Indian J. Genet., **55** (4): 438–445 (1995)

HETEROSIS BREEDING FOR GRAIN YIELD AND OTHER AGRONOMIC CHARACTERS IN RICE (*ORYZA SATIVA* L.)

M. P. PANDEY, J. P. SINGH AND HARPAL SINGH

Department of Plant Breeding, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar 263145

(Received: June 15, 1992; accepted June 9, 1995)

ABSTRACT

Thirty six hybrids evolved from nine high yielding and widely adapted cultivars were evaluated with parental lines and the standard variety, Jaya, to determine the nature and extent of heterosis for seven characters including grain yield per plant. Most of the crosses manifested significant heterosis for grain yield and panicle number per plant, panicle length, 1000-grain weight, grains per panicle, and days to maturity. Very few hybrids manifested significant heterosis for plant height. The range of heterosis for seed yield per plant was – 96.7 to 258.2% over the better parent, – 96.1 to 268.2% over midparent and – 96.3 to 301.6% over the standard variety. The highest heterotic effects for grain yield were observed in the crosses Prasad x PP 72, Govind x PP 72, Govind x Sita, Prasad x Mahsuri and Govind x Jaya hybrids, which was, respectively, 258.2, 216.8, 177.8, 161.6 and 108.8% over better parent, 268.2, 250.8, 178.1, 204.2 and 119.4% over midparent, and 301.6, 255.2, 151.6, 285.0 and 108.8% over the best check variety Jaya. A comparison between heterotic and nonheterotic hybrids for yield and its components indicated that heterosis for grain yield was due to two or more direct yield contributing characters. Implications of the nature and magnitude of heterosis for commercial exploitation in rice are discussed.

Key words: *Oryza sativa*, standard heterosis, seed yield, yield components, hybrid rice.

In the recent past, plant breeders have extensively explored and utilized heterosis to boost yield levels in several cross-pollinated crops. However, rice being a highly autogamous species, the scope for exploitation of hybrid vigour depends on the direction and magnitude of heterosis, biological feasibility and the nature of gene action.

The availability of cytoplasmic male sterility as well as fertility restoring system [1] and the development of rice hybrids and their cultivation on commercial scale in about 15.0 million ha in China during 1990, have created interest in research on heterosis breeding in the country. The study of heterosis will have direct bearing on the breeding methodology to be employed for varietal development. The present investigation aims to estimate the extent of heterosis for grain yield and its components in a nine-parent nonreciprocal diallel set of rice (*Oryza sativa* L.).

MATERIALS AND METHODS

A set of nonreciprocal diallel set was effected with nine diverse cultivars, namely, Govind, Prasad, Sita, Jaya, IET 6288, IR 54, Mahsuri, PP 72 and T 3. Thirty six F_1 hybrids along with their parents were grown in randomized complete block design with two replications at the Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. Each parent and F_1 progeny were represented by a single row of 3 m length with 20 cm spacing between rows and between plants. Observations on seven characters (Table 1) were recorded on ten random competitive plants in the parents and F_1 generation from each plot. Magnitude of heterosis over better parent (BP), midparent (MP), and the check variety Jaya (standard heterosis, SH) were calculated.

RESULTS AND DISCUSSION

For a successful exploitation of heterosis on commercial scale, production of hybrid seed on large scale and high heterotic response are essential. While possibilities of hybrid seed production in rice do exist, there is need to identify heterotic hybrids. Analysis of variance indicated significant differences among genotypes for the various characters analysed. The magnitude of heterosis for different characters among the top ranking hybrid combinations is presented in Table 1.

PLANT HEIGHT

Heterosis for this character has been estimated in terms of height reduction. Out of 36 hybrids tested, 13 and 19 hybrids showed significantly positive BP heterosis (i.e. height reduction) and SH, respectively, but none of them showed significantly positive MP heterosis. None of the crosses showed negative heterosis of any kind (Table 1).

MATURITY DURATION

Here also earliness was taken as a positive trait, and in that respect, 18, 6 and 11 hybrids showed significantly positive BP, MP heterosis and SH, respectively. The highest BP, MP heterosis and SH, respectively was observed in the crosses Govind x T 3 (20.5%), Sita x T 3 (13.5%) and IET 6288 x PP 72 (16.4). On the other hand, 1, 7 and 10 hybrids showed significantly negative BP, MP heterosis and SH, respectively. The maximum BP heterosis of – 7.5% and – 11.30% SH was recorded for earliness in the cross Jaya x PP 72. The crosses Govind x Sita and Govind x PP 72 showed – 16.0% SH.

Table 1. Estimate of heterosis over better parent (BP), midparent (MP) ana standard heterosis (SH) among selected hybrids of rice for yield and its components

Hybrid	Type of heterosis	Plant height	Days to maturity	Panicles per plant	Panicle length	1000-grain weight	No. of filled grains per panicle	Grain yield per plant
Govind x Prasad	BP	15.0	5.8	33.2**	-0.4	10.5**	-13.2	53.5**
	MP	4.1	-1.3	49.0**	1.2	13.9**	-0.1	65.7**
	SH	1.2	-15.7**	56.0**	9.3*	-10.7**	-0.8	62.7**
Govind x Sita	BP	26.2	5.4	117.6**	12.5**	13.0**	-7.8	177.8**
	MP	11.7	-3.5	117.6**	18.7**	15.8*	-5.0	178.1**
	SH	11.1	-16.0**	100.9**	19.5**	-4.1**	-17.4	151.6**
Govind x Jaya	BP	24.8	8.5**	44.9**	10.4**	0.7	-2.6	108.8**
	MP	16.9	-3.8	47.5**	13.7**	11.4**	5.7	119.4**
	SH	9.9	-13.5**	41.9**	17.3**	0.7	-2.6	108.8
Govind x IET 6288	BP	14.8	8.0*	34.5**	9.4*	9.5**	27.8	101.8**
	MP	11.5	-5.5	47.9**	21.5**	10.0**	53.5*	114.8**
	SH	0.4	-13.9**	51.7**	16.2**	-10.7**	7.8	80.5**
Govind x IR 54	BP	22.2	25.0**	44.3**	14.9**	12.3**	14.2	70.0**
	MP	6.2	5.3	70.9**	16.1**	16.6**	18.2	87.8**
	SH	7.6	-6.4	93.6**	22.0**	9.2**	3.4	89.4**
Govind x PP 72	BP	95.6*	5.4	69.0**	10.9**	-2.8**	50.0	216.8**
	MP	26.5	-10.8**	81.6**	20.2**	9.9**	90.3**	250.8**
	SH	72.2*	-16.0**	56.0**	39.4**	2.2**	119.4**	255.2**
Prasad x Sita	BP	13.1	3.5	-2.9	-6.3	1.8*	-16.8	39.9**
	MP	10.9	1.7	8.6**	0.4	7.3**	-6.7	50.0**
	SH	20.6	-5.7	13.7**	2.9	-13.7**	-4.9	47.4**
Prasad x Jaya	BP	10.1	-1.6	13.9**	4.8	-0.7	-15.7	58.9**
	MP	7.4	-6.1*	22.8**	9.7**	12.8**	-10.1	63.5**
	SH	10.9	-10.3**	33.3**	15.0**	-0.7	-3.7	68.4**
Prasad x Mahsuri	BP	47.9*	-0.8	78.8**	7.5*	6.8	3.4	161.6**
	MP	22.6	-9.4**	83.5**	11.1**	22.2**	32.2**	204.2**
	SH	55.8*	-9.6**	109.4**	18.0**	-18.8**	109.0**	285.0**
Prasad x PP 72	BP	52.9*	-2.3	40.5**	16.9**	0.4	26.7	258.2**
	MP	12.1	-10.9**	67.4**	24.8**	16.5**	42.2	268.2**
	SH	62.9*	-11.0**	64.5**	46.9*	5.5**	85.2**	301.6**
Sita x IET 6288	BP	21.7	9.4**	18.9**	14.4**	1.7*	33.0	56.4**
	MP	10.4	4.9	30.8**	20.9**	3.8**	63.6**	67.4**
	SH	12.0	3.2	34.2**	8.9*	-13.7**	19.1	41.6**

(Contd.)

Table 1 (contd.)

Hybrid	Type of heterosis	Plant height	Days to maturity	Panicles per plant	Panicle length	1000-grain weight	No. of filled grains per panicle	Grain yield per plant
Sita x Mahsuri	BP	33.6	10.2^{**}	1.2	4.7	-10.9^{**}	-0.7	49.0^{**}
	MP	14.2	2.5	10.5^{**}	8.7^{*}	6.8^{**}	37.6	84.5^{**}
	SH	48.1^{*}	3.9	12.4^{**}	7.5^{*}	-24.4^{**}	100.6^{**}	119.3^{**}
Sita x PP 72	BP	23.6	19.2^{**}	9.5^{**}	-20.2^{**}	-0.4	-85.8^{**}	-82.6^{**}
	MP	-7.1	10.9^{**}	17.7^{**}	-9.2^{**}	10.3^{**}	-82.1^{**}	-80.7^{**}
	SH	37.0	12.5^{**}	1.1	0.2	4.8^{**}	-78.9^{**}	-80.4^{**}
Sita x T 3	BP	46.4	19.2^{**}	16.7^{**}	-9.7^{**}	10.0^{**}	-62.2^{*}	-71.9^{**}
	MP	13.4^{*}	13.5^{**}	22.9^{**}	1.6	19.6^{**}	-55.5^{*}	-69.5^{**}
	SH	62.3^{*}	12.5^{**}	7.7^{*}	10.6^{**}	-6.6^{**}	-51.7	-74.6^{**}
Jaya x PP 72	BP	71.1^{**}	-7.5^{*}	-20.9^{**}	13.2^{**}	-8.4^{**}	17.6	62.7^{**}
	MP	20.4	-11.3^{**}	-11.3^{**}	-26.1^{**}	-6.1^{**}	39.6	72.1^{**}
	SH	71.7^{**}	-7.5^{*}	-20.9^{**}	42.3^{**}	-3.7^{**}	71.9^{*}	82.5^{**}
IET 6288 x IR 54	BP	15.9	6.2	-10.8^{**}	-3.2	9.1^{**}	32.1	33.5^{**}
	MP	3.3	2.7	-3.1	6.6^{*}	13.7^{**}	63.1^{*}	56.4^{**}
	SH	6.7	8.9^{**}	19.7^{**}	0.7	-11.1^{**}	19.6	48.7^{**}
IET 6288 x PP 72	BP	75.5^{**}	13.5^{**}	30.7^{**}	-16.4^{**}	-18.9^{**}	-94.8^{**}	-96.7^{**}
	MP	16.9	10.3^{**}	53.3^{**}	-0.2	-8.7^{**}	-92.5^{**}	-96.1^{**}
	SH	61.5^{*}	16.4^{**}	47.4^{**}	5.1	-14.8^{**}	-92.4^{**}	-96.3^{**}
IET 6288 x T 3	BP	68.2^{**}	9.0^{**}	31.8^{**}	-10.5^{**}	3.2^{**}	-80.4^{**}	-70.8^{**}
	MP	15.7	8.3^{**}	52.0^{**}	5.8	10.4^{**}	-72.8^{**}	-70.4^{**}
	SH	54.7^{*}	11.7^{**}	48.8^{**}	9.7^{**}	-15.9^{**}	-75.0^{**}	-77.0^{**}
IR 54 x Mahsuri	BP	41.2	-5.6	-12.1^{**}	20.4^{**}	-3.4^{**}	-3.3	35.0^{**}
	MP	22.9	-6.0^{*}	-3.8	21.2^{**}	9.8^{**}	33.6	53.9^{**}
	SH	61.8^{*}	2.49	17.9^{**}	25.2^{**}	-27.7^{**}	95.4^{**}	98.6^{**}
IR 54 x PP 72	BP	44.2	1.6	-35.7^{**}	-5.6	-0.7	-53.4	-63.9^{**}
	MP	10.6	1.1	-19.2^{**}	3.3	16.0^{**}	-42.4	-63.5^{**}
	SH	65.2^{**}	10.3^{**}	-13.7^{**}	18.6^{**}	4.4	-31.9	-59.5^{**}
IR 54 x T 3	BP	56.4^{**}	4.8	-34.7^{**}	-2.5	5.4^{**}	-17.4^{**}	-62.4^{**}
	MP	23.6	2.0	-19.3^{**}	5.5	8.1^{**}	-66.6^{**}	-56.8^{**}
	SH	79.2^{**}	8.9^{**}	-12.4^{**}	19.5^{**}	-21.0	-63.5^{*}	-58.1^{**}
Jaya (check)		90.0	140.0	12.1	22.6	27.1	85.7	21.4

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

PANICLE NUMBER PER PLANT

Out of 36 hybrids 21, 25 and 29 hybrids showed significantly positive BP, MP heterosis and SH, respectively. The hybrid Govind x Sita was the most heterotic cross for higher panicle number with 117.8% BP (also MP) heterosis. As regards SH, the cross Prasad x Mahsuri expressed maximum heterosis (109.4%) for this character.

PANICLE LENGTH

For panicle length, 15, 22 and 27 hybrids expressed significantly positive BP, MP heterosis and SH, respectively. The range of positive heterosis for larger panicle was 7.5–20.4% over BP, 6.5–20.1% over MP and 7.5–46.9% SH. The hybrids IR 54 x Mahsuri, Jaya x PP 72 and Prasad x PP 72 showed maximum expression of 20.4, 26.1 and 46.9% over BP, MP and SH, respectively.

1000-KERNEL WEIGHT

Out of 36 hybrids tested, 17, 31 and 4 hybrids exhibited significant positive heterosis over BP, MP and SH, respectively. The hybrid Prasad x T 3 showed maximum BP (24.3%) and MP (28.3%) heterosis,while Prasad x PP 72 showed highest SH 5.53% over cv. Jaya.

FILLED SPIKELETS PER PANICLE

None of the hybrids showed significant positive BP heterosis, while 4 and 7 hybrids showed significant positive MP heterosis and SH, respectively. The maximum MP heterosis (90.3%), and SH (119.4%) was recorded in the hybrid Govind x PP 72 (Table 1). Very few hybrids manifested significant negative BP (5), MP (5) heterosis and SH over the standard variety Jaya (4).

GRAIN YIELD PER PLANT

Out of 36 hybrids tested, 19, 24 and 25 hybrids had significant positive BP, MP heterosis and SH, respectively. The range of heterosis for grain yield per plant was 24.5–258.2% over BP, 20.2–268.2% over MP and 27.7–301.6% SH. The hybrid Prasad x PP 72 exhibited maximum BP, MP heterosis and SH 258.2%, 268.2% and 301.6%, respectively. The other promising cross combinations were Prasad x Mahsuri, Govind x PP 72, Govind x Sita, Govind x Jaya, Govind x IET 6288, Govind x IR 54, Jaya x PP 72 and Sita x Mahsuri.

Successful exploitation of heterosis in several cross-pollinated and often cross-pollinated crops is regarded as one of the major breakthroughs in the field of plant breeding. Heterosis is now being commercially exploited in an array of economically

Table 2. Estimates of heterosis for various characters in groups of top five heterotic and nonheterotic hybrids of rice

Hybrid	Type of heterosis	Plant height	Days to maturity	Panicles per plant	Panicle length	1000-grain weight	No. of filled grain per panicle	Grain yield per plant
Heterotic:								
Prasad x PP 72	BP	52.9*	-2.3	40.5**	16.9**	0.4	26.7	258.2**
	MP	12.1	-10.9**	67.4**	24.8**	16.5**	42.2	268.2**
	SH	62.9*	-11.0**	64.5**	46.9**	6.5**	85.2**	301.6**
Prasad x Mahsuri	BP	47.9*	-0.8	78.8**	7.5*	6.0**	3.4	161.6**
	MP	22.6	-9.4**	83.5**	11.1**	22.2**	32.2	204.2**
	SH	55.8*	-9.6**	109.4**	18.0**	-18.8**	109.0**	285.0**
Govind x PP 72	BP	95.6**	5.4	69.0**	10.9**	-2.8**	50.0	216.8**
	MP	26.5	-10.8**	81.6**	20.2**	9.9**	90.3**	250.8**
	SH	72.2**	-16.0**	56.0**	39.4**	2.2**	119.4**	255.2**
Govind x Sita	BP	26.2	5.4	117.6**	12.5**	13.0**	-7.8	177.8**
	MP	11.7	-3.5	117.6**	18.7**	15.8**	-5.0	178.1**
	SH	11.1	-16.0**	100.9**	19.5**	-4.1**	-17.4	151.6**
Govind x Jaya	BP	24.8	8.5	44.9**	10.4**	0.7	-2.6	108.8**
	MP	16.9	-3.8	47.5**	13.7**	11.4**	5.7	119.4**
	SH	9.9	-13.5**	41.9**	17.3**	0.7	-2.6	108.8**
Nonheterotic:								
IET 6288 x PP 72	BP	75.5*	-13.5**	30.7**	-16.4**	-18.9**	-94.8**	-96.7**
	MP	16.9	10.3**	53.3**	-0.2	-8.7**	-92.5**	-96.1**
	SH	61.5*	16.4**	47.4**	5.1	-14.8**	-92.4**	-96.3**
Sita x PP 72	BP	68.2**	9.0**	30.7**	-16.4**	-18.9**	-94.8**	-82.6**
	MP	15.7	8.3**	53.3**	-0.2	-8.7**	-92.5**	-80.7**
	SH	54.7*	11.7**	47.4**	5.1	-14.8**	-92.4**	-80.4**
Sita x T 3	BP	46.4	19.2**	16.7**	-9.7**	10.0**	-62.2*	-71.9**
	MP	13.4	13.5**	22.9**	1.6	19.6**	-53.2*	-69.5**
	SH	62.3*	12.5**	7.7*	10.6**	-6.6	-51.7	-74.6**
IET 6288 x T 3	BP	68.2**	9.0**	31.8**	-40.5**	3.2**	-80.4**	-70.8**
	MP	15.7	8.3**	52.0**	5.8	10.4**	-72.8**	-70.4**
	SH	54.7*	11.7**	48.8**	9.7**	-15.9**	-75.0**	-77.0**
IR 54 x PP 72	BP	44.2	1.6	-35.7**	-5.6	-0.7	-53.4	-63.9**
	MP	10.6	1.1	-19.2**	3.3	16.0**	-42.4	-63.5**
	SH	65.2**	10.3**	-13.7**	18.6**	4.4**	-31.9	-59.5**

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

important crops. The extent of heterosis reported in most of the self-pollinated crops is of moderate to high order [1–5]. Similar results have also been obtained in rice in the present study, indicating moderate to high heterosis for most of the characters including grain yield per plant. In general, commercial exploitation of heterosis in self-pollinated crops is linked with the problem of large scale seed production. However, the recent increases in area under hybrid rice in China to the extent of almost 50% (15 mil ha) of the total area under rice in 1990 is regarded as a classical example of commercial exploitation of heterosis in a self-pollinated crop in a short period. The absence of desirable heterosis for grain yield in some of the hybrids like IET 6288 x PP 72, Sita x PP 72, Sita x T 3, IET 6288 x T 3 appears to be due to absence of desirable heterosis for the component characters, mainly kernels per panicle, plant height, days to maturity, number of filled spikelets per panicle and the test weight (i.e. grain size). The comparison of heterotic and nonheterotic hybrids for the component characters revealed that the heterotic hybrids manifested heterosis for more than one component characters, whereas, the nonheterotic hybrids showed heterosis, if at all, for a single trait (Table 2). Besides, in certain hybrids, the advantageous effect of one character was cancelled by negative heterosis for some other component character. Panicles per plant, panicle length and spikelets per panicle had high heterotic effects in most of the hybrids, but these effects were cancelled due to the very high negative heterotic effect for number of filled spikelets per panicle and 1000-grain weight, as in the hybrids IET 6288 x PP 72, Sita x PP 72 and IET 6288 x T 3. The high negative heterotic effects for grain number per panicle or high positive heterotic effects for unfilled grain per panicle indicated the occurrence of high spikelet sterility which reduced heterosis for grain yield. The high negative heterotic effects for days to maturity also had important bearing on yield as in the crosses Prasad x PP 72, Prasad x Mahsuri, Govind x PP 72, Govind x Sita, Prasad x Jaya, and Prasad x Mahsuri.

Different estimates show that for hybrid vigour in a self-pollinated crop to be economically viable, it must give at least 25% more yield than the best commercial variety [6]. From this view point, the hybrids Govind x Prasad, Govind x Sita, Govind x Jaya, Govind x IET 6288, Govind x IR 54, Govind x PP 72, Govind x T 3, Sita x IET 6288, Sita x IR 54, Sita x Mahsuri, Jaya x PP 72, Jaya x IET 6288, Jaya x IR 54 and IR 54 x Mahsuri (Table 1) appeared to be most promising for exploitation of hybrid vigour.

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