Genetic analysis of some yield and quality traits in bread wheat (*Triticum aestivum* **L.**)

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Abstract

Forty five crosses derived from 10 diverse genotypes using diallel fashion were evaluated in 3-RBD for combining ability. Significant differences among treatments, parents, crosses and parent vs crosses were observed for all the traits studied. The results from the present study revealed that three parents *viz.,* K 612, HUW 648 and WCW 95-1 were found to be good general combiners due to their high general combining ability effect. Cross combinations namely; K 612/K 910-4; K 612/WCW 95-1; K 612/NW 4081; K 612/NW 4035; HUW 648/AAI 13; HUW 648/HUW 658; HUW 648/K 307; HUW 648/K 910-30; AAI 13/ K 910-30, K 910-4/NW 4081; HUW 658/K 307; HUW 658/K 910-30; K 307/NW 4035; WCW 95-1/NW 4035 showed desired specific combining ability effect for grain yield along with some attributing traits. Thus, present study suggests that these cross combinations may be utilized in the development of high yielding genotypes with desirable traits for improving the bread wheat.

Keywords: Bread wheat, combining ability, diallel analysis

1. Introduction

Bread wheat (*Triticum aestivum* L. em Thell) is one of the important cereal crops for food security all over the world. As a staple food, it contributes about 36% of the world populations. Wheat offers nearly 55 % wheat production has increased manifold from 6.60 million tonnes at the time of independence to 98.4 million tonnes in 2016-17. The productivity has scaled up 473 % (Anonymous, 2017). The population of India is increasing at an alarming rate and by 2025; the country would require about 109 million tonnes of wheat to feed up its ever growing population, which is a major challenge under changing climatic scenario (FAO, 2010). Hence, enhancing wheat production is one of the strategies to meet out the domestic demand of the country. Continous increase in wheat productivity since the green revolution is associated with genetic improvement in yield potential, resistance to diseases and adaptation to abiotic stresses as well as better agronomic practices (Evenson and Gollin, 2003). The rising worldwide demand for wheat and limited availability of land is retaining pressure on breeding programs to offer elite cultivars that can acclimatize in wide range of agro-climatic conditions without compromising agronomic performance, grain quality, diseases resistance and tolerance to abiotic stresses. To accomplish the increasing demand of world population, wheat production and productivity must be enhanced. Hence, most important step in any breeding program is the identification of suitable parents with high general combining ability (GCA) and specific combining ability (SCA) for grain yield and to create genetic variability and gather information about the genetic architecture of component traits.

The combining ability analysis provides information about the nature of gene action and relative magnitude of fixable and non-fixable genetic variances, which are useful for identification of superior parents for hybridization. Combining ability analysis was implied to study gene effect and genetic worth of parents in wheat by Romanus *et al.* (2008) and Kumar *et al.* (2015a). In addition, diallel analysis gives plant breeders the opportunity to choose the most efficient selection method by allowing them to estimate several genetic parameters (Singh and Chaudhary, 1979). Therefore, aim of the study was to identify the best combining parents on the basis of their general and specific combining ability for agro-morphological and quality traits in bread wheat.

2. Materials and methods

The present study was carried out at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during 2012-13 and 2013-2014. Geographically, the experimental farm is located between 28º 58' N latitude to 77º 42' E longitude at 228 m above mean sea level has humid subtropical climate range of 26ºC to 39ºC and 8ºC to 29ºC in summer and winter seasons, respectively. The experimental material consisted of 45 F_1s and their ten parents. The crosses were made in diallel fashion (excluding reciprocals) by using 10 diverse genotypes of bread wheat *viz;* K 612, HUW 648, AAI 13, K 9104, HUW 658, K 307, WCW 95-1, K 910-30, NW 4081 and NW 4035 during 2012-2013.

Ten parents and their 45 F_1s were evaluated in randomized block design (RBD) with three replications. Each genotype was planted in 2-rows of 1 meters length (7-10 seeds in each row), inter and intra row distance was 25 and 10 cm, respectively. All the standard agronomical practices were followed to raise the normal crop. The observations were recorded on five randomly selected competitive plants in each replication for plant height (cm), number of productive tillers/plant, number of grains/spike, number of spikelets/spike, 1000-grain weight (g), biological yield/plant (g), grain yield/plant (g), gluten content (%), ash content (%) and protein content (%) whereas days to 50 % flowering and days to maturity were recorded on all the plants in the plot. The differences between genotypes for all traits were tested for significance by using analysis of variance technique (Panse and Sukhatme, 1967). The combining ability was estimated by using the method-II and model-I as proposed by Griffing (1956b).

3. Results and discussion

The analysis of variance for 12 agro-morphological and quality traits under study is depicted in table 1. In present study, total variance was partitioned into different components namely, treatments, parents, crosses and parents vs. crosses were observed highly significant for all the traits except days to 50% flowering, days to maturity, grains/spike in parents while spikelets/spike and protein content in parents vs. crosses. Significance of variance for parents vs crosses indicted that crosses were quite different than parents. The ANOVA for combining ability (Table 2) indicated that variances due to general combining ability (GCA) were highly significant for plant height, 1000-grain weight, biological yield, grain yield, gluten, ash and protein content while significant for productive tillers/plant. Whereas specific combining ability (SCA) variance was highly significant for all the traits studied except grains/spike. Similar findings were also reported (Adel and Ali, 2013). In general, magnitude of SCA was greater than GCA variance for all the traits except plant height, biological yield, protein content and grain yield. The higher magnitude of SCA variance as compared to GCA variance has been reported for yield and its components (Siddique *et al.* 2004 and Srivastava *et al.* 2012). Significant variances due to general and specific combining ability for agro-morphological and quality traits indicated that both additive and non-additive gene action are paramount in the present set of breeding materials. Similar findings were reported by Kumar *et al.* (2010).

The estimated value of δ^2s was higher than δ^2g for all the traits under study indicating predominance of non-additive gene action. The ratio of δ^2g/δ^2s was less than unity (1.00) for all the agro-morphological and quality traits, suggesting the importance of non-additive gene action over additive gene action in the breeding material. Adel and Ali (2013) also reported the similar results in their study. The average degree of dominance (δ2s/δ2g) 1/2 was greater than unity (1.0) indicating over dominance for all the traits. Hassani *et al.* (2005) also reported the similar findings. In case of general combining ability effects of parents, none of the parent was identified as good general combiner for all the traits as given in table 3. All parents showed favourable GCA effect for one or other traits, but out of ten parents, three parents viz; K 612, HUW 648 and WCW 95-1 expressed favourable GCA effect for grain yield and also good for yield contributing traits.

Table 1. Analysis of variance (ANOVA) for yield and quality traits in bread wheat

Source of Variation	D.F.	Days to 50 % flowering	Plant height	Productive tillers	Days to maturity	Spikelets /spike	Grains / spike	1000 grain weight	Biological yield	Gluten content	Ash content	Protein content	Grain yield
Replications	2	2.64	1.43	0.47	0.42	0.17	0.34	10.13	0.18	0.00	0.02*	0.05	0.12
Treatments	54	5.98**	115.38**	2.89 **	6.39**	2.97**	21.09**	29.44**	39.23**	0.30**	0.05**	0.53**	9.00**
Parents	9	3.12	248.83 **	2.06 *	4.57	5.24 **	34.77	38.23 **	31.29 **	0.15 **	0.08 **	0.93 **	4.12 **
Crosses	44	6.34 **	83.40 **	2.64 **	6.18**	2.57 **	16.96 **	23.29 **	39.91 **	0.28 **	0.05 **	0.46 **	8.60 **
Parent vs Crosses	1	15.78 **	321.79 **	22.07 **	32.76**	0.39	79.85 **	221.50 **	81.04 **	2.35 **	0.05 **	0.00	70.98 **
Error	108	.72	1.35	0.99	2.36	1.61	3.84	4.78	1.79	0.02	0.01	0.03	0.94
Total	164	3.13	38.90	1.61	3.67	2.04	9.48	12.97	14.10	0.11	0.02	0.19	3.58

*, **; Significant at 5% & 1% probability levels, respectively

Table 2. Analysis of variance (ANOVA) of combining ability analysis for yield and quality traits in bread wheat

Source of Variation	D.F.	Days to 50 % flowering	Plant height	Productive tillers	Days to maturity	Spikelets /spike	Grains/ spike	1000 grain weight	Biological yield	Gluten content	Ash content	Protein content	Grain yield
GCA	9	0.89	46.26**	0.69*	0.95	0.82	4.06	9.08**	20.57**	0.04**	0.01**	0.18**	3.98**
SCA	45	2.21**	36.90**	1.02**	2.36**	1.02**	7.62	9.96**	11.57**	0.11**	0.01**	0.17**	2.80**
Error	108	0.57	0.45	0.33	0.78	0.53	1.28	1.59	0.59	0.006	0.001	0.01	0.31
∂^2g		0.02	3.81	0.03	0.01	0.02	0.23	0.62	1.66	0.003	0.001	0.01	0.30
∂^2s		1.63	36.45	0.68	1.58	0.48	6.34	8.36	10.97	0.10	0.01	0.16	2.48
∂^2g/ ∂^2s		0.01	0.10	0.04	0.008	0.04	0.03	0.07	0.15	0.02	0.07	0.08	0.12
∂^2s/ ∂^2g $^{1/2}$		9.02	3.09	4.76	12.56	4.89	5.25	3.67	2.57	5.77	3.16	4.00	2.87

*, **; Significant at 5% & 1% probability levels, respectively

Table 3. Estimates of mean and general combining ability effects for yield and quality traits in bread wheat

Parent	Days to 50% flowering		Plant height		Productive tillers		Days to maturity		Spikelets / spike		Grains/ spike		1000 grain weight		Biological yield	
	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca
K 612	84.00	-0.08	62.40	-1.35**	4.33	0.23	137.3	-0.28	19.0	0.52*	57.0	0.83**	43.2	1.98**	43.5	1.51**
HUW 648	83.33	-0.19	62.66	-2.50**	4.66	-0.24	139.0	-0.14	16.7	0.16	49.3	-0.42	44.5	-0.07	44.1	1.04**
AAI 13	85.66	0.56**	80.06	2.57**	5.33	-0.13	138.0	0.36	17.3	-0.40*	53.0	-1.09**	37.7	-0.30	40.1	-2.26**
K 910-4	85.00	0.36	88.30	2.30**	6.33	-0.13	137.7	0.17	14.7	-0.29	45.0	-0.59	37.0	-0.66	50.7	1.06**
HUW 658	83.66	0.06	62.06	-2.68**	5.33	-0.13	138.3	-0.44	17.0	-0.18	53.0	0.30	39.0	0.64	42.5	0.35
K 307	86.66	-0.08	64.66	-0.16	5.66	-0.05	138.7	0.36	16.7	-0.04	55.0	0.61	38.8	0.35	40.6	-1.89**
WCW 95-1	85.00	-0.28	66.66	2.46**	6.33	0.48**	138.0	-0.25	17.0	0.16	50.7	-0.23	35.8	-0.46	46.5	1.27**
K 910-30	84.33	-0.06	61.50	0.24	6.00	-0.24	140.7	0.17	15.0	0.04	49.7	0.33	35.5	0.29	44.8	-0.39
NW 4081	84.66	-0.31	62.73	0.26	7.00	0.26	136.3	-0.11	18.0	0.13	53.0	0.11	32.9	-0.85 *	44.3	-0.08
NW 4035	85.66	0.03	64.40	-1.16**	6.33	-0.02	136.7	0.17	18.0	-0.09	54.0	0.16	40.9	-0.91 *	40.4	-0.60**
SE(gi)		0.20		0.18		0.15		0.24		0.20		0.31		0.34		0.21
SE(gi-gj)		0.87		0.77		0.66		1.02		0.84		1.30		1.45		0.89

Parent	Gluten content		Ash content		Protein content		Grain yield	
	Mean	gca	Mean	gca	Mean	gca	Mean	gca
K 612	7.28	0.05*	1.53	0.01	11.63	-0.16**	20.41	0.70**
HUW 648	7.23	0.08**	1.53	0.02	11.50	-0.10**	20.57	0.50**
AAI 13	7.20	-0.04	1.57	-0.07**	12.08	-0.08**	19.92	-1.03**
K 910-4	7.26	-0.04	1.77	0.02	12.94	0.20**	20.78	-0.35 *
HUW 658	7.14	-0.12**	1.75	0.02	12.86	0.01	20.31	0.26
K 307	7.15	-0.03	1.43	0.05**	11.72	0.19**	20.64	-0.69**
WCW 95-1	7.64	-0.01	1.25	-0.02	11.65	-0.11**	23.22	0.62**
K 910-30	7.51	0.01	1.77	0.02	12.87	0.07*	20.81	-0.22
NW 4081	7.55	0.06**	1.60	0.01	12.13	0.02	21.54	0.29
NW 4035	7.78	0.05*	1.51	-0.06**	12.05	-0.04	18.60	-0.07
SE(gi)		0.02		0.01		0.02		0.15
SE(gi-gj)		0.09		0.05		0.12		0.64

*, **significant at 5% & 1% probability levels, respectively

Table 4. Estimates of specific combining ability effect for yield and quality traits in bread wheat

Cross	Days to 50 % flowering	Plant height	Productive tillers	Days to maturity	Spike-lets/spike	Grains/ spike	1000-grain weight	Biological yield	Gluten content	Ash content	Protein content	Grain yield
K 612 × K 910-4	1.27	-1.74**	0.73	-0.67	-1.06	2.94**	-0.32	1.90*	-0.34**	-0.06	-0.48**	1.41**
K 612 × WCW 95-1	0.57	-3.49**	0.79	-0.93	0.50	-0.09	-0.48	2.47**	0.21**	0.14**	0.41**	2.38**
K 612 × NW 4081	-1.07	11.83**	2.01**	1.27	-0.14	-4.76**	2.83*	1.75*	-0.19*	0.08*	0.23*	1.75**
K 612 × NW 4035	-1.06	-2.08**	-0.71	-1.01	-0.92	-4.15**	-0.71	4.16**	0.53**	-0.03	-0.38**	3.15**
HUW 648 × AAI 13	-0.48	-8.19**	0.20	-0.68	0.75	1.69	-2.65*	4.59**	0.43**	-0.04	-0.16	1.49**
HUW 648 × HUW 658	-1.65*	1.80**	0.54	-1.54	-0.47	-3.37**	-0.32	6.70**	0.07	0.06	0.49**	3.13**
HUW 648 × K 307	2.16**	-0.73	0.12	0.99	-0.61	-2.67*	1.60	6.30**	0.37**	-0.18**	-0.37**	1.96**
HUW 648 × K 910-30	1.46*	9.87**	0.98	-3.15**	1.30	3.94**	-1.08	1.14	0.40**	0.11**	-0.07	1.17*
AAI 13 × K 910-4	2.63**	1.14	0.09	-0.65	0.19	-1.81	-3.22**	0.76	-0.11	0.00	0.04	1.44*
AAI 13 × K 910-30	-1.29	-0.13	-0.13	1.02	-1.14	-2.40*	-1.89	2.13**	-0.03	-0.20**	-0.37**	1.49**
K 910-4 × NW 4081	-0.85	-9.42**	-0.63	3.82**	0.66	0.33	0.96	0.05	0.33**	-0.11**	-0.22*	1.95**
HUW 658 × K 307	-0.76	0.26	-1.33*	1.30	1.05	2.60*	0.21	3.49**	0.24**	0.10*	0.55**	2.28**
HUW 658 × K 910-30	1.55*	0.19	1.20*	-1.18	-1.36*	-1.79	2.77**	-0.68	-0.41**	-0.09*	-0.52**	1.30*
K 307 × NW 4035	-0.73	0.66	1.56**	-0.99	-0.70	-4.92**	-1.48	0.99	0.19*	-0.03	-0.22*	1.47**
WCW 95-1 × K 910-30	-0.46	-4.62**	-0.74	-1.70*	1.64*	0.74	-1.38	4.70**	-0.18*	0.07	-0.01	1.16*
WCW 95-1 × NW 4035	-0.87	5.18**	0.04	0.30	-0.22	-0.76	-4.69**	3.20**	-0.06	0.00	0.66**	1.80**
SE (Sij)±	0.69	0.61	0.53	0.81	0.67	1.04	1.16	0.71	0.07	0.03	0.09	0.51
SE (Sij-Sik)±	1.02	0.90	0.78	1.20	0.99	1.53	1.71	1.04	0.11	0.05	0.14	0.75

*, ** significant at 5% & 1% probability levels, respectively

Table 5. Mean performance of 45 F$_1$s for yield and quality traits in bread wheat

Cross	Days to 50 % flowering	Plant Height	Productive tillers	Days to maturity	Spikelets/ spike	Grains/ spike	1000 grain weight	Biological yield	Gluten content	Ash content	Protein content	Grain yield
K 612 × K 910-4	87.00	63.80	7.33	136.33	16.00	53.66	37.06	49.71	7.30	1.50	11.70	23.83
K 612 × WCW 95-1	85.66	62.20	8.00	135.66	18.00	51.00	37.11	50.49	7.88	1.66	12.28	25.78
K 612 × NW 4081	84.00	75.33	9.00	138.00	17.33	46.66	40.02	48.42	7.55	1.64	12.23	24.81
K 612 × NW 4035	84.33	60.00	6.00	136.00	16.33	47.33	36.43	50.31	8.25	1.46	11.55	25.85
HUW 648 × AAI 13	85.33	56.46	6.33	136.66	17.33	50.66	33.05	48.61	8.09	1.45	11.81	23.03
HUW 648 × HUW 658	83.66	61.20	6.66	135.00	16.33	47.00	36.32	53.33	7.66	1.63	12.54	25.96
HUW 648 × K 307	87.33	61.20	6.33	138.33	16.33	48.00	37.95	50.69	8.04	1.42	11.86	23.83
HUW 648 × K 910-30	86.66	72.20	7.00	134.00	18.33	54.33	35.21	47.03	8.11	1.69	12.05	23.52
AAI 13 × K 910-4	89.00	70.60	6.33	137.00	16.33	47.00	31.88	44.80	7.44	1.48	12.30	22.13
AAI 13 × K 910-30	84.66	67.26	6.00	138.66	15.33	47.33	34.17	44.72	7.57	1.28	11.76	22.31
K 910-4 × NW 4081	84.66	57.73	6.00	141.00	17.33	50.33	35.51	46.26	7.98	1.45	12.15	23.95
HUW 658 × K 307	84.66	62.00	5.00	138.33	17.66	54.00	37.26	47.19	7.71	1.69	12.90	23.92
HUW 658 × K 910-30	87.00	62.33	7.33	135.66	15.33	49.33	39.76	44.52	7.11	1.47	11.71	23.41
K 307 × NW 4035	84.66	63.93	8.00	136.66	16.00	46.33	34.03	43.74	7.83	1.49	12.06	22.78
WCW 95-1 × K 910-30	84.66	62.66	6.00	135.33	18.66	51.33	34.52	50.81	7.45	1.60	12.10	23.63
WCW 95-1 × NW 4035	84.33	71.06	7.00	137.33	16.66	49.66	30.01	49.10	7.60	1.45	12.65	24.42

Therefore, these parents can be used in crossing programme for improving the grain yield in wheat. Similar findings were published by Ali and Falahy (2011). K 612 was good general combiner for grain yield which also ranked amongst the best varieties with regard to the per se grain yield/plant (GY). This parent exhibited high GCA effect for spikelets/spike, grains/ spike, 1000 grain weight, biological yield and gluten content. High GCA for plant height and biological yield was largely observed to contribute to the higher GCA for grain yield. HUW 648 expressed high GCA for plant height, biological yield, grain yield and gluten content while WCW 95-1 showed for plant height, productive tillers, biological yield and grain yield, suggested that these parents could be used as donor parent for the improvement of these traits. Srivastava *et al.* (2012) was also noticed similar results in their study. In most of the cases, performance of the parents bears direct reflection of their respective GCA effects, i.e., parents showing highest GCA effects for traits and also observed to be good performer with respect to the particular trait. The high GCA effects are mostly due to the additive gene effects or additive x additive interaction as reported by Griffing (1956). A number of parents were poor in GCA for grain yield, however, exhibited good GCA for contributing traits; these were AAI 13 (days to 50% flowering and plant height), K 910-4 (plant height, biological yield and protein content) and K 910-30 (protein content). In order to synthesize a dynamic population with most of the favourable genes accumulated; it will be pertinent to make use of these parents in multiple crossing programmes as these are good general combiners for several traits. Apart from conventional breeding methods relying upon additive or additive x additive types of gene action, population improvement methods appears to be a promising alternative.

Estimates of SCA effects revealed (Table 4) that out of 45 cross combinations, 8 for days to 50% flowering, 33 for plant height, 4 for productive tillers, 4 for days to maturity, 1 for spikelets/spike, 4 for grains/spike, 3 for 1000 grain weight, 16 for biological yield, 13 for grain yield, 17 for gluten content, 8 for ash content and 11 for protein content revealed desirable and highly significant SCA effects. The most promising cross combinations for each trait are shown in Table 5. Some of the cross combinations exhibiting significant SCA effects for grain yield has significant SCA effect

for some yield components as well. For instance, K 612 x NW 4035 possesses highest SCA effect for grain yield also consists of significant SCA for plant height, biological yield and gluten content, similarly, HUW 648 x HUW658 had highly significant for grain yield along with days to 50% flowering, plant height, biological yield and protein content.

Cross HUW 648 x K 307 showed highly significant SCA effect for grain yield with yield attributing traits viz; days to 50% flowering, biological yield and gluten content. These heterotic crosses involved parents belonging to high x low general combiners. These findings indicate that it is not necessary to get best recombinants only from high x high general combiners as reported (Kulshreshtha and Singh, 2011). The most promising cross is the one that involves parents with high GCA and also reveals high SCA effects. The major portion of such variance would be fixable in crosses K 612 x K 910-4 and K 612 x WCW 95-1 for biological yield; K 612 x NW 4035 for gluten content and K612 x WCW 95-1 for grain yield/plant in later generations. The cross K612 x NW 4035 showed significant SCA effect though both the parents involved revealed low general combining ability effects for reducing the plant height. Similar findings were also reported (Singh *et al.* 2014; Kumar *et al.* 2015; Kumar *et al.* 2016) for grain yield, agro-morphological and quality traits in wheat.

The traits which show predominance of non-additive gene effects indicates that the improvement of such traits would be difficult, as simple pedigree breeding will not be able to fix the superior lines in the early generations. In such situation, maintaining considerable heterozygosity through mating of selected plants in early segregating generations could attain maximum gain. Therefore, few cycles of recurrent selection followed by pedigree breeding will be effective and useful for the improvement of yield in such cases in the present material. The present study demonstrates that both additive (fixable) and non-additive (non-fixable) components of genetic variances were involved in governing the inheritance of almost all the quantitative and quality traits. Therefore, bi-parental mating and/or diallel selective mating which may allow intermating of the selects in different cycles and exploit both additive and non-additive gene effects could be useful in the genetic improvement of the characters of bread wheat. F_1 hybrids showing high SCA and having parents with good GCA into multiple crosses could also be a worthwhile approach for tangible improvement of grain yield in spring wheat.

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