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Research Article

HETEROSIS AND COMBINING ABILITY ANALYSIS FOR YEILD TRAITS OF INDIAN HEXAPLOID WHEAT (*TRITICUM AESTIVUM*)

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ABSTRACT

The estimation of SCA variance was higher than GCA variance for all the characters under studies indicated that non additive genetic variance was higher than additive genetic variance for these characters. Seven ovule parents and four pollen parents representing diverse genotypes of *Triticum aestivum* were used to produce twelve crosses combinations in accordance with the Line x Tester. Competitive plants from each replication were used for the analysis of combining ability. The parent "PBW 343" exhibited desirable significance GCA effect for days of flowering, spike lengh, No. of spikelets per spikes, 1000- grain weight and biological yield. The parent "UP 2338" exhibited desirable significance GCA effect for days of maturity and grain yield per plant. The best cross on the basis of SCA effect were PBW343 for days of flowering, days of maturity, No. of effective tillers, grain yield per plant and 1000- grain weight and the cross UP 2338 x Pavon 76 for days of flowering. Days of maturity, Plant height, grain yield per plant, and biological yield. These best parents and cross combinations could be effectively utilized in wheat breeding for the improvement of yield components and thus their incorporation in further breeding program was suggested.

INTRODUCTION

Background

Wheat (*Triticum aestivum* L.) is a predominant cereal crop of the world and constitutes important source of carbohydrate and protein. At global level, India ranks second largest wheat producing nation with 13.43% global wheat production after China which contributes 17.7% to the world wheat production (USDA, 2012). For improvement in wheat yield, study of the genetic structure and trend of combining ability and plant behavior under water stress is of great importance for the wheat scientist, knowledge of general and specific combining ability along with mode of gene action in available breeding material is very important to start effective wheat breeding Programme. Line × tester mating is effective strategy to evaluate genotypes used as parents for combining ability effects in order to select suitable parents for developing new cultivars (Majeed *et al.,* 2011). Combining ability analysis is one of the powerful tools to compare the performance of different lines in different hybrid combinations and aid in selecting desirable parents and crosses for exploitation of heterosis (Rashid *et al.,* 2007 and Salgotra, R.K. *et al.,* 2009). For evaluating combining ability the mating design (Line x Tester) suggested by (Kempthorne, 1957) is one of the efficient methods whereby large number of inbred lines can be evaluated (Rashid, 2007). For this combining ability analysis provides useful information to select the suitable parent for hybridization program (Kakani, R.K. *et al*., 2007 and Potla, R.K.*et al*., 2013) (Bornare, S.S. *et al*., 2014 and Zhang, X. *et al.,* 2015) have also undergone combining ability analysis for selection of efficient parent and cross in barley breeding.

MATERIAL AND METHODS

Four ovule parents (Lines) and three pollen parents (Testers) were raised in a crossing block (**Table 1**). The lines and testers were sown in single rows of 3m length with the rows and plants spaced at 30cm and 10cm, respectively, were raised. Crosses were made in all possible twelve combinations. Seeds of the twelve F_1 hybrids were planted along with their parents in Randomized Block Design with five replications. The following data recorded: days to flowering, days to maturity, plant height, number of tillers per plant, spike length, number of spikelet's per spike, grain yield per plant, 1000-grain weight per plant, biological yield and harvest index (%). The data were analyzed according to (Griffing, 1956) as per requirement of a Line X Tester analyses.

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Table 1 Parents and F1 hybrids used in a study of heterosis, combining ability effects

Tester (pollen parents)	
T1	PBW 343
T2	UP 2338
T3	HD 2687
Lines (ovule parents)	
L1	Diamond Bird
L2	RL 6077
L3	Pavon 76
L4	Webstar
Line x Tester (crosses)	
C1	PBW 343 x Diamond Bird
C2	UP 2338 x RL 6077
C3	HD 2687 x Pavon 76
C4	PBW 343 x Webstar
C5	UP 2338 x Diamond Bird
C6	HD 2687 x RL 6077
C7	PBW 343 x Pavon 76
C8	UP 2338 x Webstar
C9	HD 2687 x Diamond Bird
C10	PBW 343 x RL 6077
C11	UP 2338 x Pavon 76
C12	HD 2687 x Webstar

RESULTS AND DISCUSSION

The analysis of variance for combining ability for the ten characters is presented in **Tables 2.**

The estimation of components of variation revealed that the SCA variance was larger than the GCA variance for all ten characters. This was also evident in the GCA \ SCA ratios, which were less than unity for all the characters.

Combining ability effects for quantitative characters

The GCA and SCA effects for different quantitative characters are given in **Tables 4** and **Table 5**, respectively.

Days to flowering

Only two ovule parent (L2, L3) and one pollen parent (T1) showed significant positive GCA effects. One ovule parents (L1) and two pollen parent (T2, T3) showed significant negative GCA effects. Four cross combinations (C1, C6, C7 and C11) showed significant positive SCA effects and three combinations (C2, C8 and C12) showed significant negative SCA effects. Cross C6 produced the strongest significant positive SCA effect.

Days to maturity

Only one ovule parents (L1) and pollen parent (T2) produced significant positive GCA effects. Ovule parents L3 and pollen parent T1 had significant negative GCA effects. Four cross combinations (C3, C5, C7 and C11) showed significant

Table 2 Anylysis of varience for Combining ability of effects

Source	Df	Means Squares									
		Days of Flowering	Days to maturity	Plant height	Number of effective tillers	Spike length	No of Spikelets/ spikes	Grain yield	1000-grain weight	Biological Yield	Harvest Intex
Replication	5	0.6271	4.5308	0.1269	0.0502	0.0096	0.0056	0.0049	0.2045	0.8463	0.3646
Treatment	30	56.7684**	57.6845**	12.6445**	5.8649**	3.6715**	1.6503**	1.6459**	7.6459**	10.4523**	10.2468**
Error	168	3.6415	3.2126	0.2367	0.0245	0.0064	0.0234	0.0022	0.2749	0.6214	0.2496

The analyses showed that the mean squares for GCA were significant for the ten quantitative characters viz., plant height, number of tillers per plant, spike length, number of spikelets per spike, days to flowering, days to maturity, grain yield per plant, 1000-grain weight, biological yield, harvest index. Mean squares due to SCA were also significant for all measurements. Mean squares due to GCA were larger than the mean squares due to SCA for characters plant height, number of tillers per plant, days to flowering, days to maturity, grain yield per plant, No.of spikelets, Spike length, 1000-grain weight, biological yield and harvest index. Mean squares due to SCA were larger than the mean squares due to GCA for the characters spike length, number of spike lets per spike and harvest index **(Table 3)**.

positive SCA effects and two combinations (C1and C61) showed significant negative SCA effects. Cross C5 produced the strongest significant positive SCA effect.

Plant height

`Ovule parents L4 exhibited positive (significant) GCA effects for plant height. Ovule parent L2 and pollen parent GCA values (1.5706 respectively). Ovule parents L1 and all the pollen parents showed negative GCA. Cross combinations C2, C4 and C11 exhibited significant positive SCA effects and cross combinations (C7 and C8) exhibited significant negative SCA effects. Cross combination C4 had the highest significant positive SCA value.

Table 3 Analysis of variance for combining ability effects

Source	Df	Means Squares									
		Days of Flowering	Days to maturity	Plant height	Number of effective tillers	Spike length	No of Spikelets/ spikes	Grain yield	1000-grain weight	Biological Yield	Harvest Intex
Parent	4	53.8649	52.9462	16.2789	7.9421	2.0610	1.0026	2.9516	16.1573	5.3496	6.1892
Crosses	11	30.2486	31.1020	10.9460	5.3128	2.9640	1.2037	2.2908	2.9648	4.3849	6.9351
Parent Vs Crosses	1	802.3789	798.7619	19.0060	0.8924	0.7219	0.2037	3.4925	45.6189	212.3014	130.2894
lines	3	48.6289	101.6489	26.0348	12.8164	9.1167	4.5698	5.1618	7.2429	12.2783	21.5907
Testers	2	30.0648	25.9456	20.3148	15.26479	7.9874	1.6547	5.6541	8.1547	12.9823	8.0246
Lines x Testers	6	26.8421	10.2549	4.2378	1.0687	0.9120	0.8309	0.6317	1.2070	1.8643	2.0108
Error	168	3.5482	3.4561	0.9153	0.0984	0.0098	0.962	0.9456	0.9713	1.5987	0.8617
GCA :		2.628	2.577	0.319	0.549	0.988	2.135	0.175	2.096	2.627	2.536
SCA :		6.8421	3.2549	4.2378	0.8924	0.7219	0.8309	0.9456	1.2070	1.8643	2.0108
GCA: SCA :		0.0347	0.0156	0.0348	0.0621	0.0516	0.0537	0.0429	0.0418	0.0431	0.0498

Table 4 General combining ability effects for quantitative characters

Parent		Days of Flowering	Days to maturity	Plant height	Number of effective tillers	Spike length	No of Spikelets/ spikes	Grain yield	1000- grain weight	Biological Yield	Harvest Intex
	L1	-1.0568*	0.8641*	-1.2789*	0.4510*	-0.6974*	0.4321**	-0.2317	-0.5217*	-0.6489*	-0.5543
	L2	0.0094**	-2.1547	-2.2595	0.9452*	-0.0945**	0.2006	-0.0951	-0.6448	0.5321**	0.2347*
	L3	0.2489*	-0.2147**	-1.2540	-0.9561**	-0.7634	0.8629	-1.2687**	-1.0591**	-0.3064*	0.4820
	L4	1.5631	3.6480	1.5706**	-0.2159*	0.0984**	-0.8631*	-1.2040	0.2301*	0.9465*	1.5681**
SE (gi)		0.5381	0.7584	0.7724	0.1843	0.1830	0.1643	0.3117	0.1719	0.1332	0.2941
		1.159	2.302	2.3871	0.1368	0.1354	0.1091	0.3887	0.1186	0.0717	0.3468
Cov.H.S. (lines)	T1	0.3141*	-0.3826*	-1.4512*	0.9843	-0.3465**	-0.2348*	-0.3759	0.7531*	-0.8621*	-0.9121
	T2	-1.2146**	0.4021**	-0.6153	-0.0935*	-0.7630	-0.8642**	0.4591**	-0.0561	-0.0801	-0.0963**
	T3	-1.3012*	-1.5039	-0.7631**	0.8631**	0.5612	-0.0637	-0.4631*	-0.7521**	0.9421**	-0.5617

* - significant at 0.05% ; ** - significant at 0.01 %

Table 5 Specific combining ability effects for quantitative characters

Hybrid	Days of Flowering	Days to maturity	Plant height	Number of effective tillers	Spike length	No of Spikelets/ spikes	Grain yield	1000- grain weight	Biological Yield	Harvest Intex
C1	0.0945*	-0.2006*	-0.0951	0.1547*	-0.2595**	0.9452	-0.5631	-0.6480*	-0.5706	0.2216*
C2	-0.7634**	-0.8629	0.2687*	0.2147	-0.2540	-0.9561	-0.5381**	-0.7584	0.7724	-0.9416
C3	-0.0984	0.8631**	0.2040	0.6480**	-0.5706	0.2159	0.1592**	-2.3024**	-2.3871	0.8647
C4	2.1547	2.2595	0.9452**	-0.7584	0.7724*	0.1843**	-0.4953**	0.3789	0.7319**	0.7129
C5	-0.2147	1.2540*	0.9561	-0.3021	0.3871**	-0.1368*	0.3141**	0.3826	-0.4512*	0.8798**
C6	3.6480**	-1.5706**	-0.2159	-0.1719*	-0.1332*	-0.2941	0.2058*	0.4060**	0.7193	0.4039**
C7	0.2327*	0.2749*	-0.2362*	0.1186*	-0.0717	-0.3468	0.9713**	0.4196*	0.6914	0.3719
C8	-0.1623*	-0.2274	-0.1679*	-0.0094	0.0094**	0.3674*	-0.4286	-0.6824	0.8462**	-0.3197**
C9	-1.0212	-0.4762	0.4092	-0.7531**	0.8621	0.9121	-0.4510*	-0.6974**	-0.4321**	0.2347*
C10	-0.2575	-0.2789	-0.1202	-0.0561	-0.0801	0.0963**	0.9452	0.0945	-0.2006**	0.5543*
C11	0.1991**	0.2338*	0.0433*	0.5231	0.8732	-0.1298	0.9561*	-0.7634*	0.8629*	-0.2347**
C12	-1.4610*	0.4831	-0.2082	-0.5643*	0.6471*	-0.8914**	-0.6317**	0.5631**	0.7319	0.4820

* - significant at 0.05% ; ** - significant at 0.01 %

Number of tillers per plant

Ovule parents L1 and L2 and pollen parents T3 showed significant positive GCA effects. Ovule parent L2 and pollen parent T3 had the highest GCA values (0.9452 and 0.8631, respectively). Ovule parents L3, L4 and pollen parents T2 showed significant negative GCA. Three cross combinations (C1, C3 and C7) produced significant positive SCA effects and three cross combinations (C6, C9 and C12) showed significant negative SCA effects.

Spike length

Ovule parents L4 showed significant positive GCA effects, of which the L4 value was the largest (0.0984). Ovule parents L1, L2 and pollen parents T1 showed significant negative GCA effects. Four cross combinations showed significant positive SCA effects (C4, C5, C8 and C12). Only two cross combinations viz., C1 and C6) showed significant negative SCA effects.

Number of spikelet's per spike

Ovule parents L1 showed significant positive GCA effects. Ovule parents L4 and pollen parents T1 and T2 showed significant negative GCA effects. Three crosses (C4, C8 and C10) had significant positive SCA effects. Cross combinations (C5 and C12) showed significant negative SCA effects.

Grain yield per plant

All the ovule parents negative GCA effects, which of only one parent (L3) showed significant GCA effect value and only one pollen parents T2 produced significant positive GCA effects and pollen parent T3 had significant negative GCA effect value.

Five cross combinations (C3, C5, C6, C7 and C11) resisted in significant positive SCA effects. Four cross combinations (C2, C4, C9 and C12) gave significant negative SCA effects. Cross C7 had a highly significant SCA effect of 0.9713.

1000- Grain weight

Parents L4 and T1 showed significant positive GCA effects. Parents L1, L3 and T3 showed significant negative GCA effects. Three cross combinations (C1, C2, C3, C4, C18, C25, C26) showed significant positive SCA effects, three cross combinations (C6, C7, C12) showed significant negative SCA effects. Cross C12 had a highly significant positive SCA effect (0.5631).

Biological yield

Parents L2, L4 and T3 showed significant positive GCA effects, while L1, L3 and T1 showed significant negative GCA effects. Three cross combinations (C1, C2, C3, C4, C5, C17, C24, C25) showed significant positive SCA effects, while four hybrids (C4, C8, C11) showed significant negative SCA effects. Cross C11 had a highly significant positive SCA effect.

Harvest index

Parents L2, L4 showed significant positive GCA effects. Parents T2 showed significant negative GCA effects. Cross combinations C5, C6, C9 and C10 showed significant positive SCA effects, while cross combinations C8 and C11 showed significant negative SCA effects.

Combining ability is considered to be a useful indirect criterion for parent selection. However, only one study on combining ability of hybrid barley grain yield has been reported to our knowledge (Singh, S.K. 2003). In fact, both agronomic and yield traits are important in hybrid barley breeding programs (Anwar, J. *et al*., 2011). The GCA effects were lower than SCA effects in terms of all traits evaluated in the research in contrast to (Titan *et al*. 2012). They used 4 wheat lines and three testers and they tested 12 F_1 combinations for two seasons. They observed that SCA effects were generally lower than GCA effects. Besides, (Sharma, H.C. *et al.,* 2006, Borghi, B. and Perenzin, M. 1994). The difference in the results reported by researchers may be attributed to differences of parental materials used hybridization and to genotype × environments.

In our results, it was understood that, non additive gene effects were dominant the genetic control of this traits. Likewise, dominant genetic variance was found higher than additive variance for all traits. Hence, it can be seen that non-additive genetic effects are controlling the inheritance of studied traits. It was understood that selection for the traits inherited with this manner should be performed in the further generations like F_4 or F_5. Fellahi, Z.E.A. *et al*., 2013, reported the importance of non-additive gene action for the plant height, spike length, number of fertile tillers, thousand kernel weights and kernel yield.

The ratio of GCA and SCA variances indicated that non-additive type of gene action was major in the expression of traits i.e. no of tillers per plant, grain yield per plant and 1000-grain weight (Burungale, S.V. *et al*., 2011). The preponderance of non-additive gene action in the controlling of days to 50% flowering, days to 50% maturity, plant height, spike length, spike lets per spike (Singh, M.K. *et al*., 2014). The expression of non-additive gene action in the expression of non-additive gene action for the characters of days to 50% heading and maturity (Singh, S.K. 2003).

The expression that SCA was greater than GCA effect for plant height, spike length and 1000-grain weight (Zhang, X.Z. *et al*., 2013). The expression of GCA and SCA variances for the characters like tillers per plant, spike length and 1000-grain weight. In bread wheat early flowering, early maturity, short plant height, high tillers per plant, longer spike length, high spike per spike, high grain yield and high 1000-grain weight ware considered to be the desirable characters (Anwar, J. *et al.,* 2011).

The best crosses on the basis of SCA effect were PBW 343 x Diamond bird for maturity, tillers per plant, spike length, spike lets per spike and grain yield. The crosses HD 2687 x Diamond had both promising general and specific combiner. The cross was likely to throw transgressive segregates in advanced generations.

CONCLUSIONS

This cross can be exploited vigorously in future barley breeding program to obtain segregants which would deliver a population with high yield potential. Since non-additive type of gene action was found for all of the plant traits thereby suggesting that selection of superior plants should be deferred to later generation.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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