

Gene action and heterosis studies for yield and its components in upland rice

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Rice is a staple food crop that is grown throughout many places around the globe. Rice cultivation covers 162.66 million hectares worldwide, with a production of 510.30 million tonnes (Anonymous 2021a), with India accounting for 44 million hectares and 122.27 million tonnes, making it stand third in the world's total cereal production (Anonymous 2021b). In hilly regions like Himachal Pradesh and Uttarakhand, it is also a staple food crop. It is grown on an estimated 62 thousand ha in H.P., with a production of 135 thousand tonnes and a productivity of 21.70 quintals per hectare (Anonymous 2021c). 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 gene action and heterosis of the parents and crosses among 10 rainfed upland rice lines and 3 testers, so that we can search for genetic improvement in them. Search for good combiners among the 10 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, the foregoing findings were consistent with those of Verma (1992); Mirarab *et al.* (2011); and Ghara *et al.* (2014). They also found low narrow sense heritability for the many variables they evaluated at, implying that non-additive influences are relevant in influencing the traits. Wu *et al.* (1986) reported low heritability for tiller number and grain yield, and Ahmadikhah (2008) reported low heritability for yield-related characteristics. As a result, it may be stated that hybridization is an appropriate method for exploiting heterosis in certain crosses. High heritability shows that these qualities can be genetically improved through selection. Similar results have been reported by Sarawgi *et al.* (2000) and Bisne *et al.* (2009). In this study, 10 genotypes of rice (lines) suitable for rainfed 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 used

This investigation was carried out at Rice and Wheat Research Centre, Malan, during *Kharif*, 2021 and 2022. The experimental material consisting F_1 population of 30



crosses were developed by crossing 10 lines/genotypes viz., HPR 2559, HPR 2641, HPR 2645, HPR 2655, HPR 2830, HPR 2841, HPR 2895, HPR 2847 and Bulk 22 with three testers HPR 1156, HPR 2656 and HPR 2795 in a line $\times$ tester mating design at RWRC, Malan, during *Kharif*, 2021. During *Kharif* 2022, the F_1 's of 30 crosses along with their parents [lines (10) + 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.

Observation recorded

In this study, 10 genotypes of rice (lines) suitable for rainfed upland conditions were crossed with three testers in Line $\times$ Tester mating design and the F_1 material along with parents (lines + testers) were evaluated for various parameters. These traits are days to 50% flowering, 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 centi meters from the ground level to the tip of the main panicle, excluding awns); panicle length (measured in centi meters 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. Without using any artificial irrigation, the plants were raised solely in upland environments that are rainfed.

Statistical analysis

The analysis of variance was done as per Panse and Sukhatme (1985) and combining ability analysis was done following the method of Griffing (1956). The plants were raised entirely under upland and rainfed condition without any artificial irrigation.

The results obtained from the evaluation of the material in the present investigation with respect to gene action and heterosis for all traits studied has been discussed in the following section,

The analysis of variance (Table 1) showed that among all traits under study, except grain breadth, grain length, spikelet fertility, total tillers/plants and days to 50% flowering all the others traits were significant only at 5% level of significance.

The estimates of the average degree of dominance also showed that for most of the characters, its magnitude was greater than 1, except for total tillers per plant which indicated that there was preponderance of dominant gene action or non-additive gene action in the expression of majority of the characters. The values of Additive variance, narrow sense heritability, genetic advance and Dominance variances and their ratio are given in Table 2.

Table 1: Analysis of variance of RBD with respect to total entries for all the traits studied

Source of variation	Replication	Entries	Error
Degree of freedom	2	42	84
Traits			
Days to 50% flowering	92.64	74.71	34.68
Days to maturity	298.47	117.75*	13.33
Plant height	197.37	135.34*	34.80
Panicle length	7.15	12.64*	1.70
Total tillers per plants	0.47	2.36	1.29
Effective tillers per plant	2.85	5.03*	0.85



Spikelet per panicle	204.44	893.25*	176.94
Grains per panicle	523.38	717.50*	151.66
Spikelet fertility	19.23	96.74	9.70
Grain yield per plant	3.95	95.97*	2.17
1000-Seed weight	0.09	18.05*	4
Grain length	0.003	0.19	0.09
Grain breadth	0.083	0.11	0.07
L:B ratio	0.014	0.71*	0.069

*Significant at 5 % level

Table 2: Estimates of additive (σ^2A) and dominance genetic variance (σ^2D), average degree of dominance and narrow sense heritability (%) and genetic advance as percent of mean for all the traits studied

Traits	Additive variance	Dominance variance	Average degree of dominance	Narrow sense heritability (%) as percent of mean	Genetic advance (%)
Days to 50% flowering	103	108	1.02	9.54	19.41
Days to maturity	167	186.6	1.06	8.95	20.74
Plant height	247.5	258.5	1.02	9.57	24.81
Panicle length	14.1	14.7	1.02	9.59	7.31
Total tillers per plants	3.5	3.9	1.06	8.97	2.46
Effective tillers per plant	9.5	9.96	1.02	9.54	4.64
Spikelet per panicle	1068	1091	1.01	9.79	64.11
Grains per panicle	800	818	1.01	9.78	57.62
Spikelet fertility	107	106	1	10.09	21.09
Grain yield per plant	160	197	1.11	8.12	16.46
1000-seed weight	13	20	1.24	6.5	5.99
Grain length	0.28	0.29	1.02	9.66	0.99
Grain breadth	0.18	0.18	1	10.06	0.83
L:B ratio	1.3	1.75	1.16	7.43	1.32

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 for all the traits has been given in the Table 3.



Table 3: List of heterotic crosses over standard check

Traits	Heterotic crosses
Days to 50% flowering	HPR 2641x HPR 2656 (12.80)
Days to maturity	Bulk22 x HPR 1156 (12.36) HPR 2830 x HPR 2795 (7.76) HPR 2645 x HPR 1156 (6.90)
Plant height	HPR 2641 x HPR 2795 (20.21) HPR 2830 x HPR 2656 (17.29) HPR 2841 x HPR 1156 (17.51) Bulk 22 x HPR 1156 (19.75)
Panicle length	HPR 2559 x HPR 1156(34.83) HPR 2559 x HPR2795 (38.85) HPR 2641 x HPR 2795 (32.48) HPR2847 x HPR 2795(45.43)
Total tillers per plant	Bulk 22 x HPR 1156 (44.506) HPR 2655 x HPR 2656 (35.61) HPR 2841 x HPR 1156 (121.43)
Effective tillers per plant	BULK 22 x HPR 1156 (119.64) HPR 2841x HPR 2656 (108.93) Bulk 22 x HPR 2656 (108.93)
Spikelet per panicle	HPR 2847 x HPR 2795 (131.08) HPR 2830 x HPR 2656 (120.16) Bulk 2 x HPR 2656 (101.8) HPR 2841 x HPR 1156 (91.56)
Grains per panicle	HPR 2847 x HPR 2795 (72.81) HPR 2830 x HPR 2656 (112.35) Bulk 2 x HPR 2656 (103.68)
Spikelet Fertility	HPR 2645 x HPR 2795(6.04)
Grain yield per plant	HPR2830 x HPR2656 (112.53) Bulk 2 x HPR2656 (103.68) HPR2847 x HPR2795 (119.63)
1000 Seed wt.	HPR 2655 x HPR1156 (31.47) HPR 2830 x HPR2795 (13.89) HPR 2841 x HPR1156 (15.15) HPR 2841 x HPR2795 (18.47)
Grain length	-----
Grain breadth	HPR 2645 x HPR 2656 (31.41) HPR 2830xHPR 2656 (37.82) HPR 2830 x HPR 2795 (43.27) HPR 2841 x HPR 1156 (22.92)
L:B ratio	HPR 2559 x HPR 1156 (15.71) HPR 2559 x HPR 2795 (91.62) HPR 2895 x HPR 1156 (13.82)



Nine crosses showed positive significant heterosis over better parent for grain yield per plant. These crosses were Bulk 2 x HPR 2656 (101.83), HPR 2559 x HPR 1156 (42.41), HPR 2641 x HPR 2656 (28.60), HPR 2841 x HPR 1156 (103.06), HPR 2895 x HPR 2795 (53.27), HPR 2895 x HPR 1156 (42.87), HPR 2559 x HPR 2656 (30.40), Bulk 22 x HPR 2656 (26.38) and Bulk 22 x HPR 1156 (55.52).

Twenty five crosses showed significant positive heterosis over standard check HPR 2656 for grain yield per plant, out of which the top three were HPR 2841 x HPR 1156 (238.40), Bulk 22 x HPR 1156 (218.04) and HPR 2559 x HPR 1156 (220.87).

Bulk 2 x HPR 2656 was showed significant heterosis over standard check spikelet per panicle, grains per panicle and grain yield, panicle length. HPR 2847 x HPR 2795 and HPR 2830 x HPR 2656 for spikelet per panicle, grains per panicle and grain yield. Bulk 22 x HPR 1156 for plant height, days to maturity and effective tiller per plant, HPR 2841 x HPR 1156 for plant height, total tillers per plants, 1000 seed weight and grain breadth.

Bulk 2 x HPR 2656 was showed significant heterosis over standard check spikelet per panicle, grains per panicle and grain yield. HPR 2847 x HPR 2795 and HPR 2830 x HPR 2656 for spikelet per panicle, grains per panicle and grain yield. Bulk 22 x HPR 1156 for plant height, days to maturity and effective tillers per plant, HPR 2841 x HPR 1156 and plant height, total tillers per plant, 1000 seed weight and grain breadth.

HPR 2841 x HPR 1156 (238.40), Bulk 22 x HPR 1156 (218.04) and HPR 2559 x HPR 1156 (220.87) showed high heterosis over standard check for grain yield/plant.

Conclusion

The current study found that the average degree of dominance was greater than 1, indicating that dominant gene action or non additive gene action predominated in the expression of the majority of the characters. 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.

On the basis of gene action and heterosis the lines HPR 2559, HPR 2641, HPR 2841, HPR 2847 and Bulk 22; Crosses HPR 2841 x HPR 1156, HPR 2641 x HPR 2795, HPR 2841 x HPR 2795, BULK 22 x HPR 1156, HPR 2841 x HPR 1156 were found to be promising for further improvement and for utilization in breeding programs.

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Author contributions

All authors contributed equally for preparing final version of the manuscript.

Conflict of interest

No

Declaration

The authors declare no conflict of interest.

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