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Combining Ability and Gene Action Studies for Grain Yield and Yield Contributing Traits in Wheat (*Triticum aestivum* L.)

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A B S T R A C T

Combining ability and gene action for yield and yield contributing traits was studied in 13 parental genotypes (5 lines, 8 testers) in a line x tester scheme during *rabi*, 2017-18. The purpose of the study was to identify and select superior parents and best hybrid combinations on the basis of estimates of general and specific combining abilities. The differences among genotypes were highly significant for all the characters studied. Estimates of variance due to general combining ability (GCA) and specific combining ability (SCA) and their ratio revealed that preponderance of non-additive gene action for different characters studied. The estimates of gca effects as a whole suggested that if most of the traits are to be improved through hybridization and selection, then priority should be given to parents NIAW-1994 from among the lines and Among male parents, CG-1021, PBN-4357 and UAS-379 were found to be good general combiners for seeds yield per plant, there by classifying these parents as good sources of favorable genes for increasing production of seed yield per plant. The estimates of specific combining ability effects revealed that highest SCA effect for grain yield per plant was exhibited by crosses, HD-2932 x UAS-379 followed by HD-2932 x PBN-4357 and NIAW-1994 x CG-1021.

Introduction

Wheat (*Triticum spp.*) is one of the most important and widely cultivated staple food crops among the cereals and is known for its remarkable adaption in a wide range of environments. India is one of the major producers of wheat and occupies second position after China. The total area under cultivation of wheat in India in 2016-17 was 30.23 million hectares with the production of 93.50 million tons and an average yield of 3.02 tons/ha (Anonymous, 2016-17). Much of the emphasis on wheat breeding has been placed on increasing productivity of the crop. This has been in response to the pressure for an adequate food supply caused by constantly increasing population in India and the world as a whole. Therefore, development of new improved wheat cultivars with high genetic potential for yield and yield contributing traits has become a permanent goal in the breeding programme.

In order to achieve this target one should be aware of genetic makeup and nature of gene action involved in controlling plant responses to different environments. For the breeding programme aiming at hybridization, information about better combiner possessing desirable traits is a pre-requisite. Knowledge of the combining ability is important in selecting suitable parents for hybridization, understanding of inheritance of quantitative traits and also in identifying the promising cross combinations for further use in breeding programme. The present investigation was undertaken to study the combining ability of parents for yield and yield contributing traits in wheat.

Materials and Methods

The present investigation was undertaken at the Experimental Farm, Department of Agricultural Botany, College of Agriculture, Latur, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.). Five lines of wheat, AKAW-1071, Ajantha, NIAW-1994, NIAW-1415 and HD-2932 and eight testers *viz.,* AKAW-4930, AKAW-4794, MACS-6222, GW-483, CG-1021, PBN-4888, PBN-4357 and UAS-379 were crossed in line x tester mating scheme to produce 40 crosses during *rabi*, 2016-2017. These crosses were then evaluated along with the parents and two checks, MACS-6478 and LOK-1 during *rabi*, 2017-18. The experiment was laid out in a Randomized Block Design (RBD) with two replications. Each treatment comprised of two rows of 2 m length with spacing of 30 cm between rows and 10 cm plant to plant. The data were collected on yield and yield attributing characters *viz.*, days to heading, days to 50 per cent flowering, days to maturity, plant height (cm), number of effective tillers per plant, spike length (cm), number of spikelets per spike, number of seeds per spikelet, number of seeds per spike, 1000grain weight (g) and grain yield per plant (g). The combining ability variances analysis was carried out based on method developed by Kempthorne (1957).

Results and Discussion

The analysis of variance revealed highly significant differences among the genotypes for all the characters studied, which suggest the presence of adequate diversity among the genotypes (Table 1). The estimates of general combining ability (gca) and specific combining ability (sca) variances and their ratio of (δ^2gca/δ^2sca) was less than unity for all characters studied in present investigation, which indicates that preponderance of non-additive type of gene action. These findings are in general agreements with those of Seboka *et al.*, (2009), Singh *et al.*, (2012), Bhaghyalaxmi *et al.*, (2015) and Kumar and Kerkhi (2015).

The magnitude and direction of combining ability effects provide the guidelines for the utilization of parents in hybridization programme. Significant gca effects have been recorded for all the characters studied (Table 2). It was observed that none of the parents was a good general combiner simultaneously for all the characters. Among the lines, NIAW-1994 was found to good general combiner for days to heading, days to 50 per cent flowering, days to maturity and plant height (cm), number of effective tillers per plant, 1000grain weight (g) and grain yield per plant (g), exhibiting significant GCA effect in desirable direction. The genotype, HD-2932 was identified as good general combiner for grain yield per plant (g), 1000grain weight (g) and number of effective tillers per plant. NIAW-1415 was good general combiners for number of spikelets per spike, number of seeds per spikelet and number of seeds per spike. The parental line, AJANTHA was found to be good general combiners for spike length (cm). On the other hand parents, AKAW-1071 exhibited poor general combining ability for almost all characters except for number of spikelets per spike exhibits significant GCA effects in desire direction.

Table.1 Analysis of variance (mean squares) and variances estimates for combining ability for eleven characters in wheat

Source of Variation	DF	Days to heading	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	No. of spikelets per spike	No. of seeds per spikelet	No. of seeds per spike	1000grain weight (g)	Grain yield per plant (g)
Replications	1	1.849	3.774	4.566	27.306	0.275	0.005	0.123	0.010	13.766	0.848	0.053
Treatments	52	64.762**	66.468**	20.573**	50.310**	18.532**	3.383**	2.862**	0.210**	61.537**	74.592**	29.846**
Parents	12	94.718**	98.654**	46.038**	44.077**	5.056**	4.505**	4.364**	0.165*	118.900**	59.393**	12.850**
Line	4	63.350**	84.600**	24.250**	83.502**	4.410**	4.974**	4.261**	0.295**	159.084**	16.538**	25.990**
Tester	7	46.205**	37.848**	43.634**	25.717	5.989**	3.651**	4.792**	0.111	105.103**	89.557**	7.043**
Crosses	39	53.621**	54.069**	12.833**	49.648**	19.602**	2.925**	2.469**	0.226**	45.000**	80.701**	31.287**
Line x Tester	1	559.778**	580.509**	150.024**	14.895	1.112	8.605**	1.774	0.027	54.740*	19.663**	0.942
Parents vs Hybrids	1	139.807**	163.825**	16.825	150.917**	138.481**	7.762**	0.168	0.100	18.099	18.711**	177.594**
Error	52	2.849	5.524	5.681	15.286	0.280	0.487	0.540	0.071	9.985	0.537	1.447
Estimates												
δ^2 gca (f)		12.973**	12.120**	1.687*	6.168	1.346	0.544**	0.393*	0.022	6.962*	1.567	1.475
δ^2 gca (m)		5.029	3.846	0.533	0.310	1.672	0.363*	0.185	0.011	0.953	5.096	1.639
δ^2 gca (ave.)		9.918**	8.937**	1.243**	3.915*	1.472	0.474**	0.313**	0.018*	4.651*	2.924	1.538
δ^2 sca		14.245**	15.150**	2.386*	16.494**	9.828**	0.623**	0.662**	0.069**	15.237**	47.669**	17.047**
δ^2 gca/sca		0.696	0.590	0.521	0.237	0.150	0.761	0.472	0.261	0.305	0.061	0.090

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

Table.2 Estimates of general combining ability (GCA) effect of lines and testers for eleven characters in Wheat

Parents	Days to heading	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	No. of spikelets per spike	No. of seeds per spikelet	No. of seeds per spike	1000grain weight (g)	Grain yield per plant (g)
Lines											
AKAW-1071	3.475 **	4.313 *	1.238 *	-1.956	-0.233	0.048	0.489 *	-0.015	-1.320	-0.799 **	-0.733 *
AJANTHA	-2.150 **	-1.313 *	-0.950	2.694 **	-0.389 **	0.848 **	-0.010	-0.152 *	-1.339	-0.606 **	0.195
NIAW-1994	-5.275 **	-5.188 **	-2.013 **	-2.727 **	0.374 **	0.079	-0.792 **	-0.090	-2.064 *	1.964 **	0.757 *
NIAW-1415	2.350 **	0.750	1.175	-1.006	-1.470 **	0.254	0.786 **	0.272 **	4.749 **	-1.111 **	-1.705 **
HD-2932	1.600 **	1.438 *	0.550	2.994 **	1.718 **	-1.228 **	-0.473 *	-0.015	-0.026	0.552 **	1.486 **
Testers											
AKAW-4930	-1.000	-1.713 *	-0.188	2.543 *	-1.785 **	-0.301	0.633 **	0.053	1.585	3.397 **	-0.938 *
AKAW-4794	-4.800 **	-3.813 **	-1.588 *	-0.082	-1.715 **	-0.201	-0.127	0.013	-0.705	-0.704 **	-1.028 *
MACS-6222	0.100	0.088	-0.588	-1.987	-0.505 **	0.079	0.524 *	-0.137	0.775	-2.124 **	-1.098 **
GW-483	1.400 *	0.288	0.713	0.883	0.325	-0.201	0.038	0.221 *	0.195	3.595 **	-1.362 **
CG-1021	1.900 **	1.388	1.413	-0.467	1.225 **	-0.211	-0.567 *	0.113	-0.475	0.197	1.342 **
PBN-4888	-1.100 *	-0.813	-1.088	0.593	-0.165	0.339	-0.337	0.033	0.145	-1.674 **	-0.213
PBN-4357	1.400 *	1.988 *	0.313	-0.735	1.785 **	1.349 **	0.433	-0.127	1.315	-1.604 **	1.977 **
UAS-379	2.100 **	2.588 **	1.013	-0.747	0.835 **	-0.851 **	-0.597 *	-0.167	-2.835 **	-1.084 **	1.317 **
S.E.(Gi)	0.478	0.665	0.674	1.106	0.149	0.205	0.208	0.075	0.894	0.207	0.340
S.E.(Gi-Gj)	0.676	0.941	0.954	1.565	0.212	0.279	0.293	0.106	1.265	0.293	0.481
CD @ 95%	0.966	1.345	1.365	2.239	0.303	0.339	0.421	0.152	1.809	0.420	0.688
CD @ 99%	1.294	1.801	1.826	2.997	0.405	0.534	0.563	0.204	2.422	0.562	0.922

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

Table.3 Estimates of specific combining ability (SCA) effects of crosses for eleven characters in wheat

Sr. No.	Crosses	Days to heading	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	No. of spikelets per spike	No. of seeds per spikelet	No. of seeds per spike	1000grain weight (g)	Grain yield per plant (g)
1	AKAW-1071 x AKAW-4930	-2.375	-3.413*	0.063	3.876	-1.178**	0.633	0.011	0.035	6.990**	12.629**	4.153**
2	AKAW-1071 x AKAW-4794	-5.075**	-5.313**	-2.538	0.601	2.703**	-0.567	-0.429	0.075	0.880	2.979**	3.293**
3	AKAW-1071 x MACS-6222	2.525*	1.788	2.463	-5.394	-5.358**	-0.347	0.820	-0.275	-7.200**	-5.702**	-4.437**
4	AKAW-1071 x GW-483	2.725*	2.588	2.163	3.086	1.563**	-1.118*	-0.244	0.667**	-1.370	2.131**	-0.143
5	AKAW-1071 x CG-1021	1.225	1.488	-0.038	-5.664*	4.563**	0.943	0.461	-0.325	-3.200	-2.922**	3.523**
6	AKAW-1071 x PBN-4888	1.725	0.688	-0.038	-1.874	-2.348**	0.442	-0.419	-0.545**	-5.170*	-4.152**	-2.122*
7	AKAW-1071 x PBN-4357	1.725	3.388*	0.063	7.654**	1.003*	-0.518	0.361	-0.185	2.210	-4.122**	-2.812**
8	AKAW-1071 x UAS-379	-2.475*	-1.213	-2.138	-2.284	-0.947*	0.533	-0.559	0.555**	6.860**	-0.842	-1.452
9	AJANTHA x AKAW-4930	-1.250	-3.788*	-0.750	2.926	0.729	0.082	-0.690	0.172	0.459	9.086**	3.775**
10	AJANTHA x AKAW-4794	-3.450**	-3.188	-2.350	2.551	-0.491	0.133	0.470	0.112	1.699	1.086*	-1.685
11	AJANTHA x MACS-6222	2.650*	1.913	1.650	5.506	1.599**	1.353**	0.174	0.012	2.219	8.206**	4.285**
12	AJANTHA x GW-483	-5.150**	-3.788*	-1.650	2.886	0.519	-0.117	-0.745	-0.146	-2.201	3.878**	2.099*
13	AJANTHA x CG-1021	0.350	1.613	-0.350	-5.664*	-1.281**	-0.608	0.360	-0.088	-0.531	0.986	-1.705
14	AJANTHA x PBN-4888	-5.150**	-5.688**	-2.850	-0.074	4.709**	1.193*	-0.320	-0.108	-1.151	-4.594**	4.050**
15	AJANTHA x PBN-4357	0.850	1.513	1.750	-2.746	-2.641**	0.532	0.910	-0.048	0.679	-5.564**	-6.040**
16	AJANTHA x UAS-379	11.150**	11.413**	4.550*	-5.384	-3.141**	-2.568**	-0.160	0.092	-1.171	-13.084**	-4.780**
17	NIAW-1994 x AKAW-4930	-1.625	0.088	-1.688	1.047	-2.684**	-1.249*	-0.008	-0.390*	-3.916	-11.084**	-4.687**
18	NIAW-1994 x AKAW-4794	3.675**	3.188	1.713	5.697*	1.846**	0.201	0.652	-0.150	-0.176	-3.284**	0.403
19	NIAW-1994 x MACS-6222	0.775	0.288	0.713	-0.524	0.586	-0.279	0.001	0.200	2.944	-4.364**	1.473
20	NIAW-1994 x GW-483	3.475**	2.588	0.413	-2.494	2.906**	0.751	0.437	-0.458*	-0.676	-3.832**	1.737*
21	NIAW-1994 x CG-1021	-1.025	-1.013	-0.288	3.756	2.956**	0.311	-0.508	0.450*	5.694*	7.316**	5.033**
22	NIAW-1994 x PBN-4888	-0.025	-0.313	1.213	-5.003	-0.604	0.211	0.162	0.330	2.324	4.436**	0.588
23	NIAW-1994 x PBN-4357	-2.025	-3.113	-2.688	-1.216	-1.404**	-0.399	-0.058	0.190	-3.246	0.266	0.398

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

Table.3 Continued.

Sr. No	Crosses	Days to heading	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of effective tillers per plant	Spike length (cm)	No. of spikelets per spike	No. of seeds per spikelet	No. of seeds per spike	1000grain weight (g)	Grain yield per plant (g)
24	NIAW-1994 x UAS-379	-3.225*	-1.713	0.613	-1.264	-3.604**	0.451	-0.678	-0.170	-2.946	10.546**	-4.942**
25	NIAW-1415 x AKAW-4930	4.250**	5.650**	2.625	-7.374*	4.260**	-0.074	-1.436**	0.248	-3.679	-10.159**	1.075
26	NIAW-1415 x AKAW-4794	-2.950*	-2.750	-1.475	-3.499	-0.810*	-0.074	-1.326*	-0.211	-8.389**	2.791**	1.015
27	NIAW-1415 x MACS-6222	-1.350	0.350	-0.475	0.556	3.030**	0.546	0.423	0.239	6.131**	3.211**	2.635**
28	NIAW-1415 x GW-483	0.350	-0.350	0.225	-4.264	-3.500**	0.676	0.884	-0.130	3.761	2.493**	-1.801*
29	NIAW-1415 x CG-1021	-0.650	-2.450	0.525	3.436	-5.350**	-0.164	1.414**	-0.012	2.881	-4.109**	-5.205**
30	NIAW-1415 x PBN-4888	2.350	3.750*	-0.975	2.326	-1.160**	-0.864	-0.616	-0.032	-2.039	5.511**	-1.650
31	NIAW-1415 x PBN-4357	0.350	0.950	1.125	5.204	0.890*	-0.324	-0.386	0.329	2.591	5.141**	1.860*
32	NIAW-1415 x UAS-379	-2.350	-5.150**	-1.575	3.616	2.640**	0.276	1.044	-0.432*	-1.259	-4.879**	2.070*
33	HD-2932 x AKAW-4930	1.000	1.463	-0.250	-0.474	-1.128**	0.607	2.123**	-0.065	0.146	-0.472	-4.316**
34	HD-2932 x AKAW-4794	7.800**	8.063**	4.650**	-5.349	-3.248**	0.308	0.633	0.175	5.986*	-3.572**	-3.026**
35	HD-2932 x MACS-6222	-4.600**	-4.338*	-4.350*	-0.144	0.143	-1.273*	-1.418**	-0.175	-4.094	-1.352*	-3.956**
36	HD-2932 x GW-483	-1.400	-1.038	-1.150	0.786	-1.488**	-0.193	-0.332	0.067	0.486	-4.670**	-1.892*
37	HD-2932 x CG-1021	0.100	0.363	0.150	4.136	-0.887*	-0.483	-1.127**	-0.025	-4.844*	-1.272*	-1.646
38	HD-2932 x PBN-4888	1.100	1.563	2.650	4.626	-0.598	-0.983	1.193*	0.355	6.036*	-1.201*	-0.866
39	HD-2932 x PBN-4357	-0.900	-2.738	-0.250	-8.896**	2.153**	0.708	-0.827	-0.285	-2.234	4.279**	6.595**
40	HD-2932 x UAS-379	-3.100*	-3.338	-1.450	5.316	5.053**	1.308*	0.353	-0.045	-1.484	8.259**	9.105**
	SE (±)	1.1935	1.6619	1.6854	2.7646	0.3742	0.4932	0.5196	0.1887	2.2344	0.5183	0.8506

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

Among male parents, CG-1021, PBN-4357 and UAS-379 were found to be good general combiners for seeds yield per plant, there by classifying these parents as good sources of favorable genes for increasing production of seed yield per plant. These male parents also exhibited good general combining ability for two or more important yield contributing traits. The genotype, AKAW-4794 was found to good general combiner for days to heading, days to 50 per cent flowering and days to maturity exhibiting significant GCA effect in negative direction. AKAW-4930 was good general combiners for days to 50 per cent flowering in negative direction and number of spikelets per spike and 1000grain weight (g) in positive direction.

The male parents, CG-1021 and UAS-379 were found to be good general combiner for number of effective tillers per plant and grain yield per plant (g). PBN-4357 was found to be good general combiner for number of effective tillers per plant, spike length (cm) and grain yield per plant (g). The male parent, GW-483 was found to be good general combiner for number of seeds per spikelet and 1000grain weight (g). MACS-6222 was found good general combiner for number of spikelets per spike. On the other hand parents, PBN-4888 exhibited poor general combining ability for all characters. Similar results are in accordance with Kapoor *et al.*, (2011), Jain and Sastry (2012) and Raj and Kandalkar (2013).

The estimates of specific combining ability effects are presented in Table 3 revealed the highest SCA effect for grain yield per plant was exhibited by crosses, HD-2932 x UAS-379 followed by HD-2932 x PBN-4357, NIAW-1994 x CG-1021 with parents involved in these crosses were the best general combiners for this traits, AJANTHA x MACS-6222 with the one parent average combiners and another is poor combiner and AKAW-1071 x AKAW-4930 with the both parents having poor general combiners.

Considering desire SCA effects, the best combination with their GCA effects were HD-2932 x UAS-379 for grain yield per plant, AJANTHA x GW-483, AJANTHA x PBN-4888 for days to heading, AJANTHA x PBN-4888 for days to 50 per cent flowering, HD-2932 x MACS-6222 for days to maturity, HD-2932 x PBN-4357 for plant height, HD-2932 x UAS-379 for number of effective tillers per plant, AJANTHA x MACS-6222 for spike length, HD-2932 x AKAW-4930 for number of spikelets per spike, AKAW-1071 x GW-483 for number of seeds per spikelets, AKAW-1071 x AKAW-4930 for number of seeds per spike and cross AKAW-1071 x AKAW-4930 for 1000grain weight. Above findings also reported by Jain and Sastry (2012), Singh *et al.*, (2012), Bibi *et al.*, (2013), and Lohithasawa *et al.*, (2013).

In contrast to general combining ability effect and specific combining ability effect represents dominance and epistatic components of variation, which are not fixable in nature. The crosses showing high SCA effect involving either both or one good general combiner parent could be successfully exploited for varietal improvement and expected to throw stable performance in transgressive segregants carrying fixable gene effects. The cross involving both good general combiners suggested still better possibilities of exploitation as it is expected to yield stable segregants in the advanced generations and needs further exploitation in the breeding programme. The cross combinations involving average x good general combining parents besides exhibiting favorable additive effect of good combiner parents manifested complementary interaction effects and thus, resulted in higher sca effects. While the cross showing average x average parents, magnitude of SCA was higher due to average combiner and complementary epispastic effect in the same direction. The GCA effect of the parents and SCA effect of their crosses in the present study indicated that except in few cases, the crosses between two good general combiners were not always the best specific combinations. Seboka *et al.,* (2009), Jain and Sastry (2012) and Singh *et al.,* (2012) also reported that two good combiners may not always result in high SCA effect.

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