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Combining ability analysis in bread wheat (*Triticum aestivum* L.) under different environmental conditions

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ABSTRACT

A Pooled analysis was carried out to evaluate the general and specific combining ability effects in 9 diverse genotypes of bread wheat of diverse origin of cultivation, their 36 F1's and 2 checks during Rabi 2020-21 at RCA, Udaipur in three different environments for grain yield and its component traits. Analysis of variance revealed the differences between parents and crosses for GCA and SCA, respectively due to GCA and SCA effects were significant for all the characters except days to 50 % flowering in E_3 *(GCA) on pooled basis. Similarly, mean squares due to GCA x E and SCA x E were significant for all characters revealed influence of environment on GCA and SCA, respectively. The variance due to GCA was higher than their respective SCA for all characters except spike length, awn length and harvest index indicated that additive type of gene action played role in the expression of all the traits. Among parents, DBW 173, HD 2967, GJW 463 and RAJ 4120 were exhibited significant GCA effects for grain yield and its component traits. Maximum significant positive GCA effects were exhibited by parent DBW 173 (1.80) over the environments. Among crosses, thirteen crosses recorded showed significant SCA effects for grain yield and its related traits. Cross, HD 2967 x DBW 173 was exhibited maximum positive significant SCA effects for grain yield and harvest index in the environments as well as on pooled basis. Cross, HD 2967 x DBW 173 depicted maximum SCA effects (4.00) followed by RAJ 3777 x RAJ 4120 (2.92) for grain yield over environments. Attempting cross combinations involving different parents with high GCA for desirable yield and other traits could be useful.*

***Keywords*:** Bread wheat, combining ability analysis, general combining ability, specific combining ability

INTRODUCTION

Wheat (*Triticum aestivum* L.,) is an annual self pollinated cereal plant with (2n = 42) chromosome number belongs to order cyperales, family poaceae and genus *Triticum.* It is most widely consumed cereal crop in India where it meets the basic food requirements of human population. In India, wheat occupies an area of 30.55 million ha (13.43% of global area) with the production of 107.18 million tonnes and productivity of 3508 kg/ha. It is mostly grown in Northern, North Western and Central India. Major wheat growing states in India are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar and Gujarat. Wheat is mostly grown in temperate environment due to thermo sensitive nature. Globally, it is predominantly consumed in tropical and subtropical regions which are cultivated in winter season. At the end of season wheat crop is exposed to high temperature stress i.e. at grain filling stage. During this stage it reduces the yield and quality due to exposure to higher temperature (>35ºC) or heat stress. Generation of information through combining ability analysis may be helpful for developing thermo-tolerance wheat varieties on the effects of high temperature stress on different traits. Hence, now a day's heat tolerance breeding has become an essential part of crop improvement. The knowledge of breeding behavior, combining ability effects and types of gene actions is necessary for different traits. It provides useful information regarding the selection of suitable parents for effective hybridization programmes and elucidates the nature and magnitude of different types of gene action. Since, the nature of gene action with genetic architecture of population is involved in hybridization. Large scale testing and crossing programmes using diverse gene pool will most likely have high chances of identifying widely adapted germplasm, breaking genetic linkage and pyramid desired genes that testing in a narrow environmental range restricts genetic diversity in the crossing programmes. The

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environments which are used to test breeding material, often differs widely in their effect on crop yield. It is possible to identify the genotypes with high yield with low G x E interaction by exposing a number of genotypes in a set of contrasting environments. Therefore, the present study was conducted to predict the performance of 9 diverse genotypes in 36 hybrid combinations developed through half diallel analysis, for general and specific combining ability effects for different components of grain yield and heat tolerance under three different environments.

MATERIALS AND METHODS

The present study was conducted to evaluate GCA and SCA effects in 47 genotypes along with 9 diverse parents (H1 1620, RAJ 3777, GW 451, RAJ 4120, HD 2967, GJW 463, LOK 1, DBW 173 and JW 3336), their 36 hybrids (parents crossed in diallel fashion without reciprocals) and 2 checks (RAJ 4079 and HI 1544) during *Rabi* 2020-21 with three replications and three environments in randomized block design. Plant to plant and row to row distance was maintained 10 cm and 23 cm, respectively with a row length of 3 meter. Three different environments were created by sowing the experimental material in three different dates viz., early sown (25-30 October), timely sown (10-20 November) and late sown (5-15 December). Observations were recorded on five competitive plants from each genotype were randomly selected in all the environments for 13 different various characters like, days to 50 % flowering on field plot basis, whereas, plant height, flag leaf area, effective tillers, spikelets spike^{-1}, spike length, grains spike^{-1}, biological yield^{-1}, grain yield^{-1}, harvest index (economic yield/biological yield) and test weight at maturity time. Recommended plant protection procedures were followed to raise the crop in all the environments. The analysis of variance (ANOVA) used according the standard procedures of Panse and Sukhatme (1985). Combining ability analysis was done by using Griffing's (1956) Model II (parents and one set of F_1's without reciprocals), Model I (fixed effect), and pooled analysis over environments was done according to method suggested by Singh (1973).

RESULTS AND DISCUSSION

Analysis of variance

A pooled analysis over environments was estimated to obtain less biased estimates of different types of variances and their interactions with the environments is presented (Table 1). The analysis of variance for combining ability revealed that mean squares due to general combining ability (GCA) in parents were significant in all environments for all characters except days to 50 % flowering in E_3. Mean squares due to specific combining ability (SCA) were also significant for all characters in all the environments. Similarly, Desale and Mehta (2013), Kumar *et al.* (2015) and Sharma *et al.* (2019) also reported the findings of pooled analysis. Pooled analysis was conducted for 12 traits *viz.,* days to 50 % flowering, plant height, effective tillers plant^{-1}, spike length, spikelets spike^{-1}, length of awns, grains spike^{-1}, flag leaf area, test weight, biological yield plant^{-1}, grain yield plant^{-1} and harvest index (Table 2). Mean squares due to GCA parents and SCA crosses were significant for traits over environments indicated differences between parents and crosses. Mean squares due to GCA x E and SCA x E were significant for all characters which indicated additive and non additive type of gene action in the expression of the traits. Similar findings were also reported by Kumar and Kerkhi (2015) and Mari *et al.* (2015).

General combining ability effects

For different parents the data of GCA effects indicated that the effects varied significantly for different characters and in different environments. Based on estimates of GCA effects among parents on pooled basis, DBW 173 and GJW 463 for yield and its contributing traits were good general combiners for effective tillers plant^{-1}, spike length, spikelets plant^{-1}, grains spike^{-1}, flag leaf area and test weight. Parent RAJ 4120 was exhibited maximum GCA effects in E_1 (1.44) whereas, DBW 173 in E_2 (2.71) and E_3 (1.47) environment. Parent DBW 173 also observed maximum positive significant GCA effects for spikelets plant^{-1} in E_1 (18.18), E_2 (16.07) and E_3 (10.51).

Table 1: Combining ability mean square and EMS over the environments for different characters

Characters	Source						Variance Model I			
	Env	GCA	SCA	GCAxE	SCA E	Pool Error	GCA	SCA	GCAxE	SCAxE
	[2]	[8]	[36]	[16]	[72]	[264]				
Days to 50 % flowering	177.06**	5.35**	4.76**	1.96**	1.31**	0.28	7.86	1.23	53.80	2.45
Plant height (cm)	159.39**	22.66**	22.36**	6.65**	5.05**	0.12	7.08	5.46	266.89	9.50
Effective tillers/ plant	48.01**	2.34**	1.84**	0.44**	0.25**	0.01	2.13	0.56	21.97	0.62
Spike length (cm)	12.66**	1.53**	1.85**	0.17*	0.20**	0.10	0.56	0.35	21.07	0.10
Spikelets/plant	23818.79**	452.73**	419.75**	154.42**	194.80**	3.96	1058.44	108.79	4989.54	218.85
Length of awns (cm)	3.22**	0.64**	0.77**	0.07**	0.06**	0.02	0.14	0.15	9.09	0.07
Grains/spike	52.23**	31.92**	27.42**	0.50**	0.73**	0.19	2.31	7.69	326.79	0.45
Flag leaf area (cm^2)	29.28**	5.45**	11.52**	0.21	0.30**	0.16	1.29	1.28	136.42	0.09
Test weight (g)	64.01**	3.42**	8.15**	0.98**	0.72**	0.04	2.84	0.82	97.36	1.36
Biological yield/plant (g)	68.89**	5.20**	4.00**	0.64**	1.13**	0.09	3.06	1.24	46.92	0.81
Grain yield/plant (g)	46.50**	2.75**	6.10**	0.39**	0.30**	0.05	2.06	0.66	72.65	0.50
Harvest index (%)	93.80**	20.31**	41.23**	2.08**	2.00**	0.49	4.15	4.80	488.84	2.31

, Significant at 5 and 1 %, respectively*

Parents, RAJ 3777 and RAJ 4120 were observed as good general combiners for grain yield plant^{-1} and harvest index. Parent HD 2967 was observed good general combiner for plant height and grain yield plant^{-1}. On pooled basis parent DBW 173 was observed superior for spikelets plant^{-1} (14.92), length of awns (0.53), grains spike^{-1} (1.47), flag leaf area (2.55), biological yield plant^{-1} (2.47) and grain yield plant^{-1} (1.80). Parents, RAJ 4120 and GJW 463 were observed superior for effective tillers plant^{-1}, spike length, awn length, grains spike^{-1} and grain yield plant^{-1}. Parent, JW 3336 was observed superior for early flowering (-0.39) on pooled basis. Singh *et al.* (2014), Nagar *et al.* (2018) and Ali *et al.* (2019) also reported the similar findings with good general combiners.

Specific combining ability effects

Specific combining ability is an important parameter for judging and selecting superior cross combinations (Sprague and Tatum, 1942). On pooled basis, the number of crosses were showed significant positive SCA effect for yield and its contributing traits ranged from 05 (spike length) to 10 (spikelets spike^{-1}). Among crosses, HD 2967 x DBW 173 was exhibited positive significant SCA effects for grain yield plan t^{-1} and harvest index in all environments as well as on pooled basis. Cross, DBW 173 x RAJ4120 was observed superior for effective tillers plant^{-1}, GJW 463 x RAJ 4120 for flag leaf area, cross GJW 463 x DBW 173 for grains spike^{-1}, cross RAJ 4120 x HI 1620 for biological yield plant^{-1}, cross DBW 173 x GW 451 for test weight, GW 451 x RAJ 3777 and JW 3336 x LOK 1 for awn length, RAJ 3777 x RAJ 4120 for effective tillers plant^{-1} were observed high SCA effects in all environments. For grain yield plant^{-1} HD 2967 x DBW 173 was exhibited maximum SCA effects in E_1 (3.45), E_2 (3.83) and E_3 (4.71). Cross GJW 463 x DBW 173 was exhibited maximum SCA effects for grains spike^{-1} in E_1 (6.52) and in E_3 (5.84) whereas, HD 2967 x DBW 173 in E_2 (6.15). Cross GW 451 x RAJ 3777 was observed superior for length of awns in E_1 (0.94), E_2 (1.17) and E_3 (1.00) environment. Cross GW 451 x RAJ 3777 in E_1 (3.65), E_2 (3.41) and DBW 173 x GW 451 in E_3 (3.87) were exhibited maximum positive significant SCA effects for test weight. On pooled basis, cross HD 2967 x DBW 173 was depicted maximum SCA effects (4.00) followed by RAJ 3777 x RAJ 4120 (2.92) for grain yield plant^{-1}. Cross DBW 173 x RAJ 4120 was observed maximum significant positive SCA effects for effective tillers plant^{-1} (1.78) followed by DBW 173 x GW 451 (1.68). Cross, GJW 463 x RAJ 4120 was observed superior for flag leaf area (5.40) followed by DBW 173 x RAJ 4120 (5.03) and GJW 463 x RAJ 3777 (3.66). Crosses, HD 2967 x DBW 173, RAJ 3777 x RAJ 4120, DBW 173 x RAJ 4120, GJW 463 x RAJ 4120, DBW 173 x GW 451, DBW 173 x RAJ 3777 and HD 2967 x GW 451 were observed significant SCA effects for grain yield and many yield contributing traits on pooled basis. Similarly, Singh *et al.* (2014), Kumar *et al.* (2015), Patel (2017), Patel (2018), and Sharma *et al.* (2019) also reported the same findings with SCA effects.

Table 2: General Combining Ability and Specific Combining Ability effects for different traits on pooled basis

Genotype	Days to 50 % flowering	Plant height	Effective tillers/plant	Spike length	Spikelets/plant	Length of awns	Grains/ spike	Flag leaf area	Test weight	Biological yield/ plant	Grain yield/ plant	Harvest index
RAJ 4120	-0.02	0.19*	-0.02	-0.25*	4.89	0.09	-0.48	0.7	0.54*	0.11	0.73**	0.10
HD 2967	0.41**	0.76**	0.12	-0.19*	-6.19*	0.18	0.80	0.77*	-0.81**	0.02	0.85**	0.11
DBW 173	0.03	-0.49*	0.52**	0.07	14.92**	0.53**	1.47**	2.55**	1.93**	2.76**	1.80**	0.17
GW 451	-0.02	-0.24*	-0.20	-0.05	1.99	-0.17	-0.83	-1.61	-1.36**	-1.86**	-0.69*	0.05
RAJ 3777 x HI 1620	0.29	-1.27**	0.26	0.83**	-2.48	-0.26	-1.04	-0.37	1.37	-1.07	-0.05	-0.29
RAJ 3777 x JW 3336	0.55*	-1.80**	0.10	0.55*	-4.64	0.10	-4.10**	-1.49**	-1.10*	1.01	-0.60	0.04
RAJ 3777 x RAJ 4120	1.00**	0.31	0.77*	1.55**	16.45**	0.64**	2.39**	1.96**	1.83**	0.68	2.92**	0.05
RAJ 4120 x LOK 1	-0.24	-1.50**	0.10	0.47	-3.64	-0.06	1.18	1.91**	0.46	0.24	-0.23	0.10
RAJ 4120 x HI 1620	0.49	-0.05	0.40	-0.75**	4.81	-0.77**	1.09	0.87	1.00	2.17**	0.24	0.11
RAJ 4120 x JW 3336	0.40	-2.03**	0.08	-0.43*	-6.66	-0.48	-2.71**	0.29	-1.69*	0.80	-0.40	0.17
HD 2967 x LOK 1	-0.48	-1.31**	0.31	-0.29	0.30	-0.26	0.70	-1.24**	-0.26	0.12	-0.73	-0.29
HD 2967 x HI 1620	0.21	0.45	0.40	-0.80**	-13.00**	0.07	0.96	-0.97	0.76	-0.63	0.05	0.04
HD 2967 x RAJ 4120	-0.19	0.82**	0.84*	-0.42*	10.85**	0.43	-1.89*	2.84**	1.18**	-0.66	1.14**	0.05
HD 2967 x RAJ 3777	0.69*	2.04**	0.46	-0.74**	10.57**	0.08	1.56	0.34	-0.10	1.43	-0.21	0.10
HD 2967 x GW 451	0.90**	-0.99**	0.08	1.10**	-9.28	-0.41	1.80	-0.71	1.58**	-1.26	-1.83**	0.11
HD 2967 x JW 3336	0.19	-2.21**	-0.48	-0.09	-16.37**	-0.02	-1.54	-0.99	-1.84**	0.48	0.02	0.17
HD 2967 x DBW 173	1.43**	0.92**	1.01**	1.55**	17.70**	0.29	4.87**	0.18	2.07**	0.61	4.00**	-0.29
DBW 173 x LOK 1	-0.40	-2.71**	-0.11	-0.04	0.77	-0.40	-0.08	-0.87	-0.11	-0.32	-0.63	0.04
DBW 173 x HI 1620	0.76**	0.43	-0.59*	-0.07	-8.31	-0.02	1.73	1.07	0.43	-1.66*	-0.49	0.05
DBW 173 x JW 3336	-0.69	-1.79**	-0.43	-0.85**	-5.76	-0.26	-4.50**	-1.98**	-1.97**	0.28	-0.62	0.10
DBW 173 x RAJ 4120	1.96**	1.07**	1.78**	0.12	15.87**	0.39	2.02**	5.03**	1.32**	1.31	2.56**	0.11
DBW 173 x RAJ 3777	1.03**	0.62*	0.20	0.56**	13.13**	0.15	3.81**	1.07	1.72**	0.56	2.72**	0.17
DBW 173 x GW 451	-1.28**	0.31	1.68**	-0.03	-11.74**	-0.06	-1.27	-1.68**	3.14**	0.12	-0.09	-0.29
GJW 463 x LOK 1	-1.34**	-2.81**	-0.56	-0.99**	1.87	-0.62**	0.61	-0.49	-1.59	-0.07	-1.15**	0.04
GJW 463 x HI 1620	-0.45	0.52	-0.07	0.10	-3.44	-0.09	0.89	-0.08	-0.04	-0.28	0.27	0.05
GJW 463 x JW 3336	0.09	-1.40**	0.46	-0.72*	7.66	-0.94**	-1.15	-1.21**	-0.66	-1.31	-0.79	0.10
GJW 463 x RAJ 4120	-0.17	0.83**	0.80*	0.98**	12.22**	0.48*	0.79	5.40**	-0.06	0.90	0.96	0.11
GJW 463 x RAJ 3777	2.07**	0.96**	0.03	0.90**	9.82*	0.97**	1.55*	3.66**	-0.48	-0.09	-0.51	0.17
GJW 463 x GW 451	-1.41**	-1.89**	0.59	0.95**	6.90	0.00	-1.01	-0.99	0.19	-1.59*	-1.47**	-0.29
GJW 463 x DBW 173	1.02**	0.86**	0.54	0.32	-1.48	0.16	5.84**	0.05	0.60	-0.28	1.48**	0.04
GJW 463 x HD 2967	1.42**	3.19**	0.33	0.33	-2.85	-0.03	3.05**	-1.36**	-1.12**	1.78*	0.67	0.05
GW 451 x LOK 1	-2.45	-1.01**	-0.99*	-0.66*	-0.73	-0.62**	-3.06**	-0.69	0.39	-1.86*	-2.30**	0.10
GW 451 x HI 1620	-0.87**	0.19	-1.58**	-0.13	6.97	0.21	0.99	-0.68	1.93**	0.86	-0.39	0.11
GW 451 x JW 3336	-2.80	-2.03**	0.27	0.19	-3.35	0.34	-1.29	1.43**	0.45	-0.25	-1.01**	0.17
GW 451 x RAJ 4120	-0.00	0.65*	0.14	0.46	5.24	0.59	0.94	0.71	2.19**	0.05	1.54**	-0.29
GW 451 x RAJ 3777	-2.15**	0.83**	0.58	1.07**	7.63	1.04**	4.03**	0.69	3.00**	-0.85	1.16**	0.04
JW 3336 x LOK 1	-0.06	-1.04**	-0.56	-1.35**	-2.10	0.04	1.76*	-1.77**	-1.44	-0.85	-0.86	0.10

It may be concluded that among 9 parents, DBW 173, HD 2967, GJW 463 and RAJ 4120 were good general combiners for grain yield and its contributing components over different environments. Among crosses, HD 2967 x DBW 173 was the best specific combiner for grain yield per plant followed by DBW 173 x RAJ 4120, GJW 463 x RAJ 4120, GJW 463 x DBW 173. These crosses were exhibited significant and desirable SCA effects for most of the yield related traits studied indicated the potential for exploiting hybrid vigour in breeding programme.

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