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Combining Ability Studies in Rice (*Oryza sativa* L.) Under Salinized Soil Conditions

T. Mahmood, G. Shabbir, M. Sarfraz, M. Sadiq, M. K. Bhatti, S. M. Mehdi, M. Jamil and G. Hassan
Soil Salinity Research Institute, Pindi Bhattian, Punjab, Pakistan

Abstract: An experiment involving 8 x 8 diallel crossing was conducted with rice to investigate the nature of gene action in governing the various traits studied and to explore the combining ability behaviour of various genotypes used in the studies. Twelve agro-physiological characters were included in the study in F_1 generation. High additive effects were recorded for plant height, panicle length, productive tillers/plant and primary branches/panicle. The non-additive effects were more pronounced for panicle fertility, days to maturity, shoot dry weight, paddy yield; Na, Ca and K contents of the shoot and K/Na ratio of the shoot. Out of the height parental lines/varieties studied Jhona-349 and Bas-385, respectively, proved to be the best general and specific combiners in the experiment under salinized soil conditions.

Key words: Diallel crossing, salinity, additive effects

Introduction

In Pakistan generally the saline sodic soils are under rice cultivation and here the area famous for rice production is called AKallar@ tract. Typically this tract has slight to moderate salinity and sodicity with high pH, partial water logging and poor structure. Further more, being a high delta crop as well as suitable to grow under flooded conditions, rice crop is the obvious choice during the soil reclamation, which helps quick leaching of salts from the root zone (Pearson *et al.*, 1966; Chabbra and Abrol, 1977; Aslam *et al.*, 1987; Chabbra, 1996). However, yield of Basmati rice or of coarse-grained IRRI varieties are only 45 and 39 percent, respectively, as compared to those from good land (Boje-Klein, 1986). Thus there is a tremendous scope of increasing production from the salt-affected soils.

The available information regarding genetic behaviour of different agro-physiological traits of rice is limited. Shanon and Akbar (1985) reported the feasibility of breeding of salt-tolerance in rice, as there was no antagonism between high yield and salttolerance. Experiments on the genetics of salt tolerance revealed that shoot length, Na and Ca content of shoot and the root and shoot dry weights showed significant additive effects with high degree of heritability. Genes controlling Na and Ca content were partially dominant, with at least three groups involved at the seedlings stage. Highly significant additive effects were observed for plant height, and yield/plant; and thus indicated high heritability values. Selection for shoot length, Na content of the shoots, shoot and root dry weight, plant height and plant yield were recommended when producing salt tolerant varieties (Akbar *et al.*, 1985). In another study, Mishra (1990) reported the preponderance of additive gene action in the stressed environments for plant height, total and fertile tillers/plant, grains/panicle, grain and straw/plant, days to 50% flowering, panicle weight and sterility percentage. Gregorio and Senadhira (1993) in their experiment on rice seedlings found that high K/Na ratio was governed by both additive and dominance gene effects. Present investigation was, therefore, set out to furnish information on combing ability in rice (*Oryza sativa* L.) for various agro-physiological characters in a 8 X 8 diallel cross experiment.

Materials and Methods

The experiment was conducted at soil salinity research institute, Pindi Bhattian. The experimental material comprised of 8 X 8 complete diallel cross seed. The F_1 alongwith eight parents were grown in salinized soil. The following cultivars/lines were as parents: Bas- 370, Bas- 385, Super Bas, F-9, NR- 1, IR- 6, NIAB - 6, Jhona- 349.

A soil of the required salinity-sodicity level (EC_e 7.75 d S / mG), SAR 28 (m mol lG^{1})$^{1/2}$, pH 9.0) was selected from a salt-affected field. The soil was filled into the salinity blocks. The leaching in the blocks was stopped by lining the bed of the blocks by a polythene sheet; a uniform saline soil column of ten inches depth was maintained in the blocks. Three such blocks were built each serving as one replication. Forty days old nursery was transplanted into the blocks. Single plant was transplanted per hill. Twelve plants/replication with plant to plant distance 23 cm were maintained for each of the eight parents and F_1. The data were recorded on ten plants in each of the entries of the parents and F_1. The characters included in the data were plant height, panicle length, panicle fertility, productive tillers, primary branches/panicle, days to maturity, shoot dry weight, paddy yield; Na, Ca and K content of the shoot and K/Na ratio of the shoot. The plant samples were analyzed using nitric acid and per chloric acid method (Staff, 1968). The data obtained for different traits were subjected to ordinary analyses of variance technique (Steel and Torrie, 1980), inorder to determine the significance of genotype differences. Further analyses for combining ability effects were performed by using Griffings (1956) Method I, Model II.

Results and Discussion

Combining ability analyses: Hybridization breeding for desirable genotypes always demands the parental genotypes having efficacy to combine and give rise to improved genotypic combinations. From breeding viewpoint only those parental cultivars/genotypes are considered to be superior which prove to be good donor and better combiner for desirable traits. Breeding for salinity/sodicity stress, due to its urgency, particularly in Pakistan, needs the best combiners and desirable donors, which could be helpful in evolving desirable genotypes for salinity/sodicity stress conditions. The significant differences among genotypes allowed the data for further analysis. The total genetic variability observed in the analysis for each character was partitioned into its components i.e., general, specific combining ability and reciprocal effects as defined by Griffing (1956). The components of variances are shown in Table 1. The estimates of general combining ablitiy (G. C. A.) for different parental genotypes are presented in Table 2 and estimates of specific comninind ablitiy (S. C. A.) For different cross combinations are given in Table 3. The components of variation for all the characters were cpmputed to have numerical estimates of heritable for plant heigth, panicle length, productive tillers, primary branches/pancile and paddy yield. This unfurled a high percentage of additive variation out of the total genetic variation for these characters. Additive variation (in % age) foe the above characters was 90.01, 74.63, 86.87,100.01 and 42.87, respectively. As for as S. C. A. Is concerned , high values were obtained for panicle fertility days to maturity, ahoot dry weigth,paddy yield, Na, Ca and K content of the sjoot alongwith K/Na, ratio of the shoot. High S. C. A. value indicated high non-additive effect for these characters. The non-additive variation (in %age) foe these characters was 73.80, 88.52, 113.35, 57.13, 91.66, 86.76, 108.11 and 115.41, respectively.

General combining ability effects: The general combining ability effects for different parental genotypes and critical differences (CD) for each trait are given in Table 2. Highest positive G.C.A. effects for plant height were observed in Bas-370 whereas the lowest negative G.C.A. effects were found for NIAB-6. For panicle length the greatest G.C.A. effects were exhibited by Bas-385 and lowest G.C.A. effects were shown by NIAB-6. In case of panicle

Table 1: Estimates of components of various characters/traits of rice (*Oryza sativa* L.) In a 8 X 8 diallel cross experiment (F_1 generation).

Traits	GCA) (df = 7)	SCA (df = 28)	Reciprocals (df = 28)	Error (df = 126)	Total	Additive Variance	Non-Additive Variance (%)
Height of the plant	100.453	22.310	5.896	29.278	157.397	200.907 (90.01)*	22.310 (9.99)*
Panicle length	1.724	1.172	0.133	0.917	3.946	3.448	1.172
Panicle fertility	135.794	763.355	29.113	24.217	962.182	270.994 (26.20)	763.355 (73.80)
Productive tillers	1.924	0.582	2.162	7.582	12.250	3.849 (86.87)	0.582 (13.13)
Primary branches/panicle	0.139	-0.0002	-0.0920	0.378	0.425	0.278 (100.01)	-0.0002 (-0.01)
Days to maturity	6.792	104.728	2.154	18.229	127.595	13.585 (11.48)	104.729 (88.52)
Shoot dry weight	-0.596	61.060	31.577	62.276	151.317	-7.191 (-13.35)	61.060 (113.35)
Paddy Yield	23.592	62.885	29.754	10.802	127.034	47.184 (42.87)	62.885 (57.13)
Na content of the shoot	0.001	0.0221	0.0051	0.0418	0.0700	0.0020 (8.34)	0.0221 (91.66)
Ca content of the shoot	0.00006	0.00083	0.00029	0.00094	0.00212	0.0001 (13.24)	0.0008 (86.76)
K content of the shoot	-0.00045	0.0120	0.00497	0.00753	0.02405	-0.0009 (-8.11)	0.0120 (108.11)
K/Na content of the shoot	-0.00511	0.00764	0.00339	0.0117	0.02222	-0.0010 (-15.41)	0.0076 (115.41)

*Values given in parenthesis are the percentage of the total genetic variance.

Table 2: Estimates of general combining ability (G.C.A.) effects for various characters of rice (*Oryza sativa* L.) in a 8 X 8 diallel cross experiment (F_1 generation).

S.O.V.	Plant Hight	Panicle Length	Panicle Fertility	Productive Tillers	Primary Braches/	Days to Maturity	Shoot dry Weight	paddy Yield	Shoot Content Na	ca	K	K/Na
F-9	3.742	0.352	-3.640	1.102	-0.182	-0.390	2.245	-1.036	-0.039	-0.006	0.022	0.058
Bas-370	10.103	1.622	6.075	-1.988	0.255	2.227	-2.323	-0.406	-0.124	-0.005	-0.019	0.028
Bas-385	3.948	1.837	10.021	-0.278	0.701	-1.578	-1.296	3.715	-0.004	0.027	-0.059	-0.024
Super Bas	-7.649	-0.218	5.674	0.532	-0.480	-1.106	-4.015	0.541	0.001	0.006	0.007	0.006
NIAB-6	-14.434	-1.990	-25.857	0.761	-0.483	5.543	-1.677	-8.302	-0.021	-0.001	-0.003	0.004
NR-1	9.522	0.517	10.996	-2.676	0.096	1.487	2.210	1.886	0.042	-0.019	0.041	0.001
IR-6	-13.345	-1.578	-18.520	0.675	-0.142	3.026	1.687	-6.065	-0.006	0.013	-0.035	-0.036
Jhona-349	8.112	-0.583	15.252	1.873	0.236	-9.208	3.169	9.666	0.152	-0.006	0.046	0.037
For CD (gi--gj)	3.749	0.664	4.054	1.908	0.426	2.959	5.469	2.277	0.142	0.021	0.060	0.075

Table 3: Estimates of specific combining ability (S.C.A.) effects for various characters of rice (*Oryza sativa* L.) in a 8 X 8 diallel cross experiment (f_1 generation).

Cross combination	Plant Height	Panicle Length	Panicle Fertility	Productive Tillers	Primary Branches/ Panicle	Days to Maturity	Shoot dry Weight	Paddy Yield	Shoot Contents Na	Ca	K	K/Na
F-9xBas-370	6.347	1.653	13.360	0.742	0.388	-6.027	3.210	7.757	0.305	0.009	0.115	0.219
F-9xBas-385	5.569	0.745	25.969	0.253	0.038	-5.775	-4.240	3.858	0.082	0.016	0.122	0.179
F-9xSuper Bas	6.695	0.355	22.259	0.554	0.110	-9.527	-6.181	1.935	-0.045	0.020	0.084	0.021
F-9xNIAB-6	-1.657	-0.769	-19.236	-1.424	-0.518	3.463	5.686	-5.109	-0.092	-0.036	0.140	0.127
F-9xNR-1	-0.390	0.407	-12.338	-1.402	-0.024	4.658	-3.605	-5.802	0.063	-0.012	-0.064	-0.087
F-9xIR-6	-4.859	-0.904	-25.380	-0.420	-0.156	9.786	13.854	-6.086	-0.107	0.026	-0.069	-0.016
F-9xJhona-349	1.627	-0.938	14.349	-1.896	-0.073	-1.592	-7.675	-2.916	0.042	0.005	-0.055	-0.069
Bas-370xBas-385	-0.152	-0.113	12.502	0.011	-0.511	-4.227	-7.517	3.330	-0.011	0.024	-0.144	-0.127
Bas-370xSuper Bas	0.860	1.464	19.213	-0.966	0.021	-7.086	-11.303	-1.462	-0.110	-0.002	-0.138	-0.054
Bas-370xNIAB-6	-2.241	-1.231	-30.146	1.722	0.441	10.929	15.282	-9.062	-0.325	-0.051	-0.062	0.145
Bas-370xNR-1	-1.388	-1.246	-9.778	1.073	-0.517	2.650	7.576	2.567	0.118	0.029	0.198	0.070
Bas-370xIR-6	0.390	-0.900	-34.817	-1.720	0.297	10.002	0.721	-5.676	0.021	-0.018	-0.063	-0.063
Bas-370xJhona-349	2.072	0.057	12.799	-0.641	0.020	4.512	-0.961	0.710	0.088	0.048	0.108	0.023
Bas-385xSuper Bas	-0.760	0.705	14.265	-2.123	0.409	0.882	3.616	-2.627	-0.256	-0.020	-0.106	0.017
Bas-385xNIAB-6	-7.201	-0.648	-32.759	-0.522	0.317	16.623	10.569	-8.929	0.268	-0.014	-0.096	-0.151
Bas-385xNR-1	5.568	0.438	-4.656	-0.803	0.565	0.152	0.054	-2.654	0.169	-0.048	-0.011	-0.087
Bas-385xIR-6	-4.175	-2.185	-27.205	3.290	-0.407	4.975	8.474	0.136	0.145	-0.023	-0.094	-0.102
Bas-385xJhona-349	5.966	2.032	4.298	-0.350	0.193	-6.784	-6.640	3.230	-0.369	0.049	0.008	0.123
Super BasxNIAB-6	-5.767	-2.042	-30.690	3.312	-0.704	13.762	9.353	0.311	0.048	-0.030	-0.052	-0.078
Super BasxNR-1	2.886	0.004	-1.653	3.610	0.200	3.263	10.996	4.991	-0.032	0.032	-0.081	-0.023
Super BasxIR-6	-5.633	-0.727	-35.264	-2.351	-0.100	14.447	2.014	-10.231	-0.008	0.026	0.037	0.056
Super BasxJhona-349	9.883	0.929	2.534	3.393	0.895	-6.875	7.337	14.800	0.456	-0.011	0.001	-0.089
NIAB-6xNR-1	4.950	-0.139	-0.634	-4.063	0.137	-2.165	-13.003	-5.711	-0.186	-0.013	0.072	0.110
NIAB-6xIR-6	7.651	1.956	57.284	-1.193	0.239	-24.203	-18.486	11.536	0.130	0.031	0.149	0.040
NIAB-6xJhona-349	2.855	-0.102	-24.267	-0.055	-0.566	8.754	1.742	-9.595	-0.105	0.006	-0.064	-0.024
NR-1xIR-6	6.806	1.383	19.874	1.415	0.290	-0.425	3.590	5.919	-0.156	0.051	0.101	0.124
NR-1xJhona-349	-11.983	0.089	-10.660	0.187	-0.517	2.530	0.463	-4.661	-0.318	-0.039	-0.064	0.064
IR-6 X Jhona-349	-0.784	-0.295	10.725	1.031	-0.429	9.103	9.271	-9.205	0.041	-0.044	0.114	0.051
CD (g_i B g_j)	9.920	1.756	9.929	5.048	1.126	7.828	14.468	6.026	0.375	0.0562	0.159	0.198
CD (g_i B g_j)	9.185	1.626	4.674	4.674	1.043	7.247	13.395	5.579	0.347	0.0520	0.147	0.184

fertility, the highest G.C.A. effects were exhibited by Jhona-349 whereas the lowest negative G.C.A. effects were exhibited by NIAB 6.

For productive tillers/plant, the maximal positive G.C.A. effects were displayed by Jhona-349 and lowest negative G.C.A. effects were shown by NR-1. As far as primary branches/panicle are concerned, the paramount positive G.C.A. effects were observed for Bas-385 and the lowest negative G.C.A. effects were exhibited by NIAB-6. As regards the days to maturity, the highest positive G.C.A. effects were divulged by NIAB-6 and the smallest negative effects were exhibited by Jhona-349. For shoot dry weight the greatest positive G.C.A. effects were unfurled by Jhona-349 and lowest negative G.C.A. effects were exhibited by Super Bas. As far as paddy yield is concerned, the highest G.C.A. effects were divulged by Jhona-349 and the lowest negative effects were exhibited by NIAB-6. For Na content of the shoot, the highest positive G.C.A. effects were observed for jhona-349 and the lowest negative G.C.A. effects were shown by IR-6. As regard to Ca content of the shoot, highest positive G.C.A. effects were shown by Bas-385 and the lowest negative G.C.A. effects were exhibited by Jhona-349 and F-9. As for as K content of the shoot is concerned, the paramount positive G.C.A. effects were shown by Jhona-349 and smallest negative G.C.A. effects were flaunted by Bas-385. In case of K/Na ratio of the shoot, the highest positive G.C.A. effects were exhibited by F-9 and the be used as donor parents in hybridization. Mosina (1986) and Jones (1985) also reported similar results. Narayanan and Rangasamy (1990) also reported the results of six parent diallel cross experiments they found significant additive and dominance gene effects for plant height, tiller number, panicle length, number of spikelets/panicle, thousand grain weight and dry matter accumulation under both normal and salinized conditions. Cations like Na, Ca, K and K/Na as salt tolerance parameters have been studied by many workers like Yeo and Flowers (1984), Yamanouchi *et al.* (1987) and Bui and Do (1988).

Specific combining ability effects: The estimates of S. C. A. are given in Table 3. As far as plant height is concerned the cross combination Super Bas X Jhona-349 performed the best and have the greatest S.C.A. effect. The lowest estimate of S.C.A. was found for NR-1 X Jhona-349. In case of panicle length, the highest S.C.A. effect was flaunted by cross combination Bas-385 X Jhona-349 while the lowest effect was shown by Bas-385 X IR-6. For panicle fertility, the maximal S.C.A. effect was divulged by the cross combination NIAB-6 X IR-6 and the lowest was shown by the combination Super Bas X IR-6.

As to productive tillers/plant, the highest S.C.A. effect was shown by the cross combination Super Bas X NR-1 while the lowest was exhibited by the cross combination NIAB-6 X Jhona-349. As far as primary branches/panicle are concerened, the highest estimate of S.C.A. was exhibited by Super Bas X Jhona-349 whereas the lowest by Super Bas X NIAB-6. For days to maturity, the maximal S.C.A. effect was shown by Super Bas X IR-6 and the lowest was divulged by NIAB-6 X IR-6. As far as shoot dry weight is concerned the highest S.C.A. effects were flaunted by Bas-370 X NIAB-6 and the minimal were exhibited by NIAB-6 X IR-6. For paddy yield, the highest S.C.A. effects were exhibited by the cross combination NIAB-6 X IR-6 and the lowest was shown by Super Bas X IR-6. In case of Na content of shoot, the highest S.C.A. effects were shown by the cross combination Super Bas X Jhona-349. As for as Ca content of the shoot is concerned the greatest S.C.A. effect was exhibited by the cross combination of NR-1 X IR-6 whereas, the lowest S.C.A. effect was shown by Bas-370 X NIAB-6. For K content of the shoot, the paramount S.C.A. effects were exhibited by Bas-370 X NR-1 and the lowest were shown by Bas-370 X Bas-385. In case of K/Na ratio of the shoot the highest S.C.A. effect was revealed by Bas-370 X NIAB-6 and the lowest S.C.A. effect was exhibited by the cross combination F-9 X Bas-370. With the assumptions that differences in general combining ability resulted primarily from differences in the additive gene effects, and that in specific combining ability effects were due to differences in non-additive gene effects, it was conspicuous from the material under the traits like height of the plant, panicle length, productive tillers and primary branches/panicle were controlled by additive genes and these characters could easily by manipulated for genetic improvement. The panicle fertility, shoot dry weight, paddy yield; Na, Ca and K content of the shoot and K/Na ratio were found to be controlled by non-additive effects indicating that their genetic improvement under salt stress environment was a tedious exercise. Similar findings were reported by Mishra (1990).

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