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Heterosis among line-tester crosses for grain yield and quality components in rice

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ABSTRACT

Heterosis over better parent was estimated for yield, its components and quality related traits in 36 rice hybrids produced in line x tester analysis. The crosses manifesting significant and positive heterosis for grain yield in the range of 21.33% to 47.43% were Mahamaya/Basmati 370, Abhaya/Dubraj, R 302-111/Basmati 370, Abhaya/Basmati 370, RP 2151-33-2/ Pusa Basmati-1, RP2151-33-2/ Dubraj, IET 14887/ Basmati 370, Mahamaya/ Dubraj and R 302-111/Taroari Basmati. Parents Basmati 370 and Dubraj were most frequently involved in high yielding hybrids. Of these crosses Abhaya/Dubraj, RP 2151-33-2/Dubraj and R 302-111/Taroari Basmati also seemed to be promising for elongation ratio and Mahamaya/Basmati 370 for head rice recovery percentage in addition to grain yield. Significant yield increase in high heterotic hybrids was largely attributed to yield components like harvest index, biological yield plant^{-1} spikelet density, fertile spikelets panicle^{-1} and tillers plant^{-1} All these yield components and quality traits like milling %, head rice recovery %, hundred grain weight, kernel length and breadth could be used as selection criteria for simultaneous improvement of yield and quality in rice.

Key words: Combining ability, heterosis, *Oryza sativa*, quality, yield

INTRODUCTION

The exploitation of hybrid vigour appears to be an appropriate alternative for making further breakthrough in rice yields. Assessment of heterosis is an important component of a hybrid rice breeding programme. Hybrids must be evaluated critically not only for their yield potential but also for their grain quality in comparison to the best inbred check varieties. Grain quality has become very important for the acceptance of rice varieties and hybrids to be released. The present studies were carried out to analyze the extent of heterosis for yield in some crosses and identify heterotic hybrids with acceptable grain quality.

MATERIALS AND METHODS

Nine genetically diverse rice cultivars and elite lines having semi-dwarf, desirable agronomic features with resistance to major pests and diseases were crossed as females to each of the four well adaptable and export grain quality cultivars as pollinator, in a line x tester design (Kempthrone 1975). Thirty six crosses were made during the wet season, 1996.

The F_1s and parents were grown in the field at the Research Farm of Indira Gandhi Agricultural University, Raipur, India during the wet season of 1997 in a completely randomized block design with two replications. Each plot consisted of a single row of 3m length with spacing of 20 cm between rows and 15 cm between plants. All recommended cultural practices were followed to obtain normal growth of the crop. Observations were recorded on ten plants selected randomly from each row for morphological traits *viz*., plant height (cm), number of ear bearing tillers plant^{-1}, number of fertile spikelets panicle^{-1}, spikelet density, biological yield plant^{-1} (g), harvest index (%), hundred grain weight (g) and grain yield plant^{-1} (g). Observations were recorded on milling %, head rice recovery %, length and breadth (20 whole milled rice grains were measured by means of Satake grain shape tester and the average value was recorded), length and breadth of cooked kernels (measured in graduated cardboard using method of Pillaiyar and Mohandoss 1981) and elongation ratio (determined by soaking 5g whole milled rice in 12 ml of distilled water for 10 minutes and later cooked grains for 15 minutes in water bath and then calculated by dividing the length of cooked rice by original kernel length). The extent of heterosis over the better parental values was worked out for all the morphological and quality traits.

RESULTS AND DISCUSSION

The analysis of variance indicated significant differences among genotypes for all the traits studied (Table 1). Estimates of heterosis over better parent indicated that nine out of thirty six hybrids evaluated

Table 1. Analysis of variance for Line x Tester analysis.

Characters	Mean squares							
	Replication	Line	Tester	L x T	Error	σ^2_g	σ^2_s	σ^2_g/σ^2_s
D.F	1	8	3	24	35			
Plant height	12.2	810.5*	1144.2	256.9**	8.4	110.8	124.3	0.9
Ear bearing tillers plant⁻¹	2.35	12.20	7.13	10.81**	1.46	-0.18	4.68	-0.04
Number of fertile Spikelets/panicle	1058	8431**	15840	2020**	473	1556	773	2
Spikelet density	288	123707**	598560*	21406**	4815	52266	8295	6
Biological yield plant⁻¹	152	855	3423	856**	25	259	215	1.20
Harvest index %	4.63	415.81	186.68	178.98**	9.37	18.81	84.80	0.22
100-grain weight	0.02	0.17*	0.51*	0.06**	0.0062	0.04	0.03	1.33
Grain yield/plant	21.1	586.9**	522.4	134.4**	8.05	64.65	63.19	1.02
Milling %	0.31	56.63	32.18	30.80**	1.16	2.09	14.82	0.14
Head rice recovery %	0.08	97.85	9.86	55.41**	1.19	6.30	27.11	0.23
Kernel length	0.01	0.25	4.01**	0.12**	0.02	0.31	0.05	6.20
Kernel breadth	0.00049	0.09**	0.072	0.02**	0.0061	0.01	0.02	0.50
Length:breadth Ratio	0.0029	0.48**	1.62*	0.10**	0.01	0.14	0.04	3.50
Elongation ratio	0.000014	0.02	0.03	0.0095**	0.003	0.00	0.02	0.01

*, ** = Significant at $P < 0.05$ and 0.01 levels, respectively

showed higher yield than their respective better parents (Table 2). The crosses with significant and positive heterobeltiosis for grain yield in the range of 21.33 percent to 47.43 percent (Table 3) were Mahamaya/Basmati 370, Abhaya/Dubraj, R 302-111/Basmati 370, Abhaya/Basmati 370, RP 2151-33-2/Pusa Basmati-1, RP 2151-33-2/Dubraj, IET 14887/Basmati 370, Mahamaya/Duraj and R 302-111/Taroari Basmati (Table 2). Basmati 370 and Dubraj were the most frequent parents involved in high yielding hybrids. The present finding is in agreement with those of Sarawgi and Shrivastava (1988), Sarathe and Perraju (1990), Gravois and McNew (1993), Devaraj and Nadarajan (1996) who reported high heterosis for grain yield. In addition to

Table 3. Range of heterobeltiosis for yield components and physio-chemical traits.

Characters	Range of Heterobeltiosis		Name of crosses for	
	Min	Max.	Min. heterobeltiosis	Max. heterobeltiosis
Plant height	5.79	64.67	Mahamaya/Pusa Basmati-1	Abhaya/Dubraj
Ear bearing tillers plant⁻¹	27.78	33.33	PR 111/Pusa Basmati-1	R 302-111/Pusa Basmati-1
Fertile spikelets	30.93	79.08	Abhaya/Taroari Basmati	RP 2151-33-2/Taroari Basmati
Spikelet density	27.62	69.44	Mahamaya/Basmati 370	RP 2151-33-2/Basmati 370
Biological yield plant⁻¹	25.38	75.50	RP 302-111/Pusa Basmati-1	Abhaya/Dubraj
Harvest index	11.96	29.54	R 302-111/Basmati 370	Mahamaya/Basmati 370
Hundred grain weight	07.22	35.53	RP 106/Dubraj	PR 111/Dubraj
Grain yield plant⁻¹	21.33	47.43	R 302-111/Taroari Basmati	Mahamaya/Basmati 370
Milling %	10.47	-	IET 14887/Taroari Basmati	-
Head Rice Recovery%	05.38	24.68	IET 13932/Pusa Basmati-1	PR 2151-33-2/Taroari Basmati
Elongation ratio	07.05	13.76	RP 2151-33-2/Taroari Basmati	IR 64/Dubraj

grain yield, crosses exhibiting significant and positive heterosis were Mahamaya/Basmati 370 for harvest index, spikelet density and head rice recovery %; Abhaya/Dubraj for biological yield and elongation ratio; R 302-111/Basmati 370 for harvest index; Abhaya/Basmati 370 for fertile spikelets; RP 2151-33-2/Pusa Basmati-1 for fertile spikelets, spikelet density, biological yield and head rice recovery %; RP 2151-33-2/Dubraj for harvest index and elongation ratio; IET 14887/Basmati 370 for head rice recovery %; Mahamaya/Dubraj for biological yield; R 302-111/Taroari Basmati for hunderd grain weight and elongation ratio (Table 4). None of these crosses exhibited significant and negative heterosis for dwarf plant stature indicating that most of the F_1 hybrids were taller in stature than parents. Shrivastava and Seshu (1982) also reported high heterosis for plant height and spikelets per

Table 2. Estimates of heterosis (%) over better parent for different traits.

Crosses	Better parent heterosis (%)													
	Plant height	Earbearing tillers plant⁻¹	Fertile spikelet	Spikelet density	Biological yield plant⁻¹	Harvest index %	100-grain weight	Grain yield plant⁻¹	Milling %	Head rice recovery	Kernel length	Kernel breadth	L/B ratio	Elongation ratio
PR 106 x Pusa Basmati-1	21.49*	-27.78*	19.23	-9.38	-9.34	-14.37*	10.76*	-6.76	-7.35*	-1.02	-4.22*	5.41	-13.15*	-9.04*
PR 106 x Taroari Basmati	30.40*	-47.06*	-32.17*	-27.98*	-19.30*	-42.48*	7.72*	-10.76	-2.51	-7.03*	-2.88	13.16*	-14.09*	11.54*
PR 106 x Basmati 370	39.20*	-40.00*	-24.48	-17.79	-49.57*	-46.81*	5.88	-57.66*	-1.57	4.33	-4.99	22.39*	-19.77*	-10.43*
PR 106 x Dubraj	43.75*	-48.28*	-62.25*	-25.50*	-23.05*	-54.78*	7.65*	-60.66*	-6.88*	-12.10*	-10.24*	22.86*	-12.38*	-0.64
PR 111 x Pusa Basmati-1	9.77*	27.78*	-8.94	-24.50*	15.13	-21.87*	-19.73*	-13.84	3.86	6.05*	-8.56*	7.14	-10.44*	-6.33
PR 111 x Taroari Basmati	6.85*	-47.06*	-47.90*	-52.76*	-33.68*	-41.94*	3.86	-46.31*	2.00	8.91*	-1.44	17.14*	-15.96*	-0.96
PR 111 x Basmati 370	10.61*	-30.00*	-26.83*	-45.10*	-45.51*	-36.86*	1.68	-56.29*	-2.09	8.91*	-7.19*	16.42*	-16.86*	-17.11
PR 111 x Dubraj	17.72*	-27.59*	-53.18*	-36.13*	-11.11	-56.38*	35.53*	-54.05*	-5.98*	-15.71*	-10.79*	-20.00*	-25.79*	-12.75*
IR 64 x Pusa Basmati-1	38.13*	11.11	12.81	18.18	-12.39	1.03	4.23	1.52	0.11	-3.97	-15.75*	18.72*	-29.20*	-4.52
IR 64 x Taroari Basmathi	31.86*	-58.82*	8.76	5.70	-46.59*	-12.30*	7.74*	-16.64	-2.77	-2.91	-2.16	7.89	-9.29*	7.09*
IR 64 x Basmati 370	38.08*	0.00	-13.06	8.40	3.47	-18.25*	16.80*	15.70	-2.34	-1.83	1.15	19.40*	-15.17*	-11.76*
IR 64 x Dubraj	44.89*	-31.48	-31.58*	-28.17*	25.73*	-23.91*	-6.33	0.49	-0.72	-4.05	-18.60*	28.57*	-25.87*	13.76*
IET 13932 x Pusa Basmati-1	52.70*	11.11	-16.14	-31.91*	2.72	-27.14*	16.60*	-21.42	-1.46	5.38*	-13.01*	13.51*	-23.51*	-4.18
IET 13932 x Taroari Basmati	49.82*	-47.06*	-33.60*	-47.38*	-36.33*	-1.31	5.61	5.78	-15.87*	-26.02*	-5.04*	13.16*	-15.87*	0.30
IET 13932 x Basmati 370	48.97*	-25.00	-41.53*	-42.06*	-27.49*	-46.48*	4.41	-45.58*	-3.32	-0.35	-7.35*	31.34*	-29.27*	-8.29*
IET 13932 x Dubraj	35.57*	-62.07*	-28.13*	-33.60*	-45.97*	-21.88*	19.35*	-57.74*	-1.31	-0.61	-1.28	22.86*	-10.89*	-3.88
IET 14887 x Pusa Basmati-1	9.64*	-27.78*	2.14	-10.24	-31.39*	10.30	-3.59	-24.19	-14.72*	-24.69*	-2.05	9.09	-3.76	-7.23*
IET 14887 x Taroaribasmati	32.19*	-47.06*	-30.04*	-38.56*	-50.24*	2.76	8.11*	-27.84*	10.47*	8.26*	4.32	18.18*	-9.82*	2.88
IET 14887 x Basmati 370	35.25*	15.00	21.29	-17.46	2.35	5.07	4.20	26.10*	-3.33	6.97*	-0.74	18.18*	-16.00*	-13.10*
IET 14887 x Dubraj	33.09*	-48.28*	-28.86*	-34.44*	-20.89*	-36.19*	6.00	-49.51*	3.19	-2.76	-16.80*	18.18*	-29.04*	13.76*
RP 2151-33 x Pusa Basmati-1	12.07*	-5.56	56.23*	37.12*	31.07*	1.99	2.63	34.25*	-1.89	13.92*	-8.90*	8.11	-15.93*	0.63
RP 2151-33 x Taroari Basmati	7.66*	-67.65*	79.08*	34.20*	-40.27*	-15.66*	4.89	-37.88*	3.79	24.68*	-10.07*	21.05*	-25.58*	7.05*
RP 2151-33 x Basmati 370	25.18*	-5.00	62.04*	69.44*	12.54	-13.44*	1.32	8.56	-2.32	8.09*	-8.05*	37.31*	-32.86*	-12.83*
RP 2151-33 x Dubraj	33.62*	10.34	-17.60	-10.33	9.23	17.66*	-8.80*	28.82*	-2.12	1.70	-10.08*	28.57*	-14.85*	9.73*
Abhaya x Pusa Basmati-1	-0.28	-11.11	-25.98	-15.35	-37.22*	10.43	6.28	-29.34*	1.48	2.08	-8.90*	5.41	-13.65*	-7.55*
Abhaya x Taroari Basmati	55.37*	-47.06*	30.93*	-28.09*	-15.64	-21.99*	4.45	7.65	-0.63	-3.75	-0.72	7.89	-7.90*	1.60
Abhaya x Basmati 370	35.09*	0.00	43.67*	19.23	-5.29	7.19	-7.98*	37.79*	-3.55	-2.56	-5.05*	19.40*	-20.28*	-12.03*
Abhaya x Dubraj	64.67*	0.00	-2.00	-10.73	75.50*	-19.37*	1.87	40.02*	-0.09	-9.67	-12.20*	20.00*	-18.58*	11.41*
Mahamaya x Pusa Basmati-1	5.79*	-5.56	-9.07	-19.78*	8.90	0.55	-10.06*	9.60	-2.55	15.49*	-3.42	8.11	-10.87*	-11.14*
Mahamaya x Taroari Basmati	14.27*	-52.94*	-7.11	11.39	-12.76	-3.25	-18.90*	-5.82	-14.89*	-8.59*	-2.74	11.84*	-15.46*	0.00
Mahamaya x Basmati 370	25.19*	15.00	15.69	27.62*	11.28	29.54*	-18.90*	47.43*	-0.26	6.03*	-10.33*	40.30*	-33.89*	-13.37*
Mahamaya x Dubraj	38.04*	-37.93*	-5.81	-13.79	38.04*	-15.21*	-19.82*	24.04*	-0.21	1.66	-14.07*	37.14*	-20.13*	2.88
R 302-111 x Pusa Basmati-1	34.34*	33.33*	-10.32	-3.67	25.38*	-31.53	-6.11	-10.41	-8.41*	-4.63*	-8.90*	18.92*	-23.29*	-9.34*
R 302-111 x Taroari Basmati	33.49*	-32.35*	-2.92	-8.80	-31.89*	6.74	8.78*	21.33*	-7.55*	-15.94*	-2.88	13.16*	-14.03*	8.97*
R 302-111 x Basmati 370	10.15*	15.00	12.65	1.22	-10.79	11.96*	-2.29	38.23*	-2.42	4.07	-3.45	19.40*	-19.13*	-26.47*
R 302-111 x Dubraj	49.33*	-27.59*	-21.42	-32.66*	11.35	3.51	-16.03*	15.35	-5.64	2.69	-9.45*	20.00*	-9.74*	3.69
SE	2.76	1.25	21.95	69.94	4.72	3.03	0.08	2.71	1.71	1.45	0.16	0.08	0.12	0.05

*, ** – Significant at $P < 0.05$ and 0.01 levels, respectively.

Table 4. Performance of best heterobeltiotic crosses for important traits.

Character	Cross	Heterosis over better parent	Mean
Grain yield plant^{-1}	Mahamaya/Basmati 370	47.43*	48.90
	Abhaya/Dubraj	40.02*	52.76
	R302-111/Basmati 370	38.23*	31.17
	Abhaya/Basmati 370	37.79*	31.07
	RP 2151-33-2/Pusa Basmati	34.25*	36.01
	RP 2151-33-2/Dubraj	28.82*	48.54
	IET 14887/Basmati 370	26.10*	28.43
	Mahamaya/Dubraj	24.04*	46.74
	R302-111/Taroari Basmati	21.33*	24.98
Ear bearing tillers plant^{-1}	R302-111/Pusa Basmati-1	33.33*	12.00
	PR 111/Pusa Basmati-1	27.78*	11.50
Number of fertile spikelets	RP 2151-33-2/Taroari Basmati	79.08*	175.50
	RP 2151-33-2/Basmati 370	62.04*	198.50
	RP 2151-33-2/Pusa Basmati	56.23*	219.50
	Abhaya/Basmati 370	43.67*	176.00
	Abhaya/Taroari Basmati	30.93*	127.00
Spikelet density	RP 2151-33-2/Basmati 370	69.44*	937.89
	RP 2151-33-2/Pusa Basmati	37.12*	771.95
	RP 2151-33-2/Taroari Basmati	34.20*	713.21
	Mahamaya/Basmati 370	27.62*	1105.78
Hundred grain weight	IR 64/Basmati 370	16.80*	2.78
	R302-111/Taroari Basmati	08.78*	2.85
	IET 14887/Taroari Basmati	08.11*	2.81
	IR 64/Taroari Basmati	07.74*	2.79
	PR 106/Taroari Basmati	07.72*	2.79
Head rice recovery	RP 2151-33-2/Taroari Basmati	24.68*	66.61
	Mahamaya/Pusa Basmati	15.49*	61.95
	RP 2151-33-2/Pusa Basmati	13.92*	60.96
	IET 14887/Basmati 370	06.97*	53.48
	Mahamaya/Basmati 370	06.03*	55.77
Milling %	IET 14887/Taroari Basmati	10.47*	67.81
Elongation ratio	IET 14887/Dubraj	13.76*	01.69
	IR 64/Dubraj	13.76*	01.69
	PR 106/Taroari Basmati	11.54*	01.74
	Abhaya/Dubraj	11.41*	01.66
	RP 2151-33-2/Dubraj	09.73*	01.64
	R302-111/Taroari Basmati	08.97*	01.70

*, ** = Significant at $P < 0.05$ and 0.01 levels, respectively

Table 5. Correlation coefficients among yield and quality components in rice.

Characters	Ear bearing tillers plant^{-1}	Fertile spikelets panicle^{-1}	Spikelet density	Biological yield plant	Harvest index	100-grain weight	Grain yield plant	Milling %	Head rice recovery %	Kernel length	Kernel breadth	Length: breadth ratio	Elongation ratio
Plant height	0.4081**	0.4336**	0.3383*	0.6498**	-0.2427	0.2155	0.5043**	0.0264	-0.0733	-0.2869*	0.1434	-0.2459	0.4973**
Ear bearing tiller plant^{-1}		0.2246	0.1910	0.6100**	0.0621	-0.0962	0.5691**	0.0770	-0.0874	-0.1915	-0.0575	-0.0770	0.0463
Fertile spikelets panicle^{-1}			0.8560**	0.6125**	0.3833**	-0.2148	0.7526**	0.2352	0.3423*	-0.5544**	0.1883	-0.4119**	0.0311
Spikelet density				0.5464**	0.2668	-0.3939**	0.6309**	0.1438	0.2703	-0.6816**	0.1579	-0.4580**	-0.0047
Biological yield plant^{-1}					-0.0562	0.0121	0.8513**	0.2485	0.1083	-0.4700**	0.1985	-0.3787**	0.1647
Harvest index						-0.0567	0.4547**	0.1374	0.1597	0.0771	0.0926	-0.0001	-0.3532*
100-grain weight							0.0142	0.1521	0.2807*	0.2928*	0.5934**	-0.2467	0.1763
Grain yield plant^{-1}								0.3138*	0.2130	-0.3773**	0.2377	-0.3453*	-0.0224
Milling %									0.7343**	-0.2697	0.3336*	-0.3698**	-0.1469
Head rice recovery %										0.4602**	0.2799	-0.4794**	-0.2116
Kernel length											-0.2941**	0.7627**	-0.1183
Kernel breadth												-0.8329**	0.0471
Length:Breadth ratio													-0.1053

panicle; Sarawgi and Shrivastava (1988) for biological yield; Patnaik *et al.* (1990) and Mishra and Pandey (1998) for harvest index; Peng and Virmani (1991) for harvest index and plant height; Gravois (1994) for head rice recovery % and Pendey *et al.* (1995) for hundred grain weight.

No one among nine heterotic crosses was superior for all the quality traits. Crosses which exhibited significant and positive heterosis for elongation ratio were Abhaya/Dubraj, RP 2151-33-2/Dubraj and R302-111/Taroari Basmati, while crosses Mahamaya/Basmati 370, RP 2151-33-2/Pusa Basmati-1 and IET 14887/Basmati 370 exhibited heterosis for head rice recovery %.

Correlation analysis indicated that grain yield plant^{-1} had significant and positive association with harvest index, biological yield plant^{-1}, spikelet density, fertile spikelets panicle^{-1} and tillers plant^{-1} (Table 5). Estimates of heterosis for various yield components of nine heterotic hybrids also confirmed that significant yield increase was largely attributed to the above traits. This indicates that selection for harvest index, biological yield plant^{-1}, spikelet density and fertile spikelets panicle^{-1} would be effective in increasing grain yield. Association analysis also indicated significant and positive correlation of grain yield with milling %, milling % with head rice recovery %, head rice recovery % with hundred grain weight, hundred grain weight with kernel length and breadth. Therefore, quality traits like milling %, head rice recovery %, hundred grain weight, kernel length and breadth along with yield components like harvest index, biological yield plant^{-1}, spikelet density and fertile spikelets panicle^{-1} could be used as selection criteria for simultaneous improvement of yield and quality traits.

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