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Analysis of combining ability for yield and its contributing traits in bread wheat (*Triticum aestivum* L.)

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Abstract
A half diallel cross (excluding reciprocals) was conducted to study the combining ability comprised of forty-five F_1s developed by crossing of ten diverse genotypes of bread wheat (*Triticum aestivum* L.). The data were recorded on eleven characters namely days to 50% flowering, days to maturity, plant height at maturity (cm), number of productive tillers/plant, spike length (cm), number of spikelets/spike, number of grains/spike, 1000 grain weight, biological yield/plant, grain yield/plant and harvest index (HI). The estimates showed that mean squares due to general combining ability as well as specific combining ability were highly significant for all traits under study. The ratio of estimates of variances of GCA/SCA was less than unity indicated the preponderance of non-additive gene action in their inheritance. On the basis of significant GCA effect, parents UP 262, NW 305 and HD 2285 were found good general combiners for grain yield per plant. Specific combining ability is deviation in a performance of hybrid from expected value on the basis of general combining ability effect of lines involved, and can be regarded as a measure of non–additive gene action. On the basis of significant SCA effect, fifteen crosses out of forty five crosses were found good specific combiners, of which K 9162 X DWR 544, UP 262 X HD 3086 and UP 262 X DWR 544 were the best specific combiners for grain yield per plant.

Keywords: Combining, ability, contributing, wheat, *Triticum aestivum* L.

Introduction
Wheat (*Tritium aestivum* L.), being as a staple food, is the most important cereal crop that contributes significantly to the global food and food security (Thomas *et al*., 2017) [12]. Bread wheat is hexaploid, self-pollinated crop and belongs to Poaceae family. Around 90 to 95% of the wheat produced in the world is common or bread wheat (*Tritium aestivum* L.), which is an allohexaploid (2n=6x=42, AABBDD) with the haploid content of 1.7 x 10^{10} bp approximately. Wheat ranks first among the world food crops, in terms of cultivated area in 222.27 mha and production 779.3 mmt with productivity of 35.1 qha^{-1} during rabi 2021-22 (USDA 2022) [14]. In India, the wheat crop season 2020-21 has been one of the most epoch-making year in more than 60 years of coordinated research activities in wheat that has witnessed an all-time highest production of 108.75 million tonnes (Annual Report, ICAR-IIWBR 2021).
Diallel mating design has been extensively used to identify parents with better potential to transmit desirable characteristics to its progenies and to identify the best specific crosses for yield and various quality parameters. In an effective breeding program a better understanding of the genetic basis of yield and its contributing characters, general combining ability (GCA), specific combining ability (SCA) and the action of genes in the breeding material is very important. For these purpose, the combining ability analysis is an efficient tool to discriminate good as well as poor combiners for selecting appropriate parental materials for desirable traits in the wheat improvement programme.
Keeping this in view, the present study was carried out to evaluate the performance of parents and F1 hybrids to determine general and specific combining ability of parents and F1 hybrids for various traits in bread wheat.

Materials and Methods

The experiment was carried out during Rabi 2019-20 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology Meerut-250110 (U.P.). The experimental materials comprised of ten parents and their 45 crosses of *Triticum aestivum*. Parents were crossed in diallel fashion (excluding reciprocals) to obtain 45 crosses. The particulars of wheat parental material and their crosses used are presented in Table 1.

The data were recorded on eleven characters namely days to 50% flowering, days to maturity, plant height at maturity (cm), number of productive tillers/plant, spike length (cm), number of spikelets/spike, number of grains/spike, 1000 grain weight, biological yield/plant, grain yield/plant and harvest index (HI). Analysis of variance was done by using method of Panse and Sukhatme (1967) [10] and combining ability analysis was done using Griffing's method II, model I (1956).

Table 1: A list of parents and F_1 hybrids used in present investigation

S. No	Parents	S. No.	F1 Hybrid	S. No	F1 Hybrid
1	PBW 343	18	PBW 343 X DWR 544	37	UP 262 X NW 305
2	DBW 187	19	PBW 343 X HD 3086	38	UP 262 X PBW 226
3	RAJ 3265	20	DBW 187 X RAJ 3265	39	UP 262 X DWR 544
4	UP 262	21	DBW 187 X UP 262	40	UP 262 X HD 3086
5	HD2285	22	DBW 187 X HD 2285	41	HD2285 X K 9162
6	K 9162	23	DBW 187 X K 9162	42	HD2285 X NW 305
7	NW 305	24	DBW 187 X NW 305	43	HD2285 X PBW 226
8	PBW 226	25	DBW 187 X PBW 226	44	HD2285 X DWR 544
9	DWR 544	26	DBW 187 X DWR 544	45	HD2285 X HD 3086
10	HD 3086	27	DBW 187 X HD 3086	46	K 9162 X NW 305
		28	RAJ 3265 X UP 262	47	K 9162 X PBW 226
	F1 Hybrid	29	RAJ 3265 X HD 2285	48	K 9162 X DWR 544
11	PBW 343 X DBW 187	30	RAJ 3265 X K 9162	49	K 9162 X HD 3086
12	PBW 343 X RAJ 3265	31	RAJ 3265 X NW 305	50	NW 305 X PBW 226
13	PBW 343 X UP262	32	RAJ 3265 X PBW 226	51	NW 305 X DWR 544
14	PBW 343 X HD 2285	33	RAJ 3265 X DWR 544	52	NW 305 X HD 3086
15	PBW 343 X K 9162	34	RAJ 3265 X HD 3086	53	PBW 226 X DWR 544
16	PBW 343 X NW 305	35	UP 262 X HD 2285	54	PBW 226 X HD 3086
17	PBW 343 X PBW 226	36	UP 262 X K 9162	55	DWR544 X HD 3086

Result and Discussion

In the present investigation, an effort was made to obtain information on the estimates of GCA and SCA variances and GCA and SCA effects of parents and their hybrids for different morphological traits through combining ability analysis. The total genetic variance is divided into general combining ability variance and specific combining ability variance. General combining ability variance indicating the additive gene actions while, Specific combining ability variance depicting the non-additive gene actions for various characters. The estimates showed that mean squares due to general combining ability as well as specific combining ability were highly significant for all traits under study (Table 2). The ratio of estimates of variances of GCA/SCA is less than unity indicated the preponderance of non-additive gene action in their inheritance. Similar result was also supported by the findings of Kajla *et al*. (2022) [4], Nageshwar *et al.* (2021) [9], Tayade *et al.* (2019) [11], Khokhar *et al.* (2019), Nagar *et al.* (2018) [8], Abas *et al*. (2018) [1], Tiwari *et al.* (2017) [13], Yadav *et al.* (2017), Motawea (2017) [7], Kumar *et al.* (2017) [6] and Kumar and Kerkhi (2015) [5].

Parents with significant GCA effects in the desired direction were categorized as good general combiners and those with significant GCA effects in undesirable direction were poor general combiners. The GCA effects of the parents for different traits obtained from the diallel analysis are given in Table 3. On the basis of significant GCA effect, parents UP 262, NW 305 and HD 2285 were found good general combiners for grain yield per plant. Specific combining ability is deviation in a performance of hybrid from expected value on the basis of general combining ability effect of lines involved, and can be regarded as a measure of non–additive gene action. On the basis of significant SCA effect, fifteen crosses out of forty five crosses viz., K 9162 X DWR 544, UP 262 X HD 3086, UP 262 X DWR 544, HD2285 X PBW 226, DBW 187 X NW 305, PBW 343 X DBW 187, RAJ 3265 X K 9162, UP 262 X HD 2285, NW 305 X PBW 226, PBW 343 X DWR 544, PBW 343 X UP262, HD2285 X HD 3086, HD2285 X K 9162, PBW 343 X RAJ 3265, DWR544 X HD 3086, HD2285 X NW 305 and DBW 187 X HD 2285 were found good specific combiners for grain yield per plant.

Table 2: Analysis of variance of combing ability

Sourced of variation	D.F.	Days to 50% flowering	Days to Maturity	Plant height	No. of tillers per plant	Spike length (cm)	Spikelets per spike	Grains per spike	Biological yield per plant (gm)	Harvest index (%)	1000 seed wt	Grain yield per plant (gm)
Gca	9	12.91**	15.99**	40.08**	1.10**	0.45**	1.36**	11.28**	25.50**	14.80**	10.96**	2.71**
sca	45	11.28**	13.75**	13.11**	0.70**	0.41**	0.67**	9.37**	16.77**	7.18**	7.13**	2.68**
Error	108	1.65	0.68	1.89	0.05	0.05	0.19	1.78	1.23	0.82	0.76	0.12
Var due to gca		0.94	1.28	3.18	0.09	0.03	0.10	0.79	2.02	1.16	0.85	0.22
Var due to gca		9.63	13.08	11.22	0.65	0.36	0.48	7.58	15.54	6.36	6.37	2.57
Gca/sca ratio		0.097	0.098	0.284	0.134	0.092	0.202	0.104	0.130	0.183	0.133	0.084

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

Table 3: GCA effects for parents

S.no	Parents	Days to 50% flowering	Days to Maturity	Plant height	No. of tillers per plant	Spike length (cm)	Spikelets per spike	Grains per spike	Biological yield per plant (g)	Harvest index (%)	1000 seed wt	Grain yield per plant (g)
1	PBW 343	1.29 **	1.12 **	-3.33 **	0.10	-0.31 **	0.14	0.27	-1.21 **	0.94 **	0.49 *	-0.14
2	DBW 187	-2.12 **	-2.54 **	1.14 **	0.06	0.05	0.41 **	0.97 **	1.67 **	-1.52 **	0.96 **	0.11
3	RAJ 3265	0.29	-0.63 **	-0.59	0.03	0.03	-0.03	-0.43	-0.39	-2.21 **	-0.88 **	-0.76 **
4	UP 262	0.96 **	1.51 **	1.43 **	0.50 **	0.44 **	0.30 *	1.33 **	2.23 **	-0.08	-0.20	0.79 **
5	HD2285	-0.71 *	-0.18	-0.84 *	-0.04	-0.08	-0.59 **	-1.56 **	-0.13	1.00 **	-0.22	0.28 **
6	K 9162	-0.12	0.15	-0.79 *	-0.44 **	0.11	-0.16	-0.38	0.08	-0.08	1.58 **	-0.02
7	NW 305	1.18 **	1.09 **	2.61 **	-0.54 **	0.03	0.50 **	1.42 **	0.55	0.76 **	0.50 *	0.42 **
8	PBW 226	0.21	0.21	-1.13 **	0.03	-0.08	-0.23	-0.63	-3.01 **	1.12 **	-1.51 **	-0.73 **
9	DWR 544	-0.62	-0.52 *	2.30 **	0.04	-0.08	-0.12	-0.46	0.52	-0.25	0.32	0.09
10	HD 3086	-0.37	-0.21	-0.79 *	0.27 **	-0.11	-0.23	-0.53	-0.33	0.32	-1.03 **	-0.03

Table 4: Specific combined ability (sca) for hybrids

S.No.	Hybrids	Days to 50% flowering	Days to Maturity	Plant height	No. of tillers per plant	Spike length (cm)	Spikelets per spike	Grains per spike	Biological yield per plant (gm)	Harvest index (%)	1000 seed wt	Grain yield per plant (gm)
11	PBW 343 X DBW 187	-0.18	0.46	0.90	-0.13	0.20 *	-0.14	0.57	2.16 **	4.09 **	3.89 **	2.18 **
12	PBW 343 X RAJ 3265	-0.93 *	0.88 **	4.17 **	-0.17 *	-0.15	-0.04	1.11 *	0.66	1.05 **	3.13 **	0.52 **
13	PBW 343 X UP262	-0.27	0.41	-1.25 *	0.23 **	-0.59 **	0.03	0.42	0.07	2.76 **	4.65 **	0.94 **
14	PBW 343 X HD 2285	1.73 **	2.10 **	1.35 **	0.43 **	0.10	0.39 *	1.84 **	3.46 **	-4.11 **	1.07 **	-0.09
15	PBW 343 X K 9162	0.15	0.44	-9.90 **	0.36 **	-0.34 **	-0.18	0.26	-2.55 **	2.60 **	-2.33 **	-0.18
16	PBW 343 X NW 305	2.51 **	3.49 **	-3.96 **	-0.74 **	0.52 **	1.10 **	2.52 **	-1.11 **	1.00 **	1.75 **	-0.11
17	PBW 343 X PBW 226	-3.18 **	-2.95 **	0.77	0.22 **	-0.40 **	0.16	1.25 *	-1.72 **	0.11	-0.24	-0.67 **
18	PBW 343 X DWR 544	-3.02 **	-0.23	2.21 **	0.68 **	0.23 **	0.65 **	0.80	1.91 **	1.00 **	-0.87 **	1.05 **
19	PBW 343 X HD 3086	-2.93 **	-2.20 **	-0.10	-0.55 **	0.20 *	-0.10	0.41	-2.57 **	-1.00 **	-3.92 **	-1.25 **
20	DBW 187 X RAJ 3265	-1.18 *	0.21	-3.57 **	-0.20 *	-0.45 **	-0.77 **	-0.93	-1.65 **	2.02 **	-0.74 *	0.00
21	DBW 187 X UP 262	1.48 **	1.08 **	0.35	0.60 **	-0.35 **	0.51 **	1.91 **	0.06	-0.92 **	1.97 **	-0.36 **
22	DBW 187 X HD 2285	-2.18 **	-2.23 **	-1.52 **	-0.06	-0.09	0.06	0.87	-0.65	1.63 **	-1.10 **	0.28 *

23	DBW 187 X K 9162	0.23	-3.90 **	2.50 **	-0.66 **	0.21 *	0.03	0.82	-1.99 **	-0.44	2.50 **	-0.83 **
24	DBW 187 X NW 305	-4.07 **	-4.51 **	2.77 **	1.03 **	0.17	-0.09	0.68	8.34 **	-0.45	5.49 **	2.76 **
25	DBW 187 X PBW 226	-2.77 **	-3.62 **	0.83	0.53 **	0.44 **	0.37 *	1.87 **	0.63	-1.01 **	-1.81 **	-0.07
26	DBW 187 X DWR 544	4.40 **	4.77 **	2.34 **	-0.48 **	0.14	0.26	1.76 **	-3.43 **	-3.48 **	-0.04	-2.21 **
27	DBW 187 X HD 3086	5.82 **	7.46 **	-4.90 **	-0.84 **	0.20 *	0.31	1.64 **	-0.92 *	0.42	-0.79 *	-0.17
28	RAJ 3265 X UP 262	2.40 **	1.83 **	0.41	-0.97 **	-0.03	0.67 **	2.58 **	-5.01 **	1.02 **	0.62	-1.49 **
29	RAJ 3265 X HD 2285	4.73 **	5.52 **	-1.85 **	-0.70 **	0.02	0.96 **	3.67 **	-1.62 **	-3.75 **	0.35	-1.72 **
30	RAJ 3265 X K 9162	5.15 **	4.85 **	-0.37	0.40 **	0.85 **	0.40 *	2.15 **	6.90 **	-0.58	-0.95 **	2.07 **
31	RAJ 3265 X NW 305	-0.82	-1.76 **	-0.23	0.46 **	-0.55 **	-1.19 **	-2.32 **	-1.86 **	-0.10	1.23 **	-0.71 **
32	RAJ 3265 X PBW 226	2.15 **	2.13 **	-2.77 **	-0.45 **	0.99 **	0.13	1.34 **	1.06 **	-1.46 **	-0.66 *	-0.06
33	RAJ 3265 X DWR 544	-0.35	-0.15	1.01 *	-1.12 **	0.19 *	0.02	1.10 *	-3.00 **	2.58 **	0.91 **	-0.31 *
34	RAJ 3265 X HD 3086	-0.60	-0.12	1.03 *	0.85 **	-0.20 *	-0.33 *	-0.16	3.28 **	-3.94 **	-4.85 **	-0.26 *
35	UP 262 X HD 2285	-4.93 **	-4.95 **	-0.47	0.03	0.24 **	0.30	0.91	5.86 **	-0.42	-0.64 *	2.01 **
36	UP 262 X K 9162	-2.85 **	-0.29	-0.98	-0.84 **	0.02	-0.60 **	-1.67 **	-4.27 **	0.60	-1.54 **	-1.31 **
37	UP 262 X NW 305	4.84 **	6.10 **	6.08 **	0.80 **	1.39 **	1.08 **	3.26 **	0.68	-1.34 **	-3.66 **	-0.22
38	UP 262 X PBW 226	4.15 **	6.66 **	0.02	0.29 **	0.42 **	0.81 **	1.65 **	-3.56 **	3.21 **	-3.45 **	-0.42 **
39	UP 262 X DWR 544	-0.35	-3.62 **	6.56 **	2.15 **	0.98 **	1.10 **	2.61 **	6.91 **	1.37 **	1.12 **	3.01 **
40	UP 262 X HD 3086	3.40 **	2.74 **	-0.72	0.18 *	0.42 **	0.75 **	2.28 **	9.96 **	0.19	1.47 **	3.68 **
41	HD2285 X K 9162	1.82 **	1.08 **	2.42 **	0.17 *	0.51 **	0.29	1.28 **	-0.93 *	3.28 **	-2.02 **	0.69 **
42	HD2285 X NW 305	4.18 **	2.46 **	-2.58 **	-0.60 **	-0.20 *	-0.63 **	-1.18 *	1.74 **	-1.08 **	0.67 *	0.31 *
43	HD2285 X PBW 226	0.48	-0.31	1.95 **	1.90 **	1.01 **	0.43 **	1.81 **	3.90 **	4.54 **	3.47 **	2.90 **
44	HD2285 X DWR 544	4.32 **	5.41 **	-2.94 **	-0.11	0.04	-0.82 **	-1.70 **	-5.57 **	3.53 **	0.44	-1.06 **
45	HD2285 X HD 3086	-4.27 **	-5.23 **	-0.12	0.59 **	0.44 **	0.10	0.77	1.91 **	0.08	0.99 **	0.75 **
46	K 9162 X NW 305	2.26 **	2.80 **	-1.57 **	0.20 *	-1.63 **	-1.53 **	-3.83 **	0.40	-1.49 **	-0.43	-0.27 *
47	K 9162 X PBW 226	2.57 **	1.69 **	-1.77 **	-1.04 **	-0.12	-0.27	-0.38	-0.38	-3.72 **	1.97 **	-1.16 **
48	K 9162 X DWR 544	1.07 *	0.74 *	2.48 **	1.29 **	0.61 **	1.15 **	4.05 **	12.12 **	-1.20 **	-0.66 *	3.82 **
49	K 9162 X HD 3086	-2.85 **	-0.23	8.60 **	-0.21 **	0.81 **	1.13 **	3.66 **	-2.63 **	3.91 **	-3.71 **	0.23
50	NW 305 X PBW 226	-5.07 **	-5.26 **	5.84 **	0.19 *	0.00	-0.06	0.49	2.82 **	1.79 **	1.86 **	1.62 **
51	NW 305 X DWR 544	-0.24	0.80 **	-2.52 **	1.18 **	-0.77 **	0.03	0.78	-0.74	-0.50	-1.27 **	-0.37 **
52	NW 305 X HD 3086	-3.49 **	-4.51 **	4.23 **	-0.98 **	0.43 **	1.01 **	3.52 **	-2.13 **	2.69 **	1.27 **	0.05
53	PBW 226 X DWR 544	2.73 **	3.69 **	-6.59 **	-1.05 **	0.17 *	0.49 **	2.10 **	-2.22 **	3.82 **	3.23 **	0.19
54	PBW 226 X HD 3086	3.15 **	2.05 **	-0.77	0.31 **	-0.36 **	0.21	1.18 *	-0.84 *	0.56	-0.12	-0.22
55	DWR544 X HD 3086	0.98 *	-0.90 **	1.48 **	-0.16 *	-0.23 **	-0.04	0.53	-1.30 **	2.99 **	1.05 **	0.50 **
	sca(ii)	1.18	0.76	1.27	0.20	0.21	0.40	1.23	1.02	0.84	0.80	0.31
	sca(ij)	0.47	0.30	0.51	0.08	0.08	0.16	0.49	0.41	0.33	0.32	0.13

Conclusion

The general combining ability is attributed to additive and additive x additive gene action that are fixable in nature and opposite to this is the specific combining ability is due to the non- additive gene action which are non-fixable in nature. The presence of additive gene action could be utilized through pure line selection, mass selection and progeny selection while, the non-additive gene action can be exploited for initiating the hybrid- breeding programme. Based on the above result, we get that there is great significance of both additive as well as non-additive gene action for grain yield and its contributing characters studied. Therefore, it is suggested that there is considerable scope for improving these wheat genotype yield through pure line and heterosis breeding too.

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