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K Palani Raja
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

V Ramanjaneya Reddy
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

S Vennila
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Correspondence
K Palani Raja
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Additive and dominance gene effects in rice (*Oryza sativa* L.) hybrids through Line x Tester analysis

K Palani Raja, V Ramanjaneya Reddy and S Vennila

Abstract
Twenty one hybrids generated from crossing seven lines and three testers were studied along with their parents for combining ability and gene action involved in the expression of characters in rice. The GCA and SCA variance were significant for all the characters. The magnitude of SCA variance was higher than the GCA variance for all the characters revealed the presence of predominance of non-additive gene action for all the characters studied. Among the parents MTU 1010, ADT 39, TRY 2 and IR 50 identified as good general combiner for grain yield as well as other desirable traits like days to 50 per cent flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, kernel L/B ratio, hundred grain weight and grain yield per plant. While the cross combinations *viz.*, MTU1010 x IR 50 and ADT 39 x TRY 2 with good *per se* performance and significant *sca* effect for yield and yield components may be exploited by involving them multiple cross breeding programme for obtaining transgressive segregants and broad genetic base population in rice yield improvement.

Keywords: Combaining ability, gene action, GCA, SCA, rice

Introduction
Rice is the staple food of more than 60% of Indian population. It accounts for about 43% of total food grain production and 46% of total cereal production in the country. The area under rice cultivation in India was 43.5 million hectares with a production of 104.32 million tonnes during 2016-2017 (Directorate of economics and statistics Report, 2016-17).
The knowledge of combining ability is useful to assess nicking ability among genotypes and at the same time elucidate the nature and magnitude of gene actions involved. The combining ability analysis gives an indication of the variance due to GCA and SCA which represents a relative measure of additive and non-additive gene actions respectively. Breeders use these variance components to measure the gene action and to assess the genetic potentialities of parent in hybrid combinations. Diallel (Griffing, 1956) [6] and line x tester (Kempthorne, 1956) [7] mating designs provide reliable information about the general and specific combining ability (GCA and SCA) of parents and their cross combinations and are helpful in estimating various types of gene actions within affordable resources.

Materials and Methods
The experimental material comprised of twenty one hybrids obtained from seven lines (ADT 45, ADT 39, JGL 1798, KNM 118, PKM 3, CO 51, MTU 1010) and three testers (TRY 2, ASD l6, IR 50). The set of hybrids were generated in line x tester pattern for the purpose and evaluated along with parents in Randomized Block Design with three replications during Navarai season (Dec-Mar, 2017) at Plant Breeding farm of Department of Genetics and Plant Breeding, Annamalai University, Chidambaram, Tamil Nadu. Twenty five days old seedlings of hybrids and parents were transplanted in the field. Single row of each parent and hybrid was 3 m measured with 30 x 20 cm, row to row and plant to plant spacing, respectively. Single seedling was planted in each hill. Recommended package of practices and plant protection measures were followed to obtain a good harvest. Observations were recorded on randomly selected ten plants excluding border plants in each entry in each replication for days to 50 percent flowering (days), plant height (cm), number of tillers per plant, number of productive tillers per plant and grain yield yield per plant. For panicle traits like panicle length (cm) and number of grains per panicle, observations were recorded from 10 randomly selected panicles. For kernel traits like kernel length, kernel breadth and kernel L/B ratio, observations were recorded from 10 randomly selected kernels. Combining ability analysis was carried out by the method suggested by Kempthorne (1957) [8].

Results and Discussion

Analysis of variance for combining ability

The analysis of variance revealed significant differences among the parents for all the eleven characters studied. The mean sum of squares due to general combining ability and specific combining ability for all the characters were also significant. This indicated the importance of both additive and non-additive gene action. (Table.1)

Table 1. Analysis of variance for combining ability

Source of variation	df	MSS										
		Days to 50 per cent flowering (days)	Plant height (cm)	Number of tillers per plant	Number of productive tillers per plant	Panicle length (cm)	Number of grains per panicle	Kernel Length (mm)	Kernel Breadth (mm)	Kernel L/B ratio	Hundred grain weight (g)	Grain yield per plant (g)
Replication	2	0.11	5.44	2.87	2.49	1.33	0.20	0.0163	0.00	0.035	0.008	1.61
Genotype	30	80.02**	307.78**	53.19**	64.62**	80.79**	1210.06**	0.2546**	0.0041**	0.0244**	0.15**	80.98**
Cross	20	61.53**	181.75**	56.38**	71.49**	88.70**	443.02**	0.3077**	0.0052**	0.0291**	0.12**	99.17**
Line	6	90.58**	100.21**	119.08**	159.84**	184.47**	801.06**	0.2263**	0.0056**	0.0162**	0.33*	195.71**
Tester	2	177.25**	515.34**	65.20**	52.42**	52.76**	315.87**	0.6827**	0.0102**	0.0610**	0.09**	172.95**
L×T	12	27.71**	166.92**	23.55**	30.49**	46.81**	285.18**	0.2860**	0.0042**	0.0303**	0.03**	38.60**
Error	60	3.52	3.16	0.98	1.5	1.2	1.80	0.0173	0.0001	0.0001	0.005	0.4
GCA Variance		0.88	0.38	0.85	1.06	1.09	4.11	0.0006	0.0001	0.0089	0.0026	1.57
SCA Variance		8.06	54.58	7.52	9.66	15.2	94.46	0.0895	0.0014	0.2835	0.0084	12.73
GCA/SCA Variance		0.1	0.006	0.11	0.1	0.07	0.43	0.006	0.071	0.031	0.3	0.12

*,** Significant at 5 and 1 per cent respectively

General combining ability effects of parents

Dhillon (1975) [4] pointed out that the combining ability gives useful information on the choice of parents. Singh and Nanda (1976) [13] suggested to select at least one parent with high *gca* effect as a selection index for parental evaluation. The *gca* effect is considered as intrinsic genetic value of the parent for a trait which is due to additive gene effect and it is fixable (Simmonds, 1979) [12]. In the present investigation, the *gca* effects of the lines indicated that the lines MTU 1010 and ADT 39 was positive and significant for all the yield attributing characters *viz.*, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, kernel L/B ratio, hundred grain weight and grain yield per plant and with negative significant *gca* effect for days to 50 per cent flowering and plant height. Among the testers, TRY 2 possessed desirable *gca* effects for all the yield attributing characters. The next best tester, IR 50 recorded desirable positive significant *gca* effects for the traits *viz.*, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, kernel L/B ratio, hundred grain weight and grain yield per plant and with negative significant *gca* effect for days to 50 per cent flowering and plant height. The above results indicated that different parents recorded significant *gca* results for different traits. Based on the *gca* effects recorded, among the lines, MTU 1010, ADT 39 and among the testers, TRY 2 and IR 50 could be found to be suitable in hybridization programme for subsequent improvement in grain yield (Table 2).

Table 2. General combining ability effects of parents

PARENTS		50% F	PH	NTP	NPTP	PL	GP	KL	KB	KL:B	HGW	GYP
1	ADT 45	-0.59	0.40	0.13	0.25	1.49 **	0.17	0.10 *	0.01 **	0.01 ns	1.19	1.19
2	ADT 39	-2.70 **	3.17 **	4.24 **	4.81 **	3.60 **	10.51 **	0.15 **	0.02 **	0.04 *	3.97 **	3.97 **
3	JGL 1798	4.97 **	1.95 **	-3.43 **	-4.52 **	0.60	-7.83 **	-0.08	-0.02 **	-0.05 *	-12.59 **	-12.59 **
4	KNM 118	2.63 **	-1.16	-4.65 **	-5.19 **	-7.17 **	-5.38 **	-0.20 **	-0.02 **	-0.07 **	-16.37 **	-16.37 **
5	PKM 3	-4.03 **	-3.38 **	1.79 **	1.92 **	1.16 **	2.62 **	0.12 **	0.03 **	0.07 **	5.41 **	5.41 **
6	CO 51	1.41 *	3.95 **	-2.43 **	-2.41 **	-5.06 **	-12.83 **	-0.21 **	-0.04 **	-0.06 *	3.63 **	3.63 **
7	MTU 1010	-1.70 **	-4.94 **	4.35 **	5.14 **	5.38 **	12.73 **	0.12 *	0.02 **	0.06 **	14.75 **	14.75 **
8	TRY 2	-1.84 **	-4.21 **	1.11 **	0.89**	0.67**	2.70**	0.09**	0.01**	0.03*	3.51**	3.51**
9	ASD 16	3.35 **	5.46 **	-2.03 **	-1.83**	-1.81**	-4.44**	-0.21**	-0.03**	-0.06**	-8.25**	-8.25**
10	IR 50	-1.51 **	-1.25 **	0.92**	0.94**	1.14**	1.74**	0.12**	0.02**	0.03*	4.75**	4.74**

50% F-Days to 50percent flowering, PH-Plant height, NTP- Number of tillers per plant, NPTP- Number of productive tillers per plant, Pl-Panicle length, GP- Grains per panicle, KL- kernel length, KB- Kernel breadth, KL:B- kernel L/B ratio, HGW- Hundread grain weight, GYP-Grain yield per plant; *,** Significant at 5 and 1 per cent respectively

Specific combining ability effects of hybrids

The specific combining ability is the deviation from the performance predicted on the basis of *gca* (Allard, 1960) [1]. According to Sprague and Tatum (1942) [14], the Specific combining ability is controlled by non-additive gene action. The specific combining ability of any cross is helpful in predicting the performance of a particular hybrid in relation to the *gca* of its parents (Peng and Virmani, 1990) [10]. Among the hybrids studied, the hybrids MTU 1010 x IR 50 and ADT 39 x TRY 2 identified with positive significant *sca* effects for the characters *viz.*, number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, kernel length, kernel breadth, kernel L/B ratio, hundred grain weight, grain yield per plant and negative significant *sca* effects for days to 50 per cent flowering and plant height. Similar results were obtained by Chaudhari *et al.*, (2017) [3], Upadhyay and Jiswal (2015) [16] and Vadivel (2015) [17] in their studies on rice. The crosses, ADT 39 x IR 50 and PKM 3 x IR 50 registered positive non significant *sca* effects for all the traits studied except for days to 50 per cent flowering and plant height since they were recorded with negative non-significant *sca* effects. Similar results were found by Ram Kishor *et al.* (2017) [11] and Gayathri (2015)[5] in their studies on rice. (Table 3).

Table 3: Specific combining ability effects of hybrids

Crosses		50% F	PH	NTP	NPTP	PL	GP	KL	KB	KL:B	HGW	GYP
1	$L_1 \times T_1$	-0.49	-4.02**	1.44*	1.89 *	2.56 **	4.86 **	0.11	0.03 **	0.02	0.06	5.17 **
2	$L_1 \times T_2$	4.65**	11.98**	-3.75**	-4.73 **	-4.97 **	-17.33 **	-0.15	-0.02 **	-0.04	-0.07	-7.25 **
3	$L_1 \times T_3$	-1.49	-7.97**	2.30**	2.84 **	2.41 **	12.48 **	0.04	-0.01	0.03	0.01	2.08 **
4	$L_2 \times T_1$	-3.16**	-4.46**	1.78**	2.27**	2.11 **	3.63 **	0.19 *	0.03 **	0.09 **	0.11 **	2.51 **
5	$L_2 \times T_2$	2.32*	1.87	-0.52	-0.62	-3.41 **	-6.56 **	-0.32 **	-0.03 **	-0.11	-0.04	-0.94 *
6	$L_2 \times T_3$	-1.83	-1.46	0.19	0.38	0.92	1.25	0.13	0.00	0.06	0.05	0.63
7	$L_3 \times T_1$	1.84	4.76**	-1.67**	-1.33	-3.56 **	-5.37 **	-0.02	-0.04 **	0.04	-0.01	-3.32 **
8	$L_3 \times T_2$	-4.02**	-12.90**	2.81**	3.05 **	8.25 **	4.11 **	0.38 **	0.06 **	0.05	0.06	3.32 **
9	$L_3 \times T_3$	2.17	8.14**	-1.14	-1.71 *	-4.70 **	2.92 **	-0.36 **	-0.02 **	-0.13 **	-0.10 *	-0.91
10	$L_4 \times T_1$	-1.16	2.59*	-1.78**	-2.67 **	-0.44	4.19 **	-0.25 **	-0.01 **	-0.09 *	-0.17 **	-0.43
11	$L_4 \times T_2$	-0.02	1.21	3.37**	3.71 **	1.37 *	10.00 **	0.49 **	0.05 **	0.05	0.09 *	1.95 **
12	$L_4 \times T_3$	1.17	0.25	-1.59**	-1.05	-0.92	-15.79 **	-0.24 **	-0.04 **	-0.06	-0.02	-1.52 **
13	$L_5 \times T_1$	-0.49	0.43	0.33	1.22	-0.44	2.30 **	0.13	0.02 **	0.05	-0.02	-1.58 **
14	$L_5 \times T_2$	0.65	3.43**	-4.08**	-4.06 **	-2.97 **	-0.56	-0.28 **	-0.03 **	-0.09 *	-0.07	-0.17
15	$L_5 \times T_3$	-0.16	-1.97	1.08	0.95	0.19	1.35	0.15	0.01	0.04	0.04	0.46
16	$L_6 \times T_1$	2.73*	5.76**	1.33*	1.56 *	0.78	-7.03 **	-0.22 **	-0.01 *	-0.09 *	0.07	-2.99**
17	$L_6 \times T_2$	-1.94	-8.57**	1.81*	0.67	1.30 *	11.44 **	0.16 *	-0.00	0.07 *	0.05	3.80**
18	$L_6 \times T_3$	2.06	2.81**	-3.14**	-3.83 **	-1.70 **	-5.91 **	0.06	0.01 **	0.02	-0.13 **	-0.81**
19	$L_7 \times T_1$	0.73	-1.02	-1.44*	-1.33	-1.00	-2.59 **	0.07	0.00	0.02	-0.00	-1.57**
20	$L_7 \times T_2$	1.23	2.98**	0.37	-0.05	0.81	-1.11	-0.28 **	-0.04 **	-0.08 *	-0.04	-0.72
21	$L_7 \times T_3$	-4.79**	-3.84	2.30**	2.84 **	3.41 **	3.72 **	0.21 **	0.04 **	0.15 **	0.13 **	2.29**

50% F-Days to 50 % flowering, PH-Plant height, NTP- Number of tillers per plant, NPTP- Number of productive tillers per plant, Pl- Panicle length, GP- Grains per panicle, KL- kernel length, KB- Kernel breadth, KL:B- Kernel L/B ratio, HGW- Hundred grain weight, GYP- Grain yield per plant ; L1- ADT45,L2-ADT39,L3-JGL179,L4- KNM118,L5- PKM 3, L6- CO 51,L7-MTU 1010,T1-TRY 2,T2-ASD16,T3-IR 50 ; *,** Significant at 5 and 1 per cent respectively

Relationship between *gca* and *sca* effects

The consistency between *gca* and *sca* effects might be due to complex interaction of genes as suggested by Matzinger and Kempthorne (1954) [9]; 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, MTU 1010 x IR 50 and ADT 39 x TRY 2 exhibited high mean performance and significant *sca* effects with high x high *gca* combinations for grain yield per plant and all its component traits studied. Such high x high *gca* combinations resulting in highly significant *sca* effects may be attributed due to interaction between positive x positive alleles that is additive x additive type of gene action between favorable alleles contributed by both the parents which is fixable and hence may be utilized to develop superior hybrids as these hybrids also combine high per se performance for almost all the characters studied including grain yield per plant. Similar results were obtained by Ammar Gholizadeh Ghara *et al.* (2014) [2] and Srinivasa Rao (2015) [15]. Hence these two hybrids could be exploited for heterosis breeding.

The other two hybrids viz., ADT 39 x IR 50 and PKM 3 x IR 50 recorded non-significant *sca* effects for all the traits studied. These two crosses also had superior mean performance for grain yield and all its component traits studied. This indicated that these genotypes were governed by additive gene action which is fixable and were found to be suitable for recombination breeding.

Conclusion

Thus, based on the *per se* performance and *gca* effects the lines ADT 39, MTU 1010 and PKM 3 and the testers, TRY 2 and IR 50 determined to be the superior for the grain yield and its component traits as well. The hybrids namely, MTU 1010 x IR 50, ADT 39 x TRY 2, ADT 39 x IR 50 and PKM 5 x IR 50 were rated as superior crosses since they possessed high *per se* performance for most of the economic traits studied with earliness and short stature plant. Based on *sca* effects, the hybrids MTU 1010 x IR 50 and ADT 39 x TRY 2 adjudged as the best since they were found to be highly significant for grain yield and its component traits which indicated the predominance of non-additive gene action. The other two hybrids, ADT 39 x IR 50 and PKM 3 x IR 50 were also recorded with high mean for grain yield and its component traits had non-significant *sca* effects for grain yield and its component traits indicated the presence of additive gene action.

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