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Study on gene action and combining ability for yield and its component traits in rice for rainfed upland condition in Himachal Pradesh

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Abstract

The objective of this research was to determine the gene action and combining ability of 10 lines and 3 testers for rainfed upland condition, 30 cross combinations developed using a line x tester mating design in the *Kharif* 2021 and 2022 growing seasons. The crossing was completed in *Kharif* 2021, and in *Kharif* 2022, the developed material was grown and tested along with its parents using a randomized block design. The observed data were recorded for 14 yield and yield-related quality traits were analyzed statistically, and it was shown that for all the traits examined, the dominant variance was greater than the additive variance for majority of the traits. 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 various traits.

Key words: gene action, general combining ability and specific combining ability

Rice is a staple food crop that is grown throughout many places around the globe. India accounts for 44 million hectares and 122.27 million tonnes of production and 510.30 million tonnes of rice produced worldwide, which is grown on 162.6 million hectares (Anonymous 2021a). It is also a key food crop in hilly areas like Himachal Pradesh and Uttarakhand. Upland rice accounts for 42 per cent of the total rice cultivation area in H.P., where it is grown over an estimated area of 62 thousand ha with a yield of 135 thousand tonnes and productivity of 21.7 quintals per hectare (Anonymous, 2021b).

Lowland transplanted rice requires a significant amount of labour and water during the initial stages of cultivation as well as later stages. Due to less availability of labour and unpredictable rainfall in hilly areas, it is very difficult to grow transplanted rice. Additionally, the retention of water in rice fields is challenging due to the undulating topography. As a result, upland and rainfed conditions are used for the rice cultivation in hilly areas. For direct sowing, it is therefore necessary to develop high yielding cultivars suited for upland and rainfed environments. Additionally, a significant increase in rice yield potential is needed to maintain food security for a population that is expanding exponentially because the area under cultivation is decreasing as a result of urbanisation and industrialization. To secure future food security, we must encourage the breeding and cultivation of single cross rice hybrids (Rasheed *et al*., 2021).

The selection of parents for various hybridization programmes and the selection of an appropriate breeding method for the genetic enhancement of certain quantitative characteristics, both require studies on gene action and heterosis. As measures of gene action, both genetic variations and combining ability are used. Combining ability analysis can be used to choose parents with good general combining ability, which can then be utilized in a hybridization programme to produce segregants that are acceptable for further generations. High GCA is the result of the hybridizing parent's genes interacting in an additive dominance. It has already been used to generate high yielding rice varieties in a number of nations. Dominance and epistasis effects between the parents of the hybrid cause high SCA. Also, if two parents share distinct genes for the questioned characteristics, their genetic makeup will tend to complement one another. Non-additive gene activity is still not being used. In rice, both types of gene activities seem to be important. Selecting parents and crosses to breed for high producing crop plants is a challenge that breeders frequently face. In order to take advantage of heterosis or to create new recombinants, it is constantly necessary to screen germplasm, isolate prospective combining lines and selective cross combinations. So, the breeders would benefit from any strategy that made selecting desirable parents and crosses easier. According to Behera and Monalisa (2016), Morais *et al*. (2017), Faiz *et al*. (2006), Sarker *et al*. (2002) and Kargbo *et al*. (2002), there are specific combining ability (SCA) effects for yield and attributes associated to yield in rice hybrid. The choosing of parents for various hybridization programmes and the selection of the best breeding method for the genetic enhancement of specific quantitative features both require studies on gene activity. El Mowafi *et al*. (2021) further emphasised the need of using hybrid rice parental lines with strong combining skills as a productive strategy for raising rice yields.

Materials and Methods

Materials used

This investigation was carried out 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, Bulk 2, Bulk 22 with three testers HPR 1156, HPR 2656 and HPR 2795 in line × tester mating design at RWRC, Malan, during Kharif, 2021. During *Kharif* 2022, the F_1's of 30 crosses [lines (10) + testers (3)], along with their parents, 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 15 cm, respectively.

Observations recorded

In this study, 10 genotypes of rice (lines) suitable for upland conditions were crossed with three testers in line ×tester mating design and the F_1 material along with parents (lines + testers) were evaluated for 14 morphological traits. These traits are days to 50% flowering, days to maturity, plant height (cm), panicle length (cm), total tillers per plant, effective tillers per plant, spikelets per panicle, grains per panicle, spikelet fertility (%), grain yield per plant (g), 1000-grain weight (g), grain length (mm), grain breadth (mm), length:breadth (L:B) ratio. All the observations were made on five randomly selected plants of each genotype and cross combination for various variables, with the exception of days to 50% flowering and days to maturity, which were recorded on a plot basis. Without using any artificial irrigation, the plants were raised solely in upland environments that are rainfed.

Statistical Analysis

The analysis of variance (ANOVA) was done as per Panse and Sukhatme (1985) and combining ability analysis was done following the method of Griffing (1956).

Results and Discussion

The following results were obtained from the present investigation with respect to ANOVA, gene action and combining ability for all the traits studied which are presented in this section.

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

The estimation of additive and dominance components of variance was done and the results have been shown in (Table 2). Dominance variance was significantly higher than additive variance for all traits. The average degree of dominance for most of the characters was greater than 1, indicating that dominant gene action or non-additive gene action predominated in the expression of the majority of characters, revealing their potential for exploitation of non-additive gene action for grain yield and other component traits by using genotypes in heterosis breeding and it also shows that the early selection will not be effective for these genotypes since most of the genotypes will segregate for many characters in future generations. For the traits plant height, number of tillers/plant, panicle length, grain weight/panicle, and grain yield/plant, Karthikeyan *et al*. (2009) discovered

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

Sources of variation	Mean sum of square		
	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-Grain 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) and average degree of dominance

Traits	Additive variance	Dominance variance	Average degree of dominance
Days to 50% flowering	103.00	108.00	1.02
Days to maturity	167.00	186.60	1.06
Plant height	247.50	258.50	1.02
Panicle length	14.10	14.70	1.02
Total tillers per plants	3.50	3.90	1.06
Effective tillers per plant	9.50	9.96	1.02
Spikelet per panicle	1068.00	1091.00	1.01
Grains per panicle	800.00	818.00	1.01
Spikelet fertility	107.00	106.00	1.00
Grain yield per plant	160.00	197.00	1.11
1000-Grain weight	13.00	20.00	1.24
Grain length	0.28	0.29	1.02
Grain Breadth	0.18	0.18	1.00
L:B ratio	1.30	1.75	1.16

that the ratio between the estimates of additive and dominance variances suggested a prepondrance of non-additive gene action. Similar findings were reported by Singh *et al*. (2019) and Shikari *et al*. (2009). For days to 50% flowering, plant height, effective tillers per plant, panicle length, grains per panicle, 1000-grain weight, and grain yield per plant, Utharasu and Anandakumar (2013) discovered that dominance variance (σ^2D) was higher than additive variance (σ^2A) for most of the traits studied and Singh (2016) also observed higher dominance variance than additive variance for most of the traits studied.

From the estimates of GCA and SCA for the genotypes, it was found that HPR 2847 is good general combiner for spikelet per panicle and grains per panicle, panicle length and grain yield per plant, Bulk 22 is good general combiner for panicle length, grain length, total tillers per plant, effective tillers per plant and grain yield per plant, HPR 2645 for days to maturity and spikelet fertility, HPR 2841 for 1000 seed weight and effective tillers per plant, HPR 2895 for grain yield per plant and days to 50% flowering.

There were some crosses that were found to be good specific combiners (Table 3) for various traits Bulk 2 x HPR 2656 was good specific combiner for grains per panicle and panicle length. HPR 2847 x HPR 2795 and HPR 2830 x HPR 2656 were good specific combiners for spikelet per panicle and grains per panicle. Bulk 22 x HPR 1156 for plant height and

Table 3. List of good general combiners and good specific combinations

Traits	Specific combiners	General combiners
Days to 50%	HPR 2645 x HPR 2656 (12.80)	HPR 2895 (5.39)
flowering	HPR 2641 x HPR 2795 (8.13)	
Days to maturity	Bulk 22 x HPR 1156 (11.20)	HPR 2641 (2.52)
	HPR 2641x HPR 2656 (5.88)	HPR 2645(6.08)
	HPR 2559 x HPR 2656 (4.77)	HPR 2830 (5.30)
Plant height	HPR 2641 x HPR 2795 (12.94)	———
	Bulk22 x HPR 1156 (8.11)	
Panicle length	Bulk 2 x HPR 2656 (11.20)	HPR 2559(1.70)
	HPR 2830 x HPR 2656 (2.07)	HPR 2847 (2.44)
	HPR 2641x HPR 2795(1.55)	Bulk 22 (1.19)
Total tillers per plant	HPR 2830 x HPR 1156 (2.07)	Bulk 22 (1.04)
Effective tillers per plant	HPR 2895 x HPR 2795 (1.19)	HPR 2841 (1.45)
		Bulk 22 (1.20)
Spikelet per panicle	HPR 2559 x HPR 1156 (17.58)	HPR 2847 (18.33)
	HPR 2830x HPR 2656 (25.54)	
	HPR 2847 x HPR 2795 (17.22)	
Grains per panicle	HPR 2830 x HPR 2656 (22.16)	HPR 2847 (18.83)
	HPR 2847 x HPR 2795 (14.99)	
	Bulk2 x HPR 2656 (20.98)	
Spikelet fertility	HPR 2641 x HPR 1156 (4.38)	HPR 2645 (3.48)
	HPR 2645x HPR 2795 (3.99)	
	HPR 2841 x HPR 1156 (5.84)	
	HPR 2841 x HPR 2795 (4.83)	
Grain yield per plant	HPR 2559 x HPR 1156 (5.50)	HPR 2895 (1.42)
	HPR 2641 x HPR 2795 (2.27)	HPR 2847 (1.06)
	HPR 2830 x HPR 2656 (5.38)	Bulk 22 (3.31)
1000 seed weight	HPR 2655 x HPR 2656 (3.24)	HPR 2841 (1.67)
	HPR 2655 x HPR 2795 (2.67)	Bulk 2 (1.55)
Grain length	HPR 2840 x HPR 2656 (23.815)	Bulk 22 (0.26)
	HPR 2866 x HPR 1156 (26.833)	
	HPR 2873 x HPR 2656 (19.25)	
	HPR 2871 x HPR 2795 (15.99)	
Grain breadth	HPR 2830 x HPR 1156 (0.47)	———————
L:B ratio	HPR 2559 x HPR 2795 (1.62)	———————
	HPR 2641 x HPR 1156 (0.30)	
	HPR 2645 x HPR 2656 (0.29)	

days to maturity and HPR 2559 x HPR 1156 for spikelet per panicle and grain yield per plant.

The role of non-additive genes in the expression of yield and its components has already been investigated by Dalvi and Patel (2009), Saidaiah *et al*. (2010) and Selvaraj *et al*. (2011). SCA variances for grain quality measurements were greater than GCA variances, according to Sreelakshmi and Babu (2017) and Thakare *et al*. (2010). The effects of GCA were investigated and it was discovered that there were good general combiners for grain yield and other attributes among lines and testers. Significant SCA effects for diverse characters suggested a preponderance of non-additive gene actions in the inheritance of the characters under research, according to Akansha and Jaiswal (2019). Different lines and hybrids were discovered to be the best general and specific combiners for various yield and quality attributes. As a result, significant specific cross-combiners can be successfully used in crop improvement programmes to generate varieties, as well as additional confirmation of specific genes to develop gene-based ideal markers in rice breeding. Kargbo *et al*. (2019) also found similar results in their experiment in which they evaluated 27 hybrids along with their parents in L×T mating design. Kumar *et al*. (2019) and El-Mowafi *et al*. (2021) found in their experiments that both SCA and GCA were equally significant and both were responsible for expression of different traits. So, both additive and non-additive gene action equally contributed in governing various characters.

Hence, these good general combiners of males and females may be used in future for hybrid rice breeding programme and the good specific combiners can be further tested for heterosis and utilized in heterosis breeding programme.

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. Additionally, the average degree of dominance revealed that their magnitude was greater than 1, utilising the genotypes in heterosis breeding, reducing their potential for use in the exploitation of non-additive gene action for grain yield and other component traits and it also demonstrates that early selection was ineffective for these genotypes since the majority of the genotypes will segregate for many characters in subsequent generations.

On the basis of combining ability and gene action, the lines HPR 2645, HPR 2841, HPR 2895, HPR 2847 and Bulk 22 and crosses HPR 2559 x HPR 1156, HPR 2645 x HPR 2656, HPR 2645 x HPR 2795, HPR 2830 x HPR 2795, HPR 2841 x HPR 1156 were found to be promising for further improvement and utilization in rice breeding programmes.

Conflict of interest: The authors declare that there is no conflict of interest in this research paper.

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