**	17.90**	-8.69**	0.56	-4.58**	2.33	-5.13**	-1.27	20.26**	0.20	-11.14**	8.46**	0.20	9.37**
L_1xT_2	-28.82**	0.62	-23.20**	1.79	-1.58	7.91**	-8.01**	3.66**	14.25**	0.34	-7.67**	12.69**	-2.65	6.25**
L_1xT_3	-18.97**	-2.47*	-6.51**	-3.81*	-6.89**	-3.42	-3.46**	0.47	-4.16**	-8.55**	-15.35**	3.32	-10.15**	-1.93
L_2xT_1	-14.22**	19.14**	-9.30**	-0.12	-3.63*	5.05**	-3.11**	0.00	12.73**	5.81**	-0.26	17.22**	-9.63**	-3.31
L_2xT_2	-14.41**	20.99**	-17.64**	9.15**	-7.18**	1.76	-8.65**	2.94**	7.12**	5.37**	-11.57**	3.93	12.19**	20.04**
L_2xT_3	-4.59**	15.43**	0.31	3.21*	-11.37**	-3.39	-0.12	-1.15	1.64*	7.71**	-15.17**	-0.30	0.43	7.45**
L_3xT_1	-28.89**	-1.23	-10.67**	-1.62	-3.04	3.99*	-3.22**	-0.12	9.01**	1.08	6.65**	6.65**	-11.41 **	-11.41**
L_3xT_2	-30.13**	-1.23	-9.82**	19.52**	-0.21	9.40**	-3.66**	8.55**	6.09**	3.14**	-0.91	-0.91	10.02 **	10.02**
L_3xT_3	-16.92**	0.00	4.34**	7.36**	10.17**	10.17**	4.19**	4.19**	2.68**	7.64**	-7.25**	-7.25**	-11.77 **	-11.77**
L_4xT_1	-29.78**	-2.47*	-12.25**	-3.37*	-3.84*	3.12	-4.11**	-1.04	6.28**	-2.62**	-3.13	2.72	15.50**	-1.89
L_4xT_2	-27.95**	1.85	-23.70**	1.12	-8.03**	0.83	-4.91**	7.14**	5.02**	0.95	-2.28	3.63	-6.14**	-10.11**
L_4xT_3	-14.87**	2.47*	-6.79**	-4.09*	0.72	-2.76	3.41**	-1.43	-4.00**	-0.42	-9.97**	-4.53*	-1.02	-11.01**
L_5xT_1	-8.00**	27.78**	-9.17**	0.02	-8.58**	-1.96	-10.16**	-7.28**	-0.71	-14.50**	17.68**	22.66**	6.82**	-4.69*
L_5xT_2	-7.42**	30.86**	-20.11**	5.88**	-4.94**	4.22*	-15.18**	-4.42**	2.33**	-7.28**	0.58	4.83*	8.9 **	4.30*
L_5xT_3	2.44**	29.63**	-8.51**	-2.29	-0.07	-3.52*	-0.19	-7.48**	-2.83**	-4.57**	-4.93*	-0.91	-6.32 **	-15.78**

Table 2: Contd….

Crosses	DFF		PH		NPT		PL		NFG		HGW		SPY	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
L_6xT_1	-5.78**	30.86**	-6.80**	2.64	-7.50**	-0.80	-7.83**	-4.46**	13.43**	4.74**	-4.86*	6.34**	-2.07	-1.11
L_6xT_2	-9.17**	28.40**	-8.20**	21.67**	0.00	9.63**	-4.53**	7.57**	-1.62*	-4.73**	-0.27	11.48**	-0.44	0.53
L_6xT_3	1.93*	30.25**	-7.25**	-0.49	24.79**	22.09**	-3.81**	-0.29	-12.31**	-8.41**	-5.95**	5.14*	-6.79 **	-5.88**
L_7xT_1	-5.78**	30.86**	-0.15	9.96**	3.93*	11.46**	0.66	3.89**	-0.53	2.03*	-15.21**	-0.60	-9.25**	-12.68**
L_7xT_2	-6.11**	32.72**	-18.04**	8.63**	-8.36**	0.47	-4.71**	7.38**	-11.09**	-8.80**	-3.87*	12.69**	1.34	-2.48
L_7xT_3	0.00	29.63**	-6.26**	1.15	-8.07**	-4.98**	-1.04	0.14	-22.98**	-15.55**	-11.08**	4.23	-7.47**	-10.95**
L_8xT_1	-3.11**	34.57**	-0.09	10.02**	-10.85**	-2.82	-3.54**	2.94**	8.57**	1.34	12.56**	35.35**	-11.60**	-9.53**
L_8xT_2	-8.30**	29.63**	-19.80**	6.30**	-4.36**	4.85**	-7.90**	3.78**	12.76**	6.50**	5.78**	27.19**	13.76**	16.43**
L_8xT_3	-4.74**	24.07**	-3.66*	1.21	-11.80**	-3.85*	-8.75**	-2.62**	-8.28**	0.57	-16.33**	0.60	-1.23	1.08
L_9xT_1	-28.44**	-0.62	-12.33**	-3.45*	-13.57**	-7.31**	-2.60**	0.53	-21.45**	-17.60**	1.41	30.21**	-8.6**	5.80**
L_9xT_2	-28.82**	0.62	-19.99**	6.05*	9.03**	19.53**	-5.54**	6.44**	-0.13	4.76**	-6.82**	19.64**	-9.20**	5.20*
L_9xT_3	-18.97**	-2.47*	-7.46**	-3.68*	2.78	3.22	6.51**	2.82**	-0.40	9.22**	-9.41**	16.31**	-15.21**	-1.77
$L_{10}xT_1$	-27.11**	1.23	-8.60**	0.65	-7.47**	7.48**	3.22**	6.54**	4.93**	-10.33**	-4.10*	20.24**	-19.43**	-10.87**
$L_{10}xT_2$	-27.07**	3.09**	-20.28**	5.66**	-16.02**	-2.46	-7.80**	3.89**	-9.07**	-14.12**	4.34*	30.82**	-23.33**	-15.18**
$L_{10}xT_3$	-15.90**	1.23	-3.71*	-0.93	-17.28**	-3.92*	8.22**	0.49	-23.84**	-16.49**	-4.82**	19.34**	-23.75**	-15.64**
SE±	0.88	0.88	1.42	1.42	0.25	0.25	0.24	0.24	1.71	1.71	0.03	0.03	0.65	0.65

DFF- days to 50% flowering, PH- plant height, NPT- number of productive tillers per plant, PL- panicle length, NFG- number of filled grains per panicle, HGW- hundred grain weight and SPY- Single plant yield; L_1- ADT 36, L_2- ADT 39, L_3- ADT 43, L_4- ADT 45, L_5- ADT 49, L_6- CO 43, L_7- CO (R) 49, L_8- CO (R) 50, L_9- ASD 16, L_{10}- ASD 20, T_1- BPT 5204, T_2- Improved white ponni and T_3- JGL 3855.

* & ** Significant at 5% and 1% level, respectively

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 three hybrids ADT 43 x I.W.Ponni, ASD 20 x I.W.Ponni and CO 43 x JGL 3855 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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