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RELATIONSHIP AMONG MEAN, COMBINING ABILITY AND STANDARD HETEROSIS IN RICE (*Oryza sativa* L.)

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Abstract

The present investigation was carried out in rice involving 7 lines and 3 testers. The resultant twenty one hybrids were evaluated for ten characters *viz.,* days to 50 per cent flowering, plant height at maturity, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, flag leaf length, flag leaf breadth, thousand grain weight, grain yield per plant. The genetic cause of heterosis in rice was elucidated by using line × tester analysis. It was found out that combining ability is important for heterosis and not the gene distribution. Based on *per se* performance and *gca* effect, the line L_1 and the tester T_1 were adjudged as the best for most of the traits studied. Among the hybrids, $L_1 \times T_1$ followed by $L_3 \times T_1$ exhibited high *per se* and *sca* effect for most of the economic traits. Maximum significant positive standard heterosis was possessed by the hybrid $L_1 \times T_1$ followed $L_6 \times T_2$ for most of the economic traits. The hybrid $L_2 \times T_2$ showed desirable performance based on *per se, sca* and standard heterosis for most of the yield attributing characters and so this hybrid could be exploited for further crop improvement.

Keywords: Rice, combining ability, heterosis.

Introduction

Rice *(Oryza sativa* L.*)* is the staple food crop which is grown extensively in India and Asia. In India, rice cultivated in an area of 44.5 million hectares and the annual rice production is about 131.9 million tonnes as per FAO stat. Division, 2015. In Tamil Nadu, rice is cultivated in an area of 17.23 lakh hectares with the production of 51.678 lakh tonnes and productivity of 2.965 tonnes per hectare. By the year of 2025, about 756 million tonnes of paddy, which is 70 per cent more than the current production, will be needed to meet the growing demand. To cop up with the ever increasing demand for rice present production levels need to be increased by 2 million tonnes every year, which is possible through heterosis breeding and other innovative breeding approaches (Pandey *et al.,* 2010). Therefore, the major focus of rice research in the next decade must be the development of high-yielding and early maturing varieties in order to ensure food security and efficient use of natural resources (Swain, 2005).

Combining ability analysis is being extensively used to study the nature and magnitude of genotypic variability and to facilitate the selection of the parents in hybrid programme. There is the wider scope for exploitation of heterosis. Proper choice of parents for hybridization is very crucial in generating heterotic hybrids. Further, the relevant information about the inheritance of different quantitative characters plays an important role in deciding proper selection strategies besides creation of variability.

Materials and Methods

The present investigation was carried out at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar. Ten genotypes of rice viz., STBN 12-14 (L1), IVT 1235 (L2), STBN 3 (L3), STBN 2 (L4), MTU 1001 (L5), IVT 1208 (L6), STBN 13-11 (L7), ADT 45 (T1), IR 50 (T2) and IR 66 (T3) were crossed in line × tester fashion resulting in twenty one hybrids. The experimental materials consisted of twenty one hybrids with their ten parents were raised in the nursery and transplanted in rows spacing of 30cm between rows and 20 cm between plants. Twenty five days old seedlings per hill was maintained. The row length of 3 m was maintained for each genotype. The experiment was laid out in a randomized block design with three replications. Recommended agronomic practices and need based plant protection measures were also adopted. The resultant twenty one hybrids along with their parents were evaluated for ten characters viz., days to 50 per cent flowering, plant height at maturity, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, flag leaf length, flag leaf breadth, thousand grain weight, grain yield per plant. The observations were recorded on six competitive plants both in parents and hybrids in each replication and subjected to line × tester analysis.

The general combining ability effects of parents and specific combining ability effects of different crosses were worked out based on the method developed by Kempthorne (1957). The parents or cross combinations which showed significant positive *gca* or *sca* effects were given the score +1. The parents or cross combinations which recorded significantly negative *gca* effects were given the score -1. The parents or cross combinations which registered non-significant *gca* or *sca* were given the score 0. For days to 50 per cent flowering and plant height at maturity, negative significant *gca* or *sca* effects were given the score +1 and positive significant *gca* or *sca* effects were given the score -1. The genotype, which exhibited a total score more than +1 was considered as a good combiner. The genotype, which scored a total score of -1 was considered as a poor combiner. The genotype, which scored a total score of 0, was considered as an average combiner. The F1 hybrid performance was calculated as the estimates of heterosis over standard parent (Fonseca and Patterson, 1968) and their significance of heterosis was tested using the formula suggested by Wynne *et al.* (1970).

Results and Discussion

The variance due to lines and testers were significant for all the characters studied. The variance due to line × testers and hybrids were also significant for all traits. The results of the present study indicated that existence of significant differences among the lines, testers and hybrids. Therefore, further analyses were appropriate (Table 1).

The contribution of individual lines to hybrid performance was accomplished by comparing the general combining ability effects. When the parents were assessed for their overall combining ability, the parents namely, L_1 and L_7 found out as good general combiner followed by L_3. The high *per se* performance coupled with high *gca* effects in the parents *viz.*, L_1 and T_1 indicated that these genotypes have enormous amount of additive genetic variability. When the cross combinations were assessed for their overall specific combining ability effects, the cross combinations *viz.*, $L_2 \times T_2$ followed $L_4 \times T_1$ and $L_5 \times T_3$ scored maximum.

Standard heterosis for grain yield per plant was maximum with $L_2 \times T_2$ (37.56), $L_1 \times T_1$ (35.74) and $L_6 \times T_3$ (31.71). Most of the cross combinations which exhibited high *sca* effects had both the parents with high *gca* effects. However, in some crosses, at least one of the parents of the cross combination which exhibited high *sca* effects, had high *gca* effects too. Most of the cross combinations which portrayed high standard heterosis were endowed with high mean performance and *sca* effects. Hence, *sca* effects could well be utilized as a biometrical marker in heterosis breeding of rice.

The *per se* performance and *gca* effects were related with each other which reflects the breeding behavior of individual genotype (Rao *et al.,* 1996). The *per se* performance of the parent might not always serve as an index of their genetic nicking ability. The combining ability has an equal importance to indicate the genetic behavior of the parent material enabling the breeder to select upon and utilize it for further exploitation (Sood and Gartan, 1991). The *per se* performance of the parents may not necessarily correspond with the *gca* effect as evident from the finding of the rice workers, Kavimani (2004) and Faiz *et al.* (2006). However, Chawla and Gupta (1983) stated that parents with high *per se* and *gca* could produce transgressive segregants in F_2 as well as in later generations. Therefore, the knowledge on combining ability coupled with mean performance of parents would be of great importance in selecting the suitable parents for hybridization. The line which recorded high grain yield per plant *Viz.,* L_1 was good combiner for days to 50 per cent flowering, number of productive tillers plant, panicle length, number of grains per panicle and flag leaf breadth. The parents namely L_5 which recorded high grain yield per plant was good combiner for plant height at maturity. The tester, T_1 which recorded high grain yield per plant was good general combiner for days to 50 per cent flowering, number of tillers per plant, number of grains per panicle and thousand grain weight. When the parents were assessed for overall *gca* effects, the parent namely L_1 followed by L_7 and L_3 were found good general combiners. The result is in corroboration with the findings of Satheesh kumar *et al.* (2010). The high *per se* performance coupled with high *gca* effects in the parents L_1 and T_1 indicated that these genotypes have enormous amount of additive genetic variability.

According to Simmonds (1979) the *gca* effects itself is considered to be due to the presence of large number favourable genes in parents for traits concerned. As the aforementioned lines and testers had additive gene action, their ability to transmit desirable characters to the progeny could be predicated on the basis of their phenotypic performance. For an autogamous crop like rice, additive gene effects could be efficient to use by hybridization and selection. It mainly involves crossing of two or more diverse genotypes and then selecting in the segregating generations to fix the additive genetic variance. The result is in corroboration with the findings of Satheesh kumar *et al.* (2010).

The selection of hybrids based on the contribution of the criteria namely mean, *sca* and standard heterosis will be meaningful than either alone. Riccharia and Singh (1983) stressed that the selection criteria for good cross is that it should have high *per* se coupled with high *sca* effects. The consistency between *gca* and *sca* effects might be due to complex interaction of genes as suggested by Matzinger and Kempthorne (1954).

It is a well known phenomenon that the crosses involving high *gca* parents generally evolve high *sca* effects of hybrids. In the present study the hybrids *viz.,* $L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_2$, $L_2 \times T_3$, $L_3 \times T_1$, $L_3 \times T_2$, $L_4 \times T_2$, $L_5 \times T_2$ and $L_6 \times T_3$ recorded high mean for grain yield per plant. Among these hybrids, $L_2 \times T_2$ recorded high *sca* effects for six out ten characters namely plant height at maturity, number of tillers per plant, number of grains per panicle, flag leaf length and grain yield per plant. The hybrid $L_3 \times T_2$ registered high *sca* effects for six out of ten characters studied. It indicated the *sca* effects could well be utilized as a biometrical marker in heterosis breeding in rice. The cross combination namely $L_2 \times T_2$ had high mean, high *sca* effects with high standard heterosis for grain yield per plant. This hybrid would be advantageous for heterosis breeding. In general many of the cross combinations which registered high mean had also possessed high *sca* and standard heterosis. Most of the cross combinations which exhibited high *sca* effects also had either both the parents at least one parents with high *gca* effects.

Table 1 : Analysis of variance

S.No.	Characters	Hybrids Df=20	Lines Df=6	Testers Df=2	Line × Tester Df=12	Error Df=60
1.	Days to 50 per cent flowering	27.51**	83.49**	30.11**	25.83**	1.32
2.	Plant height at maturity	189.76**	888.04**	47.79**	233.83**	0.44
3.	Number of tillers per plant	35.45**	195.94**	36.92**	51.55**	0.17
4.	Number of productive tillers per plant	9.75**	31.46**	2.05*	7.42**	0.93
5.	Panicle length	19.39**	1.46*	24.10**	5.65**	1.33
6.	Number of grains per panicle	723.34**	2285.65**	2617.75**	569.68**	0.37
7.	Flag leaf length	35.42**	164.44**	49.05**	36.56**	0.11
8.	Flag leaf breadth	0.06**	0.06**	0.02*	0.03**	0.004
9.	Thousand grain weight	8.74**	60.65**	70.02**	6.33**	0.04
10.	Grain yield per plant	94.59**	275.35**	94.37**	86.44**	0.09

*significant at 5% level **significant at 1% level

Table 2 : Scoring based on *gca* effects

S. No	Genotypes	50 per cent of flowering	Plant height at maturity	No. of tillers per plant	No. of productive tillers per plant	Panicle length	No. of grain per panicle	Flag leaf length	Flag leaf breadth	Thousand grain weight	Grain yield per plant	Total
1.	L_1	+1	0	0	+1	+1	+1	0	+1	0	+1	+6
2.	L_2	-1	-1	0	0	0	+1	0	-1	-1	+1	-3
3.	L_3	0	+1	0	-1	0	-1	0	+1	+1	+1	+4
4.	L_4	+1	-1	+1	-1	-1	-1	0	-1	-1	-1	-5
5.	L_5	0	+1	-1	-1	-1	-1	0	0	-1	-1	-5
6.	L_6	-1	+1	+1	-1	+1	+1	0	-1	+1	-1	+1
7.	L_7	+1	+1	+1	+1	+1	-1	0	-1	+1	-1	+6
8.	T_1	+1	-1	+1	-1	-1	+1	0	0	+1	-1	0
9.	T_2	-1	+1	0	0	0	+1	-1	0	+1	+1	+2
10.	T_3	-1	-1	-1	0	0	-1	-1	+1	-1	-1	-6

+1 = Positive significant 0 = Non-significant -1= Negative significant

@- negative significant effect taken as +1 and vice versa

Table 3 : Scoring based on *sca* effects

S. No	Crosses	50 per cent of flowering	Plant height at maturity	No. of tillers per plant	No. of productive tillers per plant	Panicle length	No. of grain per panicle	Flag leaf length	Flag leaf breadth	Thousand grain weight	Grain Yield per plant	Total
1.	$L_1 \times T_1$	0	-1	+1	+1	0	+1	-1	0	-1	+1	+1
2.	$L_2 \times T_1$	-1	-1	+1	0	0	+1	+1	0	+1	-1	+1
3.	$L_3 \times T_1$	-1	+1	0	0	+1	-1	-1	-1	-1	0	-3
4.	$L_4 \times T_1$	+1	+1	+1	+1	0	+1	-1	0	+1	-1	+4
5.	$L_5 \times T_1$	-1	-1	+1	-1	-1	-1	-1	0	+1	-1	-5
6.	$L_6 \times T_1$	+1	-1	-1	0	0	+1	+1	+1	-1	-1	0
7.	$L_7 \times T_1$	+1	-1	-1	-1	0	-1	+1	0	-1	+1	-2
8.	$L_1 \times T_2$	-1	-1	-1	0	0	-1	+1	0	-1	-1	-5
9.	$L_2 \times T_2$	0	+1	+1	+1	0	+1	+1	0	-1	+1	+5
10.	$L_3 \times T_2$	+1	-1	+1	0	-1	+1	-1	+1	-1	+1	+3
11.	$L_4 \times T_2$	0	-1	-1	-1	0	-1	0	0	-1	+1	-5
12.	$L_5 \times T_2$	+1	+1	-1	0	0	+1	+1	0	-1	+1	+3
13.	$L_6 \times T_2$	0	+1	+1	0	0	+1	-1	-1	+1	-1	+1
14.	$L_7 \times T_2$	0	0	+1	-1	0	-1	-1	0	+1	-1	-2
15.	$L_1 \times T_3$	+1	+1	-1	0	0	+1	-1	0	+1	-1	+1
16.	$L_2 \times T_3$	+1	+1	-1	0	0	-1	-1	0	-1	-1	-3
17.	$L_3 \times T_3$	0	-1	-1	0	0	+1	+1	0	+1	-1	0
18.	$L_4 \times T_3$	-1	0	+1	0	0	-1	+1	0	+1	-1	+1
19.	$L_5 \times T_3$	0	+1	+1	0	+1	+1	+1	+1	-1	-1	+4
20.	$L_6 \times T_3$	-1	-1	+1	-1	+1	-1	0	0	-1	+1	-2
21.	$L_7 \times T_3$	-1	+1	+1	+1	0	+1	0	0	-1	-1	0

+1 = Positive significant 0 = Non-significant -1= Negative significant

@- negative significant effect taken as +1 and vice versa

Table 4 : Relationship among mean, combining ability and standard heterosis

S. No	Characters	Mean	*gca*	*sca*	Standard heterosis
1.	Days to 50 per cent flowering	$L_4 \times T_1$ (73.32), $L_1 \times T_3$ (73.37), $L_1 \times T_3$ (73.63)	-0.89 × -2.09, -1.36 × -2.09, -1.28 × 0.77	$L_1 \times T_3$ (-3.64), $L_2 \times T_3$ (-3.34), $L_4 \times T_1$ (-3.22)	$L_4 \times T_1$(-7.97), $L_7 \times T_1$ (-7.57), $L_1 \times T_3$ (-5.40)
2.	Plant height at maturity	$L_6 \times T_2$ (66.66), $L_4 \times T_1$ (77.26)), $L_7 \times T_3$ (77.38)	-0.71 × -1.51. 3.69 × 0.74, -5.02 × 0.74	$L_6 \times T_2$ (-15.37), $L_4 \times T_1$ (-11.42), $L_1 \times T_3$ (-6.46)	$L_6 \times T_2$ (-24.36), $L_4 \times T_1$ (-12.34), $L_7 \times T_3$ (-12.21)
3.	Number of tillers per plant	$L_6 \times T_2$ (23.73), $L_2 \times T_1$ (22.92), $L_4 \times T_1$ (22.67)	0.55 × 0.07, 0.21 × 0.34, 0.74 × 0.34	$L_6 \times T_2$ (4.24), $L_2 \times T_1$ (3.45), $L_1 \times T_1$ (2.84)	$L_6 \times T_2$ (38.50), $L_2 \times T_1$ (33.79), $L_7 \times T_3$ (30.54)
4.	Number of productive tillers per plant	$L_7 \times T_3$ (18.30), $L_1 \times T_1$ (16.57), $L_1 \times T_2$ (15.38)	1.56 × 0.20, 1.55 × -0.36, 1.55 × 0.16	$L_7 \times T_3$ (2.45), $L_2 \times T_2$ (1.84), $L_4 \times T_1$ (1.66)	$L_7 \times T_3$ (27.08), $L_1 \times T_1$ (15.09), $L_7 \times T_3$ (30.54)
5.	Panicle length	$L_6 \times T_3$ (26.83), $L_7 \times T_2$ (24.03), $L_1 \times T_2$ (23.90)	3.51 × 0.54, 1.44 × 0.23, 1.51 × 0.23	$L_3 \times T_1$ (2.56), $L_6 \times T_3$ (1.53), $L_5 \times T_3$ (1.40)	$L_6 \times T_3$ (26.36), $L_7 \times T_2$ (13.17), $L_1 \times T_2$ (12.57)
6.	Number of grains per panicle	$L_1 \times T_1$(130.48), $L_6 \times T_2$(121.71), $L_6 \times T_1$(119.78)	16.26 × 0.33, -4.08 × 1.49, 11.23 × 0.33	$L_5 \times T_2$ (21.33), $L_4 \times T_1$ (11.79), $L_1 \times T_1$ (10.32)	$L_1 \times T_1$ (6.32)
7.	Flag leaf length	$L_3 \times T_3$ (32.71), $L_2 \times T_2$ (30.37), $L_4 \times T_3$ (30.01)	1.80 × -0.16, 0.13 × -0.32, -1.63 × -0.16	$L_3 \times T_3$ (4.68), $L_7 \times T_1$ (4.42), $L_2 \times T_2$ (4.18)	$L_3 \times T_3$ (6.33)
8.	Flag leaf breadth	$L_1 \times T_3$(1.44), $L_1 \times T_1$(1.40), $L_3 \times T_2$ (1.38)	0.25 × 0.16, 0.25 × -0.02, 0.07 × -0.01	$L_3 \times T_2$ (0.17), $L_4 \times T_3$ (0.17), $L_6 \times T_3$ (0.14)	$L_1 \times T_3$ (22.58), $L_1 \times T_1$ (19.74), $L_3 \times T_2$ (18.03)
9.	Thousand grain weight	$L_7 \times T_2$ (19.59), $L_6 \times T_2$ (19.49), $L_5 \times T_1$ (18.49)	0.81 × 0.16, 0.85 × 0.16, -0.24 × 1.16	$L_7 \times T_2$ (2.14), $L_6 \times T_2$ (2.02), $L_1 \times T_3$ (1.40)	$L_7 \times T_2$ (34.34), $L_6 \times T_2$ (33.70), $L_5 \times T_1$ (26.79)
10.	Grain yield per plant	$L_2 \times T_2$ (37.56), $L_1 \times T_1$ (35.74), $L_6 \times T_3$ (31.71)	5.14 × 1.32, 4.16 × -0.90, -2.14 × -0.42	$L_6 \times T_3$ (8.44), $L_1 \times T_1$ (6.65), $L_2 \times T_2$ (5.28)	$L_2 \times T_2$ (7.02), $L_1 \times T_1$ (1.89)

Standard Parent T_1

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