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RESEARCH PAPER

Combining ability analysis for yield and quality traits under different locations of U.P. in wheat (*Triticum aestivum* L.)

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Abstract : Combining ability analysis was done through a 10 x10 parent diallel cross, excluding reciprocals, for grain yield and quality traits under varying environmental conditions in wheat. The pooled analysis of variance showed highly significant variances due to general and specific combining ability for all the characters studied in both F_1 and F_2 generations, indicating importance of both additive and non-additive gene effects involved in the inheritance of all the characters studied. The magnitude of additive genetic variance was considerably higher than non-additive genetic variance for all the traits in both the generations, indicating preponderance of additive gene action in controlling the expression of these attributes. Both GCA x environment and SCA x environment interactions also exhibited highly significant differences for all the traits in both F_1 and F_2 generations, indicating both the gene effects were highly influenced by the environments. However, GCA x environment interaction variance was higher than SCA x environment interaction variance for all the characters in both F_1 and F_2 generations which further indicating the importance of additive genetic variance for all the attributes. The parents K 68, K 9107 and K 8027 were the good general combiner for grain yield/plant. The parents K 9107, HP 1633 and K 9644 were observed as good general combiner to breed for high protein content. The best specific combiner for yield and protein content was HP 1633 x K 9644 and K 68 x K 9107, respectively. The breeding approaches like, biparental mating followed by diallel selective mating and reciprocal recurrent selection might be more meaningful to evolve high yield potential cultivars with high protein content and other quality traits in wheat.

Key Words : Wheat, Diallel, Combining ability, Gene action

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INTRODUCTION

Wheat is a most important and widely cultivated cereal crop on the earth. India has tremendous progress in the food grain production, specially wheat. It is grown in India over an area of about 29.1 million hectare with a production of about 84.27 million tones, still maintaining second position in the world (Agriculture Ministry, Govt. of India, 2011). The national productivity is about 2.9 tones/hectare, while in China and US is about 4.7 and 3.1 tones/hectare, respectively (Chakarbarti, 2011). With all these achievements, the issue ahead is even more challenging. The population of India is growing at 1.8 per cent per year, it is necessary to further increase the productivity level to meet the requirement of 109 million tones up to 2020. It is used in the form of *chapatti, bread, naan, tandori, rumali roti, puri, pudding, bhatore, bran* and *fodder* etc. In India wheat grain is used by human beings mainly in the form of chapatti, hence wheat cultivars with high baking quality will be preferred. The medium hard, medium grain size and appearance is preffered for non-

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fermented flat Indian bread *(Chapatti)* and a number of other ethnic food preperations such as *naan, tandori, rumali roti, puri, bhatore* etc. The protein content is a chief component of nutritional quality. Therefore, the improvements in characters related to produce quality along-with grain yield is very essential. For this, combining ability studies are frequently used by plant breeders to evaluate newly developed genotype for their usefulness and to asses the gene action involved in the expression of various characters, so as to design an efficient plan for further genetic improvement of exiting material. However, the combining ability studies in a single environment may not provide precise information as environmental effects play an important role and greatly influence the combining ability estimates. Therefore, the main aim of the present study was to identify best combining parents and their crosses on the basis of their general and specific combining ability under different environments for grain yield and quality traits.

MATERIALS AND METHODS

Ten diverse genotypes of wheat; *viz*., K 68, DL 784-3, K 9107, K 8027, C 306, K7903, GW 373, K123, HP 1633 and K 9644 were crossed in all possible combinations excluding reciprocals during *Rabi* 2005-06. Half of the seeds of each cross was advanced in off season nursery at Wellington (Neelgiri hills),Tamil Nadu to raise F_1 population in order to get the seeds for raising F_2 population. The ten parents and their 45 F_1s and 45 F_2s were grown in Randomized Block Design with three replications at three locations; *viz*., Crop Research Farm, Nawabganj (Kanpur), Mauranipur (Jhansi) and Etawah, of C.S.A. University of Agriculture and Technology, Kanpur (U.P.). The plots of parents and F_1s consisted single row of 3 m length, while each plot of F_2 consisted of three rows of 3 m length with inter and intra row distance of 25 and 15 cm, respectively. The usual cultural practices were applied to raise a good crop. The observations were recorded in each plot on 10 randomly selected plants in parents and F_1 generation and 20 plants in F_2 generation for grain yield and quality traits; namely, 1000-grain weight (g), seed hardness (kg/seed), harvest index (%), protein content (%), phenol colour reaction (score) and grain yield/plant (kg). Combining ability analysis was work out according to the procedure suggested by Griffing's (1956b) method 2 model 1 and pooled analysis was carried out according to the procedure proposed by Singh (1973 and 1979).

RESULTS AND DISCUSSION

The pooled analysis of variance for combining ability revealed that both general combining ability (GCA) and specific combining ability (SCA) variances were highly significant for all the characters studied in both F_1 and F_2 generations, indicating importance of both additive and non-additive gene effects involved in the inheritance of all these characters (Table 1).The magnitude of additive (GCA) variance was considerably higher than non-additive (SCA) variance for all the traits in both the generations, indicating preponderance of additive gene action in controlling the expression of these attributes. Similar results were also reported by Joshi *et al*. (2004), Kamaluddin *et al*. (2011) and Akram *et al*. (2011). Both GCA x environment and SCA x environment interactions also exhibited highly significant differences for all the traits in both F_1 and F_2 generations, indicating role of environment in influencing the gene effects, which further

Table 1 : Pooled analysis of variance (parents+ F_1s and parents+ F_2s) for combining ability in respect of yield and quality traits over locations in wheat

Source of variation	d.f.	Generation	1000-grain weight (g)	Seed hardness (kg/seed)	Harvest index (%)	Protein content (%)	Phenol colour reaction (score)	Grain yield / plant (g)
GCA	9	F_1	33.34**	1.11**	6.65**	2.34**	0.25**	4.46**
		F_2	36.05**	2.33**	6.94**	2.41**	0.28**	3.04**
SCA	45	F_1	15.10**	0.70**	3.61**	0.60**	0.11**	2.16**
		F_2	19.82**	1.42**	1.42**	0.58**	0.15**	2.45**
GCA x E	18	F_1	2.27**	0.21**	0.79**	0.13**	0.16**	0.82**
		F_2	2.24**	0.19**	0.75**	0.17**	0.17**	1.02**
SCA x E	90	F_1	1.30**	0.12**	0.44**	0.07**	0.09**	0.63**
		F_2	1.21**	0.10**	0.52**	0.10**	0.11**	0.88**
Error	324	F_1	1.08	0.07	0.33	0.05	0.08	0.57
		F_2	1.04	0.09	0.28	0.06	0.06	0.40
$\delta^2 g$		F_1	0.83	0.009	0.08	0.047	0.002	0.05
		F_2	0.42	0.023	0.07	0.049	0.002	0.01
$\delta^2 s$		F_1	4.60	0.190	1.06	0.177	0.007	0.51
		F_2	6.20	0.440	1.18	0.160	0.013	0.52

* and ** indicate significance of values at P=0.05 and 0.01, respectively

complicated the problem of identification of promising parents and crosses. However, GCA x environment interaction variance was higher than SCA x environment interaction variance for all the characters in both F_1 and F_2 generations which further indicating the importance of additive genetic variance for yield and quality traits. Thus, it may concluded that the GCA variances are more important in wheat.

The GCA effects over the environments showed that none of the parent was identified as good general combiner for all the traits in both non-segregating (F_1) and segregating (F_2) generations (Table 2). However, the parent K 9107 for 1000-grain weight, harvest index, protein content and grain yield/plant; K 68 for 1000-grain weight, harvest index and grain yield/plant; C 306 for 1000-grain weight and harvest index; HP 1633 for seed hardness and protein content; K 9644 for protein content and phenol colour reaction and K 7903, GW 373 and K123 only for seed hardness were observed to be good general combiners in both the generations over different locations. The parent DL 784-3 was observed poor general combiner for all the attributes over locations. Almost equal magnitude of GCA effects in F_1 and F_2 generations revealed that the good general combiners were stable in their performance over generations as well as over environments. It might be due to diversity of the parents, diverse eco-geographical origin and variability in other agronomic attributes. The performance of poor general combiner was not consistent over the generations. Stability for improvement in agronomic traits has always been one of the important parameter in breeding objective (Allard and Bradshaw, 1964).

High GCA effects consists of both additive and non-additive components of gene action (Griffing, 1956a, 1956b, Sprague, 1966 and Gilbert, 1967) which is fixable. The additive effects of parents are of practical use, whereas non-allelic interactions are not predictable and could not be easily manipulated. In view of this, the breeder may utilize the good general combiners in specific breeding programme for improvement in yield and quality traits. On the basis of overall performance, the parents K 68, K 9107 and K 8027 were the good general combiner for grain yield/plant, while K 68, K 9107, K 8027 and C 306 for 1000-grain weight; K 7903,GW 373 and K 123 for seed hardness; K 68, K 9107, K 8027 and C 306 for harvest index; K 9107, HP 1633 and K 9644 for protein content and K 9644 for phenol colour reaction were good common parents for quality traits in both F_1 and F_2 generations

Table 2 : General combining ability effects of parents for grain yield and quality traits over locations in wheat

Sr. No.	Parents	Generation	1000-grain weight (g)	Seed hardness (kg/seed)	Harvest index (%)	Protein content (%)	Phenol colour reaction (score)	Grain yield/plant (g)
1.	K 68	F_1	1.51**	0.01	0.39**	-0.13**	-0.12**	0.48**
		F_2	0.59*	-0.24**	0.14*	-0.16**	-0.03	0.31**
2.	DL 784-3	F_1	-0.28	-0.02	-0.36**	-0.13**	-0.03	0.05*
		F_2	0.28	-0.12**	0.30**	0.30**	-0.09**	0.00
3.	K9107	F_1	1.15**	-0.12**	0.30**	0.66**	0.17**	0.43**
		F_2	1.72**	0.13**	0.16*	0.66**	0.09**	0.45**
4.	K 8027	F_1	0.82**	-0.30**	0.78**	-0.20**	0.05*	0.47**
		F_2	0.56	-0.39**	0.56**	-0.20**	-0.02	0.32**
5.	C 306	F_1	0.71**	-0.07**	0.07*	-0.11**	-0.04	-0.02
		F_2	1.41**	-0.14**	0.57**	-0.10**	-0.04	-0.06*
6.	K 7903	F_1	-0.83**	0.23**	-0.09*	-0.08**	0.06*	-0.19**
		F_2	-1.12**	0.48**	0.16**	-0.01	-0.02	-0.26**
7.	GW 373	F_1	-0.31	0.21**	-0.58**	-0.02**	-0.04	-0.44**
		F_2	0.61*	0.24**	-0.32**	-0.06**	-0.02	-0.45**
8.	K 123	F_1	-0.55	0.10**	-0.57**	-0.19**	0.05*	-0.30**
		F_2	0.47	0.06**	-0.51**	-0.20**	0.13**	-0.27**
9.	HP 1633	F_1	-1.20**	0.04**	-0.06	0.08**	-0.03	-0.37**
		F_2	-1.02**	0.11**	0.58**	0.11**	-0.05*	-0.12**
10.	K 9644	F_1	-0.98**	-0.09**	0.12**	0.14**	-0.07**	-0.15**
		F_2	-1.07**	-0.12**	-0.47**	0.11**	-0.13**	-0.04
SE (gi) ±		F_1	0.27	0.01	0.03	0.006	0.02	0.02
		F_2	0.26	0.01	0.05	0.006	0.02	0.02
SE (gi-gj)±		F_1	0.38	0.02	0.05	0.009	0.03	0.03
		F_2	0.34	0.02	0.06	0.009	0.04	0.03

* and ** indicate significance of values at P=0.05 and 0.01, respectively

as well as pooled over locations. These parents may be utilized for simultaneous improvement in grain yield and quality characters through an intermating population involving all possible combinations among themselves.

In order to synthesize a dynamic population with most of the favourable genes accumulated, it will be pertinent to make use of these parents, which are good general combiner for several characters, in multiple crossing programme. Apart from conventional breeding methods relying upon additive and additive x additive types of gene action, population improvement appears to be a hopeful alternative. Diallel selective mating system (Jensen, 1970) seems to be a good technique, which delays quick fixation of gene complexes, permits break down of linkage, general fostering of recombination and concentration of favourable genes/gene complexes, into central gene pool, by a series of multiple crosses.

The SCA effects representing dominance and epistatic component of variability which may be utilized through heterosis breeding. It would not make any worthwhile contribution in the improvement of self pollinated crops, except where commercial exploitation of heterosis is feasible. Jinks

Table 3 : Top five specific combiners among 45 F_1 and F_2 crosses of wheat for quality traits over locations

Characters	Cross combinations	SCA effects		GCA effects			
				F_1		F_2	
		F_1	F_2	P_1	P_2	P_1	P_2
1000-grain weight (g)	DL 784-3 x GW 373	2.00**	1.74**	Low	Low	Low	High
	GW 373 x K 123	1.73**	2.92**	Low	Low	High	Low
	K 7903 x HP 1633	1.17**	1.30**	Low	Low	Low	Low
	SE (Sij) ±	0.33	0.52				
	SE (Sij-Sik) ±	0.49	0.63				
Seed hardness (kg/seed)	HP 1633 x K 9644	0.84**	1.04**	High	Low	Low	Low
	DL 784-3 x K 9107	0.82**	0.20**	Low	Low	Low	High
	DL 784-3 x K 8027	0.78**	0.86**	Low	Low	Low	Low
	K 9107 x K 8027	0.43**	0.58**	Low	Low	High	Low
	K 68 x DL 784-3	0.38**	0.42**	Low	Low	Low	Low
	SE (Sij) ±	0.02	0.03				
	SE (Sij-Sik) ±	0.03	0.05				
Harvest index (%)	K 68 x K 9107	1.02**	0.41**	High	High	High	High
	K 7903 x HP 1633	0.76**	0.61**	Low	Low	High	High
	DL 784-3 x K 123	0.69**	0.94**	Low	Low	High	Low
	K 8027 x GW 373	0.52**	0.44**	High	Low	High	Low
	K 68 x K 9644	0.45**	1.93**	High	High	High	Low
	SE (Sij) ±	0.10	0.15				
	SE (Sij-Sik) ±	0.15	0.22				
Protein content (%)	K 68 x K 9107	0.97**	0.98**	Low	High	Low	High
	DL 784-3 x GW 373	0.74**	0.78**	Low	Low	High	Low
	K 9107 x K 9644	0.67**	0.64**	High	High	High	High
	C306 x K 9644	0.64**	0.81**	Low	High	Low	High
	C 306 x HP 1633	0.51**	0.50**	Low	High	Low	High
	SE (Sij) ±	0.02	0.02				
	SE (Sij-Sik) ±	0.03	0.03				
Phenol colour reaction (score)	K 9107 x C 306	-0.35**	-0.21**	Low	Low	Low	Low
	K 7903 x K 123	-0.30**	-0.15*	Low	Low	Low	Low
	DL 784-3 x GW 373	-0.23*	-0.27**	High	Low	Low	Low
	K 8027 x GW 373	-0.14*	-0.19*	Low	Low	Low	Low
	K 9107 x K 9644	-0.14*	-0.17*	Low	High	Low	High
	SE (Sij) ±	0.07	0.07				
	SE (Sij-Sik) ±	0.11	0.12				

* and ** indicate significance of values at P=0.05 and 0.01, respectively

and Jones (1958) also suggested that superiority of many hybrids may not be indicated by their ability to produce transgressive segregants due to non-fixable gene effects. Desirable transgressive segregants are expected to be produced by making a large number of crosses (Khrostovska, 1975). The cross involving good general combiners and showing high effects may be utilized in further breeding programmes. Therefore, study of SCA effects in segregating generations would be important for grain yield and quality traits.

The analysis of specific combining ability effects revealed that none of the cross combination was found superior for all the characters under different environments (Table 3 and 4). The cross combinations; *viz*., DL 784-3 x GW 373, GW 373 x K 123 and K 7903 x HP 1633 100-grain weight; HP 1633 x K 9644, DL 784-3 x K 9107, DL 784-3 x K 8027, K 9107 x K 8027 and K 68 x DL 784-3 for seed hardness; K 68 x K 9107, K 7903 x HP, DL 784-3 x K 123 1633, K 8027 x GW 373 and K 68 x K 9644 for harvest index; K 68 x K 9107, DL 784-3 x GW 373, K 9107 x K 9644, C306 x K 9644 and C 306 x HP 1633 for protein content; K 9107 x C 306, K 7903 x K 123, DL 784-3 x GW 373, K 8027 x GW 373 and K 9107 x K 9644 for phenol colour reaction were observed as top specific combiners (on the basis of significant and desirable SCA effects) in both non-segregating (F_1) and segregating (F_2)generations as well as pooled over locations. The desirable crosses (on the basis of positive and significant SCA effects) for grain yield/plant were HP 1633 x K 9644, K 9107x K9644, C 306 x HP 1633, C 306 x K 9644, K 123 x HP 1633, K 68 x K 123, K 68 x K 8027 and K68 x K 9644 in both F_1 and F_2 progenies under different environments. These crosses were also found superior for one or more quality traits *i.e.*, HP 1633 x K 9644 for seed hardness and protein content; K 9107 x K 9644 for protein content and phenol colour reaction; C 306 x HP 1633 and C 306 x K 9644 for phenol colour reaction; K 123 x HP 1633 and K 68 x K 123 for seed hardness; K 68 x K 8027 for protein content and K 68 x K 9644 for harvest index.

The desirable and significant SCA effects obtained in crosses involving both parents with high GCA effects (high x high) may be due to additive and additive x additive type of gene actions, which are fixable in nature, indicating possibility of genetic improvement for those particular characters through conventional methods; like, pedigree selection. For example, the crosses, K 68 x K 9107 and K 68 x K 9644 for harvest index; K 9107 x K 9644 for protein content and K 68 x K 8027 for grain yield/plant, may produce transgressive recombinants. Similarly crosses showing high SCA effects and involving both parents as low general combiner (low x low) for a trait indicated the presence of non-additive gene actions, which are non-fixable in nature. This suggested that these crosses could be exploited through heterosis breeding for further improvement of the respective trait. Jensen (1970) and Redden and Jensen (1974) have suggested intermating in F_2 for realizing worthwhile genetic improvement of the productivity or increases in the number of superior combinations with the desirable genotypes. These type of crosses include DL 784-3 x GW 373, GW 373 x K 123 and K 7903 x HP 1633 100-grain weight; DL 784-3 x K 9107, DL 784-3 x K 8027, K 9107 x K 8027 and K 68 x DL 784-3 for seed hardness; K 7903 x HP1633 and DL 784-3 x K 123 1633 for harvest index; DL 784-3 x GW 373 for protein content; K 9107 x C 306, K 7903 x K 123 and K 8027 x GW 373 for phenol colour reaction and HP 1633 x K 9644, C 306 x HP 1633, C 306 x K 9644 and K 123 x HP 1633 for grain yield/plant. The cross combinations representing desirable and significant SCA effects and involving at least one parent with high GCA (high x low) indicated the involvement of additive dominance gene interaction for the expression of that particular trait. This situation was indicated in HP 1633 x K 9644 for seed hardness; K 8027 x GW 373 for harvest index; K 68 x K 9107, C306 x K 9644 and C 306 x HP 1633for protein content; DL 784-3 x GW 373 and K 9107 x K 9644 for phenol colour reaction and K 9107 x K9644, K 68 x K 123 and K68 x K 9644 for grain yield/plant. The presence of both additive (fixable) and non-additive (non-

Table 4 : Best specific combiners for grain yield/plant among 45 F_1 and F_2 crosses of wheat over locations

Best crosses in both F_1 and F_2 generations	SCA effects		GCA effects				Traits for which cross also exhibited desirable SCA effects
	F_1	F_2	F_1		F_2		
			P_1	P_2	P_1	P_2	
HP 1633 x K 9644	1.36**	1.21**	Low	Low	Low	Low	Seed hardness and protein content
K 9107x K9644	0.68**	0.61**	High	Low	High	Low	Protein content and phenol colour reaction
C 306 x HP 1633	0.65**	0.56**	Low	Low	High	Low	Phenol colour reaction
C 306 x K 9644	0.59**	0.33*	Low	Low	High	Low	Phenol colour reaction
K 123 x HP 1633	0.50**	0.86**	Low	Low	Low	Low	Seed hardness
K 68 x K 123	0.44**	0.44**	High	Low	High	Low	Seed hardness
K 68 x K 8027	0.38*	0.33*	High	High	High	High	Protein content
K68 x K 9644	0.33*	0.81**	High	Low	High	Low	Harvest index
SE (Sij) ±	0.02	0.02					
SE (Sij-Sik) ±	0.03	0.03					

* and ** indicate significance of values at P=0.05 and 0.01, respectively

fixable) components of genetic variability suggested the breeding approaches like, biparental mating followed by diallel selective mating and reciprocal recurrent selection might be more meaningful to evolve high yield potential cultivars with high protein content and other quality traits in wheat. Redden and Jensen (1974) demonstrated significant gain in seed weight through mass selection with concurrent random mating and suggested this technique could be useful breeding procedure for wheat and barley.

Conclusions:

The study revealed that both additive (fixable) and non-additive (non-fixable) components of genetic variance were involved in the inheritance of yield and quality traits, although additive genetic variance was predominant. Therefore, bi-parental mating followed by diallel selective mating and reciprocal recurrent selection, which may allow intermating of the selects in different cycles and exploit both additive and non-additive genetic effects, could be utilized in developing wheat cultivar having high yield, protein content and other quality traits.

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