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COMBINING ABILITY STUDIES IN BREADWHEAT (*TRITICUM AESTIVUM* L. EM THELL) UNDER SALT STRESS ENVIRONMENTS

K. N. SINGH AND RAVISH CHATRATH

Division of Crop Improvement, Central Soil Salinity Research Institute Karnal 132001

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ABSTRACT

Combining ability for grain yield and other related characters under salt stress conditions was studied in a set of diallel crosses involving ten cultivars of breadwheat. Both additive and nonadditive gene effects were important in the inheritance of most of the traits. The parent varieties HD 2285, KRL 1-4 and PBW 65 and cross KRL 3-4 x KRL 1-4 had high gca and sca, respectively, and they could be utilized for further selection of high yielding progenies under salt stress conditions.

Key words *Triticum aestivum*, combining ability, salt stress.

Breeding for salt tolerance in wheat primarily depends on intensive hybridization using salt tolerant donors and high yielding commercial cultivars. To evolve an effective hybridization programme combining ability analysis is used to test the performance of parents in different cross combinations and characterize the nature and magnitude of gene effects in the expression of the quantitative traits. Singh et al. [1] and Singh and Rana [2] on the basis of combining ability effects identified superior combining parents which were subsequently used in the breeding programme with good results. Thus, the main objective of this experiment was to identify the best combining parent and their crosses, on the basis of their general and specific salt tolerant and high yielding wheat genotypes under saline conditions.

MATERIALS AND METHODS

Ten wheat varieties were crossed in diallel mating design without reciprocals. The parent varieties were Kharchia 65 from the Rajasthan, which is the most widely used salt tolerant genotype used in hybridization programmes all over the world; KRL 3-4 and

KRL 1-4, the salt tolerant and high yielding cultivars recently developed at the Central Soil Salinity Research Institute, Karnal; Pissi Local, a confirmed source of heat and drought tolerance; Sorawaki, a salt tolerant, low yielding tall variety from Pakistan; PBW 65, HD 2329, HD 2009, and HD 2285, the high yielding Indian varieties recently commercialized under normal soil conditions; and CIMK 2, a tissue culture derivative from CIMMYT showing mild salt tolerance.

The experiment with 45 F_1 and 10 parent varieties was conducted in randomized block design with three replications. Each entry had a single 1m long row and spaced 23 cm apart. Saline environment was created by four irrigations with saline water having an EC_{iw} (iw — irrigation water) of 30 dSm^{-1}. The first saline water irrigation was applied after 20 days of sowing. The four subsequent irrigations were given as and when required. Observations were recorded for grain yield and other related traits on five random selected plants per row and analysed following Griffing's Method 2, Model I [3].

RESULTS AND DISCUSSION

Analysis of variance for gca and sca (Table 1) indicated significant effects for all the characters studied under salt stress. Baker [4] suggested that the importance of general and specific combining ability should be assessed by estimating the components of variance and expressing them as $2\sigma^2g/(\sigma^2g/+\sigma^2s)$ ratio. The closer this ratio to unity the greater the magnitude to additive genetic effects. The ratio computed for all the characters (Table 1) showed that dominant gene effects were more important for grain yield and number of productive tillers per plant, while both additive and dominant gene effects were important for ear length, number of spikelets and grains per spike, and 1000-grain weight. For plant

Table 1. Analysis of variance (M.S.S.) for gca and sca for grain yield and other traits under high salt conditions in wheat

Source	d.f.	Grain yield per plant	Ear length	No. of spikelets per spike	No. of grains per spike	1000-grain weight	No. of productive tillers per plant	Plant height
Gca	9	7.38**	1.11**	3.25**	241.4**	113.4**	1.29**	779.7**
Sca	45	3.50**	0.29**	0.58**	24.7**	14.1**	0.88**	44.3**
Error	108	0.50	0.14**	0.32	4.9	3.9	0.16	15.0
σ^2g		0.57	0.08	0.24	19.7	9.1	0.09	63.7
σ^2s		3.00	0.14	0.26	19.8	10.1	0.71	29.3
$2\sigma^2g/(2\sigma^2g+\sigma^2s)$		0.28	0.53	0.65	0.7	0.6	0.20	0.8

*, **Significant at P = 0.05 and 0.01 levels, respectively.

height, additive gene effects were relatively more important. High estimates of sca variances (σ^2s) were observed for grain yield. The presence of repulsion phase linkage and linkage disequilibrium might have resulted in an over estimation of nonadditive component. Sokol and Baker [5] concluded that negative association between genes results in relatively larger estimates of sca variances. Under such situations population improvement by recurrent selection to accumulate desirable genes and breaking of undesirable linkages would be more appropriate.

The general combining ability effects of the parents (Table 2) indicated that varieties HD 2285 followed by KRL 1-4 and PBW 65 were the best general combiners for grain yield per plant. Similarly parents exhibiting high general combining ability for other traits were, KRL 1-4, HD 2285 and CIMK 2 for ear length; CIMK 2 and PBW 65 for spikelets/spike; PBW 65, CIMK 2 for grains/spike; HD 2285 and KRL 3-4 for 1000-grain weight; Kharchia 65 for productive tillers/plant; and HD 2009, HD 2329 and KRL 1-4 for plant height. Parents HD 2285, KRL 1-4, and PBW 65 proved to be high general combiners for grain yield along with other component characters. Parent HD 2285 was also good combiner for ear length and 1000-grain weight, KRL 1-4 for ear length, grains/spike and plant height while PBW 65 was also a good combiner for spikelets/spike and grains/spike.

Table 2. General combining ability effects of parent varieties for grain yield and other related under high salt conditions in wheat

Parent variety	Grain yield per plant	Ear length	No. of spikelets per spike	No. of grains per spike	1000-grain weight	No. of productive tillers per plant	Plant height
Kharchia 65	0.28	-0.41**	-0.46**	-3.63**	0.70	0.73**	9.78**
KRL 3-4	0.07	0.10	-0.38*	-0.78	2.17**	0.14	7.83**
KRL 1-4	0.53**	0.28**	0.24	3.07**	0.80	-0.12	-7.24**
Pissi Local	-0.32	-0.52**	-0.59**	-6.69**	0.62	0.23**	8.77**
Sorawaki	-1.07**	-0.36**	-0.20	-6.70**	-6.75**	0.05	8.96**
PBW 65	0.50**	0.14	0.70**	6.16**	0.28	-0.24**	-1.75
CIMK 2	0.02	0.25*	1.00**	5.04**	-2.50**	-0.14	-6.77**
HD 2329	-0.06	0.15	0.15	0.61	0.52	-0.33**	-8.75**
HD 2009	-0.57**	0.10	-0.30*	1.86**	-0.93	-0.39**	-9.54**
HD 2285	1.26**	0.27*	-0.16	1.07	5.08**	0.08	-1.31
S.E. (g_i)	0.19	0.10	0.15	0.61	0.54	0.11	1.06
S.E. (g_i-g_j)	0.29	0.15	0.23	0.90	0.81	0.33	4.47

*, **Significant at P= 0.05 and 0.01 levels, respectively.

The sca effects of the crosses for grain yield and other related characters are presented in Table 3. Crosses KRL 3-4 x KRL 1-4, Kharchia 65 x Sorawaki and Sorawaki x CIMK 2 had high sca effects for grain yield under high salinity conditions. No cross had high sca for all

Table 3. Crosses with significant sca effects for grain yield of wheat and other traits under high salt conditions

Character	Cross	Sca effect	Gca effect of parents	Character mean in F_1
Grain yield per plant (g)	KRL 3-4 x KRL 1-4	5.66	Medium x high	14.0
	Kharchia 65 x Sorawaki	2.89	Medium x low	9.2
	Sorawaki x CIMK 2	2.63	Low x medium	8.7
	Kharchia 65 x HD 2329	2.59	Medium x medium	10.6
	HD 2009 x HD 2285	2.56	Low x high	11.0
	Pissi Local x HD 2329	1.58	Medium x medium	9.0
	CIMK 2 x HD 2009	1.55	Medium x low	8.8
	S.E. (S_{ij})	0.58		
Ear length (cm)	Sorawaki x HD 2285	1.18	Low x high	10.9
	HD 2009 x HD 2285	1.06	Medium x high	11.3
	KRL 1-4 x HD 2009	0.98	High x medium	10.9
	S.E. (S_{ij})	0.31		
No. of spikelets per spike	Kharchia 65 x Sorawaki	1.82	Low x medium	18.8
	Pissi Local x HD 2009	1.19	Low x low	17.9
	S.E. (S_{ij})	0.52		
No. of grains per spike	KRL 3-4 x KRL 1-4	7.54	Medium x high	52.3
	Sorawaki x CIMK 2	6.05	Low x high	46.8
	KRL 1-4 x HD 2009	5.71	High x high	53.1
	KRL 3-4 x Sorawaki	5.04	Medium x low	40.0
	S.E. (S_{ij})	2.04		
1000-grain weight (g)	Sorawaki x HD 2285	6.05	Low x high	46.1
	CIMK 2 x HD 2285	4.97	Low x high	44.0
	CIMK 2 x HD 2009	4.95	Low x medium	43.3
	HD 2329 x HD 2009	4.67	Medium x medium	46.0
	Pissi Local x Sorawaki	4.67	Medium x low	40.3
	KRL 3-4 x PBW 65	4.59	High x medium	48.8
	S.E. (S_{ij})	1.64		
No. of productive tillers per plant	Kharchia 65 x PBW 65	2.18	High x low	7.0
	KRL 3-4 x KRL 1-4	1.85	Medium x medium	6.2
	Kharchia 65 x HD 2285	1.73	High x medium	6.9
	Sorawaki x CIMK 2	1.70	Medium x medium	5.9
	Kharchia 65 x Sorawaki	1.70	High x medium	6.8
	KRL 3-4 x Pissi Local	1.51	Medium x high	6.2
	S.E. (S_{ij})	0.37		
Plant height (cm)	Kharchia 65 x CIMK 2	-11.42	Low x high	85.7
	Sorawaki x HD 2009	-9.38	Low x high	84.1
	S.E. (S_{ij})	3.57		

the characters, although the cross KRL 3-4 x KRL 1-4 with the highest sca and high grain yield per plant also had high sca effects for number of grains per spike and productive tillers per plant. Most of the crosses with high sca for yield had at least one high gca parent. However, some of the crosses with high sca had one or both parent with average gca. The superiority of average x average or average x low combination may be due to the presence of genetic diversity among the parents and there could be some complementation indicating importance of nonadditive effects.

The study of associations between per se performance of the parents and crosses in F_1 with that of the gca and sca effects (Table 4) revealed very high correlations between gca effects and per se performance for number of spikelets/spike, grains/spike and plant height, while moderately high correlation was observed for grain yield and non significant correlation for number of productive tillers/plant. High correlation among per se

Table 4. Promising parents and crosses for grain yield and other related traits in wheat under high salt conditions

Character	Best parents based on			Best crosses based on		
	gca	per se performance	r	sca	per se performance	r
Grain yield per plant	HD 2285 KRL 1-4 PBW 65	PBW 65 KRL 1-4 CIMK 2	0.65	KRL 3-4 x KRL 1-4 Kharchia 65 x Sorawaki Sorawaki x CIMK 2	KRL 3-4 x KRL 1-4 HD 2009 x HD 2285 Kharchia 65 x HD 2329	0.88
Ear Length	KRL 1-4 HD 2285 PBW 65	CIMK 2 KRL 1-4 KRL 3-4	0.77	Sorawaki x HD 2285 HD 2009 x HD 2285 KRI 1-4 x HD 2009	HD 2009 x HD 2285 KRL 1-4 x HD 2009 KRL 1-4 x HD 2285	0.76
No. of spikelets per spike	CIMK 2 PBW 65	CIMK 2 PBW 65	0.95	Kharchia 65 x Sorawaki Pissi Local x HD 2009 Kharchia 65 x PBW 65	Sorawaki x CIMK 2 PBW 65 x HS 2009 CIMK 2 x HD 2009	0.69
No. of grains per spike	PBW 65 CIMK 2 KRL 1-4	PBW 65 CIMK 2 KRL 1-4	0.97	KRL 3-4 x KRL 1-4 Sorawaki x CIMK 2 KRL 1-4 x HD 2009	PBW 65 x HD 2009 CIMK 2 x HD 2285 KRL 1-4 x HD 2009	0.61
1000-grain weight	HD 2285 KRL 3-4	KRL 1-4 KRL 3-4	0.85	Sorawaki x HD 2285 CIMK 2 x HD 2285 CIMK 2 x HD 2009	KRL 3-4 x HD 2285 Pissi Local x HD 2285 HD 2329 x HD 2285	0.74
No. of productive tillers per plant	Kharchia 65 Pissi Local	CIMK 2 KRL 1-4	–0.07	Kharchia 65 x PBW 65 KRL 3-4 x KRL 1-4 Kharchia 65 x HD 2285	Kharchia 65 x PBW 65 Kharchia 65 x HD 2285 Kharchia 65 x Sorawaki	0.92
Plant height	HD 2009 HD 2329 KRL 1-4	HD 2329 HD 2009 HD 2285	0.94	Kharchia 65 x CIMK 2 Sorawaki x HD 2009 CIMK 2 x HD 2329	CIMK 2 x HD 2329 KRL 1-4 x HD 2329 KRL 1-4 x CIMK 2	0.41

performance and gca effects is indicative of the importance of additive genetic effects. Thus, ability to transmit desirable characters to progeny can be predicted even from phenotypic performance of a plant. The best parents both on the basis of gca effects and per se performance are also listed in Table 4. For the characters with high correlation between gca and per se performance the ranking of the parents in both the cases were nearly the same except for number of productive tillers per plant which had a nonsignificant correlation.

High correlation between the sca effects and per se performance of the F_1 crosses was observed for number of productive tillers per plant, correlations were moderate for grain yield, ear length, number of spikelets per spike, number of grains per spike and 1000-grain weight, while it was low for plant height. High correlation signifies the contribution of nonadditive gene effects in the inheritance of the character.

These results signify the importance of exploitation of both additive and nonadditive genetic effects for attaining maximum improvement in yield and other yield attributes. It is also suggested that high gca parents for grain yield and its components, like HD 2285, KRL 1-4 and PBW 65 and cross like KRL 3-4 x KRL 1-4 should be given due consideration in developing superior varieties for salt conditions.

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