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Combining ability and heterosis studies for yield and its components in upland rice

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Abstract

The present study was conducted to work out combining ability and heterosis studies using Line × Tester mating design in rice using 12 lines suitable for upland conditions of H.P. and 3 testers in *Kharif* 2019 and 2020 (for crossing and evaluation, respectively). Significant GCA and SCA effects were found for the lines and crosses, respectively. The lines showing significant GCA effects were HPR 2884, HPR 2871, HPR 2873 and HPR 2889, while the crosses HPR 2866 x HPR 2656, HPR 2866 x HPR 1156 and HPR 2840 x HPR 1156 showed high SCA for most of the traits. The cross combinations that showed significantly high heterosis over the standard check for grain yield per plant were HPR 2866 x HPR 1156 (68.82%), HPR 2840 x HPR 1156 (58.37%), HPR 2840 x HPR 2795 (57.82%) and HPR 2873 x HPR 2795 (40.64%).

Key words: general combining ability, specific combining ability, heterosis, lines, testers

Rice is a staple food crop that is grown throughout many places around the globe. Rice cultivation covers 160.6 million hectares worldwide, with a production of 492.2 million tonnes (Anonymous 2019a), with India accounting for 42.2 million hectares and 104 million tonnes, making it stand first in the world's total cereal production (Anonymous 2019b). In hilly regions like Himachal Pradesh and Uttarakhand, it is also a staple food crop. It is grown on an estimated 77 thousand ha in H.P., with a production of 131.6 thousand tonnes and a productivity of 17.05 quintals per hectare (Anonymous 2019c), with upland rice accounting for 42% of total rice cultivation area. Countries and regions with low labour costs and high rainfall are well suited for rice cultivation as it is labour-intensive crop and requires ample water. Lowland transplanted rice requires huge amount of labour and water for puddling as well as in later stages of cultivation. Due to less availability of labour and unpredictable rainfall in hilly areas, it is very difficult to grow transplanted rice. Also, due to undulated topography, the retention of water in rice fields is difficult. As a result, major rice cultivation in hilly areas is done in upland and rainfed conditions. Hence, developing high yielding cultivars suitable for upland/ rainfed conditions is necessary for direct sowing. In view of the above problems, the following study was carried out to estimate the combining ability and heterosis of the parents and crosses among 12 upland rice lines and 3 testers, so that we can search for genetic improvement in them. Search for good combiners among the12 lines and 3 testers was done for grain yield per plant, panicle length, total tillers, effective tillers and ten other yield related traits. The findings will have an important role on future breeding strategies for improving the concerned traits.

There is also a constant need to screen germplasm, isolate potential combining lines and desirable cross combinations either to exploit heterosis or to obtain new recombinants. Thus, any strategy that aids in the selection of desirable parents and crosses would be beneficial to breeders. Commercial exploitation of heterosis in rice is being exploited at present in all the rice growing countries (Yuan,1994) and presence of heterosis and specific combining ability (SCA) effects for yield and yield related traits in rice hybrids are reported by Behera and Monalisa (2016), Morais *et al*. (2017), Faiz *et al*. (2000) and Sarker *et al*. (2002). In this study, 12 genotypes of rice (lines) suitable for upland conditions were crossed with three testers in

Line x Tester mating design and the F_1 material along with parents (lines + testers) were evaluated for various parameters.

Materials and Methods

This investigation was carried out at Rice and Wheat Research Centre, Malan, during *Kharif*, 2019 and 2020. The experimental material consisting F_1 population of 36 crosses was developed by crossing 12 lines/genotypes *viz., HPR 2643, HPR 2648, HPR 2840, HPR 2843, HPR 2866, HPR 2870, HPR 2871, HPR 2873, HPR 2877, HPR 2884, HPR 2887, HPR 2889* with three testers *HPR 1156, HPR 2656* and *HPR 2795* in a line × tester mating design at RWRC, Malan, during *Kharif*, 2019. During *Kharif* 2020, the F_1's of 36 crosses along with their parents [lines (12) + testers (3)], were evaluated in RBD with three replications in a single row of 2m length, with row to row and plant to plant spacing of 20 cm and 15 cm, respectively. Except for days to 50% flowering and days to maturity, which were recorded on a plot basis, the other observations were made on five random plants of each genotype/cross combination. These observations included plant height at maturity (measured in centimeters from the ground level to the tip of the main panicle, excluding awns); panicle length(measured in centimeters from the base of main rachis to the tip of the top most grain of panicle, excluding awns); total tillers/plant (total number of tillers per plant counted at maturity), effective tillers per plant (total number of panicle bearing tillers/hill counted at the time of maturity); spikelets/panicle(no.); grains/panicle(no.) (counted after threshing the main panicle separately at maturity); spikelet fertility (calculated as the percentage of ratio of spikelets bearing grains and total number of spikelets); grain yield/plant (g); 1000-grain weight (g); grain length and grain breadth (measured using vernier calliper to measure the length of five dehusked grains of each genotype from the bulk produce of each replication recorded in millimetres). Length: Breadth ratio (L: B) was calculated by dividing the grain length by its breadth.

The analysis of variance was done as per Panse and Sukhatme (1985) and combining ability analysis was done following the method of Kempthorne (1957). The plants were raised entirely under upland and rainfed condition without any artificial irrigation.

Results and Discussion

The results obtained from the evaluation of the material in the present investigation with respect to combining ability and heterosis for all the traits studied has been discussed in the following section, which revealed that the GCA variance was highest for grains per panicle followed by grain yield per plant and plant height. Highest SCA variance was recorded for spikelets per panicle followed by grains per panicle. In the majority of traits, the SCA variance was more than GCA variance which indicated the preponderance of non-additive gene action in the inheritance of these traits. The values of GCA and SCA variances and their ratio are given in Table 1.

Table 1. Estimates of GCA and SCA variances

Traits	σ^2GCA	σ^2SCA	σ^2GCA/ σ^2SCA
Days to 50% flowering	-0.94	46.03	-0.02
Days to maturity	-0.60	34.37	-0.05
Plant height	6.84	33.79	0.20
Panicle length	0.05	0.44	0.12
Total tillers/plant	0.03	0.06	0.55
Effective tillers/plant	-0.05	0.99	-0.05
Spikelets/panicle	-4.28	348.77	-0.01
Grains/panicle	20.76	235.03	0.08
Spikelet fertility	4.13	13.43	0.31
Grain yield/plant	10.28	13.81	0.75
1000-Grain weight	0.39	1.74	0.22
Grain length	0.007	0.15	0.05
Grain breadth	0.001	0.002	0.5
L: B Ratio	-0.001	0.005	-0.2

Higher values of SCA variance than GCA variance and the ratio of (σ^2_{GCA}/ σ^2_{SCA}) being less than one further indicated the importance of non-additive gene effects in the manifestation of all the traits. These findings show that non-additive gene action predominates for all of the traits tested, implying that non-additive gene action for these traits might be exploited through hybrid breeding or it may be stated that hybridization is an appropriate method for exploiting heterosis in certain crosses and selection in segregating generations should be done at later generations since early testing and selection would not be effective in the tested material. Similar results were obtained by Jayasudha and Sharma (2009), Saidaiah *et al*. (2010)

and Dalvi and Patel (2009) where non-additive gene action dominated over additive gene action as indicated by low GCA/ SCA ratio.

The aim of estimation of heterosis in the present investigation was to find out the superior cross combinations giving high degree of useful heterosis and characters of parents for their prospectus for future use in breeding programme. List of heterotic crosses over standard check, good specific combiners and good general combiners for all the traits has been given in the Table 2.

It was found that HPR 2889 is good general combiner for days to 50% flowering, days to maturity, and grain length; HPR 2843 is good general combiner for days to 50% flowering, days to maturity; HPR 2648 for days to maturity, effective tillers per plant and grain yield per plant; HPR 2840 for plant height, panicle length, grains per panicle, spikelet per panicle and grain yield per plant; HPR 2884 for plant height, 1000 seed weight, spikelet per panicle and grains per panicle; HPR 2871 for days to 50% flowering, effective tillers per plant and grain length; HPR 2873

Table 2. List of heterotic crosses over standard check (%), good specific combiners and good general combiners

Traits	Heterotic crosses (%)	Specific combiners	General combiners
Days to 50%	HPR 2840 x HPR 2656 (-20.00)	HPR 2884 x HPR 2656 (12.57)	HPR 2889 (7.37)
flowering	HPR 2866 x HPR 2795 (-19.36)	HPR 2866 x HPR 2656(12.13)	HPR 2843 (6.04)
	HPR 2643 x HPR 2795 (-19.36)	HPR 2840 x HPR 1156 (8.38)	HPR 2871 (3.04)
	HPR 2884 x HPR 2795 (-16.55)	HPR 2871 x HPR 2795 (5.49)	HPR 2870 (2.59)
Days to maturity	HPR 2840 x HPR 2656 (-13.04)	HPR 2840 x HPR 1156 (11.48)	HPR 2843 (5.65)
	HPR 2643 x HPR 2795 (-9.42)	HPR 2884 x HPR 2656 (11.65)	HPR 2889 (5.21)
	HPR 2866 x HPR 2795 (-8.93)	HPR 2866 x HPR 2656 (9.76)	HPR 2648 (3.44)
		HPR 2643 x HPR 1156 (4.26)	HPR 2873 (3.32)
			HPR 1156 (0.52)
Plant height	HPR 2889 x HPR 2656 (-21.29)	HPR 2866 x HPR 1156 (9.98)	HPR 2840 (8.95)
	HPR 2866 x HPR 2795 (-16.7)	HPR 2843 x HPR 2656 (9.92)	HPR 2884 (4.99)
	HPR 2871 x HPR 2656 (-13.63)	HPR 2871 x HPR 2795 (9.42)	HPR 1156 (2.83)
	HPR 2889 x HPR 1156 (-12.63)	HPR 2840 x HPR 2795 (8.85)	
Total tillers	HPR 2648 x HPR2656(57.99)	-	-
per plant	HPR 2873 x HPR1156(54.51)		
	HPR 2866 x HPR 1156 (47.24)		
	HPR2887 x HPR 2795(46.37)		
Panicle length	-	-	HPR 2840 (2.10)
Effective tillers	HPR 2648 x HPR 2656 (56.66)	HPR 2866 x HPR 1156 (2.31)	HPR 2648 (0.96)
per plant	HPR 2866 x HPR 1156 (56.1)	HPR 2643 x HPR 2795 (2.09)	HPR 2871 (11.24)
	HPR 2873 x HPR 2795 (47.69)	HPR 2648 x HPR 2656 (1.91)	
	HPR 2643 x HPR 2795 (41.23)		
L:B ratio	HPR 2889 x HPR 2656 (27.92)	-	-
	HPR 2843 x HPR1156 (23.02)		
	HPR 2843 x HPR 2656 (22.64)		
	HPR 2889 x HPR 1156 (22.64)		
1000 grain wt.	HPR 2840 x HPR 2795 (28.85)	HPR 2840 x HPR 2795 (4.99)	HPR 2884 (2.60)
Grain length	HPR2889 x HPR2656 (25.87)	HPR 2866 x HPR 2795 (0.53)	HPR 2889 (0.41)
	HPR2871 x HPR2656 (18.89)	HPR 2889 x HPR 2795 (0.71)	HPR 2871 (0.44)
	HPR2871 x HPR2795 (18.89)	HPR 2870 x HPR 2795 (0.56)	
	HPR 2643 x HPR2656 (17.3)		

Grain breadth	-	HPR 2884 x HPR 2656 (0.21)	HPR 2873 (0.18)
Grains per panicle	HPR 2840 x HPR 2656 (89.31) HPR 2866 x HPR 1156 (73.7) HPR 2840 x HPR 1156 (56.42) HPR 2887 x HPR 2656 (47.41)	HPR 2840 x HPR 2656 (23.82) HPR 2866 x HPR 1156 (26.83) HPR 2873 x HPR 2656 (19.25) HPR 2871 x HPR 2795 (15.99)	HPR 2840 (36.00) HPR 2866 (15.14) HPR 2887 (14.04) HPR 2884 (12.15)
Spikelets per panicle	HPR 2840 x HPR 2656 (77.71) HPR 2884 x HPR 2656 (70.87) HPR 2866 x HPR 1156 (61.91) HPR 2887 x HPR 1156 (55.34)	HPR 2840 x HPR 2656 (40.76) HPR 2866 x HPR 1156 (28.50) HPR 2884 x HPR 2656 (27.14) HPR 2887 x HPR 1156 (19.81)	HPR 2840 (37.85) HPR 2884 (17.24)
Grain yield per plant	HPR 2866 x HPR 1156 (68.82) HPR 2840 x HPR 1156 (58.37) HPR 2840 x HPR 2795 (57.82) HPR 2873 x HPR 2795 (40.64)	HPR 2866 x HPR 1156 (10.65) HPR 2877 x HPR 2795 (5.49) HPR 2648 x HPR 2656 (4.47) HPR 2887 x HPR 2795 (4.16)	HPR 2840 (10.84) HPR 2873 (6.224) HPR 2648 (3.159)

for days to maturity, grain breadth and grain yield per plant and HPR 2889 is good general combiner for days to 50% flowering, days to maturity and grain length.

There were some crosses that were found to be good specific combiners for various traits. HPR 2884 x HPR 2656 was good specific combiner for days to 50 % flowering, days to maturity, spikelet fertility and grain breadth. HPR 2866 x HPR 2656 and HPR 2840 x HPR 1156 were good specific combiners for days to 50% flowering and days to maturity; HPR 2866 x HPR 1156 for plant height, effective tillers per plant, spikelets per panicle, grains per panicle and grain yield per plant; HPR 2871 x HPR 2795 for days to 50% flowering, plant height and grains per panicle; HPR 2840 x HPR 2656 for grains per panicle and spikelets per panicle.

Seven crosses showed positive significant heterosis over better parent for grain yield per plant. These crosses were HPR 2840 x HPR 1156 (135.32%), HPR 2840 x HPR 2656 (101.24%), HPR 2840 x HPR 2795 (57.76%), HPR 2873 x HPR 2795 (40.59%), HPR 2887 x HPR 2795 (30.22%), HPR 2873 x HPR 1156 (65.72%) and HPR 2877 x HPR 2795 (31.83%). Eight crosses showed significant positive heterosis over standard check, out of which, the top three were HPR 2866 x HPR 1156 (68.78%), HPR 2840 x HPR 1156 (58.34%), HPR 2840 x HPR 2795 (57.79%). The cross combinations which showed significant positive heterosis for grain yield, both over standard check and better parent were HPR 2840 x HPR 1156, HPR 2840 x HPR 2656, HPR 2840 x HPR 2795, HPR 2873 x HPR 2795, HPR 2887 x HPR 2795 and HPR 2877 x HPR 2795 and had capability for utilization in hybrid rice programme. Also, it can be seen from the heterosis tables that the crosses which showed significant heterosis over standard check for grain yield per plant, were also heterotic for one or other yield attributes. This has also been earlier reported by workers like Sarawgi *et al*. (2000); Rosamma and Vijay Kumar (2005) and Mirarab *et al*. (2011).

The number of heterotic cross combinations for grain yield per plant formed from parents with various sorts of GCA and SCA effects are given in Table 3. From every type of parental combination, almost all types of SCA and GCA effects were obtained. Hybrids with high heterosis and SCA were produced by parents with high, medium, and low general combining ability. The interaction between positive alleles in the good combiner and negative alleles from the poor combiner is responsible for the high yield potential in cross combinations (high x low), whereas heterosis in high x high combiners is caused by interaction between positive x positive alleles. In high x high combinations having positive heterosis but low SCA can be attributed to epistasis responsible for heterosis. Low x low combinations yielded high SCA hybrids in the current investigation, which can be attributed to overdominance or epistasis. Rahimi *et al*. (2010) also discussed similar findings in their paper. All of these findings demonstrated that the GCA effects of parents and the SCA effects of hybrid combinations are unrelated. This can also be explained in terms of gene action, as GCA is more dependent on additive gene action, whereas SCA is dependent on dominance and epistasis.

On the basis of performance, combining ability and heterosis, lines HPR 2840, HPR 2873, HPR 2889,

Table 3. List of potential heterotic crosses, their SCA and GCA of their parents involved in producing F_1 for grain yield per plant

Heterotic crosses	Heterosis over standard check (%)	SCA of crosses	GCA of parents	
			Lines	Testers
HPR 2866 x HPR 1156	68.78	10.65	2.91	0.93
HPR 2840 x HPR 1156	58.34	0.63	10.84	0.93
HPR 2840 x HPR 2795	57.79	-1.04	10.84	2.49
HPR 2873 x HPR 2795	40.61	0.14	6.22	2.49
HPR 2887 x HPR 2795	30.24	4.16	-0.84	2.49
HPR 2877 x HPR 2795	31.82	5.45	-0.84	2.49
HPR 2873 x HPR 1156	35.72	0.73	6.22	0.93
HPR 2840 x HPR 2656	35.39	0.41	10.84	-3.43

crosse combinations *viz*. HPR 2840 x HPR 2656, HPR 2866 x HPR 1156, HPR 2871 x HPR 2795 were found to be promising for further improvement and utilization in breeding programmes.

Conflict of interest: There is no conflict of interest between the authors in this paper.

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