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Combining ability analysis for grain yield and other associated traits in rice

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ABSTRACT

Combining ability analysis was carried out for grain yield, its components and some of the quality characters in a 9 x 9 diallel cross (excluding reciprocals). Both general combining ability (GCA) and specific combining ability (SCA) variances were highly significant for all the characters indicating the importance of both additive and non-additive gene actions. However, preponderance of additive gene action was recorded for the traits viz., plant height, days to 50% flowering, dry matter, net assimilation rate, days to maturity, harvest index, 100 grain weight and grain length, while both additive and non-additive gene effects were almost equally important for grain yield plant^{-1}, biological yield plant^{-1}, leaf area index and grain length: breadth ratio. Preponderance of non-additive gene action was recorded for length of panicle and grain length. Parents HPR2047, VL93-3613 and JD8 were good general combiners for grain yield and other related characters. Parents HPR1164 and JD8 were good combiners for shorter plant height and earliness. These crosses involving the above mentioned parents were promising as revealed by their SCA effects. The cross combinations HPR2047xVL93-3613, HPR1164xIR57893-08, VL91-1754xJD8, VL93-3613xJD8 and VL91-1754xVL93-3613 showed significant positive specific effects for grain yield plant^{-1} and some associated characters and were expected to produce transgressive segregants. Since both additive and non additive gene effects played important role in the inheritance of yield and its components, their simultaneous exploitation through adoption of biparental approach in early generation mating is advocated.

Key words: *Combining ability, gene action, rice net-assimilation rate, yield*

Breeding method for the improvement of a crop depends primarily on the nature and magnitude of gene actions involved in the expression of quantitative and qualitative traits. Combining ability analysis helps in the identification of parents with high general combining ability (GCA) effects and cross combinations with high specific combining ability (SCA) effects. Additive and non-additive gene actions in the parents estimated through combining ability analysis may be useful in determining the possibility for commercial exploitation of heterosis and isolation of pure lines among the progenies of the heterotic F_{-1-}. The present study was conducted to obtain the information on combining ability of nine high yielding cultivars of rice for yield, its components and some of the quality traits.

MATERIALS AND METHODS

Nine high yielding rice cultivars namely HPR1164, HPR2047, China988, VL91-1754, VL93-3613, VL93-6052, IR57893-08, VLDhan221 and JD8 were crossed in a diallel mating design without reciprocals at the Experimental Farm of Department of Plant Breeding and Genetics, Choudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur in wet season, 2003. The experiment consisting of nine parents and their thirty six hybrids (F_1's) were laid out in complete randomized block design (R.B.D.) with three replications. Each replication comprised of three rows of each parent and a single row of each hybrid having 3m length in 20x15cm spacing under recommended agronomical cultural practices. Data were recorded on ten randomly selected plants from each replication and their mean values were used for statistical analysis. Combining ability analysis were carried out according to Method 2 and Model 1 of Griffing (1956). The observations were recorded on eleven quantitative traits viz., days to 50% flowering, plant height (cm), leaf area index (%), dry matter (g), net assimilation rate (g m^{-2} day^{-1}), days to maturity, harvest index (%), 100grain weight (g), panicle length (cm), biological yield (g), grain yield (g) and some of the quality traits were also recorded like grain length (mm) and grain length: breadth ratio.

RESULTS AND DISCUSSION

Analysis of variance for combining ability (Table1) revealed that both GCA and SCA variances were significant for all the characters studied except grain breadth which indicated the importance of both additive and non additive gene action in the inheritance of these characters. The ratio of GCA\SCA indicated the preponderance of additive gene action for days to 50% flowering, plant height and 100 grain weight. Similar results were also reported by Ghosh (1993). However, preponderance of non-additive gene action was indicated by the GCA / SCA ratio. Preponderance of non-additive gene action for length of panicle was reported by (Singh and Singh 1991), for biological yield $plant^{-1}$(Verma et al., 1995) and for grain length (Singh et al. 1993). The estimates of GCA effects revealed wide differences among the parents. Parent VL93-3613 ranked first as good general combiner for grain yield $plant^{-1}$, plant height, harvest index, dry matter and net assimilation rate, but was poor combiner for days to 50% flowering, days to maturity, biological yield and leaf area index (Table2). Parent JD8 ranked second as good general combiner for grain yield $plant^{-1}$ and other traits except harvest index, leaf area index, panicle length and net-assimilation rate for which it had significant GCA effect. It is clear that almost all combinations involving HPR2047, VL93-3613 and JD8 as one of the parents that possessed high mean and significant heterosis for grain yield and yield components. Incidentally, the above two parents were the best general combiners when scored across the traits. So, these could be used as the base parents to improve yield and its components.

The performance of parents *per se* was an indication of their GCA effects for all the above traits, which has also been reported by Singh and Richharia (1978), Sharma *et al.* (1987), and Kalaimani and Sundram (1988) in rice. The behavior of parents was good indication of the performance of their hybrids as reported by Gilbert (1958). Hence, *per se* performance (Table3) itself may be regarded as criteria for selecting parents as also suggested by Panwar *et al.* (1985). HPR1164 x HPR2047, HPR1164 x VL93-3613, HPR1164 x VL91-1754, HPR1164 x IR57893-08, HPR2047 x VL93-6052, HPR2047 x JD8, China988 x VL91-1754, China988 x VLDhan221, VL91-1754 x

Table 1 Analysis of variance of combining ability for yield, its components and grain quality traits in rice

Character	Mean sum of square due to		
Source df	GCA8	SCA36	Error160
Days to 50% flowering	81.01**	53.51**	2.22
Plant height	150.58**	92.13*	7.35
Leaf area index	0.40*	0.36*	0.008
Dry matter	77.79**	42.91**	0.66
Net assimilation rate	10.92**	6.07**	0.003
Length of panicle	3.60**	4.67**	1.13
Days to maturity	68.17**	45.77**	2.19
Grain yield $plant^{-1}$	20.05**	19.48**	0.76
Biological yield $plant^{-1}$	126.84**	127.86**	6.96
Harvest index	62.88**	43.81**	5.75
100 grain weight	0.13*	0.10*	0.006
Grain length	0.13*	0.26*	0.04
Grain breadth	0.02	0.13	0.03
Length breadth ratio	0.08*	0.07*	0.008

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

Table 2 Estimates of general combining ability effects for yield, its components and grain quality traits in rice

Traits/ Genotypes	Plant height	Days to 50% flowering	Grain yield	Biological yield	Harvest index	Days to maturity	LAI	DM	PL	100 grain weight	NAR	GL	L/B ratio
HPR 1164	-3.83**	-0.92*	-0.14	-2.09**	-1.09	-0.57	0.02	-2.34**	-1.07**	-0.10**	-1.32**	0.01	-0.03
HPR2047	4.12**	1.99**	0.49*	0.66	-1.35*	1.70**	0.16**	-1.19**	0.23	-0.12**	-0.83**	-0.03	0.08**
China 988	-3.86**	1.73**	-1.13**	-0.69	1.37*	1.47**	-0.01	-3.06**	-0.11	-0.16**	-0.54**	-0.16**	0.00
VL91-1754	2.73**	4.20**	0.10	-0.89	-0.84	3.92*	0.37**	0.52**	0.69**	0.12**	0.55**	0.02	-0.13**
VL93-3613	-4.64**	1.92**	2.69**	-6.38**	4.81**	1.64**	-0.06**	5.10**	0.41	0.05**	2.13**	0.08	-0.06*
VL 93-6052	4.22**	0.22	-0.23	-0.56	1.21	0.38	0.09**	3.37**	0.42	0.16**	0.30**	0.12*	0.02*
IR-57893-08	0.16	-2.07**	-0.55*	0.63	1.20	-2.17**	-0.17**	-1.38**	-0.21	0.04*	0.29**	-0.12*	-0.04*
VL-Dhan221	3.34**	-3.08**	-2.14**	0.92	-2.58**	-2.44**	-0.25**	-0.84**	0.31	0.03	-0.26	-0.07	-0.01
JD-8	-2.24**	-3.99**	0.92**	6.63**	-2.72**	-3.91**	-0.16**	-0.17	-0.67**	-0.03	-0.32**	0.15*	0.17**
GCA / SCA	0.54	1.51	1.03	0.99	1.44	1.49	1.11	1.81	0.77	1.30	1.80	0.50	1.14
S.E (gi)	0.77	0.42	0.24	0.74	0.67	0.42	0.02	0.23	0.30	0.02	0.015	0.06	0.02
S.E (gi-gj)	1.15	0.63	0.13	1.12	1.02	0.63	0.03	0.34	0.45	0.07	-0.023	0.09	0.039
C.D. (gi) at5%	1.50	0.82	0.47	1.45	1.31	0.82	0.04	0.45	0.58	0.03	0.029	0.11	0.03

* Significant at 5 per cent probability, ** Significant at 1 percent probability

LAI – leaf area index, DM – dry matter, GL – grain length, L/B ratio NAR – net assimilation rate, and PL – panicle length

Table 3. Mean values of parents and hybrids for grain yield, its components and grain quality traits of rice

Genotypes Hybrids	PH	DFFL	GY(g)	BY(g)	HI	DTM	L\B ratio	LAI	DM (g)	PL	GB	GL	100G wt	NAR
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HPR 1164	106.01	87.87	18.35	42.83	42.81	119.87	3.33	2.00	16.08	18.89	2.05	6.83	2.69	3.70
HPR 2047	111.68	87.95	18.20	43.81	41.51	117.95	3.99	1.09	18.11	19.57	1.63	6.52	2.07	2.34
China 988	99.07	95.09	17.71	35.74	48.61	125.09	3.28	2.27	16.27	20.37	1.96	6.45	2.52	3.96
VL91-1754	121.35	100.48	19.78	44.50	44.55	130.48	3.50	3.19	20.49	25.77	1.89	6.64	2.71	4.50
VL93-3613	95.40	88.75	20.97	37.67	55.64	118.75	3.37	0.94	14.76	20.51	1.83	6.18	2.33	9.10
VL93-6052	118.85	93.06	18.37	39.60	46.32	123.06	3.59	2.27	20.34	22.90	1.94	6.96	2.95	3.40
IR57893-08	92.93	95.06	18.01	34.06	52.79	125.06	3.37	1.83	14.96	20.17	1.84	6.21	2.29	3.53
VLDhan 221	111.55	71.84	14.34	33.76	41.40	106.84	3.58	0.84	15.50	20.63	1.76	6.30	2.37	0.59
JD-8	95.52	75.36	17.21	43.32	39.73	107.36	4.16	1.44	15.32	18.57	1.76	7.32	2.33	0.58
HPR 1164x HPR2047	121.35	100.48	25.26	44.50	44.55	130.48	3.50	3.19	24.99	25.77	1.89	6.64	2.71	4.67
HPR 1164x China-988	95.40	88.75	15.95	37.67	55.64	118.75	3.37	0.94	15.02	20.51	1.83	6.18	2.33	3.38
HPR 1164x VL91-1754	118.85	93.06	22.68	39.60	46.32	123.06	3.59	2.27	20.21	22.90	1.94	6.96	2.95	3.54
HPR 1164x VL93-3613	92.93	95.06	24.35	34.06	52.79	125.06	3.37	1.83	32.20	20.17	1.84	6.21	2.29	4.79
HPR-1164x VL93-6052	111.55	71.84	15.20	33.76	41.40	106.84	3.58	0.84	17.13	26.63	1.76	6.30	2.37	1.50
HPR-1164x VL57893-08	95.52	75.36	23.95	43.32	39.73	107.36	4.16	1.44	20.78	18.57	1.76	7.32	2.33	1.96
HPR-1164x VLDhan-221	114.44	83.40	19.39	62.85	40.17	113.40	3.56	1.48	18.71	23.12	1.88	6.54	2.81	1.45
HPR-2047x China-988	114.18	85.74	16.34	37.01	43.11	115.74	3.41	1.13	15.56	23.47	1.97	6.72	2.78	1.50
HPR-2047x China988	122.89	83.88	19.18	56.28	40.27	113.88	3.60	1.74	15.76	23.09	1.83	6.62	2.58	1.31
HPR-2047x VL91-1754	117.82	86.04	18.83	63.05	38.62	116.04	3.27	2.64	12.71	23.55	1.96	6.41	2.77	2.14
HPR-2047x VL93-3613	120.61	100.50	18.65	32.46	46.80	130.50	4.09	2.92	18.40	22.68	1.90	7.77	2.68	2.37
HPR-2047x VL93-6052	116.87	87.01	25.85	46.67	51.27	117.01	3.52	1.40	30.92	25.65	2.02	7.11	3.09	3.83
HPR-2047x IR57893-08	118.83	83.95	18.91	47.88	40.37	113.95	3.36	1.48	18.50	20.50	1.83	6.12	2.78	3.59
HPR-2047x VLDhan-221	120.59	96.73	13.53	36.40	44.93	126.73	3.75	1.50	20.91	23.58	1.88	7.07	2.66	3.94
HPR-2047x JD-8	101.44	90.89	30.09	33.83	56.68	120.89	3.31	1.67	31.04	23.21	1.61	5.36	2.34	8.34
China-988x VL91-1754	99.85	88.82	24.25	39.81	47.29	118.82	3.34	1.31	24.40	22.92	1.76	5.88	2.24	3.28
China-988x VL93-3613	96.87	90.96	19.23	32.07	58.15	120.96	3.26	1.16	23.59	22.72	1.85	6.04	2.36	3.50
China-988x VL93-6052	104.60	89.64	17.09	62.52	41.34	119.64	3.92	2.21	21.12	24.73	1.78	6.97	3.08	5.38
China-988x IR57893-08	125.37	91.40	19.10	47.71	39.09	121.40	3.71	2.56	16.71	23.55	1.86	6.91	2.94	4.30
China-988x VLDhan-221	112.69	85.45	19.54	32.90	41.13	115.65	3.42	1.16	15.88	23.74	1.78	6.09	2.45	2.73
China-988x JD-8	120.27	93.55	19.12	53.42	56.30	123.55	4.37	1.20	23.85	21.47	1.61	7.06	2.24	4.28
VL91-1754x VL93-3613	118.96	92.90	22.33	45.53	53.28	122.90	3.55	1.84	30.16	21.23	2.04	7.26	3.17	10.59

VL91-1754x VL93-6052	115.40	93.62	12.64	39.17	49.10	123.62	3.53	2.18	30.74	22.29	1.94	6.85	3.09	5.55
VL91-1754x IR57893-08	113.40	82.58	19.47	32.15	53.25	112.58	3.09	1.18	28.00	23.13	2.01	6.19	2.88	5.66
VL91-1754x VLDhan-221	107.95	93.43	18.86	49.37	38.75	128.43	3.17	1.69	25.58	21.12	2.01	6.38	2.72	5.95
VL91-1754x JD-8	113.57	93.35	23.86	53.61	36.41	123.35	3.58	1.51	15.52	23.59	2.07	7.46	3.12	2.41
VL93-3613x VL93-6052	113.67	97.42	23.81	38.75	49.31	127.42	3.16	2.23	40.20	24.58	2.18	6.89	2.75	10.41
VL93-3613x IR57893-08	113.19	75.82	29.13	40.38	55.31	105.82	3.43	0.98	38.56	26.18	1.83	6.27	2.86	8.13
VL93-3613x VLDhan-221	112.85	90.35	24.77	32.05	39.46	120.35	3.65	1.63	35.50	26.11	1.95	7.11	3.29	7.86
VL93-3613x JD-8	107.51	84.17	26.76	40.66	47.89	114.17	3.68	1.84	30.50	24.49	2.02	7.43	3.54	1.65
VL93-6052x IR57893-08	117.67	90.13	16.79	36.11	52.97	120.13	3.56	1.51	21.77	22.62	1.82	6.49	3.10	4.58
VL93-6052x VLDhan-221	134.87	94.03	28.20	46.61	51.17	124.03	3.81	1.64	26.51	24.57	1.86	7.07	2.92	3.01
VL93-6052x JD-8	112.50	76.09	22.52	52.50	45.45	106.09	3.47	1.34	30.59	18.47	1.79	6.23	2.51	5.70
IR57893-08x VLDhan-221	122.91	81.93	9.17	49.91	58.35	111.93	3.33	1.00	14.69	23.27	1.96	6.55	3.13	4.12
IR57893-08x JD-8	127.49	89.52	22.71	82.78	29.91	119.52	3.68	1.21	18.45	24.16	1.87	6.88	2.86	5.82
VLDhan-221x JD-8	105.71	75.61	15.63	73.95	36.20	105.61	3.64	2.41	24.50	21.33	1.74	6.33	2.68	2.94

PH- plant height, DFFL- days to 50% flowering, GY- grain yield, BY- biological yield, HI -harvest index, PL- panicle length, GB- grain breadth, GL- grain length, L\B ratio-length breadth ratio, NAR- net assimilation rate(g $cm^{-2}day^{-1}$), LAI- leaf area index, DTM days to maturity, DM dry matter and 100GW- 100 grain weight

Table 4 Hybrid combinations with desirable SCA effects for grain yield, its components and grain quality traits of rice

Traits	Cross combinations
Plant height	HPR 1164xChina 988, HPR 1164xVL93-3613, HPR 1164xIR57893-08, HPR 2047xJD-8, China 988xVL91-1754, China 988xVL93-3613, China 988xVL93-6052, VL91-1754xVL Dhan 221, VL Dhan 221xJD-8
Days to 50% flowering	HPR 1164xVL93-6052, HPR 1164xIR57893-08, HPR 2047xChina 988, HPR 2047xVL91-1754, HPR 2047xVL93-6052, HPR 2047xIR57893-08, China 988xVL91-1754, VL91-1754xIR57893-08, VL93-3613xIR57893-08, VL93-6052xJD-8, VL Dhan 221xJD-8
Grain yield	HPR 1164xHPR 2047, HPR 1164xVL91-1754, HPR 1164xVL93-3613, HPR 1164xIR57893-08, HPR 2047xVL93-6052, HPR 2047xJD-8, China 988xVL91-1754, China 988xVL Dhan 221, VL91-1754xJD-8, VL93-3613xIR57893-08, VL93-3613xVL Dhan 221, VL93-3613xJD-8, VL93-6052xVL Dhan 221, VL93-6052xJD-8
Biological yield	HPR 1164xVL Dhan 221, HPR 2047xChina 988, HPR 2047xVL91-1754, China 988xVL93-6052, VL91-1754xVL93-3613, IR57893-08xJD-8, VL Dhan 221xJD-8
Harvest index	HPR 1164xChina 988, HPR 2047xVL93-6052, HPR 2047xJD-8, China 988xVL93-3613, China 988xJD-8, VL91-1754xIR57893-08, VL93-6052xIR57893-08, VL93-6052xVL Dhan 221, VL93-6052xJD-8, IR57893-08xVL Dhan 221,
Days to maturity	HPR 1164xVL93-6052, HPR 1164xIR57893-08, HPR 2047xChina 988, HPR 2047xVL91-1754, HPR 2047xVL93-6052, HPR 2047xIR57893-08, China 988xVL91-1754, VL91-1754xIR57893-08, VL93-3613xIR57893-08, VL93-6052xJD-8, VL Dhan 221xJD-8
LAI	HPR 1164xHPR 2047, HPR 1164xVL91-1754, HPR 1164xVL93-3613, HPR 2047xVL91-1754, HPR 2047xVL93-3613, China 988xVL93-6052, China 988xIR57893-08, VL93-3613xVL93-6052, VL93-3613xJD-8, VL Dhan 221xJD-8
DM	HPR 1164xHPR 2047, HPR 1164xVL93-3613, HPR 1164xIR57893-08, HPR 2047xVL93-6052, HPR 2047xJD-8, China 988xVL91-1754, China 988xJD-8, VL91-1754xVL93-3613, VL91-1754xVL93-6052, VL91-1754xIR57893-08, VL91-1754xIR57893-08, VL93-3613xVL93-6052, VL93-3613xIR57893-08, VL93-3613xVL Dhan 221, VL93-3613xJD-8, VL93-6052xJD-8, VL Dhan 221xJD-8
PL	HPR 1164xHPR 2047, HPR 1164xJD-8, HPR 2047xVL93-6052, China 988xIR57893-08, VL91-1754xJD-8, VL93-3613xVL93-6052, VL93-3613xIR57893-08, VL93-3613xVL Dhan 22, VL93-3613xJD-8, VL93-6052xJD-8, VL Dhan 221xJD-8
100 grain weight	VL Dhan 221xJD-8, HPR 1164xVL91-1754, HPR 1164xVL Dhan, HPR 1164xJD-8, HPR 2047xChina 988, HPR 2047xVL93-6052, HPR 2047xIR57893-08, China 988xVL93-6052, China 988xIR57893-08, VL91-1754xJD-8, VL93-3613xVL Dhan 221, VL93-3613xJD-8, VL93-6052xIR57893-08, IR57893-08xVL Dhan 221
NAR	VL Dhan 221xJD-8, HPR 1164xChina 988, HPR 1164xVL91-1754, HPR 2047xVL Dhan 221, HPR 2047xJD-8 China 988xVL93-6052 China 988xIR57893-08, China 988xJD-8, VL91-1754xVL93-3613, VL91-1754xVL93-6052, VL91-1754xIR57893-08, VL91-1754xVL Dhan 221, VL93-3613xVL93-6052, VL93-3613xIR57893-08, VL93-3613xVL Dhan 221, VL93-6052xJD-8, IR57893-08xJD-8, VL Dhan 221xJD-8
GL	HPR 1164xIR57893-08, HPR 2047xVL93-3613, HPR 2047xVL Dhan 221, China 988xIR57893-08, China 988xJD-8 VL91-1754xVL93-3613, VL91-1754xJD-8, VL93-3613xVL Dhan 221, VL93-3613xJD-8
L/B ratio	HPR 1164xVL91-1754, HPR 1164xIR57893-08, HPR 2047xVL93-3613, VL91-1754xVL93-3613, VL93-6052xVL Dhan 221

LAI = Leaf area index (%); DM = Dry matter (g); PL = Panicle length (cm); NAR = Net-assimilation rate (g cm^{-2} day^{-1}); GL = Grain length (mm); GB = Grain breadth (mm)

JD8, VL93-3613 x JD8, VL93-3613 x IR57893-08, VL93-3613 x VLDhan221, VL93-6052 x JD8, IR57893-08 x JD8, VL93-6052 x VLDhan221 were the best specific cross combinations for grain yield per plant (Table 4). These crosses also showed good specific combinations for other traits like panicle length, dry matter, 100 grain weight, net-assimilation rate, plant height, harvest index and biological yield per plant. The mean performance of these hybrids (Table 3) revealed that among fifteen top specific combinations for yield and yield components, four crosses have either VL93-3613 or JD8 as one of the parents. This indicated that the crosses involving the above two parents were the most promising as revealed by their SCA effects. The high SCA effects in the above crosses could be favorably exploited in breeding programmes.

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