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Combining Ability for Grain Yield and Its Components Different Environments in Wheat

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A B S T R A C T

Combining ability analysis was done in Line X Tester mating design by using 7 lines, 3 testers and 21 F_1's in a randomized block design with two replications during 2013-14 in sowing under water stress and non-stress environments. The analysis of genetic components revealed that both additive as well as non-additive components were prevalent for the control of grain yield and its components under both water stress and non-stress environments except spike length in under stress environment. The combining ability effects revealed that parent DL 803-3 was identified as good general combiners for grain yield under both water stress and non-stress environments and GW190 and GW 173 for grain yield under stress environment. The significant specific good combing cross 'GW 322 X GW 173' having one promising parent for grain yield under stress condition would be advanced through simple / recurrent selection in segregating generations. Most of the good specific combinations for various traits involved parents with high X low or low X low or low X high GCA effects. These genotypes may be used in breeding programs targeting high potential under drought stress. These parents may be used for varietal improvement through the simple / recurrent selection in segregating generations to increase in yield potential of wheat. This may lead in the fixation of both additive and non-additive components while making improvement in grain yield and its attributes.

Introduction

Wheat (*Triticum aestivum L.*) is the second most important cereal crop after rice in the context to its antiquity and its use as source of food and energy in India. Wheat crop has occupied almost 29.9 million hectares and producing 95.85 million tones in India (Anonymous, 2016). Improvement in wheat production can be achieved by enhancing through the development of new cultivars having wider genetic base and better performance. Earlier research review revealed that both general and specific combining abilities were involved in the inheritance of grain yield and its components (Singh *et al.,* 2000; Murliya and Sastry, 2001). Selection of parents together with information on nature and magnitude of gene action controlling grain yield and its attributing characters is prerequisites while improving the plant type efficiently.

Hence an attempt has been made to study suitable parents through general combining ability and specific combining ability for improvement in yield potential under stress and non-stress conditions.

Materials and Methods

An experiment consisting 21 F_1s and their 10 parents was conducted along with 2 checks *viz*., MP-4010 and RVW-4106 in randomized block design with two replications during winter season 2013-14. Twenty one crosses were developed in Line x Tester mating design using 7 lines *viz*., C-306, DL 803-3, GW-190, GW-322, PBW-175, MACS 6222, HI 1544 and 3 tester's viz., HD-2932, GW-173 and PBW-343.

The sowing was done by dibbling seeds in rows with spacing of 20 cm apart and 4-6 cm within row under water stress and non-stress environments. The recommended packages of practices were adopted for optimum crop growth. Observations were recorded on five randomly selected plants in each line for grain yield and its attributes (Table 1*)*. Combining ability analysis was worked out in Line X Tester mating design by following Kempthorne (1957).

Results and Discussion

Combining ability variances

The mean sum of square due to genotypes in the non-stress condition, lines were significant only for biological yield and grain yield whereas testers were significant for days to maturity**,** plant height, spike length and grain filling period. But in stress condition, lines were significant for grain yield per plant**,** grain per spike and test weight and testers for grain yield per plant**,** days to heading, days to flowering, grain weight per spike, grain per spike, flag leaf area and biological yield. Crosses were significant for grain yield per plant, flag leaf area and biological yield in non-stress and days to heading and test weight in stress condition (Table 1, 2). The similar reports were also published earlier by Drikvand *et al.,* (2005) and Dhadhal *et al.,* (2008) for seeds per spike, tillers per plant and grain yield per plant under both water stress and non-stress conditions.

General combining ability (GCA) or specific combining ability (SCA) variances were substantial for most of the characters, thereby, indicating impotence of both additive as well as non-additive components of genetic variance in the control of these traits. These results are in agreement with reported earlier on GCA and SCA variances for yield and yield components in wheat (Mahmood and Chowdhry, 2000). The additive components of variances were higher compared to dominance components of variances for all characters studied under both stress and non-stress environments. The ratio of genetic components "σ^2gca / σ^2sca" also showed more than one, indicating predominance of additive variances for almost all characters under both water stress and non-stress environments. The similar reports were also published earlier by Vanpariya *et al.,* (2006) for days to heading, plant height, spike length and spikelet per spike. Yadav and Behl (2002) for days to flowering, plant height, tillers per plant, grain per spike, flag leaf area, test weight and grain yield per plant.

General combining ability effects in under stress and non-stress condition

The significant estimates of significant positive GCA effects revealed that 'DL 803-3' was good general combiner for grain yield per plant; C 306 for harvest index; GW 190 for plant height; HD 2932 for spike length in non-stress situation (Table 3). However, genotype PBW 343 was bad general combiner as showed longer days to maturity and grain filling period. Present results are in agreement with those of Vanpariya *et al.,* (2006) for days to heading, plant height, spike length, spikelet per spike under non-stress condition; Ali and Khan (1998) for grain yield per plant.

Table.1 Analysis of Variance for combining ability for grain yield and yield contributing characters in wheat

Sources	DF	Days to heading		Days to flowering		Days to maturity		Grain filling period		Plant height		Tiller/plant		Spike length	
		S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
Lines	6	10.13	4.66	8.97	4.11	1.76	1.67	11.05	7.39	96.00	82.19	5.07	6.63	3.98	0.67
Tester	2	140.21**	9.93	158.79**	3.17	2.21	30.31**	129.07**	37.50**	29.45	297.61**	11.00	17.16	1.42	2.68**
L X T	12	5.99	5.79	7.98	6.19	1.30	4.06	8.07	9.06	83.66	18.26	5.62	9.40	1.15	1.37
Error	32	9.07	4.69	14.72	3.80	5.28	4.06	15.75	7.25	51.64	64.56	4.94	12.74	1.73	1.03

Conti…………

Sources	DF	Grain weight per spike		Grain per spike		Test weight		Grain yield per plant		Flag leaf area		Harvest Index		Biological Yield	
		S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
Lines	6	0.12	0.27	160.22*	70.22	85.94**	14.19	19.62**	32.29**	173.54	65.41	39.40	225.53	68.96	186.29**
Tester	2	1.04**	0.12	382.24**	16.88	15.99	21.74	51.68**	10.85	438.01**	83.51	745.51	134.91	272.40**	106.16
L X T	12	0.12	0.26	80.56	95.47	53.71**	29.07	28.25**	27.17**	48.80	153.87**	277.02	231.68	103.51**	237.90**
Error	32	0.23	0.37	79.69	117.01	23.50	29.21	4.89	9.93	99.97	67.12	293.64	232.33	28.04	54.34

*, ** significant at 5 and 1 percent levels, respectively,

Table.2 Genetic components estimates for 14 characters in wheat crosses in line X tester mating design

Covariance	Days to heading		Days to flowering		Days to maturity		Grain filling period		Plant height		Tiller/plant		Spike length	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
Cov HS (Line)	0.690	-0.188	0.165	-0.347	0.077	-0.399	0.496	-0.278	2.057	10.655	-0.092	-0.461	0.471	-0.117
Cov HS (Tester)	9.587	0.296	10.772	-0.216	0.065	1.875	8.643	2.032	-3.872	19.954	0.384	0.555	0.019	0.093
Cov HS (Average)	-5.992	-5.790	-7.980	-6.194	-1.298	-4.060	-8.071	-9.056	-83.661	-18.261	-5.619	-9.395	-1.153	-1.371
Cov FS	29.510	8.772	32.570	8.606	-0.031	9.389	27.587	17.441	120.580	58.411	8.635	11.686	1.765	2.099
Genetic components														
σ2gca (Lines)	0.690	-0.188	0.165	-0.347	0.077	-0.399	0.496	-0.278	2.057	10.655	-0.092	-0.461	0.471	-0.117
σ2gca(Testers)	2.762	-0.754	0.659	-1.389	0.310	-1.595	1.984	-1.111	8.228	42.622	-0.369	-1.843	1.883	-0.467
σ2gca (Parents)	876.58	25.77	981.22	-21.76	6.42	168.23	789.47	183.22	-340.00	1879.71	34.426	47.71	4.57	7.79
σ2sca	-1.540	-11.57	-15.96	-12.38	-2.595	-8.11	-16.143	-18.11	-167.32	-36.52	-11.23	-18.79	-2.30	-2.74
σ2gca / σ2sca	-569.05	-2.23	-61.48	1.76	-2.47	-20.72	-48.91	-10.12	2.03	-51.47	-3.06	-2.54	-1.98	-2.84
σ2 A	1753.17	51.54	1962.44	-43.52	12.84	336.46	1578.95	366.44	-680.00	3759.43	68.85	95.43	9.14	15.59
σ2 D	65.571	2.621	72.034	-0.315	-1.533	13.125	56.662	15.126	-11.094	116.525	3.029	2.209	-0.153	0.824

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Covariance	Grain weight per spike		Grain per spike		Test weight		Grain yield per plant		Flag leaf area		Harvest Index		Biological Yield	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
Cov HS (Line)	0.000	0.000	13.276	-4.208	5.371	-2.480	-1.323	0.853	20.790	-14.743	-39.604	-1.025	-5.759	-8.601
Cov HS (Tester)	0.065	-0.010	21.54	-5.613	-2.694	-0.524	1.039	-1.166	27.801	-5.025	33.464	-6.912	12.063	-9.410
Cov HS (Average)	-0.121	-0.264	-80.561	-95.471	-53.708	-29.071	-22.55	-27.17	-48.80	-153.86	-277.02	-231.679	-103.51	-237.89
Cov FS	0.258	0.274	171.405	99.219	85.803	34.991	39.779	42.982	125.142	222.064	399.530	291.425	198.144	378.420
Genetic components														
σ2gca (Lines)	0.000	0.000	13.276	-4.208	5.371	-2.480	-1.323	0.853	20.790	-14.743	-39.604	-1.025	-5.759	-8.60
σ2gca(Testers)	-0.001	-0.010	53.10	-16.83	21.48	-9.92	-5.29	3.41	83.16	-58.97	-158.41	-4.10	-23.03	-34.40
σ2gca (Parents)	5.94	-0.94	2040.54	-536.07	-212.92	-62.52	86.60	-100.98	2654.63	-545.77	2807.57	-635.14	1063.17	-907.90
σ2sca	-0.24	-0.52	-161.12	-190.94	-107.41	-58.14	-45.10	-54.34	-97.59	-307.73	-554.04	-463.35	-207.02	-475.79
σ2gca / σ2sca	-24.59	1.79	-12.665	2.807	1.982	1.075	-1.920	1.85	-27.19	1.77	-5.06	1.371	-5.13	1.90
σ2 A	11.88	-1.89	4081.09	-1072.1	-425.85	-125.05	173.21	-201.97	5309.26	-1091.54	5615.15	-1270.28	2126.35	-1815.81
σ2 D	0.40	-0.12	151.27	-50.06	-3.75	-3.73	15.87	0.45	169.02	8.19	225.93	-48.71	122.17	25.91

Table.3 Estimates of general combining ability effects of lines and tester parent's in wheat

Parents	Days to heading		Days to flowering		Days to maturity		Grain filling period		Plant height		Tiller/plant		Spike length	
Lines	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
MACS 6222	-1.976	-1.738	-1.810	-1.333	0.452	0.667	2.262	2.000	-1.322	-6.445	-0.249	-0.346	0.512	-0.151
GW 322	-1.310	0.095	-1.310	0.667	0.286	0.167	1.595	-0.500	0.635	-2.353	-0.880	0.250	1.280**	0.179
GW 173	0.857	0.595	1.024	0.167	0.119	-0.667	-0.905	-0.833	-2.719	1.935	0.076	1.752	0.275	0.598
HI 1544	0.190	-0.238	0.190	-0.167	-0.048	0.167	-0.238	0.333	-6.215	-0.682	-1.362	-1.310	-0.416	-0.426
PBW 175	0.524	-0.238	0.024	-0.833	-0.881	-0.167	-0.905	0.667	3.258	1.825	0.485	0.084	0.229	0.138
DL 803-3	-0.143	0.762	0.190	0.667	-0.548	-0.667	-0.738	-1.333	0.268	0.492	0.596	0.669	-0.875	-0.166
C 306	1.857	0.762	1.690	0.833	0.619	0.500	-1.071	-0.333	6.095	5.228	1.333	-1.100	-1.005	-0.173
SE (gca for line)	1.230	0.884	1.566	0.796	0.938	0.822	1.620	1.099	2.934	3.280	0.908	1.457	0.536	0.414
Tester														
PBW 343	-3.643**	0.214	-3.857**	0.119	-0.357	1.548**	3.500**	1.429**	-1.116	-1.603	0.695	-0.460	-0.108**	-0.031**
HD 2932	1.571	0.714	1.500	0.405	-0.071	-1.381**	-1.571	-1.786**	-0.523	-3.595	-0.998	1.263	-0.251**	0.452**
GW 190	2.071**	-0.929	2.357**	-0.524	0.429	-0.167	-1.929	0.357	1.640	5.198**	0.303	-0.803	0.359**	-0.421**
SE (gca for tester)	0.805	0.579	1.025	0.521	0.614	0.538	1.061	0.719	1.921	2.147	0.594	0.954	0.351	0.271

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Parents	Grain weight per spike		Grain per spike		Test weight		Grain yield per plant		Flag leaf area		Harvest Index		Biological Yield	
Lines	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
MACS 6222	-0.151	0.085	1.078	2.467	-7.979**	0.314	-0.755	0.655	5.341	4.336	0.162	-3.354	-2.672	4.739
GW 322	0.118	0.256	6.080	0.859	-0.832	-0.361	-0.198	-0.003	-1.154	0.368	1.297	-2.364	-1.487	-2.526
GW 173	0.227	0.220	-1.308	5.189	1.863	0.269	2.447**	2.052	0.221	3.518	2.544	1.194	-3.722	6.641
HI 1544	0.008	-0.359	-7.422**	-0.308	1.498	-2.915	-1.835**	-2.378	-5.326	-4.299	0.337	-4.480	-1.460	-3.648
PBW 175	0.033	-0.114	3.025	-4.032	1.095	0.855	-0.236	-1.905	-0.762	-1.367	2.620	-5.383	0.271	-1.294
DL 803-3	-0.158	-0.062	4.522	0.302	0.568	-0.300	2.460**	3.715**	-6.686	-3.567	-3.540	1.962	3.438	4.779
C 306	-0.077	-0.027	-5.975	-4.477	3.788	2.139	-1.883**	-2.136	8.366	1.011	-3.421	12.424**	5.633**	-8.691**
SE (gca for line)	0.197	0.249	3.644	4.416	1.979	2.206	0.903	1.287	4.082	3.345	6.996	6.223	2.162	3.009
Tester														
PBW 343	-0.187	0.074	-1.708	1.238	-0.040	1.318	-0.200	0.129	-3.949	2.517	-5.046	-3.532	4.729	2.939
HD 2932	-0.125	-0.103	-4.157	-0.380	-1.048	-1.159	-1.814**	0.809	-2.452	-2.360	-3.321	2.295	-0.725	-0.419
GW 190	0.312**	0.029	5.865**	-0.857	1.088	-0.159	2.013**	-0.938	6.401**	-0.158	8.367	1.237	-4.004	-2.520
SE (gca for tester)	0.129	0.163	2.386	2.891	1.295	1.444	0.591	0.842	2.672	2.190	4.580	4.074	1.415	1.970

*, ** significant at 5 and 1 percent levels, respectively,

Table.4 Crosses showing significant specific combining ability (SCA) effect for grain yield and its attributes

Crosses	Days to heading		Days to flowering		Days to maturity		Grain filling period		Plant height		Tiller/plant		Spike length	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
GW 322 X GW 173	-1.405	0.119	-1.833	-0.738	-1.429	0.548	0.405	1.286	-3.433	-1.310	2.033	1.545	-0.236	0.168
HI 1544 X PBW 343	2.429	-1.381	3.333	-1.238	0.738	-0.619	-2.595	0.619	-3.470	1.652	-0.674	1.544	-1.366	-0.525
MACS 6222 X PBW 343	-1.571	0.262	-2.024	0.190	-0.762	-0.333	1.262	-0.524	2.277	-0.401	2.941	-1.476	0.875	-0.542
HI 1544 X HD 2932	-0.238	0.095	-0.524	0.190	0.238	-0.833	0.762	-1.024	-5.460	0.789	0.032	0.778	-0.009	-0.312
MACS 6222 X HD 2932	-0.357	-2.048	0.024	-1.952	0.190	-0.048	0.167	1.905	7.196	-0.347	1.443	1.350	0.351	-0.949
SE (sca)	2.130	1.531	2.713	1.378	1.625	1.425	2.806	1.904	5.081	5.682	1.572	2.524	0.929	0.718

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Crosses	Grain weight per spike		Grain per spike		Test weight		Grain yield per plant		Flag leaf area		Harvest Index		Biological Yield	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
GW 322 X GW 173	0.067	-0.102	1.826	-3.622	1.651	3.389	4.514**	1.770	-1.810	1.151	3.373	2.313	4.110	2.836
HI 1544 X PBW 343	-0.207	0.255	-7.286	-0.286	0.171	3.379	-4.091	6.845**	-2.795	-3.584	-4.009	-8.005	-0.030	18.919**
MACS 6222 X PBW 343	0.111	-0.107	6.191	-2.974	0.750**	1.499	5.417**	-5.129**	-0.567	-2.751	-14.929	7.838	7.999**	-11.230**
HI 1544 X HD 2932	-0.235	-0.054	-2.807	-0.589	-2.082	0.612	-1.145	5.343**	-0.194	-0.996	3.438	13.617	-8.165**	2.580
MACS 6222 X HD 2932	0.355	0.434	-2.915	2.982	1.514**	1.650	4.071	2.991	2.649	-4.176	9.676	-5.247	3.771	13.757**
SE (sca)	0.341	0.431	6.312	7.649	3.428	3.822	1.564	2.229	7.070	5.793	12.117	10.778	3.744	5.212

*, ** significant at 5 and 1 percent levels, respectively,

Significant negative GCA effects reveled that genotypes GW 190 and PBW 343 showed bad general combiner for spike length and C 306 for biological yield. However, HD 2932 was good general combiner for earliness to maturity and grain filling period as reflected by negative GCA effects. Rests of the parents were average combiner for grain yield having non-significant GCA effects. These results are in agreement with those of Singh *et al.,* (1988) for grain per spike and biological yield; Yadav and Behl (2002) for days to flowering, tillers per plant, grain per spike, test weight and grain yield per plant.

Under stress environment, GW 190 were recorded good general combiner for grain yield per plant, spike length, grain weight per spike, grain per spike and flag leaf area; DL 803-3 for grain yield per plant and C 306 for biological yield under stress condition. Whereas PBW 343 were good general combiner for earliness as showing significant negative GCA effects for days to heading and days to flowering and bad general combiner for grain filling period. Significant negative GCA effects revealed that HD 2932 showed bad general combiner for grain yield per plant and spike length; C 306 for grain yield per plant and PBW 343 for spike length (Table 3). The similar reports were also published earlier by Drikvand *et al.,* (2005) for days to heading, days to flowering, day to maturity, plant height, grain yield; Kamaluddin *et al.,* (2007) for seeds per spike, tillers per plant and grain yield per plant under both water stress and non-stress conditions.

Specific combining ability effects in under stress and non-stress condition

Under non-stress condition, Significant positive SCA effects revealed that cross ‘HI 1544 X HD 2932’ and ‘HI 1544 X PBW 343’ having higher grain yield and also was good specific combiner for grain yield per plant; ‘MACS 6222 X HD 2932’ for biological yield. It was noticed that the crosses with high SCA had either one or both parents with average or good GCA effects. The similar results were also reported earlier by Khalifa *et al.,* (1998) and Jatav *et al.,* (2014) for grain yield per plant.

Under stress condition, significant positive SCA effects revealed that ‘GW 322 X GW 173’ and ‘MACS 6222 X PBW 343’ were good specific combiner for grain yield per plant; ‘MACS 6222 X HD 2932’ for test weight. Whereas cross ‘DL 803-3 X PBW 343’ showed high mean grain yield but was average specific combiner for biological yield but it showed good specific combiner for yield. The superiority of average X average or average X low combination may be due to the presence of genetic diversity among the parent and there could be some complementation indicating importance of non-additive effects. The similar results were also reported earlier by Srivastava *et al.,* (2012) and Pansuriya *et al.,* (2014) for grain yield per plant.

Analysis of combining ability in the present wheat material suggested an idea about breeding methodology to be applied and use of promising crosses for further improvement in wheat. In self–pollinated crops like wheat, SCA effects are not much important as they are mostly related to non-additive gene effects excluding those of arising from complementary gene action or linkage effects they cannot be fixed in pure lines. Further superiority of the hybrids might not indicate their ability to yield transgressive segregates; rather SCA would provide satisfactory criteria and expected to throw desirable transgressive segregates in later generations. Grain yield and major yield components revealed the significance of both additive and non-additive gene action for grain yield and its different components. The presence of both significant additive and non-additive genetic variances for grain yield and major yield attributing traits suggested that high performance of yield and contributing traits can be fixed in subsequent segregating generation of 'HI 1544 X HD 2932' and 'HI 1544 X PBW 343' in sown non-stress conditions and 'GW 322 X GW 173' and 'MACS 6222 X PBW' in sown stress conditions (Table 4). The good general combining parents DL 803-3, GW 190 and GW 173 may be used for varietal improvement through the recurrent selection, inter-mating and bi-parental mating in F_2 generation of promising crosses consisting for early sown stress situation. The parents DL 803-3 in early sowing, GW 322 and PBW 343 in late sowing identified as higher yielder under non-stress condition would be used for improvement for high yielding varieties through the simple / recurrent selection from segregating generations in wheat. DL 803-3 appeared to be promising under both water stress and non-stress condition may be used for varietal improvement through the recurrent selection, inter-mating and bi-parental mating in F_2 generation. The significant specific cross 'GW 322 X GW 173' having one promising parent for grain yield under stress condition would be advanced through simple / recurrent selection in segregating generations, which may lead in the fixation of both additive and non-additive components while making improvement in grain yield and its attributes.

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