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Combining ability studies in wheat (*Triticum aestivum* L.) for genetic improvement under salt stress

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Abstract

Combining ability, heritability and gene action estimates for yield and yield attributes under saline (EC_{iw}: 15 dS/m) and normal irrigated conditions were studied using 8x8 diallel crosses in wheat. Both additive and non-additive gene action were found important in the inheritance of yield and yield attributes under normal as well as saline irrigation conditions. Under normal conditions all the traits were found to be governed by non additive gene action with low heritability, whereas under salt stress, plant height and spikelets/spike exhibited high heritability with importance of additive effects. All other traits under salt stress exhibited medium to low heritability with non-additive gene action. The genotypes Kharchia 65, KRL 19, HD 2189 and KRL 129-1 exhibited high gca and *per se* performance for grain yield/plant under salt stress. The crosses UP 2338/Kharchia 65 and Kharchia 65/KRL 129-1 were found to be the best combinations under salt stress for grain yield/plant.

Key words: Wheat, combining ability, salinity tolerance

Introduction

In India 6.73 million ha area is affected by salt stress (Sharma *et al.* 2004). Salinity in agricultural lands and irrigation water is one of the major environmental factors, which limits the growth and yield of wheat crop. Land reclamation is one of the major activities in these areas to get good wheat productivity. In addition to land reclamation, use of salt tolerant genotypes provides an important economic option to the farmers. In areas where irrigation water is of poor quality, the only option left for the farmers is to grow salt tolerant varieties. However, breeding of salt tolerant varieties requires selection of parents based on their combining ability/heterosis, gene action and heritability of the trait. The present study was therefore designed to estimate the genetic parameters for some yield and yield contributing characters in eight varieties/genotypes crossed in diallel fashion without reciprocals.

Materials and Methods

Eight diverse genotypes of wheat were crossed in a set of 8x8 dialled cross without reciprocals. UP 2338, PBW 343 and HD 2009 are the high yielding varieties of North Western Plane Zone, HD 2189 has been released for Peninsular zone, Kharchia 65 is the most widely used salt tolerant genotype in hybridization programme all over the world; KRL 19 is the salt tolerant variety and KRL 129-1 is the salt tolerant genotype developed at the Central Soil salinity research Institute, Karnal; Ducula 4 is developed at CIMMYT, Mexico and considered to be a waterlogging tolerant variety for normal soils. Eight parents and 28 F_1s were evaluated under two sets of conditions at CSSRI (ICAR), experimental farm Karnal, India. The first set was irrigated with normal water of ECiw 0.05 dS/m . The second set was provided saline irrigation of ECiw 15 dS/m.

The experiment was conducted in a randomized block design with two replications. The plot size was one row of 1m long with inter and intra row spacing of 0.23 and 0.05m respectively. Standard agronomic packages of practices were used in raising the crop. The crop received four irrigations (50 mm during the season).

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Five competitive plants were randomly taken in each plot for observations. Observations were recorded on plant height, tillers/ plant, spike length, spikelets/spike, biomass/plant, grains/spike, 1000 grain weight and grain yield/plant on individual plants. Plant height was recorded at physiological maturity. The data on days to heading were recorded on plot basis. Mean of 5 plants per plot for grain yield and yield attributes were subjected to statistical analysis. Combining ability analysis (Griffing 1956) was conducted using the statistical software package of INDOSTAT.

Results and Discussion

Breeding for salinity tolerance is different from other approaches on account of different selection criteria under stress and very little information available on salt tolerant genotypes, their combining abilities and heritability of traits. The diallel analysis of genotypes under salt stress provides information related to these genetic parameters and help to select the breeding strategies. Singh and Chatrath (1997) conducted such study under salt stress condition and involved different salt tolerant and widely adapted varieties prevalent at that time. During past years a number of other salt tolerant and high yielding varieties have been released and being used for hybridization. There is a need to understand the combining ability of these varieties and estimation of components of variance to design breeding programmes. Therefore the present study was carried out to involve different set of varieties.

The parents and hybrids used in the present study showed highly significant differences for the yield and all yield contributing traits studied. ANOVA for yield attributes for combining ability revealed significant variation for all the characters studied (Table 1).

Table 1. Anova for yield attributes in wheat crosses

Source	DF	Days to heading	Plant height	Spike length	Spikelets/ spike	Tillers/ plant	Biomass/ plant	Grains/ ear	Thousand grain weight	Grain yield/ plant
Normal irrigation										
GCA	7	35.936**	561.242**	198.58**	2.489**	1.418**	5.576**	394.887**	83.905**	1.254**
SCA	28	6.223**	95.846**	266.962**	1.612**	1.287**	6.29**	128.327**	20.675**	0.952**
Error	35	1.064	2.97	0.201	0.153	0.014	0.068	5.268	0.916	0.012
Saline Irrigation										
GCA	7	43.136**	395.689**	3.232**	7.508**	2.934**	13.747**	332.956**	69.027**	0.799**
SCA	28	7.475**	20.992**	0.329**	0.616**	0.582**	2.724**	82.984**	16.228**	0.312**
Error	35	0.718	1.526	0.054	0.159	0.009	0.026	4.039	0.791	0.005

*,** Significant at 5% and 1% level respectively

Highly significant variation due to general combining ability (gca) and specific combining ability (sca) indicated that additive as well as non-additive components of heritable variance are involved in the inheritance of these characters. The importance of general and specific combining ability was assessed by estimating the components of variance expressed as $2\,^{2}g/(2\,^{2}g+\,^{2}s)$ ratio (Baker 1978). The closer this ratio to unity the greater magnitude will be to additive gene effects. Under normal irrigation, dominance effects were important for spike length, spikelets/spike, tillers/plant, biomass/plant, grains/ear and grain yield/plant. Other traits (days to heading, plant height and thousand grain weight) were controlled by both additive and dominance effects (Table 3). Ahmad *et al.* (2011) reported the additive gene action for spike length, grains/spike, 1000 grain weight and harvest index in normal irrigated conditions. The dominance component was found significant for spike length, tillers per plant and grain yield per plant. Sener *et al.* (2000) reported the importance of additive effects for spikelets per ear and grains per ear and dominance effects for grain yield per plant. Singh et al (2003) reported the importance of both additive and dominance components for plant height, tillers per plant, 1000 grain weight and grain yield per plant under normal soils. Ali and Khan (1998) however reported additive gene action for all the traits studied. Ajmal *et al.* (2011) reported over-dominance for plant height, spike length, tillers per plant and grain yield per plant. In comparison, additive gene effects were found to be important for days to heading, plant height and thousand grain weight. These traits also exhibited high heritabilities suggesting that selection can substantially improve these characters for normal soils. All other traits exhibited dominance gene effects with medium to low heritabilities suggesting that spike length, spikelets/spike, tillers per plant, biomass per plant, grains per ear and grain yield per plant can be improved not only by considering the gca of parents but by giving due emphasis to sca of specific cross combinations. Dhayal and Sastry (2003) reported the importance of both additive as well as non-additive effects with preponderance of additive effects for days to heading, plant height and 1000 grain weight under salinity. Singh and Chatrath (1997) found the importance of both additive and nonadditive gene effects in the inheritance of most of the traits under salinity. In the present study, grain yield/plant was found to be governed by dominant gene action, plant height by additive effects and 1000 grain weight by both additive and dominant effects under salinity. Similar results for these traits were obtained by Singh and Chatrath (1997). Preponderance of additive effects was found for spikelets/ spike under saline irrigation whereas both additive and dominance effects were important for tillers/plant, biomass/ plant, spike length and days to heading. Grains/ear was found to be goverened by dominance effects. In contrast Singh and Chatrath (1997) found both additive and dominant effects for spikelets/spike and dominant effects for tillers/ plant. Therefore some disparity of results from Singh and chatrath (1997) was obtained. The disparity of the results may be due to different genetic background of the material and different soil/climatic conditions. The traits governed by non additive effects therefore can be improved upon by biparental matings in early segregating generations and/or diallel selective mating under salt stress.

Estimates of gca effects of parents and their mean performance are presented (Table 2). Under normal irrigation conditions, none of the genotype exhibited significant gca effects for grain yield. The gca effects for grain yield per plant were found to be maximum for Kharchia 65 and minimum for HD 2009 under salt stress. Both the genotypes are also known for their tolerant and sensitive nature to stress. The importance of non-additive effects for grain yield also demand that sca effects should also be considered for designing breeding programmes. In this case the cross combinations UP2338/Kharchia 65 and Kharchia 65/KRL 129-1 exhibited higher sca effects and heterosis for grain yield/plant. These combinations did not exhibit high sca for other traits. As the heritability of grain yield under saline irrigation was low, other yield attributes are also important in designing breeding programme. The gca effects for thousand grain weight were the best for PBW 343 for both normal and stress environments. Similar results for 1000 grain weight were obtained by Mani *et al.* (2003) for normal conditions. The sca effects for this trait were important for UP2338/KRL 19 and Kharchia 65/Ducula 4. The top heterotic combinations were PBW 343/HD 2189 and UP 2338/KRL 19. Kharchia 65 also exhibited significant gca effects for biomass/plant, tillers/plant, and plant height under stress. The salt tolerant variety KRL 19 showed significant gca effects for grain yield/plant, grains/ear, biomass/plant, tillers/plant, spikelets/plant and spike length. HD 2189 and KRL 129-1 were the other two genotypes which exhibited significant gca for grain yield under stress. HD 2189 also exhibited significant gca effects for grain weight , biomass/plant, tillers/plant and plant height. KRL 129-1 exhibited significant gca effects for all traits under stress except thousand grain weight.

Table 2. Estimates of gca effects of parents and their *per se* performance under normal and stress condition

Characters			UP 2338	PBW343	Kharchia65	KRL19	HD2189	KRL129-1	HD2009	DUCULA4	S.E.±
Days to heading	gca	N	-0.175	0.925**	-1.175**	-2.775**	-0.925**	2.475**	-1.025**	2.675**	0.30
		S	1.125**	1.675**	-0.825**	-2.475**	-2.675**	1.875**	-1.325**	2.625**	0.25
	days	N	96	93	93	88	92	98	92	104	2.10
		S	95	95	92	87	90	96	88	99	0.50
Plant height	gca	N	-1.815**	1.645**	16.285**	-7.335**	2.385**	-0.565	-6.985**	-3.615**	0.50
		S	-3.625**	-0.275	11.165**	-7.715**	5.175**	2.975**	-6.525**	-1.175**	0.37
	cm	N	93	95	129	86	104	105	86	104	3.60
		S	88	90	110	78	104	98	82	89	2.50
Spike length	gca	N	-2.405**	6.875**	-2.794**	-1.925**	7.492**	-1.718**	-2.526**	-2.998**	0.13
		S	-0.247**	0.141	-0.619**	0.286**	-0.154*	1.148**	0.056	-0.609**	0.07
	cm	N	10.6	10.2	9.3	12.1	11.8	13.5	10.4	9.3	0.90
		S	10.5	10.4	9.6	11.8	10.3	13.2	11.2	9.4	0.20
Spikelets/spike	gca	N	0.58**	-0.12	-0.515**	0.5**	-0.735**	0.545	-0.185	-0.07	0.12
		S	0.218	0.282*	-1.232**	0.477**	-1.098**	1.208**	-0.523**	0.667**	0.12
	No.	N	21.1	17.6	16.0	20.0	18.8	20.8	17.6	19.7	0.80
		S	19.5	17.2	16.0	19.5	16.6	20.0	17.2	19.4	0.80
Tillers/ plant	gca	N	-0.039	-0.229**	0.509**	-0.436**	0.228**	0.013	0.445**	-0.489**	0.03
		S	-0.696**	-0.597**	0.873**	0.232**	0.465**	0.081**	-0.414**	0.056	0.03
	No.	N	3.8	4.7	4.8	4.6	4.5	5.1	5.2	3.0	0.20
		S	1.4	1.8	5.0	4.4	4.1	2.8	1.7	2.7	0.20
Biomass/ plant	gca	N	1.21**	-0.625**	0.295**	-0.35**	0.8**	0.17*	-0.9**	-0.6**	0.08
		S	-1.048**	-0.582**	1.968**	0.258**	0.642**	0.527**	-1.882**	0.118*	0.05
	g	N	10.6	7.1	8.9	10.4	9.1	9.8	8.8	6.8	0.50
		S	3.9	4.1	8.6	6.9	7.7	7.2	2.9	6.7	0.40
Grains/ ear	gca	N	0.938	-6.413**	-6.912**	4.348**	-6.092**	11.108**	0.357	2.667**	0.68
		S	0.148	-0.082	-1.372*	7.428**	-3.052**	8.328**	-9.722**	-1.672**	0.59
	No.	N	72	50	54	67	52	86	62	47	4.80
		S	47	39	51	66	44	67	35	43	3.10
Thousand grain weight	gca	N	1.062**	5.362**	-0.588*	-2.388**	2.662**	-3.138**	-2.338**	-0.638*	0.28
		S	2.662**	2.912**	0.062	-2.988**	1.712**	0.462	-4.538**	-0.288	0.70
	g	N	40	50	39	37	46	42	38	44	2.00
		S	42	47	37	35	42	41	34	38	1.20
Grain yield/ plant	gca	N	0.671	0.149	-0.256	-0.168	0.254	-0.157	-0.47	-0.024	0.03
		S	-0.199**	-0.232**	0.368**	0.174**	0.2**	0.157**	-0.485**	0.016	0.02
	g	N	4.3	4.4	2.6	3.2	3.2	2.8	3.5	3.5	0.20
		S	1.8	1.5	2.2	2.4	2.2	2.2	1.0	1.8	0.10

*,** Significant at 5% and 1% level respectively, N: Normal Irrigation, S: Saline Irrigation

Table 3. Predominant gene action and heritability effects for yield attributing characters under salt stress

Character	Normal Irrigation				Saline Irrgation			
	^2g	^2s	2 ^2g/ (2 ^2g+^2s)	h^2 narrow sense	^2g	^2s	2 ^2g/ (2 ^2g+ ^2s)	h^2 narrow sense
Days to heading	3.5	5.2	0.57	0.53	4.2	6.8	0.56	0.53
Plant height	55.8	92.9	0.55	0.54	39.4	19.5	0.80	0.79
Spike length	19.8	266.8	0.13	0.13	0.3	0.3	0.70	0.66
Spikelets/spike	0.2	1.5	0.24	0.23	0.7	0.5	0.76	0.71
Tillers/ plant	0.1	1.3	0.18	0.18	0.3	0.6	0.51	0.50
Biomass/ plant	0.6	6.2	0.15	0.15	1.4	2.7	0.50	0.50
Grains/ ear	39.0	123.1	0.39	0.38	32.9	78.9	0.45	0.44
Thousand grain weight	8.3	19.8	0.46	0.45	6.8	15.4	0.47	0.46
Grain yield/ plant	0.1	0.9	0.21	0.21	0.1	0.3	0.34	0.34

The gca effects of Ducula 4 were significant for days to heading for both normal and stress environment. In majority of the cases, good general combiners for grain yield/plant under salt stress showed better per se performance, which indicated that parents may be selected either on the basis of gca or per se performance or in combination. Some of the important combinations based on sca effects and heterosis are presented (Table 4).

Table 4. Best crosses selected on the basis of sca and heterotic effects under salt stress

Character	Top combinations based on sca	Gca effects of parents	Top heterotic combinations
Days to heading	UP 2338/KRL 129-1	Med x High	UP 2338/KRL 129-1
	KRL 19/HD 2009	Low x Low	PBW343/DUCULA4
Plant height	Kharchia 65/Ducula 4	High x Low	Kharchia 65/DUCULA4
	PBW343/HD2009	Low x Low	Kharchia 65/KRL 129-1
Spike length	UP2338/HD2189	Low x Low	_
	PBW343/HD2009	Low x Low	_
Spikelets/spike	PBW343/KRL 129-1	Med x High	PBW343/KRL 129-1
	PBW343/DUCULA4	Med x Med	_
Tillers/ plant	KRL 129-1/HD2009	Med x Low	_
	Kharchia 65/KRL 129-1	High x Med	_
Biomass/ plant	PBW343/KRL 129-1	Low x Med	Kharchia 65/KRL 129-1
	KRL19/DUCULA4	Med x Med	Kharchia 65/HD2189
Grains/ ear	UP2338/Kharchia 65	Low x Low	UP2338/KRL19
	UP2338/HD2009	Low x Low	KRL 129-1/DUCULA4
1000 grain weight	UP2338/KRL19	High x Low	PBW343/HD2189
	Kharchia 65/DUCULA4	Med x Low	UP2338/KRL19
Grain yield/ plant	UP2338/Kharchia 65	Low x High	UP2338/Kharchia 65
	Kharchia 65/KRL 129-1	High x Med	Kharchia 65/KRL 129-1

A number of cross combinations were identified for multiple traits based on sca effects and heterosis. The magnitude of sca effects is important in selecting the crosses for obtaining transgressive segregants. Kharchia 65/KRL 129-1 exhibited sca effects for grain yield/plant and tillers/plant and heterosis for plant height and grain yield/plant. Kharchia 65/Ducula 4 was having significant sca effects for plant height and thousand grain weight and heterosis for plant height. UP 2338/Kharchia 65 exhibited significant sca effects for grain yield/plant and grains/ear and heterosis for grain yield/plant. PBW 343/KRL 129-1 exhibited significant sca effects for spikelets/spike and biomass/plant and heterosis for spikelets/spike. Significant sca effects were also found for UP 2338/KRL 129-1, UP 2338/HD 2189 and KRL 129-1/HD 2009 for days to heading, spike length and tillers/plant respectively. The crosses exhibiting high sca for yield and yield attributes generally had at least high or medium gca parent. However some of the crosses with high sca had both the low gca parents. The superiority of low x low gca combinations may be due to presence of genetic diversity among parents, transgressive segregation and complementation indicating importance of nonadditive effects. Thus the results indicated that the crosses with superior sca effects can be obtained by crossing parents both with high and low gca effects. These combinations can also provide the transgressive segregants for salinity tolerance.

Results of the present study indicated the presence of additive gene action for some traits under salinity thus suggesting that a part of heterosis can be fixed in subsequent generations through selection. Cross combinations based on their sca effects may be identified and may be used for genetic improvement. This information may be clubbed with the previous information as some of the parents used (Singh and Chatrath, 1997) are still important with respect to breeding for salt tolerance. Presence of heterosis and non additive gene action for a number of cross combinations and traits was found. Under such situations, diallel selective mating may be useful for further improvement.

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