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Combining Ability for Yield and its Contributing Traits in Rice (*Oryza sativa* L.) Under Salt Affected Soil

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Abstract: ***The present study was conducted to assess the gene action, general combining ability and specific combining ability for yield and its contributing traits in rice (Oryza sativa L.). The experiment was laidout in randomized block design with three replications, at the Genetics and Plant Breeding farm of Narendra Deva University of Agriculture and Technology, Narendra Nagar, (Kumarganj) Faizabad (U.P.) during kharif, 2013 (under salt affected soil (pH=9.1; EC= 3.2; ESP=41.0). The experiment was based on evaluation of a line x tester set of 36 hybrids (F_1's) and their 15 parents along with 2 checks (CSR 43 and FL 478) for nine traits. The analysis of variance for treatments, parents and crosses was highly significant for all the traits indicating the existence of sufficient variability in the treatments, parents and crosses for all the traits. The dominance variance was more then additive variance. In general, maximum contribution to the total variance was due to females higher than due to males for all the traits except days to 50% flowering and L/B ratio. Among the parents, best genotype was IR55179-3B-11-3 which exhibited significant gca effect for grain yield plant^{-1}, indicating the involvement of additive gene action for yield and component traits. Among the crosses the best hybrids was Narendra Usar Dhan 2009 x NDRK 50026 which exhibited significant sca effect for grain yield plant^{-1}, indicating the preponderance of non-additive gene action for yield and its contributing traits. Results revealed that (σ^2 s) was more than (σ^2 g), degree of dominance > 1 and general predictability ratio < 1 in all the traits, indicating the preponderance of non-additive gene action, emphasizing heterosis breeding for rice improvement under salt affected soil.***

Keywords: Gene action, general combining ability and specific combining ability, rice (*Oryza sativa* L.), sodic soil.

Abbreviations

PBTP = Panicle bearing tillers plant^{-1}, **PL** = Panicle length (cm) **SP** = Spikelets panicle^{-1}, **SF** = Spikelet fertility (%), **BYP** = Biological yield plant^{-1}, **GYP** = Grain yield plant^{-1}, **HI** = Harvest index, **TW** = Test weight (g) **LBR** = Length: breadth ratio, **NUD** = Narendra Usar Dhan. ***gca*** = general combining ability, ***sca*** = specific combining ability.

1. Introduction

Rice is most important food crop of the world and it has been estimated that half the world's population subsists wholly or partially on rice. Ninety percent of the world crop is grown and consumed in Asia. American consumption, although increasing, is still only about 25 lb (11 kg) per person annually, as compared with 200 to 400 lb (90–181 kg) per person in parts of Asia. Rice is the only major cereal crop that is primarily consumed by humans directly as harvested, and only wheat and corn are produced in comparable quantity. Plant breeders at the International Rice Research Institute in the Philippines, attempting to keep pace with demand from a burgeoning world population, have repeatedly developed improved varieties of "miracle rice" that allow farmers to increase crop yields substantially. Studies have shown that rice yields are adversely affected by warmer nighttime temperatures, leading to concerns about the effects that global warming may have on rice crops. Brown rice has a greater food value than white, since the outer brown coatings contain the proteins and minerals; the white endosperm is chiefly carbohydrate. As a food rice is low in fat and (compared with other cereal grains) in protein. The miracle rices have grains richer in protein than the old varieties. Rice provides 21% of global human per capita energy and 15% of per capita protein. Although rice protein ranks high in nutritional quality among cereals, protein content is modest. Rice also provides minerals, vitamins, and fiber, although all constituents except carbohydrates are reduced by milling. For the development of high yielding pure line as well as hybrid varieties in rice or any crop, the information on various genetic aspects of important plant characters is essential for planning and execution of a successful breeding programme. The understanding of gene actions involved in expression of important plant characters and direct and indirect selection parameters of agronomically important traits help in deciding the type of variety to be developed and the breeding methodology to be followed in a particular situation. In order to develop high yielding pure line or hybrid varieties, it is essential to screen germplasm lines for combining ability. The information provided by combining ability analysis not only helps in discriminating the superior parents for use in hybridization programme and identification of crosses of higher genetic worth for further exploitation but also reveals the nature of gene action governing the characters. Breeding strategies based on hybrid production require a high level of heterosis as well as the specific combining ability (SCA) of crosses. One of the main problems of plant breeders for improving high yielding varieties is to select good parents and crosses. Line x tester analysis is one of the most powerful tools for estimating the general combining ability (GCA) of parents and selecting of desirable parents and crosses with high SCA for the exploitation of heterosis. Significant GCA and SCA for yield and yield components were also reported by Borgohain and Sarma (1998). These researchers showed a high GCA to SCA ratio for grain yield/plant, plant height and days to 50% flowering, that indicated higher share of additive gene action than non-additive gene action.

2. Materials and Methods

The research was conducted in the experimental area of the Genetics and Plant Breeding Research Farm of Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad (U. P.) during *kharif* seasons of 2013. The physic chemical characteristics of the soil was PH=9.1; EC=3.2; ESP=41.0. The experimental materials of rice for this investigation comprised of three testers *viz*., NDRK-50026, Narendra Usar Dhan 3 and Narendra Usar Dhan 2008 were used as male lines and twelve diverse salinity and alkalinity resistant/ tolerant rice varieties/ genotypes i.e., Improved PB 1, Pusa Basmati 1, Jaya, Narendra Usar Dhan 2009, Narendra Usar Dhan 2, FL 449 (IR 66946-3R-149-1-1), IR 11T164, IR 11T159, CSR 28, IR 55179-3B-11-3, NDRK 5026-1R, IR 58025 B were used as female lines and 36 crosses obtained through crossing in a **"line × tester"** mating design (Kempthorne, 1957). A total set of 53 genotypes were grown in *Kharif* 2013 and evaluated along with their parental lines and two checks (CSR 43 and FL 478) varieties in a Randomized Block Design with three replications. The observations were recorded for nine characters *viz;* panicle length (cm), panicle bearing tillers plant^{-1}, spikelets panicle^{-1}, spikelet fertility (%),biological yield plant^{-1} (g), L/ B ratio, harvest index (%), test weight (g) and grain yield plant^{-1}(g).

3. Results

The estimates of greater components (σ^2_A and σ^2_D), degree of dominance, and predictability ratio are given in Tables 1 and 2. The estimates of *sca* variance (σ^2_{sca}) was found higher than the *gca* variance (σ^2_{gca}) for majority of the characters, except L/B ratio. Thus, except of L/B ratio indicating the predominance of non-additive gene action. Degree of dominance was higher than the unity (>1) for all the traits, except spikelets panicle^{-1} and L/B ratio indicating the presence of over dominance gene action. The highest magnitude of degree of dominance was recorded for grain yield plant^{-1} (5.35%), L/B ratio (4.68%), harvest index (4.41%), biological yield plant^{-1} (2.71%) and spikelet fertility (2.23%), panicle length (1.73%), panicle bearing tillers/ plant (1.53%) and test weight (1.24%). Dominance variance (σ^2_D) was greater than additive variance (σ^2_A) for majority of the traits, except spikelets panicle^{-1} and L/B ratio. The combining ability analysis was carried out for nine traits *viz*., panicle length (cm), panicle bearing tillers plant^{-1}, spikelets panicle^{-1}, spikelet fertility, biological yield plant^{-1}, L/B ratio, harvest index, test weight (g) and grain yield plant^{-1}. The details of the analysis are given in Table 3and 4. The analysis of variance (Table 2) for combining ability revealed that the variation among lines (females) for two characters *viz;* spikelets panicle^{-1} and test weight were highly significant. The variation among testers (males) was highly significant for only one character *viz*; L/B ratio. The significance of mean square due to line × tester for all traits provides a direct test indicating that (i) non-additive variance and (ii) combining ability contributed heavily in the expression of these traits interaction between females and males was also significant for all the characters. The estimates of general combining ability (*gca*) effects of 15 parents and specific combining ability (*sca*) effects of 36 crosses nine traits are presented in Table 3 and 4, respectively. The male line, NDRK 50026 (0.55) and female lines, Jaya (0.85), IR-11T159 (2.21), IR55179-3B-11-3 (4.76) and IR58025B (0.72) showed significant positive *gca* effects for grain yield plant^{-1}. Among the crosses, manifestation of significant positive *sca* effects in order of performance were obtained from the Narendra Usar Dhan 2009 x NDRK 50026 (6.74), Jaya x Narendra Usar Dhan 2008 (4.61), IR-11T164 x Narendra Usar Dhan 2008 (3.69), CSR 28 x NDRK 50026 (3.49), Jaya x Narendra Usar Dhan 3 (2.06), Pusa Basmati 1 x Narendra Usar Dhan 2008 (1.89), Improved Pusa Basmati 1 x Narendra Usar Dhan 3 (1.81), IR-11T159 x Narendra Usar Dhan 3 (1.54), IR55179-3B-11-3 x Narendra Usar Dhan 3 (1.45), IR58025 B x NDRK 50026 (1.81), and FL 449 x Narendra Usar Dhan 3 (1.13) were found good specific combiners for grain yield plant^{-1}.

Table 1: Estimates of genetic components of variance among different traits in rice

Trait	*Genetic components of variance*	
	Additive variance (σ^2_A)	*Dominance variance* (σ^2_D)
Panicle length (cm)	0.81	2.43
Panicle bearing Tillers per plant	2.01	4.75
Spikelets per panicle	321.82	288.22
Spikelet fertility (%)	0.58	2.94
Biological yield per plant (g)	8.25	61.03
Grain yield per plant (g)	@	10.72
Harvest index (%)	0.36	7.18
Test weight (g)	0.94	1.46
L/B ratio	0.76	0.20

@ = Negetive value.

4. Discussion

Degree of dominance was higher than the unity (>1) dominance for majority of the characters, except spikelets panicle-1 and L/B ratio indicating the presence of over dominance. These findings showed that non-additive gene action had greater role in the inheritance of these traits as reported earlier by Kiran et al. (2012) and Warkad et al. (2013). They found that yield traits were governed by non-additive gene action. Analysis of variance for combining ability indicated that mean squares due to lines (female) were highly significant for two characters viz; spikelets panicle^{-1} and test weight, indicating normal genetic diversity among the lines, thus greater contribution by these characters towards combining ability. The variation among testers (males) was highly significant for only one character viz; L/B ratio. The females x males interaction component also emerged significant for all the traits, which proved that the specific combining ability contributed more in the expression of the traits. The higher magnitude of sca than gca variance and greater values of degree of dominance were observed in mostly 9 characters indicating greater importance of non-additive gene actions for these traits. The high estimates of sca variances (biological yield plant^{-1}, spikelets panicle^{-1}) are more desirable in the present context as female lines taken in present investigation. The present finding

Table 2: Analysis of variance for combining ability following lines and testers among different traits in rice

Source of variation	*df*	*Panicle length (cm)*	*Panicle bearing Tillers per plant*	*Spikelets per panicle*	*Spikelet fertility (%)*	*Biological yield per plant (g)*	*Grain yield per plant (g)*	*Harvest index (%)*	*Test weight (g)*	*L/B ratio*
Lines	11	294.62*	12.37	6366.98**	21.78	192.93	35.92	16.97	29.17**	1.80
Testers	2	241.96	63.90	2669.37	14.06	362.53	20.91	37.44	1.76	16.93**
Lines × Testers	22	79.83**	15.43**	897.65**	11.3**	184.83**	32.61**	23.05**	4.83**	0.79**
Error	70	1.16	1.18	27.73	2.89	1.53	0.49	1.64	0.50	0.18
Variance GCA		8.37	1.00	160.91	0.29	4.12	-0.18	0.18	0.47	0.38
Variance SCA		26.19	4.75	288.22	2.94	61.03	10.72	7.18	1.46	0.20
Degree of Dominance		1.25	1.53	0.94	2.23	2.71	5.35	4.41	1.24	0.52
Predictability Ratio		0.38	0.29	0.52	0.16	0.11	-0.03	0.04	0.39	0.79

**,*= Significant at 5% and 1% probability levels, respectively.

Table 3: Estimates of general combining ability (GCA) effects of parents among different traits in rice

Parents	*Panicle length (cm)*	*Panicle bearing Tillers per plant*	*Spikelets per panicle*	*Spikelet fertility (%)*	*Biological yield per plant (g)*	*Grain yield per plant (g)*	*Harvest index (%)*	*Test weight (g)*	*L/B ratio*
Lines									
Imp.PB 1	-1.06**	-2.37**	43.98**	0.81	-2.24**	-1.02**	0.07	-3.43**	-0.45*
Pusa Basmati 1	0.37	-0.04	27.64**	-2.62**	-1.02	-0.88**	-0.76	-2.99**	0.37
Jaya	0.32	-0.81	-18.24**	2.25**	0.23	0.85**	1.56**	0.81**	0.53**
NDRK 2009	-0.31	-0.70	36.87**	-0.74	-0.80	-1.01**	-3.67**	1.57**	0.41*
NUD 2	0.27	0.52	14.98**	-0.52	1.52**	0.41	0.07	0.29	-0.35
IR-11T164	1.1**	-0.15	-20.12**	-0.19	-4.07**	-1.25**	0.98	0.46	0.74**
IR-11T159	-0.55	0.30	-22.35**	0.37	4.98**	2.21**	0.69	1.48**	-0.64**
IR55179-3B-11-3	-1.42**	1.96**	-13.46**	2.48**	11.55**	4.76**	0.31	-0.85**	-0.07
IR58025B	0.11	1.96**	3.20	0.59	0.35	0.72*	1.43**	2.62**	-0.44*
CSR 28	0.15	-0.15	-27.46**	0.26	-3.79**	-1.95**	-0.75	-0.89**	0.20
NDRK 5026	1.6**	-0.04	9.87**	-2.51**	-6.06**	-2.55**	-0.04	0.04	-0.25
FL 449	-0.57	-0.48	-34.9**	-0.19	-0.64	-0.28	0.10	0.89**	-0.06
SE(g) Line	0.22	0.36	1.91	0.52	0.43	0.22	0.40	0.21	0.14
SE(gi-gj) Line	0.31	0.50	2.70	0.74	0.61	0.31	0.57	0.30	0.20
CD5%	0.44	0.72	3.82	1.04	0.87	0.44	0.81	0.43	0.28
CD1%	0.58	0.95	5.06	1.38	1.15	0.59	1.08	0.57	0.37
Testers									
NDRK 50026	-0.8**	1.21**	-0.80	-0.71*	1.78**	0.55**	-0.14	0.22	-0.53
NUD 3	-0.12	-1.42**	8.98**	0.26	-3.66**	-0.86**	1.08**	-0.22	0.77**
NUD 2008	0.92**	0.21	-8.18**	0.45	1.87**	0.31*	-0.94**	-0.01	-0.23*
SE(g) Tester	0.11	0.18	0.95	0.26	0.21	0.11	0.20	0.10	0.07
SE(gi-gj) Tester	0.15	0.25	1.35	0.37	0.30	0.15	0.28	0.15	0.10
CD5%	0.22	0.36	1.91	0.52	0.44	0.22	0.41	0.22	0.14
CD1%	0.29	0.47	2.53	0.69	0.57	0.29	0.54	0.28	0.18

**,*= Significant at 5% and 1% probability levels, respectively.

Table 4: The mean performance of top ten high yielding genotypes in rice for other characters

Genotypes	High mean performance for other characters
Narendra Usar Dhan 2 (21.67 g)	Plant bearing tillers plant^{-1} and harvest-index.
IR 55179-3B-11-3 (21.43 g)	Plant bearing tillers plant^{-1}, and spikelet fertility.
IR 11T159 (19.96 g)	Panicle length, spikelet fertility, harvest Index, test weight and L/B ratio.
CSR 28 (19.63 g)	Flag leaf area, plant height, biological yield plant^{-1}, L/B ratio and chlorophyll content.
Jaya (19.46 g)	Flag leaf area, spikelets fertility and harvest-index.
IR58025B (18.73 g)	Test weight and L/B ratio.
NUD 3 (18.60 g)	Plant bearing tillers plant^{-1}, spikelets panicle^{-1}, biological yield plant^{-1} and chlorophyll content.
FL 449 (18.20 g)	Flag leaf area and test weight.
NDRK 50026 (17.40 g)	Panicle length, test weight and chlorophyll content.
Improved Pusa Basmati 1 (17.26 g)	Panicle length, plant bearing tillers plant^{-1}, spikelets panicle^{-1}, spikelets fertility and biological yield plant^{-1}.

Table 5.5: Top ten crosses based on mean performance, heterobeltiosis and standard heterosis (CSR 43 & FL 478) for grain yield plant^{-1}

S. No.	Crosses	*per se* Performance (g)	*gca* effects of parents	Heterosis over better-parent	Heterosis over CSR 43	Heterosis over FL 478
1	Narendra Usar Dhan 2009 x NDRK 50026	25.20	$H^- \times H^+$	44.88^{**}	49.41^{**}	44.55^{**}
2	Jaya x Narendra Usar Dhan 2008	24.70	$H^+ \times L^+$	26.88^{**}	46.45^{**}	41.68^{**}
3	IR55179-3B-11-3 x Narendra Usar Dhan 3	24.26	$H^+ \times H^-$	13.22^{**}	43.87^{**}	39.20^{**}
4	IR55179-3B-11-3 x Narendra Usar Dhan 2008	24.06	$H^+ \times L^+$	12.29^{**}	42.10^{**}	38.05^{**}
5	IR55179-3B-11-3 x NDRK 50026	22.70	$H^- \times H^+$	5.91^{*}	34.58^{**}	20.21^{**}
6	IR-11T159 x NDRK 50026	22.13	$H^+ \times H^+$	12.73^{**}	31.23^{**}	26.96^{**}
7	IR58025B x NDRK 50026	22.00	$L^+ \times H^+$	17.44^{**}	30.43^{**}	26.20^{**}
8	IR-11T159 x Narendra Usar Dhan 3	21.80	$H^+ \times H^-$	11.04^{**}	29.25^{**}	25.05^{**}
9	IR-11T164 x Narendra Usar Dhan 2008	21.66	$H^- \times H^+$	25.48^{**}	28.46^{**}	24.28^{**}
10	CSR 28 x NDRK 50026	21.00	$H^- \times H^+$	5.18	24.51^{**}	20.46^{**}

Note: H^+ = High significant and positive, H^- = High significant and negative, L^+= significant and positive

are in full consonance with the predominance of non-additive gene action as supported by Ghosh (1993) for panicle number plant^{-1}, grains panicle^{-1}, spikelets panicle^{-1}, 1000-grain weight, harvest index and yield plant^{-1}; Verma *et al.* (1995), and Bhanumathy *et al.* (2003) for plant height, panicle plant^{-1}, grain weight panicle^{-1} and yield plant^{-1}; Punitha *et al.* (2004), Rosamma and Vijayakumar (2005) for grain yield plant^{-1}, panicles plant^{-1} and panicle length; and Singh *et al.* (2005) reported predominance of non-additive gene action for biological yield and number of effective tiller plant^{-1}. Meanwhile, contrary to these, the pre-dominant roles of additive gene effects have also been observed for yield and its component traits Vijayakumar *et al.* (1994), Sharma *et al.* (1996) and Lavanya (2000). The information regarding general combining ability (*gca*) effects of the parent is of prime importance as it helps in successfully prediction of genetic potentiality of crosses, which provid desirable individuals in segregating population of self pollinated crops. However, it was noted that, IR55179-3B-11-3, IR 11T159, Jaya, IR 58025 B and NDRK 50026 were good general combiners for grain yield plant^{-1}. The line IR55179-3B-11-3 was also good general combiner for panicle bearing tillers plant^{-1}, spikelet fertility (%) and biological yield plant^{-1}. The *gca* effects together with relative *per se* performance is useful for selecting desirable parent with favorable genes for different components of yield. The *per se* performance of the parents and their *gca* effects for all the traits were almost in close correspondence which indicated that the *per se* performance of the parent for these traits could possibly be taken as a critera for selection of parent. However, the results of present findings are in agreement with the nature of gene action but not for magnitude of gene action. Lines IR55179-3B-11-3, IR 11T159 and Jaya were good general combiners for grian yield plant^{-1} on the basis of *per se* performance and *gca* effects. In general, specific combining ability is associated with interaction effects, which may be due to dominance and epistatic components of variation that are non-fixable in nature. Hence, it can be utilized in generation like F_1 in developing good F_1 hybrid. In the present investigation, crosses Narendra Usar Dhan 2009 x NDRK 50026, Jaya x Narendra Usar Dhan 2008, IR11T164 x Narendra Usar Dhan 2008, CSR 28 x NDRK 50026 and Jaya x Narendra Usar Dhan 3 good specific combiners for grain yield plant^{-1}. The cross Narendra Usar Dhan 2009 x NDRK 50026 was also good specific combiner for Spikelets panicle^{-1}, Biological yield plant^{-1} (g), Harvest index (%) and L/B ratio. In general, the crosses showing significant and desirable *sca* effects were associated with better *per se* performance for respective traits. However, the crosses having high *sca* effects in desirable direction did not always have high mean performance for the characters in question. Thus, the *sca* effect of the crosses may not be directly related to their *per se* performance. This may be attributed to the *per se* performance is a realized value, whereas, *sca* effect is an estimate of F_1 performance over parental one. Therefore, both *per se* performance along with *sca* effects should be considered for evaluating the superiority of a cross although the former may be more important if development of F_1 hybrids is the ultimate objective. The top ten promising crosses having desirable *per se* performance along with significant *sca* effects for grain yield plant^{-1} were Narendra Usar Dhan 2009 x NDRK 50026, Jaya x Narendra Usar Dhan 2008, IR55179-3B-11-3 x Narendra Usar Dhan 3, IR55179-3B-11-3 x Narendra Usar Dhan 2008, IR55179-3B-11-3 x NDRK 50026, IR-11T159 x NDRK 50026, IR58025B x NDRK 50026, IR-11T159 x Narendra Usar Dhan 3 , IR-11T164 x Narendra Usar Dhan 2008 and CSR 28 x NDRK 50026, the majority of which possesses high x high general combiners (seven combinations) while only three combinations had high x low general combiners. These hybrids emphasizes heterosis breeding for commercial exploitation in rice improvement under salt effected soil.

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