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STUDIES FOR HETEROSIS AND COMBINING ABILITY IN RICE

SYED SULTAN ALI AND MUHAMMAD GHAYYUR KHAN
Rice Research Institute, Kala Shah Kaku, Pakistan

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A 4 x 4 diallel cross experiment was conducted to estimate the manifestation of heterosis, heterobeltosis and combining ability for plant height, number of tillers per plant, panicle length number of spikelets per panicle, number of grains per panicle, percentage filled spikelet density, panicle weight and grain yield per plant. The magnitude of positive and significant heterosis was quite high in all the characters except plant height, percentage filled spikelets and spikelet density. As regard heterobeltosis, number of tillers per plant, panicle weight and grain yield per plant showed significant positive values over the better parent in most of the crosses. A wide range of variation was noted for all the nine characters for general and specific combining abilities. Non-additive gene actions were observed for all the traits except plant height and panicle length, for which only additive gene effect were important. The mean varietal performance was linearly related to GCA values for grain yield and yield components. Basmati 385 proved to be a good general combiner for most of the traits. Based on mean performance coupled with SCA effects of the crosses and varietal GCA effects, crosses Basmati 370 X Basmati 385, 4048 X Basmati 198 and Basmati 370 x Basmati 198 could be recommended for pure line development.

Key words: Heterosis, Heterobeltosis, Combining ability, Yield components.

Introduction

In recent years plant breeders have extensively explored and utilized heterosis in boosting yield of many crops [1-3] and reported varying degree of heterosis for some of the yield and quality components in rice. From the past few years, the yield of rice stagnant, so the identification of parents with greater yields potential and better agronomic traits is the need of the time to increase the yield level of rice as a wrong choice of parents could undo a meticulously planned and well executed follow up programm [4]. The combining ability analysis (CAA) developed by Griffing [5] provides useful information on prepotency of parents in the F_1 generation, which can be useful for more efficient utilization of genetic variability to improve present yield levels.

Most of the reports on combining ability for plant height, components of yield and grain yield in wheat have attributed the preponderance of variability to GCA [6-7]. However, reports on SCA vary from statistically significant [6-8] to statistically non-significant values [4,9].

The objective of this study was to determine the extent of heterosis and breeding value of four rice cultivars in a 4 x 4 diallel set (excluding reciprocals) for yield and yield components and to devise a practical breeding strategy to handle elite crosses.

Materials and Methods

The experimental material consisted of 4 rice cultivars, Basmati 370, Basmatic 385, 4048 and Basmati 198, which were corssed in all possible combinations excluding reciprocals. Four parents along with 6 F_1 hybrids were grown in 1993 at Rice Research Institute, Kala Shah Kaku using a Randomised complete block design, replicated thrice and keeping row to row and plant to plant distance of 30 and 25 cm, respectively. Each entry consisted of a single row of 4 meter length. All the genotypes received identical cultural and agronomic practices. Normal plant protection measures were adopted.

Ten plants of each entry were tagged at random from each plot and data were recorded on the parameters like plant height (cm), number of tillers/plant, panicle length (cm), number of spikelets/panicle, number of grains/panicle percentage filled spikelets, spikelet density, panicle weight (g) and grain yield/plant (g).

Heterosis was estimated according to Wynne *et al.* [10] and Heterobeltosis was calculated following the formula (F_1-better parent)/better parent X 100, given by Fonsea [11]. Whereas general combining ability (GCA) and specific combining ability (SCA) effects were calculated following Griffing's [5] approach, Methods 2, Model 2.

Results and Discussions

The mean values of parents, F_1's along with heterosis revealed that the magnitude of positive heterosis was quite high in all the characters under study except plant height, percentage filled spikelets and spikelet density (Table 1AB). As regards heterobeltosis, number of tillers/plant, panicle weight and grain yield/plant showed positive and significant values over the better parent in most of the crosses. The cross

TABLE 1A. ESTIMATES OF HETEROSIS (MID PARENT) AND HETEROBELTOSIS (BETTER PARENT) IN RICE AT RICE RESEARCH INSTITUTE, KALA SHAH KAKU.

	Plant Height (cm)					No. of Tillers/plant					Panicle length (cm)				
Crosses	P1/P2	MP	F_1 hybrid	%age increase (+) or(-) over MP	BP	P1/P2	MP	F_1 hybrid	%age increase (+) or(-) over MP	BP	P1/P2	MP	F_1 hybrid	%age increase (+) or(-) over MP	BP
Bas.370 x Bas.385	160.86/ 140.63	150.75	155.40	3.08*	-3.39*	17.33/ 21.20	19.27	49.37	156.20**	132.80**	30.77/ 36.27	33.52	34.53	3.01	-4.80
Bas.370 x 4048	160.86 129.23	145.05	142.76	-1.58	-11.25**	17.33/ 34.20	25.77	68.54	165.97**	100.40**	30.77/ 29.91	30.37	30.35	0.03	-1.36
Bas. 370 x Bas. 198	160.86/ 117.77	139.32	143.58	3.06*	-10.7488	17.33/ 28.13	22.73	62.08	173.12**	120.00**	30.77/ 27.09	28.93	34.57	19.50**	12.35**
Bas. 385 x 4048	140.63/ 129.23	134.93	120.30	10.84**	-14.16**	21.20/ 34.20	27.70	58.77	112.17**	71.80**	36.27/ 29.93	33.10	29.63	-10.48**	-18.31**
Bas.385 x Bas. 198	140.63/ 117.77	129.20	125.27	-3.04*	-10.92**	21.20/ 28.13	24.67	62.67	154.03**	122.00**	36.27/ 27.09	31.68	30.04	-5.18	-17.18**
4048 x Bas. 198	129.63/ 117.77	123.70	112.87	-8.76**	-12.93**	34.20/ 28.13	31.17	65.75	110.94**	92.20**	29.93/ 27.09	28.51	29.64	3.96	-0.97

	No. of spikelet/panicle					No. of grains/panicle					Percentage filled spikelets				
Crosses	P1/P2	MP	F_1 hybrid	%age increase (+) or(-) over MP	BP	P1/P2	MP	F_1 hybrid	%age increase (+) or(-) over MP	BP	P1/P2	MP	F_1 hybrid	%age increase (+) or(-) over MP	BP
Bas.370 x Bas.385	154.00/ 201.80	177.90	164.00	-7.81*	-18.73**	136.10/ 170.90	153.50	150.70	-1.82	-11.82	88.49/ 84.61	36.55	92.02	6.32*	3.99
Bas.370 x 4048	154.00/ 133.20	143.60	145.87	1.58	-5.28	136.10/ 117.50	126.80	112.70	-11.12	-17.19*	88.49/ 88.13	88.31	77.51	-12.23*	-12.40**
Bas. 370 x Bas. 198	154.00/ 162.13	158.07	143.57	-9.17*	-11.45*	136.10/ 139.20	137.65	130.60	-5.12	-6.18	88.49/ 85.83	87.16	83.93	-3.71	-5.15
Bas. 385 x 4048	201.80/ 133.20	167.50	199.48	19.09**	-1.15	170.90/ 117.50	144.20	156.90	8.80	-8.19	84.61/ 88.13	86.37	80.82	-6.43*	-6.29*
Bas.385 x Bas. 198	201.80/ 162.13	181.97	217.33	19.43**	7.70*	170.90/ 139.20	155.05	160.70	3.64	-5.97	84.61/ 85.83	85.20	73.37	-13.91**	-14.50**
4048 x Bas. 198	133.20/ 162.13	147.67	260.80	76.61**	60.86**	117.50/ 139.20	128.35	206.50	60.89**	48.35**	88.13/ 85.83	86.98	78.26	-10.03**	-11.20**

P1/P2 top value indicates the mother parent while lower value pollen parent; MP-Mid parent; BP-Better parent; *,**-Significant at 0.05 and 0.01 probability levels, respectively.

combinations Basmati 370 X Basmati 198 (number of tillers/plant, panicle length and panicle weight), 4048 X Basmati 198 (number of tillers/plant, number of spikelets/panicle, number of grains/panicle, spikelet density, panicle weight and grain yield/plant) and Basmati 370 X Basmati 385 (number of tillers/plant and grain yield/plant) showed positive significant values over the better parent. Tahir *et al.* [2] and Singh *et al.* [3] also reported heterosis for grain yield and its components in rice.

A summary of heterotic effects on different characters depicted that none of the F_1 hybrids showed heterobeltosis for plant height (Table 2). However, in the case of number of tillers/plant, heterosis over the better parent was observed in all the 6 F_1 crosses. Panicle weight and grain yield/plant also indicated heterosis over better parent in 4 out of 6 crosses. None of the F_1 crosses yielded below the lower parent for number of tillers/plant and grain yield/plant. Maximum number of crosses falling below the lower parent were observed in percentage filled spikelets. More than 50% of the F_1 crosses showed heterosis over mid parent for panicle length, number of spikelets/panile weight and grain yield/plant.

The analysis of variance for combining ability (Table 3) showed that mean squares due to both GCA and SCA effects were highly significant in almost all the traits except percentage filled spikelets and panicle weight for which GCA mean squares were non-significant. Nevertheless, SCA mean squares were more pronounced for all the traits except plant height and panicle length. This indicated that non-additive type of gene actions were involved in the inheritance of all the traits except plant height and panicle length which showed additive type of gene action. The GCA/SCA ratios also confirm these results. Other authors [6,7, 12]. also noted higher GCA than SCA in most of the characters in rice and wheat and low GCA for number of tillers/ plant. High SCA has also been reported in wheat and rice for these traits [6-9,13].

Basmati 385 proved to be a good general combiner followed by Basmati 198 for most of the traits; whereas 4048 (-6.66") and Basmati 370 (2.33") showed good GCA for plant height and percentage filled spikelets, respectively. The results showed that none of the lines possessed all the genes having positive effect for all the characters under study and that each line can be utilized as a donor parent for specific character(s). The mean varietal performance also showed linear relationship to their GCA values for grain yield and yield components (Table 4).

Estimates of SCA effects for each cross and character (Table 5) exhibit the greatest positive effects for most of the traits in the crosses, Basmati 370 X Basmati 385, 4048 X Basmati 198 and Basmati 370 X Basmati 198, respectively. However, all the F_1 crosses showed positive and highly significant SCA effects for number of tillers/plant. The mean performance of crosses and magnitude of their SCA effects

TABLE 1B. ESTIMATES OF HETEROSIS (MID PARENT) AND HETEROBELTOSIS (BETTER PARENT) IN RICE AT RICE RESEARCH INSTITUTE, KALA SHAH KAKU.

Crosses	Spikelet density					Panicle weight (gm)					Grain yield per plant (gm)				
	P1/P2	MP	F_1 Hybrid	Percentage increase(+) or decrease (-) of F_1 over MP	Percentage increase(+) or decrease (-) of F_1 over BP	P1/P2	MP	F_1 Hybrid	Percentage increase(+) or decrease (-) of F_1 over MP	Percentage increase(+) or decrease (-) of F_1 over BP	P1/P2	MP	F_1 Hybrid	Percentage increase(+) ordecrease (-) of F_1 over MP	Percentage increase(+) ordecrease (-) of F_1 over BP
Bas-370 x Bas-385	4.42/ 4.71	4.57	4.39	-3.34	-6.79	3.09/ 4.09	3.59	4.18	16.43	2.20	29.31/ 36.79	33.05	43.23	30.80	17.50
Bas-370 x 4048	4.42/ 3.93	4.18	3.71	-11.24	-16.06	3.09/ 2.88	2.99	2.62	-12.37	-15.21	29.31/ 32.80	31.06	30.50	-1.80	-7.01
Bas-370 x Bas-198	4.43/ 5.17	4.80	3.06	-36.25	-40.81	3.09/ 3.18	3.14	4.55	44.90	43.08	29.31/ 34.0	31.66	37.30	17.81	9.71
Bas-385 x 4048	4.71/ 3.93	4.32	3.86	-10.65	-18.05	4.09 2.88	3.49	4.20	20.34	2.69	36.79/ 32.80	34.80	40.22	15.57	9.32
Bas-385 x Bas-198	4.71/ 5.17	4.94	5.34	8.10	3.29	4.09/ 3.18	3.64	2.70	-25.82	-33.99	36.79/ 34.0	35.40	35.39	-0.03	-3.81
Bas-4048 x Bas-198	3.93/ 5.17	4.55	6.30	38.46	21.86	2.88/ 3.18	3.03	5.03	66.01	58.18	32.80/ 34.0	33.40	38.21	14.40	12.38

P1/P2 = Top value indicates the mother parent while lower value pollen parent. MP = Mid parent, BP = Better parent, *,**, significant at 0.05 and 0.01 probability levels, respectively.

showed similar pattern (for plant height, percentage filled spikelets and grain yield/plant in Basmati 370 X Basmati 385, for number of spikelets/pancile, number of grains/pancile, panicle weight and spikelet density in 4048 X Basmati 198, for number of tillers/plant in Basmati 370 X 4048 and for panicle length in Basmati 370 X Basmati 198.

It is concluded that GCA and SCA effects of parents and crosses coupled with mean performance may be the

TABLE 2. SUMMARY OF HETEROTIC EFFECT ON DIFFERENT CHARACTERS IN RICE AT RICE RESEARCH INSTITUTE KALA SHAH KAKU.

Parameter	Plant height	No. of tillers/ plant	Panicle length	No. of spikelets/ panicle	No. of grains/ panicle	Percent filled spikelets	Spikelets density	Panicle weight	Grain yield/ plant
Mean value of mid parent	137.16	25.22	31.01	162.79	140.93	86.77	4.56	3.31	33.23
Heterosis	-2.77	142.66	1.45	15.80	8.58	-6.66	-2.63	17.22	12.79
Hetero-beltosis	-10.44	103.93	-5.75	4.37	-0.98	-7.89	-9.2	7.18	6.48
No. of croses below the lower parent	1	0	1	1	2	5	4	2	0
Above the mid parent	2	6	4	4	3	1	2	4	4
Above the better parent	0	6	1	2	1	1	2	4	4
Highest/lower parent ratio	1.19	1.47	1.17	1.25	1.21	1.03	1.16	1.21	1.13

TABLE 3. MEAN SQUARES FROM THE ANALYSIS OF VARIANCE FOR COMBINING ABILITY OF NINE AGRONOMIC TRAITS.

		Mean squares								
S.O.V.	df	Pl.Ht.	NT/P	PL.	NS/P	NG/P	PFS	PW	SD	SYPP
GCA	3	713.708^{**}	95.751^{**}	8.208^{**}	1604.0108^{**}	694.6033^{**}	10.828^{NS}	0.1167^{NS}	0.7524^{**}	15.9693^{*}
SCA	6	39.632^{**}	535.145^{**}	2.591^{**}	1644.605^{**}	801.411^{**}	41.558^{**}	1.0387^{**}	0.9385^{**}	19.7473^{**}
Error	18	2.718	4.461	0.2969	28.5874	65.642	5.3605	0.0424^{**}	0.1044	4.4838
GCA/SCA ratio		18.01	0.18	3.17	0.98	0.87	0.26	0.11	0.80	0.81

** Significant at 0.01 probability level, NS-Non-significant, PL-Plant height, NTP-No. of tillers per plant, PL-Panicle length, NS/P-No. of spikelets per panicle, NG/P-No. of grains per panicle, PFS-Percent filled spikelets, PW-Panicle weight, SD-Seed density.

TABLE 4. ESTIMATES OF GCA EFFECTS AND MEAN PERFORMANCE OF PARENTS FOR DIFFERENT CHARACTERS IN RICE.

	Mean squares								
Varieties/lines	Pl.ht.	NT	Pl	NPP	NGPP	PW	SD	GYPP	% FS
Basmati 370	14.85^{**}	-3.23^{**}	0.76^{NS}	-21.61^{**}	-12.45^{**}	-0.12^{NS}	-0.41^{**}	-1.54^{**}	2.33^{*}
	160.86^{**}	17.33^{**}	30.77^{**}	154.00^{**}	136.1^{**}	3.09^{**}	4.42^{**}	29.31^{**}	88.49^{**}
Basmati 385	1.32^{**}	-3.47^{**}	1.72^{**}	15.55^{**}	11.53^{**}	0.17^{*}	0.09^{NS}	2.26^{**}	-0.18^{NS}
	140.63^{**}	21.2^{**}	36.27^{**}	201.8^{**}	170.9^{**}	4.09^{**}	4.71^{**}	36.79^{**}	84.61
4048	-6.66	4.57^{**}	-1.16^{**}	3.09^{NS}	-4.97^{NS}	-0.11^{NS}	-0.12^{NS}	-0.73^{NS}	-0.61^{NS}
	129.23	34.2^{**}	29.93^{**}	133.2^{**}	117.5^{**}	2.88^{**}	3.93^{**}	32.8^{**}	88.13^{**}
Basmati 198	-9.51	2.12^{**}	-1.33^{**}	9.15^{**}	5.88^{NS}	0.06^{NS}	0.43^{**}	0.003^{NS}	-1.55^{NS}
	117.77	28.13^{**}	27.09^{**}	162.13	139.2^{**}	3.18^{**}	5.17^{**}	34.00^{**}	85.83^{**}
S.E.	0.33	0.75	0.12	1.89	2.86	0.07	0.11	0.75	0.82

** Significant at 0.01 and 0.05 levels of probability. Pl. Ht-Plant height, NT-No. of tillers per plant, PL-Panicle length, NSPP-No. of spikelets per panicle, NGPP-No. of grains per panicle, PW-Panicle weight, SD-Spikelet density, GYPP-Grain yield/plant, %FP-Percent filled spikelets,

TABLE 5. SCA EFFECTS AND MEAN PERFORMANCE OF SIX RICE CROSSES DERIVED FROM A FOUR PARENT DIALLEL CROSS FOR NINE AGRONOMIC TRAITS.

Crosses	Characters								
	Pl.ht.	NT	Pl	NSPP	NGPP	PW	SD	GYPP	% FS
Bas. 370 x Bas. 385	4.36**	9.26**	0.76^{NS}	-8.16*	3.44^{NS}	0.48**	0.21^{NS}	6.73**	6.57**
	155.4**	49.37**	34.53**	164**	150.7**	4.18**	4.39**	43.23**	92.02**
Bas. 370 x 4048	-0.31^{NS}	20.39**	-0.55^{NS}	-7.65	-18.06**	-0.81**	-0.26^{NS}	-3.01*	-7.51**
	142.76**	68.54**	30.35**	145.87**	112.7**	2.62**	3.71**	30.5**	77.51**
Bas.370 x Bas. 198	3.37**	13.38**	3.85**	-22.19**	11.01*	0.95**	-1.46**	3.06*	-0.15^{NS}
	143.58**	62.08**	34.57**	143.57**	130.6**	4.55**	3.06**	37.3**	83.93**
Bas. 385 x 4048	-9.23**	10.8**	-2.22**	8.8*	2.16^{NS}	0.48**	-0.61**	2.91*	-1.7^{NS}
	120.3**	58.77**	29.63**	199.48**	156.9**	4.2**	3.86**	40.22**	80.82**
Bas. 385 x Bas. 198	-1.4^{NS}	17.21**	-1.64**	-3.44^{NS}	-4.89^{NS}	-1.19**	0.32^{NS}	-2.65^{NS}	-8.21**
	125.27**	62.67**	30.04**	217.33**	160.7**	2.7**	5.34**	35.39**	73.37**
4048 x Bas. 198	-5.83**	12.25**	0.84^{NS}	76.52**	57.41**	1.42**	1.49**	3.15*	-2.89**
	112.87**	65.75**	29.64**	260.8**	206.5**	5.03**	6.3**	38.21**	78.26**
S.E.	1.08	1.34	0.39	3.38	5.12	0.13	0.2	1.34	1.46

** Significant at 0.01 and 0.05 levels of probability, Pl. Ht-Plant height, NT-No. of tillers per plant, PL-Panicle length, NSPP-No. of spikelets per panicle, NGPP-No. of grains per panicle, PW-Panicle weight, SD-Pikelet density, GYPP-Grain yield/plant, %FP-Percent filled spikelets.

reliable criteria to select the better ones.

On the basis of present investigations, it may also be concluded that direct selection for plant height and panicle length should be effective due to additive type of gene action whereas for grain yield and its components especially number of tillers/plant, selection in later segregating generations will be most effective due to non-additive gene action. However, by increasing the number of tillers/plant, a major yield contributing factor, grain yield can be effectively enhanced. The cross combinations, Basmati 370 x Basmati 385, 4048 X Basmati 198 and Basmati 370 X Basmati 198 could be recommended for pure line development.

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