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Heterosis for yield and some physiological traits of rice (*Oryza sativa* L.) under mid hills of Himachal Pradesh

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Abstract

Hybrid rice has unique advantage of better physiological efficiency. Present study, was undertaken using nine diverse genotypes of rice crossed in diallel mating design excluding reciprocals. The 36 hybrids (F_1's) obtained were evaluated in randomized block design for nature and magnitude of heterosis for four physiological traits viz., leaf area index, dry matter, net assimilation rate, biological yield along with grain yield per plant. Data on 36 hybrids along with nine parents were used to calculate mid parent heterosis (Mh), heterobeltiosis (Hb) and standard heterosis (Sh). On the basis of mean values, parents viz., VL 91-1754, VL 93-3613 and China 988 were identified for hybridization programme. Mid parent heterosis, heterobeltiosis and standard heterosis for grain yield ranged from 18.99 to 70.00%, 13.94 to 65.32% and 23.73 to 65.32%, respectively. Hybrids HPR 2047 x JD 8, VL 93-3613 x IR 57893-08 and VL 93-6052 x VL Dhan 221 were identified as the best crosses on the bases of grain yield per plant along with net assimilation rate, dry matter and leaf area index. This information on the extent of heterosis would help in the choice for furher breeding programmes.

Keywords: Rice, heterosis, heterobeltiosis, physiological traits.

Introduction

Rice (*Oryza sativa* L., 2n = 2x = 24) is one of the most important staple cereal crop of the world and provides food for half of the world population. In Himachal Pradesh, rice occupies 81.3 thousand hectares area with production 120.6 thousand tonnes and productivity 1400 kg/ha (Anonymous, 2003) and is the major Kharif crop next to maize. The average yield of milled rice in Himachal Pradesh is lower (1500 kg/ha) than the national average 1600 kg /ha (State Statistical Abstract, H.P. 1999). Among the various possible genetic approaches to enhance yield productivity per unit area, hybrid rice technology is the most feasible and readily adaptable one. Physiological parameters like net-assimilation rate, biological yield, leaf area index, harvest index and dry matter at 90 days after transplanting are vital for increasing the grain yield of rice. Hybrid rice had a yield advantage of 20 per cent over semi dwarf varieties (Yuan Long Ping, 1976). Vermani and Edward (1983) reviewed the status and prospectus for breeding hybrid rice and concluded that exploitation of heterosis through hybrid breeding offered an important option to increase the yield in this self pollinated crop. Hence, the present investigation was initiated with the objective to exploite the physiological traits for increasing the extent of heterosis and to identify heterotic hybrids for higher grain yield.

Material and Methods

Nine diverse genotypes of rice viz., HPR-1164, HPR-2047, China-988, VL91-1754, VL 93-3613, VL 93-6052, IR 57893-08, VL Dhan-221 and JD-8 were crossed in all possible combinations in a diallel mating design excluding reciprocals in glasshouse at the Experimental Farm of the Department of Plant Breeding and Genetics of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during Kharif 2001 and 2002. In Kharif 2003, all the 36 hybrids (F_1's) along with nine parents including (HPR-2047) were raised in randomized block design with three replications with single row of each parent and hybrid having 3m length with 20 and 15 cm, row to row and plant to plant spacing, respectively. The recommended agronomical practices were followed. Observations were recorded on 10 randomly selected plants of parents and 15 plants of hybrids on the following traits viz.

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grain yield per plant (g), biological yield per plant (g), leaf area index, dry matter (g), harvest index and net assimilation rate. Net-assimilation rate (NAR) gm cm^{-2} day^{-1} was computed by

(i) ***Leaf area (cm^2):*** It was computed by plucking all the leaves and recording the leaf area with the "Basic Area Measurement System" at 60 and 90 days after transplanting.

(ii) ***Leaf area index (%):*** It was calculated as below:

$$\text{Leaf Area Index} = \frac{\text{Leaf area plant}^{-1}\ (cm^2)}{\text{Area of land covered by that plant}\ (cm^2)}$$

(iii) ***Net-assimilation rate (NAR)***

$(W_2-W_1)\ (\ln A_2-\ln A_1)\ /\ (A_2-A_1)\ (t_2-t_1)$, where, $\ln A_2$ and $\ln A_1$ are the natural log values of leaf area at time t_2 and t_1, respectively.

The per cent heterosis over mid parent, better parent and standard heterosis were calculated as per the method prescribed by Turner (1953).

Results and Discussion

Estimates of heterosis per cent based on mid parent (MH), Heterobeltiosis (Hb) and standard check (Sh) are presented in table 1. Six hybrids exhibited significant mid parental heterosis were in positive direction for leaf area index. Similarly, 4 hybrids exhibited significantly positive heterobeltiosis for this trait. The maximum heterosis recorded for this trait was 107.40 per cent over mid parent and 73.40 per cent heterobeltiosis. The range of mid parental heterosis and heterobeltiosis were between -52.01 to 107.40 and -58.93 to -73.40 per cent per cent respectively. The highest level of heterosis exhibited by most of the hybrids expressed luxuriant vegetative growth during maximum tillering stage. Among parents, VL91-1754 recorded highest leaf area index. Cross combinations HPR-1164 x HPR-2047, VL 93-3613 x VL Dhan-221 and VL 93-3613 x JD8 recorded maximum mid parental heterosis and heterobeltiosis for leaf area index. Eight hybrids showed significant mid parental heterosis in positive direction for net assimilation rate. Mid parental heterosis and heterobeltiosis for net assimilation rate ranged from -65.90-471.23 per cent and -81.86 to 256.41 per cent. Maximum heterosis was shown by cross combination HPR-2047 x JD8 for both mid parental heterosis and heterobeltiosis. Among parents, VL 93-3613 manifested highest mean performance for this trait followed by VL91-1754 and China-988. For dry matter production, maximum heterosis was manifested by VL93-3613 x IR57893-08 (MH) over both mid and better parent. Ranges for different heterosis for this trait were MH (-13.29-100.38 %) and Hb (-24.25-157.75 %). Highest mean performance was exhibited by parent VL91-1754. Peng and Virmani (1991) reported similar results for this trait. Thirteen hybrids exhibited mid parental heterosis, while one heterobeltiosis. Fifteen hybrids exhibited mid parental and heterobeltiosis for higher grain yield. This variable heterosis for dry matter production and grain yield may be due to crosses, fertilizers application and climatic conditions (Table2). Similar results were also reported by Virmani *et al.* (1982). Three hybrids manifested significant and positive mid parental and heterobeltiosis for biological yield per plant. Maximum heterosis was exhibited by hybrid VL93-6052 x VL Dhan-221 for both mid parental and heterobeltiosis. Fifteen hybrids exhibited mid parental heterosis and heterobeltiosis for grain yield per plant. Hybrid HPR-2047 x JD-8 exhibited maximum heterobeltiosis. Out of 36 hybrids, 15 hybrids showed mid parental heterosis and heterobeltiosis. For harvest index, three crosses indicated mid parental and one heterobeltiosis. Maximum mid parental and heterobeltiosis were observed for cross combinations HPR-2047 x JD-8. VL93-3613 was observed as the best parent for harvest index. Among the three types, standard heterosis is more important since the hybrid to be released is expected to out perform the superior local variety. In the present study, HPR-1164 x HPR-2047 showed highest heterosis for leaf area index (107.40%). Similarly hybrid HPR-2047 x JD-8 exhibited highest standard heterosis for grain yield along with higher level of leaf area index. These observations suggested that to identify heterotic hybrids for grain yield, leaf area index should be higher at maximum tillering stage as the two hybrids manifested higher leaf area index along with higher grain yield. Similar trend was observed for dry matter. Hybrids having higher dry matter exhibited higher grain yield. Hybrids exhibited higher net assimilation rate also exhibited higher grain yield. However, biological yield did not show positive

Table 1. Mean values of grain yield, its components and grain quality traits

Genotypes/ hybrids		Grain yield/ plant (g)	Biological yield/ plant (g)	Harvest index (%)	Leaf area index	Dry matter	NAR
HPR-1164	P_1	18.35	42.83	42.81	2.00	16.08	3.70
HPR-2047	P_2	18.20	43.81	41.51	1.09	18.11	2.34
China-988	P_3	17.71	35.74	48.61	2.27	16.27	3.96
VL91-1754	P_4	19.78	44.50	44.55	3.19	20.49	4.50
VL93-3613	P_5	20.97	37.67	55.64	0.94	14.76	9.10
VL93-6052	P_6	18.37	39.60	46.32	2.27	20.34	3.40
IR57893-08	P_7	18.01	34.06	52.79	1.83	14.96	3.53
VL Dhan-221	P_8	14.34	33.76	41.40	0.84	15.50	0.59
JD-8	P_9	17.21	43.32	39.73	1.44	15.32	0.58
HPR-1164 x HPR- 2047	F_1	25.26	44.50	44.55	3.19	24.99	4.67
HPR-1164 x VL 91-1754	F_1	22.68	39.60	46.32	2.27	20.21	3.54
HPR-1164 x VL 93-3613	F_1	24.35	34.06	52.79	1.83	32.20	4.79
HPR-1164 x VL 57893-08	F_1	23.95	43.32	39.73	1.44	20.78	1.96
HPR-2047 x VL 93-6052	F_1	25.85	46.67	51.27	1.40	30.92	3.83
HPR-2047 x JD-8	F_1	30.09	33.83	56.68	1.67	31.04	8.34
China-988 x VL 91-1754	F_1	24.25	39.81	47.29	1.31	24.40	3.28
VL91-1754 x JD-8	F_1	23.86	53.61	36.41	1.51	15.52	2.41
VL93-3613 x VL 93-6052	F_1	23.81	38.75	49.31	2.23	40.20	10.41
VL93-3613 x IR 57893-08	F_1	29.13	40.38	55.31	0.98	38.56	8.13
VL93-3613 x VL Dhan-221	F_1	24.77	32.05	39.46	1.63	35.50	7.86
VL93-3613 x JD-8	F_1	26.76	40.66	47.89	1.84	30.50	1.65
VL93-6052 x VL Dhan-221	F_1	28.20	46.61	51.17	1.64	26.51	3.01
VL93-6052 x JD-8	F_1	22.52	52.50	45.45	1.34	30.59	5.70
IR57893-08 x JD-8	F_1	22.71	82.78	29.91	1.21	18.45	5.82

correlation with grain yield. Majority of the hybrids showing positive standard heterosis for leaf area index showed higher grain yield per plant. Among the components, dry matter and leaf area index are yield determining traits, this study revealed greater role of leaf area index and dry matter to contribute higher grain yield per plant. It showed higher efficiency of converting source into sink in high yielding hybrids.

The hybrids HPR-1164 x HPR-2047, HPR-2047 x JD-8, and VL93-3613 x VL93-6052 were superior and recorded more than 30 per cent mid parental, heterobeltiosis and standard heterosis for grain yield per plant along with physiological (net assimilation rate, dry matter and leaf area index) traits in desired magnitude and direction. Hence, it is suggested that hybrid breeding programme should be applied to evolve F_1 hybrids in rice with higher net assimilation rate, dry matter and leaf area index to get maximum grain yield per plant.

Table 2. Mean performance and range for physiological traits and grain yield in rice

Characters	Mh	Hb	Sh	Range		Based on mean performance	
				Parents	Hybrids	Best parent	Best hybrids
Leaf area index	-52.01-107.40 (6)	-58.93-73.40 (4)	-	0.84-3.19	0.84-0.98	VL 91-1754 VL 93-6052,China 988	HPR-1164 x HPR- 2047, **HPR-1164 x VL91-1754,VL 93-3613 x VL 93-6052**
Net assimilation rate	-65.90-471.23 (8)	-81.86-256.41 (6)	-	0.58-9.10	1.65-10.41	VL 93-3613, VL91-1754, China 988	VL 91-1754 x VL 93-3613, **VL 93-3613 x VL 93-6052, HPR-2047 x VL Dhan-221**
Dry matter	-13.29-1000.38 (13)	-24.25-157.75 (11)	-	14.76-20.49	20.21-40.20	VL 91-1754, VL 93-6052, HPR-2047	VL 93-3613 x VL 93-6052 **VL 93-3613 x IR** 57893-08 VL 93-3613 x **VLDhan-221,**
Biological yield/plant (g)	-114.02-22.09 (1)	-22.78 (3)	-	33.76-44.50	32.05-82.78	VL 91-1754, HPR-2047, HPR-1164	IR 57893-08 x JD-8, **VL Dhan-221x JD-8,** VL93-6052 x JD8
Harvest Index (%)	-35.34-39.53 (3)	-43.34-36.54 (1)	-	39.73-55.64	29.91-56.68	VL 93-3613, IR 57893-08, China 988	HPR-2047 x JD8,VL 93-3613 **x IR 57893-**08,HPR-1164 x VL 93-3613
Grain yield/plant (g)	18.99-70.00 (15)	13.94-65.32 (15)	23.73-65.32 (15)	14.34-20.97	22.52-30.09	VL 93-3613, VL 91-1754, VL 93-6052	HPR-2047 x JD8 VL93-3613x **IR 57893-08,VL** 93-6052 x VL Dhan221

Mh-Mid parental heterosis, Hb-Heterobeltiosis, Sh-Standard heterosis
Parenthesis values-Number of crosses

Table 3. Estimates of mid parent heterosis (Mh) and heterobeltiosis (Hb) for physiological traits in crosses showing significant heterbeltiosis for grain yield / plant

Parents/Hybrids	Biological yield/plant		Harvest Index		Grain yield/plant		Leaf area Index		Dry matter		Net assimilation rate	
	Mh	Hb	Mh	Mh	Mh	Hb	Mh	Hb	Mh	Hb	Mh	Hb
HPR-1164/ HPR 2047	1.57	1.57	Rh	107.4**	59.50**	54.63**	54.63**	59.50**	46.22**	37.99**	54.63**	26.21
HPR-1164/ VL 91-1754	-11.01	-11.01	5.66	-12.35**	-28.84**	-13.65**	-13.65**	-28.84**	10.55	-1.36	-13.65**	-21.33
HPR-1164/VL 93-3613	-20.40*	-20.40**	6.04	24.48**	-8.50	-25.15**	-25.15**	-8.50	108.81**	100.24**	-25.15**	-47.36**
HPR-1164/IR57893-08	12.69	2.31	-7.09*	-24.60**	-28.00	-45.70**	-45.70**	-28.00	33.89**	29.22**	-45.70**	-47.02**
HPR 2047/VL 93-6052	6.52	6.52	-16.88**	-16.66**	-38.32**	33.44**	33.44**	-38.32**	60.87**	52.01	33.44**	12.64**
HPR-2047/JD-8	-22.33**	-22.78**	3.68*	32.53**	15.97**	471.23**	471.23**	15.97**	85.75**	71.39**	471.23**	256.41**
China 988/VL 91-1754	-10.53	-10.53	39.53**	-52.01**	-58.93**	-22.45**	-22.45**	-58.93**	32.75**	19.08**	-22.45**	-27.11**
VL 91-1754/JD-8	22.09**	20.47*	15.24	-34.63**	-52.66**	-5.11	-5.11	-52.66**	-13.29*	-24.25**	-5.11	-46.44**
VL 93-3613/VL 93-6052	0.31	-2.14	-13.59	39.37**	-1.76	66.56**	66.56**	-1.76	129.05**	97.64**	66.56**	14.39**
VL 93-3613/IR 57893-08	12.60	7.19	-3.27	-28.98**	-46.44**	28.84**	28.84**	-46.44**	159.48**	157.75**	28.84**	-10.65**
VL 93-3613/VL Dhan 221	-10.24	-14.91	2.06	83.14**	73.40**	62.39**	62.39**	73.40**	100.38**	99.08**	62.39**	-13.62**
VL 93-3613/ JD-8	-0.19	-6.14	-18.67**	54.62**	27.77**	-65.90**	-65.90**	27.77**	101.58**	129.03**	-65.90**	-81.86**
VL 93-6052/VL Dhan 221	27.07**	17.70	0.44	5.80	-27.75**	51.25**	51.25**	-27.75**	47.93**	30.33**	51.25**	-11.47**
VL 93-6052/ JD-8	26.62**	21.19**	16.66*	-27.56**	-40.96**	186.43**	186.43**	-40.96**	71.56**	50.39**	186.43**	67.64**
IR 57893-08/ JD-8	114.02**	-33.87	5.64	-25.76**	-33.87**	182.52**	182.52**	-33.87**	21.86**	20.43	182.52**	64.87**
S.E.±	3.22	9.08**	-35.34**	0.10	0.12	0.06	0.06	0.12	0.99	1.15	0.06	0.08

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