



Combining ability analysis in bread wheat (*Triticum aestivum*) over environments

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ABSTRACT

The purpose of the study was to analyze combining ability in bread wheat (*Triticum aestivum* L.) for yield and its contributing traits over environments. Ten genetically diverse parents were crossed in half diallel fashion excluding reciprocals and the trial was arranged in a Randomized Block Design with three replications during *rabi* 2016-17 at research farm, Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur. The outcomes from current study demonstrated significance of GCA and SCA for all the characters indicated the importance of both type of gene action. The GCA/SCA variance ratio indicated the preponderance of non-additive gene action except Number of tillers per plant for F_1 generation in very late sown environment which showed preponderance of additive gene action. An overall evaluation of GCA effects and *per se* performance over the environments showed that the parent PBW 343, Raj 4079 and Raj 4083 in all three environments; PBW 590 in normal sowing and late sowing environment emerged as good general combiners while the cross Raj 4079 $\times$ Raj 4083 in all the three environments emerged as good specific cross combinations for grain yield.

Key words: Environment, General combining ability, Specific combining ability, Wheat

Wheat (*Triticum aestivum* L.) is the most important cereal crops of worldwide which are grown under a wide range of climatic conditions that provides 20% of the total energy requirement in human food (Shewry 2009). China, India, USA, the Russian Federation, and Australia together contribute more than half of the global wheat production. Globally, demand for wheat by the year 2020 is forecasted around 950 million tons to meet future demands imposed by population and prosperity growth. This target may be achieved only, if global wheat production is increased by 2.5% per annum (Singh *et al.* 2007) especially in developing countries. World production of wheat in 2018-19 was 732.4 million tonnes, making it the third most-produced cereal after maize and rice (Anonymous 2020). The area and production of wheat in India during year 2016-17 was recorded 30.72 million ha and 97.44 million tonnes with an average productivity of 3172 kg/ha (Anonymous 2017).

Wheat is an important crop of India not only in terms of acreage, but also in terms of its versatility for adoption under wide range of agro climatic conditions and crop growing situations. Trials over environments play an important role for plant breeders due to the high Genotype $\times$ Environment Interaction (GEI). Elahmadi (1994) reported that heat stress is one of the main constraints of wheat production and is

known to cause stunted plant growth, reduced tillering and accelerated development leading to small heads, shriveled grains and low yield. Wheat cultivars that can withstand abiotic stresses particularly terminal heat tolerance will be able to fulfill the food demand in coming years Iqbal *et al.* (2017). Therefore, development of new improved wheat cultivars with high genetic potential for yield under stress environment has become a major objective in the wheat breeding. The efficiency of breeding program increases by careful assortment of parents and populations capable of producing progeny with desirable trait combinations (Kumar *et al.* 2015)

MATERIALS AND METHODS

The present study was carried out to collect information on the genetic base of yield and its contributing traits in wheat. Ten wheat genotypes selected on the basis of genetic diversity and their stability for major yield and its component traits. Crosses among the 10 genotypes were made in diallel fashion excluding reciprocals during *rabi* 2015-16 at research farm, Rajasthan Agricultural Research Institute (RARI), Durgapura, (SKNAU, Jobner), Jaipur. Half of the F_1 's seed was raised at Indian Agricultural Research Institute, Regional station, Wallington (T N) during *kharif* 2016 off season to advance the generation. Ten genotypes along with their 45 F_1 's and 45 F_2 's progenies were evaluated in 3 environments, viz. three different dates of sowing, timely sown, late sown and very late sown respectively, with 3

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replications during *rabi* 2016-17. Each replication contained two parts. First part consist 10 parents and 45 F_1 's sown in two rows plot while the plots of second part consisted four rows of 45 F_2 's. Row length was 3 m. Row to row and plant to plant distance was kept 30 cm and 10 cm, respectively. Recommended uniform agronomical practices were followed for raising the crop in all the three environments. Observations were recorded on days to heading, flag leaf area, plant height, heat susceptibility index, number of tillers per plant, canopy temperature, days to maturity, spike length, number of grains per ear, grain yield per plant, biomass per plant, 1000-grain weight, harvest index and protein content. Non-experimental rows were planted all around the experiment to eliminate the border effects, if any. The mean of each plot used for statistical analysis. The data were first subjected to the usual analysis followed for a Randomized Block Design for individual environment as suggested by Panse and Sukhatme (1985) and combining ability analysis was done following Griffing (1956).

RESULTS AND DISCUSSION

The significant differences among all the three environments for all the studied characters revealed diversified effect of environment on the expression of these characters. The pooled analysis of variance also exhibited significant mean sum of squares due to genotypes including parents and generations (F_1 's and F_2 's) for all the characters under investigation. The combining ability analysis revealed that the GCA and SCA variances were significant for all the characters in both F_1 and F_2 generations of each three environments, indicating the importance of both additive and non-additive genetic control of all the characters under study.

As a general consequence of these interactions, the

estimates of GCA and SCA effects frequently changed from environment to environment, complicating the problem of identification of promising parents and crosses. This might be attributed to the presence of GCA $\times$ environment interaction. Result showed that days to heading, PBW 590 revealed significant negative GCA effect in E_1 and E_2 for both the generations (except E_1F_2) but in E_3 possessed positive non-significant (F_1) and positive significant (F_2) GCA effects while in days to maturity, PBW 590 had significant negative GCA effect in E_1 and E_2 but in E_3 was showed non-significant negative; for plant height PBW 343 showed significant negative GCA effect in E_1 and E_2 but its effect changed to positive in E_3 ; for number of tillers per plant Raj 4083 in E_1 and E_2 possessed desirable positive GCA effects while its magnitude changed in E_3 , for flag leaf area Raj 4079 possessed high desirable positive GCA effects in E_2 but its effect negative to negative in E_1 (except F_1) and E_3 ; for protein content PBW 343 had significant positive GCA effect in all the environments except E_2F_2 . Such changes in the direction and magnitude of GCA effects of several parents in different environments for F_1 and F_2 were also observed for other characters. Thus, it is suggested that breeding for these characters would be effective only when material is tested over a wide range of environments and selection practiced in target environment. Best parents having desirable GCA effects for grain yield per plant in different environments are presented in Table 1.

The parents, viz. PBW 343 for number of tillers per plant, flag leaf area, biological yield, canopy temperature and grain yield per plant; Raj 4079 for days to heading, days to maturity, plant height, number of grains per spike, spike length, 1000-grain weight, biological yield, protein content and grain yield per plant and Raj 4083 for days to heading,

Table 1 Best wheat parent possessing high GCA along with their *per se* performance grain yield per plant and significant desirable GCA effects for other traits in both generations over the environments

Environments	Generation	Best parents	GCA effect	Grain yield per plant	Days to heading	Days to maturity	Plant height	Number of tillers per plant	Flag leaf area	Spike length	No. of grains per ear	1000-grain weight	Biomass per plant	Harvest index	Canopy temperature	Protein content
E_1	F_1	Raj 4083	0.45**	29.23	-2.21**	-2.06**	-1.06**	0.43**	1.13**	0.38**	1.82**	1.44**	0.75**	-	-0.33**	0.31**
	F_2	Raj 4079	0.24*	29.63	-1.56**	-	-1.62**	-	-	0.33**	1.29**	1.46**	0.75**	-	-0.25**	0.13**
		Raj 4083	0.35**	29.23	-2.11**	-1.18**	-1.79**	0.33**	0.81**	0.32**	1.42**	1.3**	0.58**	-	-	0.19**
E_2	F_1	Raj 4079	0.96**	19.97	-1.52**	-2.37**	-2.77**	-	1**	0.32**	1.46**	0.51*	1.64**	-	-0.58**	0.17**
		Raj 4083	0.7**	19.60	-1.18**	-2.37**	-2.62**	0.5**	-	0.34**	0.75*	0.83**	0.63*	0.51**	-0.66**	0.14*
	F_2	Raj 4079	0.54**	19.97	-0.48**	-1.62**	-2.53**	0.25**	0.81**	0.27**	2.38**	1.14**	0.49**	0.3**	-0.25**	0.09**
		PBW 590	0.55**	18.73	-0.42**	-	-1.46**	-	-	-	0.78**	0.24*	1.26**	-	-	0.11**
E_3	F_1	Raj 4079	0.55**	13.73	-0.72**	-0.69**	-0.72**	-	-	0.49**	0.34*	0.89**	1.66**	-	-0.14**	0.16**
		Raj 4083	0.39**	13.53	-0.91**	-1.06**	-0.91**	-	-	0.12*	1.39**	1.08**	1.37**	0.23*	-0.17**	0.2**
	F_2	Raj 4079	0.34**	13.73	-0.69**	-0.69**	-0.69**	-	-	0.63**	0.41**	0.8**	0.51*	0.08**	-	0.16**
		Raj 4083	0.53**	13.53	-1.06**	-1.06**	-1.06**	-	-	0.15**	-	0.73**	1.53**	-	-	0.19**

days to maturity, plant height, spike length, 1000-grain weight, protein content and grain yield per plant, performed consistently for desirable GCA estimates. In addition to this, some parents also accomplished desirable stable performance over environments for a specific character. The parent Raj 4079 and Raj 4083 for days to heading, days to maturity, plant height, spike length, 1000-grain weight, protein content and grain yield per plant, PBW 343 and Raj 4079 for biological yield per plant, PBW 343 for number of tillers per plant, flag leaf area, canopy temperature and grain yield per plant and Raj 4079 for number of grains per spike, precedent about the desirable consistence performance over environments. Therefore, these parents have good potential and may be used in synthesizing a dynamic population with most of the favorable genes accumulated. On the basis of GCA effects and *per se* performance over the environments, an overall evaluation showed that the parent PBW 343, Raj 4079 and Raj 4083 in all three environments; PBW 590 in E_1 and E_2 environment emerged as good general combiners for grain yield with simultaneous consideration of other

characters. Therefore, these parents could be intensively used in the hybridization programme to develop lines with several desirable characters for further tangible advancement of wheat yield.

In the present study, none of the crosses showed consistently high SCA effects for all the characters over the environments. However, some crosses performed consistently regarding desirable and undesirable SCA estimates for more than one specific character over the environment with varied magnitudes. Best crosses possessing desirable SCA effects for different characters in individual environment are presented in Table 2. The crosses, which showed desirable SCA effects for grain yield per plant, also exhibited desirable SCA effects for one or more yield attributing traits. The crosses PBW 590 $\times$ Raj 4083, Raj 4079 $\times$ Raj 4083, PBW 502 $\times$ Raj 1482, PBW 343 $\times$ DBW 88 and PBW 396 $\times$ DBW 88 in E_1 ; Raj 4079 $\times$ Raj 4083, PBW 343 $\times$ PBW 590, PBW 502 $\times$ DBW 88 and Raj 1482 $\times$ Raj 4120 in E_2 and Raj 4079 $\times$ Raj 4083, PBW 502 $\times$ PBW 590 and PBW 502 $\times$ DBW 88 in E_3

Table 2 Best crosses possessing high SCA effects with their *per se* performance of grain yield and significant desirable SCA effects for other traits in both F₁ and F₂ over the environments

Environments	Generation	Best cross	SCA effect	Grain yield per plant	Days to heading	Days to maturity	Plant height	Number of tillers per plant	Flag leaf area	Spike length	No. of grains per ear	1000-grain weight	Biomass per plant	Harvest index	Canopy temperature	Protein content
E ₁	F ₁	PBW 590 × Raj 4083	3.12**	31.57	-	-	-5.54**	-	-	1.59**	4.15**	-	5.09**	-	-	0.95**
		Raj 4079 × Raj 4083	3.28**	30.83	-3.61**	-8.47**	-	0.55*	-	1.04**	-	2.35**	-	6.31**	-0.72**	0.49*
	F ₂	PBW 502 × Raj 1482	3.49**		-	-4.99**	-	0.59**	-	-	-	0.8*	-	6.94**	-0.22*	0.36**
		Raj 4079 × Raj 4083	-0.44	30.83	-2.24**	-15.02**	-6.33**	-	0.23**	1.72**	-	-	-	1.79*	-1.33**	0.54**
		PBW 396 × DBW 88	2.83**	25.03	-2.71**	-	-3.68**	0.29*	-	-	4.5**	3.8**	-	7.49**	-1.31**	-
	E ₂	F ₁	Raj 4079 × Raj 4083	2.9**	21.87	-3.56**	-4.55**	-5.82**	-	-	-	6.19**	-	3.28**	4.43**	-0.5**
PBW 343 × PBW 590			3.16**	21.47	-2.37*	-	-	-	-	-	-	-	-	5.03**	-1.3**	0.45*
F ₂		PBW 502 × DBW 88	4.35**	18.20	-	-9.91**	-3.18**	-	2.01**	-	3.7**	-	3.58**	5.31**	-1.75**	0.53**
		Raj 1482 × Raj 4120	3.68**	20.40	-2.85**	-	-2.93**	-	1.71**	-	-	-	-	6.95**	-	-
E ₃	F ₁	Raj 4079 × Raj 4083	4.06**	17.30	-4.97**	-4.97**	-4.97**	-	-	0.22*	1.34*	-	-	8.34**	-1.75**	0.64**
		PBW 502 × PBW 590	2.89**	11.73	-	-	-	0.43**	-	-	1.59**	-	-	6.34**	-	-
	F ₂	Raj 4079 × Raj 4083	3.67**	17.30	-5.86**	-5.86**	-5.86**	-	-	0.94**	-	0.98**	5.24**	4.92**	-2.67**	1.51**
		PBW 502 × DBW 88	2.56**	14.80	-	-	-	-	-	0.6**	-	1.86**	-	6.63**	-2.23**	0.19*

appeared as good specific cross combinations for grain yield and some associated traits were identified as good specific cross combinations for grain yield and some associated traits. These crosses have great potential for improvement of wheat and may be utilizing further in multiple crossing programme.

It is interesting to note that SCA effects of the best crosses and GCA effects of their parents indicated that the good specific cross combinations were the result of good $\times$ good, good $\times$ poor or poor $\times$ poor combinations. Thus, it was evidenced that a good cross combination is not necessarily the result of good $\times$ good general combiners; rather it might occur from good $\times$ poor or poor $\times$ poor combiners as well. However, In the present study, comparison of SCA effects of these top crosses and GCA effects of their parents indicated that such crosses in general involved one parent with good GCA effect. Hence, the presence of at least one good general combiner appeared to be desirable for getting the better hybrids. Cross combinations involving good $\times$ good general combiner parent are of greater relevance in self-pollinated crop like wheat, because genes controlling these effects may be fixed in the end product of a breeding programme. Bi-parental progeny selection suggested by Andrus (1963) may be used to get some transgressive segregates from crosses involving good $\times$ good and good $\times$ poor combiners. These findings were corroborative with the results obtained by Joshi *et al.* (2004), Pancholi *et al.* (2012) and Singh *et al.* (2013).

An overall appraisal revealed that the cross Raj 4079 $\times$ Raj 4083 in all the three environments emerged as good specific cross combinations for grain yield. SCA effects of best crosses and GCA effects of their parents indicated that the good specific cross combinations were the result of good $\times$ good, good $\times$ poor or poor $\times$ poor combinations. These crosses hold great promise in improving the grain yield in future breeding programme of bread wheat. The crosses involving good $\times$ good general combiner may be utilize to develop pure line. The parents Raj 4079, Raj 4083, PBW 343 and PBW 590 involved in these crosses were good general combiners for grain yield and one or two yield contributing traits while the other parents were emerged as poor general combiners.

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