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Combining Ability and Gene Action for Yield Traits for Selected Crosses of Rice (*Oryza sativa* L.)

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ABSTRACT

Combining ability analysis for yield and yield components in some important rice germplasm through line x tester analysis of 24 intervarietal crosses developed by crossing 4 testers with 6 lines. The 24 crosses were grown in a randomized block design with three replications and were evaluated for grain yield per plant and other yield components. The experiments were conducted at the Department of Plant breeding and genetics, Faculty of Agriculture, Annamalai University. Analysis of variance for line x tester revealed highly significant differences between the characters studied. The mean squares ratio of GCA and SCA were below one for all the characters studied. This might be due to the effect of non-additive gene action. The estimates of gca performance indicated that the lines viz., ADT - 37, ADT - 45, ADT - 43 and the testers viz., Kuzhi Adichan, Kalurundai Samba and Kalanmak are good general combiners for grain yield per plant. The best sca performance were observed in the crosses, ADT - 45 x Kalurundai Samba and ADT - 37 x Kalurundai Samba.

Keywords Additive, Crosses, General combining ability, Germplasm, Non-additive, Specific combining ability.

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INTRODUCTION

The staple food for the majority of world's population is rice (*Oryza sativa*). The majority of the world's rice is cultivated in Asia, Africa and Australia (Dogara *et al.* 2014). The daily calorie requirement of upto 50% is provided by Rice in Asia (Muthayya *et al*. 2014). The global demand for the rice consumption increases with increase in population. Nonetheless, throughout the last ten years, the average yearly increase in rice output was the greatest among rice-producing nations, at just 1% (Kumar 2018, Gaballah *et al.* 2022). The main factor for the low increase in production is due to some biotic and abiotic factors especially the salinity. Salinity is an abiotic stress mainly caused by the accumulation of salts by natural accumulation or by irrigation. Because of salinity, which may be caused by climatic and geological factors, places that are ideally suited for rice cultivation are either left uncultivated or produced with low yields. One important component of plant productivity is its ability to withstand salinity (Momayezi *et al.* 2009).

The growth, development, plant response to stress and adaptation is affected by salinity. It also affects pollination and fertilization which inturn lowers flower production and results in lower yields. Growth differences among various genotypes in response to salinity are dependent on the salt concentration and the degree of salt tolerance (Eynard *et al.* 2005). Production could be increased by comprehending the process of high salinity stress, creating crops that can withstand it, and improving the variety. The varietal improvement could be done by hybridisation. The successful hybridisation could be done by selecting suitable parents. By using the combining ability analysis one can select the parents for effective breeding, in addition to clarifying the nature and magnitude of gene interaction involved in the inheritance of various characters (Panwar 2005). Combining ability analysis gives an idea about the relative importance and magnitude of additive and nonadditive types of gene action in the expression of the traits (Griffing 1956). Combining ability analysis of the parents and their crosses provide information on additive and dominance gene action, which are important to decide the parents to be used for breeding programme as well as used to be selected for appropriate breeding procedure to be followed to select desirable segregant (Patel *et al*. 2015).

The average performance of a line or parent in hybrid combinations is evaluated. assesses two specific parents' communication style. (Thirumalai *et al.* 2018). (Dianga *et al*. 2020). A set of testers (males) are used to cross a set of lines (females) in a statistical procedure to evaluate the ability to combine. (Kempthorne 1957). (Saidaiah *et al.* 2010). The current study sought to find the best combining parents in chosen rice varieties under salinity circumstances based on their general and specfic combining abilities for yield and yield-contributing trait quality enhancement.

MATERIALS AND METHODS

The present study on combining ability studies in rice was undertaken at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Annamalai University, Chidambaram located at Cuddalore district of Tamil Nadu during the experimental farm is situated at 11º39' N latitude, 79º71' E longitude and at an elevation of 7.34 meters. Six parents were selected based on the desirable morphological traits. Thus, the experimental material comprised of six-line (female) parents viz., ADT - 37, ADT – 39, ADT – 42, ADT– 43, ADT – 45, ADT – 47 and four tester (male) parents viz., Kuzhi adichan, Kalurundai samba, Kalanmak, Kalarpalai which were mated in Line x Tester mating pattern developed by (Kempthorne 1957). Twenty-four F1 hybrids were derived by crossing six lines with each of four testers and these were evaluated along with parents in randomized block design with three replications. Five plants from each genotype in each replication were randomly selected for recording the eight quantitative observations viz., days to fifty % flowering, plant height, panicle length, number of tillers per plant, number of productive tillers per plant, Number of grains per plant, 1000 seed weight and yield per plant. For computing the effects of combining ability and heterosis, AGRISTAT statistical software (Manivannan 2014) was employed.

RESULTS AND DISCUSSION

Analysis of variance

The categorization of distinct groups among lines, testers, crosses, and their interactions across all examined attributes is presented in Table 1. Significant differences were observed for all lines, testers and hybrids for all the characters studied. This suggests that the variation seen in the eight characters was due to the genetic influence of parents i.e. lines, testers and hybrids (Nainu *et al.* 2016).

Gene action

In the present study the values of GCA were less than that of SCA indicating the dominance of non-additive gene action for all the characters. The mean squares ratio of GCA and SCA were below one for all the characters studied. This indicates that SCA variance influences all the characters studied. The ratio below one suggests that dominant alleles has major role in shaping phenotypic expression and also suggest the influence of non-additive gene action (Zewdu and Yildiz 2020, Abd El-Aty *et al*. 2022) recorded gene effects for various quantitative traits in rice. Since the

Table 1. ANOVA for eight quantitative traits in rice genotypes.

Source of variation	Replication df =4	Genotype df =33	MSS Cross df =23	Line df =5	Tester df =3	L x T df =15	Error df =92	GCA	SCA	GCA/SCA	Gene Action
DFF	13.54	206.20	177.13	83.03	907.04	62.52	3.27	1.73	11.84	0.14	Non-Additive
PH	2.85	1074.57	911.58	1347.73	1277.35	693.05	8.72	3.30	136.86	0.02	Non-Additive
PL	6.33	45.69	33.16	47.49	77.47	19.53	1.60	0.20	3.58	0.05	Non-Additive
NTPP	0.75	48.87	39.51	24.19	162.50	20.01	1.17	0.29	3.76	0.07	Non-Additive
NPTPP	1.82	50.32	46.89	23.61	177.71	28.48	1.50	0.27	5.39	0.05	Non-Additive
NGPP	8.76	847.13	666.41	1105.29	1994.55	254.49	4.76	6.23	49.94	0.12	Non-Additive
1000 SW	1.43	42.62	42.80	76.44	65.81	26.98	1.35	0.23	5.12	0.04	Non-Additive
SPY	4.34	40.87	30.58	41.58	38.17	25.39	2.63	0.07	4.55	0.01	Non-Additive

variation of SCA was greater than that of GCA, it was evident that non-additive gene activity predominated in grain yield. This outcome supports the conclusions of several researchers who found that non-adiditive gene action predominates for grain yield (Vennila *et al.* 2018, Hasan *et al.* 2013, Bano and Singh 2019).

General combining ability of parents

The general combining ability estimates of the parents for all the traits are presented in Table 2. According to the Table 2, the line ADT - 37 exhibited highest gca for number of tillers per plant and 1000 grain weight, ADT – 39 for days to fifty percent flowering, ADT - 45 for number of primary tillers per plant, number of grains per plant and grain yield, ADT– 47 for plant height and panicle length. Among the testers, Kalurundai samba exhibited highest gca for plant height, panicle length, number of tillers per plants, number of productive tillers per plant, number of grains per plant, 1000 seed weight and yield per plant. For the trait days to fifty percent flowering Kalarpalai exhibited highest favourable gca performance (Aruna *et al*. 2024).

Mean performance of hybrids

The mean performance of the hybrids is given in Table 3. From the Table 3 the hybrid ADT - 45 x Kalurundai samba outperformed than others for all the traits studied except for days to fifty percent flowering and plant height.

Specific combining ability of hybrids

The magnitude of sca effects is of vital importance in selecting the cross combinations with higher probability of obtaining desirable transgressive segregants.

Table 2. General Combing Ability of parents.

	DFF	PH	PL	NTPP	NPTPP	NGPP	1000 GW	SPY
ADT - 37	-0.34ns	-8.33 **	-1.31 **	1.82 **	0.94 **	0.45ns	2.95 **	1.81 **
ADT - 39	2.65 **	-3.48 **	-1.87 **	-0.9 **	-1.69 x x	-1.36 **	-0.69 **	-1.04 **
ADT - 42	1.91 **	0.67ns	-0.79 **	-1.24 **	0.22ns	-13.34 **	0.36ns	-0.56ns
ADT - 43	-0.81*	-7.99**	1.03 **	-0.37ns	-0.76 **	0.39ns	-3.01 *	-1.05 **
ADT - 45	-3.03 **	7.54 **	0.89 **	0.35ns	1.24 **	6.94 **	0.79 **	1.88 **
ADT - 47	-0.38ns	11.59 **	2.05 **	0.34ns	0.05ns	6.92 **	-0.4ns	-1.05 **
KUZHI ADICHAN	-1.7 **	-4.87 **	-0.47 *	-0.32ns	-0.4ns	-2.08 **	-1.76 **	0.12ns
KALURUNDAI SAMBA	-5.76 **	7.3**	2.39 **	3.38 **	3.29 **	12.04 **	1.13 **	1.46 **
KALANMAK	0.06ns	3.67 **	-0.92 **	-1.56 **	-0.3ns	-5.48 **	-0.69 **	-0.32ns
KALARPALAI	7.39 **	-6.1 **	-0.99 **	-1.51 **	-2.59 **	-4.48 **	1.32 **	-1.26 **

DFF- Days to fifty per cent flowering PH – Plant height PL- Panicle length NTPP – Number of tillers per plant NPTPP- Number of productive tillers per plant NGPP- Number of grains per panicle 1000 GW -1000 grain weight SPY- Single plant yield

Table 3. Mean Performance of hybrids.

Hybrids	DFF	PH	PL	NTPP	NPTPP	NGPP	1000 SW	SPY
ADT - 37 x Kuzhi adichan L1 x T1	70.89	69.68	15.63	15.42	11.44	111.04	18.86	20
ADT - 37 x Kalurundai samba L1 x T2	71.79	107.82	16.35	22.06	18.76	127.39	25.21	28.99
ADT - 37 x Kalanmak L1 x T3	72.43	82.53	15.52	17.03	12.2	104.84	22.11	25.2
ADT - 37 x Kalarpalai L1 x T4	81.82	67.6	14.83	15.95	9.27	106.75	23.2	22.95
ADT - 39 x Kuzhi adichan L2 x T1	74.73	75.91	11.32	16.69	11.84	112.21	16.83	22.55
ADT - 39 x Kalurundai samba L2 x T2	65.71	95.24	17.52	16.81	11.17	121.59	19.37	22.81
ADT - 39 x Kalanmak L2 x T3	80.84	106.8	15.24	13	10.3	101.26	17.38	19.74
ADT - 39 x Kalarpalai L2 x T4	87.61	69.05	16.01	13.05	7.84	107.73	21.26	20.65
ADT - 42 x Kuzhi adichan L3 x T1	80.74	89.87	14.83	12.69	11.57	95.11	18.84	22.67
ADT - 42 x Kalurundai samba L3 x T2	66.21	107.18	19.39	16.71	15.6	108.46	19.62	22.66
ADT - 42 x Kalanmak L3 x T3	76.26	92.79	14.33	15.29	11.33	102.17	19.16	21.09
ADT - 42 x Kalarpalai L3 x T4	82.76	73.77	15.85	13.5	10.32	89.11	21.39	21.27
ADT - 43 x Kuzhi adichan L4 x T1	70.42	83.88	21.43	15.53	10.65	111.96	15.04	22.45
ADT - 43 x Kalurundai samba L4 x T2	70.44	74.85	19.13	19.77	14.24	120.91	13.34	19.92
ADT - 43 x Kalanmak L4 x T3	71.38	75.24	16.16	12.84	10.52	106.15	17.57	22.94
ADT - 43 x Kalarpalai L4 x T4	82.82	94.98	14.97	13.56	9.49	110.79	19.61	20.42
ADT - 45 x Kuzhi adichan L5 x T1	68.25	98.03	15.38	16.78	12.81	109.49	16.67	25.92
ADT - 45 x Kalurundai samba L5 x T2	70.37	96.04	22.88	22.98	20.52	147.57	26.61	28.68
ADT - 45 x Kalanmak L5 x T3	72.6	99.54	16.48	11.58	9.46	107.62	17.94	21.9
ADT - 45 x Kalarpalai L5 x T4	74.97	97.48	16.38	13.25	10.09	111.32	19.54	20.94
ADT - 47 x Kuzhi adichan L6 x T1	72.23	94.76	19.91	15.75	11.19	120.04	19.58	21.99
ADT - 47 x Kalurundai samba L6 x T2	68.41	104.1	20.39	16.72	11.34	118.68	18.99	20.54
ADT - 47 x Kalanmak L6 x T3	74.29	106.48	18.09	15.69	16.25	117.4	18.1	22.11
ADT - 47 x Kalarpalai L6 x T4	81.84	101.93	17.36	16.37	9.34	119.77	19.31	21.08

DFF- Days to fifty per cent flowering PH – Plant height PL- Panicle length NTPP – Number of tillers per plant
NPTPP- Number of productive tillers per plant NGPP- Number of grains per panicle 1000 GW -1000 grain weight SPY- Single plant yield

In the present study not a single hybrid consistently performed better than the others in the investigation of specific combining influences in hybrids in terms of all characteristics. This indicates that the gca effects of the parents did not always determine the specific combining ability. The crosses ADT - 37 x Kalurundai Samba, ADT - 45 x Kalurundai Samba, ADT - 43 x Kalanmak, ADT - 45 x Kuzhi adichan were the top four combiners for yield. The hybrid ADT - 45 x Kalurundai Samba and ADT - 37 x Kalurundai samba exhibited specific combining effects for all the traits. The hybrid ADT - 43 x Kalanamak and displayed significant effects in four traits viz., days to fifty percent flowering, plant height, number of tillers plant, 1000 seed weight and yield. It also displayed non-significant effect for panicle length, number of primary tillers per plant and number of grains per plant. The hybrid ADT - 45 x Kuzhi Adichan showed significant effect for plant height, panicle length, number of grains per plant, 1000 seed weight and grain yield. Different parental gca combinations resulted superior in the present sca analysis such as ADT - 45 x Kalurundai Samba and ADT - 45 x Kalurundai Samba were two superior general combiners involved. That some of the crosses with the best particular combinations for grain production per plant were produced by combining average parents with either good or poor parents. This could be the result of a genetic component that is not fixable and an additive x dominant interaction with epistatic gene activity for grain production per plant. By using selection or a bi-parental breeding program, it may be possible to get desired transgressive segregates and hybrid vigor from such crossings. From this study, it is suggested that non-additive gene actions were important in controlling various characters. The crosses having highest significant positive sca effects for grain yield per plant could be used for exploitation of heterosis for yield in F1 generation. It can be concluded that the best combining parents were ADT - 37, ADT - 45, ADT – 43 among the lines and Kuzhi Adichan, Kalurundai Samba and Kalanamak among the testers studied. The superior hybrids were ADT - 45 x Kalurundai Samba and ADT - 37 X Kalurundai Samba. In addition to clarifying the kind and extent of gene interaction involved in the inheritance of different traits, the combining ability studies offer valuable information for the selection of high order parents for successful breeding (Palaniraja *et al.* 2018).

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