

Original Research Article

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## Estimation of Combining Ability in F<sub>1</sub> and F<sub>2</sub> Generations of Diallel Crosses in Winter Wheat (*Triticum aestivum* L. Em. Thell)

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### ABSTRACT

The F<sub>1</sub> 45 genotypes and F<sub>2</sub> 45 genotypes including ten - parents' produced through diallel cross (excluding reciprocal) of winter wheat (*Triticum aestivum* L. Em. Thell) were analyzed for combining ability for yield and yield associated traits. Highly significant variances due to gca and sca in both the generations of present study for all the traits revealed that additive as well as non-additive genetic effects were involved in determining the traits. The results indicated significant differences among the parents for general combining ability and crosses for specific combining ability for all the characters studied. Among the parents considering simultaneously the per se performance and gca effects, good general combiners common in F<sub>2</sub> generations were K0402 and HD2888 for number of reproductive tillers; K8027 and K9351 for spikelets/ spike and PBW343 and K0607 for grain yield per plant. On the basis of overall performance, parents PBW343, K9351, K9533 and K0607 were best general combiners for grain yield and other important yield contributing characters. In respect of grain yield per plant; the positive and significant values of sca were associated with four combinations with high per se performance like PBW343/K0607, K9533/NW2036, K0424/K0607 and K0402/K0607; out of these in F<sub>1</sub> K9533/NW2036, K0424/K0607, K9351/HD2888 and PBW343/K0607 were best with good specific combinations. All the three possible combinations namely, high x high, high x low and low x low were observed between the parents of high and low gca effects.

#### Keywords

*Triticum aestivum* L., Diallel cross, Combining ability, Genotypes.

#### Article Info

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### Introduction

Wheat (*Triticum aestivum* L.) is the principal food grain of the world population. It constitutes the major food for billions people of the world. Among the cereals, wheat has the pride place because of vast acreage covered under cultivation, and nutritional value which supplies about 20% of the calories for the world growing population. It is the most important staple food of about two

billions people (36% of the world population). The importance of the wheat is evident from the dependency of more than half of the world's population on wheat as a basic food. During 2012-13 the production of wheat fall by 2.42 mt as comparison to 2011-12 owing to the productivity decline by 58 kg/ha (1.84%) followed by marginal reduction in area by 0.22 m ha (0.73%) (Directorate of

Economics and Statistics, Government of India, New Delhi), which is mainly due to lack of high yielding, disease and pest resistance and stable varieties besides and with some other reasons. Therefore, there is an urgent need to develop varieties having high yield as well as high quality protein with multiple resistances which may get fitted in intensive cropping system for boosting up its production. Further advancement in the yield of wheat requires adequate information regarding the nature of combining ability of the parents available in a wide array of genetic material to be used in the hybridization program and also the nature of gene actions involved in the expression of quantitative traits of economic importance (Joshi *et al.*, 2004).

Earlier research review revealed that both general and specific combining abilities were involved in the inheritance of grain yield and its components (Singh *et al.*, 2000; Murliya and Sastry, 2001). Combining ability is a very important and effective genetic parameter and accordingly has been widely adopted in plant breeding to compare performances of lines in hybrid combinations (Griffing 1956; Li *et al.*, 1991). Thus the proposed study “Genetic studies for yield and its contributing characters in bread wheat (*Triticum aestivum* L.)” has been taken up to achieve the targets.

### **Materials and Methods**

Ten genotypes of wheat (*Triticum aestivum* L. Em. Thell) namely K9533, K9423, PBW343, HD2888, K0607, K0424, K9351, K8027, NW2036 and K0402 as basic material which had been taken on the basis of their differences in origin, adaptability and morphological characters from the germplasm maintained at Section of Economic Botanist (Rabi Cereals), C.S.Azad University of Agriculture and Technology, Kanpur. All these parents have genetic variability for yield

level as well as for various good yield components. In the present investigation all possible crosses among the selected parents were made in one direction only, i.e. direct crosses. Here each parent was used either as male or as female in the mating. The number of single crosses attempted was equal to  $[n(n-1)/2]$ , where n is the number of parents used. Half diallel design was used in the present study because reciprocal differences are not significant in wheat crops.

All possible single crosses were made during the year 2011-12 to complete a 10x10 half diallel set without reciprocal due to absence of extra nuclear inheritance in wheat (Whitehouse, *et al.* 1958) The experiment was conducted in randomized block design (RBD) with 45 F<sub>1</sub>, 45 F<sub>2</sub> with ten diversified parents during the year 2013-2014) at Crop Research Farm, Nawabganj, Kanpur. The experimental material was sown in each replication, parents and F<sub>1</sub>s were sown in single row while F<sub>2</sub>s were sown in two rows. The length of each row was 3.0m with inter and intra-row distance of 25 and 10cm respectively. Recommended doses of fertilizers @ 120 kg N + 60 kg P<sub>2</sub>O<sub>5</sub> + 40 kg K<sub>2</sub>O per hectare were applied in the experimental area along with four irrigations at all critical stages.

Quantitative data were collected on five plants in each row. Days to 75% flowering, plant height, number of reproductive tiller per plant, number of spikelets per spike, spike length, number of grain per spike, days to maturity, 1000-seed weight, ear density, duration of reproductive phase, seed hardness, protein content and yield per plant. Regarding statistical analysis data recorded on parents with forty five F<sub>1</sub> and forty five F<sub>2</sub> were analyzed together.

The combining ability analysis was worked out in diallel analysis mating design by following Griffings (1956).

## Results and Discussion

### Combining ability variances

The analysis of variance for combining ability was carried out for all the characters in both  $F_1$  and  $F_2$  generations and result are presented in Table 1. The mean squares due to general combining ability (gca) effects and specific combining ability (sca) effect were found highly significant for all the characters in both the generations  $F_1$  and  $F_2$ . The magnitude of estimates of gca variances were higher for days to 75% flowering, plant height, number of grain per spike, days to maturity, seed hardness, duration of reproductive phase, protein content and yield per plant than the respective estimates of sca variances in both the generations. General predictability ratio did not reach near to unity for any of the traits in both the generations.

Highly significant variances due to gca and sca in both the generations of present study for all the traits revealed that additive as well as non-additive genetic effects were involved in determining the traits. Estimated variances indicated higher contribution on non-additive gene effects for all the characters in both the generations. Genetic components analysis also indicated predominance of non-additive genetic estimate for all the characters. Such results have also been reported by Sharma *et al.*, (1991), Singh and Rai (1991), Kulshrestha *et al.*, (1991), Kumar *et al.*, (2002), Srivastava (2005) for grain yield and its components traits. Most of the characters also reported by Bede (1980), Yunus *et al.*, (1981), Kraljevic *et al.*, (1982), Singh *et al.*, (1987).

### General combining ability (gca) effects

The gca effects include both additive and additive x additive interaction components of genetic variability (Griffing, 1956; Sprague,

1966) which represents fixable genetic variance as also reported by Gilbert (1967). The additive parental effects as measured by gca effects are of practical use, whereas non-allelic interactions are unpredictable and cannot be easily manipulated. The per se performance of the parents was compared with their gca effects in both the generations for all the characters under study presented in Table 4. It was concluded that the parents having high per se performance were proved to be the best general combiners for all the traits. It may be noted that if the character is unidirectionally controlled by a set of alleles and additive effects are important, choice of the parents on the basis of per se performance in most of the cases may be correct. But the choice of parents should be made on the basis of their combining ability estimates where non-allelic interactions are important.

Considering simultaneously the per se performance and gca effects, good general combiners common in the and  $F_2$  generations were K9351 for days to 75 per cent flowering, K0424 and PBW343 for plant height; K0402 and HD2888 for number of reproductive tillers; for spikelets/ spike and spike length are K8027 and K9351; number of grains per spike are PBW343 and K8027; Days to maturity are K0424 and K9533; for 1000-seeds weight K9423; for seeds hardness K8027; ear density K402 and K0424; duration of reproductive phase HD2888; K9423, PBW343 and K0424 for protein content and PBW343 and K0607 for grain yield per plant. The consistency of aforesaid combiners for yield and quality contributing traits in both the generations indicated that good general combiners were stable in their performance over generation.

On the basis of overall performance, parents PBW343, K9351, K9533 and K0607 were best general combiners for grain yield and other important yield contributing characters.

**Table.1** ANOVA for combining ability and related statistics of 13 characters in a 10 parent diallel cross in F<sub>1</sub> and F<sub>2</sub> generations of wheat

Source of variation	d.f.	Days to 75% flowering		Plant height		Reproductive tiller/plant		Spikelets/spike		Spike length		Grains/spike		Days to maturity	
		F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>
<b>GCA</b>	9	46.68**	55.58**	54.68**	39.40**	0.38	0.68	1.79**	1.99**	0.25**	0.32**	10.55**	18.81**	49.12**	55.27**
<b>SCA</b>	45	7.40**	6.93**	29.79**	19.03**	0.70**	0.78**	2.74**	1.87**	0.51**	0.36**	6.24**	7.39**	6.72**	6.02**
<b>Error</b>	108	0.41	0.39	3.57	4.97	0.36	0.36	0.68	0.73	0.08	0.05	2.42	2.44	0.39	0.42
$\sigma_g^2$		3.93	4.59	4.25	2.86	0.01	0.02	0.09	0.10	0.01	0.02	0.67	1.36	4.06	4.57
$\sigma_s^2$		6.98	6.52	26.21	14.06	0.32	0.40	2.04	1.12	0.42	0.29	3.82	4.94	6.32	5.59
<b>GPR</b>		0.52	0.58	0.24	0.28	0.01	0.11	0.08	0.15	0.06	0.12	0.26	0.35	0.56	0.62

Contd.....

Source of variation	d.f.	1000-seed weight		Seed hardness		Ear density		Duration of reproductive phase		Protein content		Yield/plant	
		F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>1</sub>	F <sub>2</sub>
GCA	9	1.72**	1.16	0.70**	0.94**	0.02**	0.02**	11.58**	26.34**	0.76**	0.62**	2.32**	1.97**
SCA	45	2.42**	3.65**	0.34**	0.27**	0.03**	0.01**	8.78**	12.04**	0.14**	0.17**	0.39**	0.32**
Error	108	0.53	0.87	0.01	0.03	0.01	0.01	0.41	0.55	0.01	0.01	0.13	0.09
$\sigma_g^2$		0.09	0.02	0.05	0.07	0.01	0.01	0.93	2.14	0.06	0.05	0.18	0.15
$\sigma_s^2$		1.88	2.77	0.32	0.23	0.02	0.01	8.36	11.49	0.13	0.17	0.25	0.23
GPR		0.09	0.01	0.26	0.38	0.09	0.19	0.18	0.27	0.47	0.36	0.58	0.57

\* Significant at 5% level; \*\* significant at 1% level; GCA= general combining ability; SCA= specific combining ability;  $\sigma_g^2$  = estimates of gca variance;  $\sigma_s^2$  = estimates of sca variance; GPR =general predictability ratio

**Table.2** Estimates of GCA effects corresponding mean performance of the parents for 13 characters in a 10 parents diallel cross in F<sub>1</sub> and F<sub>2</sub> generations of wheat

Parents	Days to 75% flowering			Plant height			Reproductive tillers/plant			Spikelets/spike			Spike length		
	gca effect		Mean	gca effect		Mean	gca effect		Mean	gca effect		Mean	gca effect		Mean
	F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>	
K9533	-2.27**	-2.51**	72.33	2.11**	1.42*	87.00	-0.13	-0.25	8.00	-0.68**	-0.37	21.66	0.02	0.05	9.16
K0424	-2.63**	-2.98**	72.66	-2.41**	-2.91**	78.00	0.11	0.10	8.33	-0.29	-0.48*	20.33	-0.17*	-0.20**	8.76
PBW343	2.92**	3.37**	84.33	-1.18**	-1.27*	83.66	0.02	-0.08	8.33	-0.12	0.45	21.66	0.02	0.16*	9.33
K0402	-1.52**	-1.60**	79.66	-2.71**	-0.52	83.66	0.31	0.35*	8.33	0.67**	0.23	21.66	-0.02	-0.07	8.86
K9351	-2.16**	-2.07**	74.66	-0.99**	0.55	89.33	0.07	0.07	7.00	0.48*	0.45	22.33	0.12	0.19**	9.43
NW2036	1.61**	1.84**	80.33	-0.85**	-0.24	91.33	-0.03	-0.14	8.33	0.09	-0.26	20.33	0.18*	0.01	9.43
K0607	1.72**	1.78**	80.00	3.89**	3.75**	99.00	0.03	-0.28	8.00	-0.18	-0.04	19.66	-0.09	-0.08	8.43
HD2888	0.27	0.26	77.66	1.58**	0.39	105.33	0.14	0.10	8.33	-0.10	-0.60*	18.33	0.03	-0.14*	7.90
K8027	1.16**	1.03**	77.33	1.36**	1.08	105.00	0.06	0.35*	9.00	0.15	0.28	21.00	0.16	0.25***	9.00
K9423	0.86**	0.81**	80.33	-0.80	-1.16	82.33	-0.10	-0.22	7.00	-0.01	0.34	19.66	-0.26	-0.16*	8.43
SE(gi)	0.17	0.17		.051	0.61		0.16	0.16		0.22	0.23		0.07	0.06	
SE(gi-ji)	0.26	0.25		0.77	0.91		0.24	0.24		0.33	0.35		0.11	0.09	

Continued

Parents	Grains/spike			Days to maturity			1000-seed weight			Seed hardness		
	gca effect		Mean	gca effect		Mean	gca effect		Mean	gca effect		Mean
	F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>	
K9533	-0.38	0.28	50.66	-1.80**	-2.37**	117.66	0.21	0.12	38.33	-0.08*	-0.28**	18.36
K0424	-0.57	-0.20**	45.33	-3.77**	-4.01**	114.33	-0.64**	-0.71**	36.66	-0.23**	-0.15**	18.30
PBW343	1.64**	0.16*	50.66	3.30**	2.82**	128.66	-0.31	0.12	39.66	0.24**	0.38**	18.23
K0402	-0.30	-0.07	47.33	0.38*	1.31**	123.33	0.13	0.26	41.00	-0.36**	-0.28**	17.46
K9351	0.01	0.19**	50.00	-1.86**	-1.84**	116.66	0.18	-0.12	41.66	0.16**	0.31**	18.30
NW2036	1.08*	0.07	52.00	-0.13	-0.67**	121.66	0.05	0.01	38.33	0.13**	0.29**	19.30
K0607	-0.30	-0.08	45.33	1.61**	1.26**	124.66	0.49*	0.31	37.66	-0.27**	-0.20**	17.46
HD2888	-1.49**	-0.14*	44.66	0.75**	1.37**	123.33	-0.53**	-0.26	37.66	0.16**	0.05	18.46
K8027	0.89*	0.25**	50.66	1.22**	1.51**	123.00	0.02	0.28	39.00	0.34**	0.20**	19.20
K9423	-0.57	-0.16*	44.33	0.30	0.60**	117.66	0.38	-0.01	40.66	-0.10**	-0.31**	16.40
SE(gi)	0.42	0.42		0.17	0.17		0.20	0.25		0.03	0.05	
SE(gi-ji)	0.63	0.63		0.25	0.26		0.29	0.38		0.04	0.07	

Continued

Parents	Ear density			Duration of reproductive phase			Protein content			Yield/plant		
	gca effect		Mean	gca effect		Mean	gca effect		Mean	gca effect		Mean
	F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>		F <sub>1</sub>	F <sub>2</sub>	
K9533	-0.06*	-0.06**	2.33	0.50**	0.08	45.33	-0.07**	0.02	11.29	-0.01	0.07	12.23
K0424	0.01	0.02	2.37	-1.13**	-1.24**	41.66	0.26**	0.22**	12.21	-0.32**	-0.22**	11.38
PBW343	-0.01	0.01	2.32	0.25	-0.55**	44.33	0.31**	0.33**	12.28	0.55**	0.50**	13.50
K0402	0.06**	0.02	2.44	1.77**	2.95**	43.66	-0.07**	-0.13**	10.23	0.35**	0.35**	11.28
K9351	0.01	-0.01	2.36	0.36*	0.14	42.00	-0.51**	-0.42**	10.28	0.24*	0.19*	12.30
NW2036	-0.04*	-0.02	2.15	-1.75**	-2.52***	41.33	-0.05**	-0.05**	11.45	0.08	0.01	10.91
K0607	0.01	0.01	2.32	-0.63**	-0.99**	42.66	-0.01	-0.11**	11.61	0.57**	0.46**	12.18
HD2888	-0.01	-0.02	2.31	0.55	1.14**	45.66	-0.07**	0.01	11.44	-0.28**	-0.16	10.68
K8027	-0.03	-0.03*	2.32	0.01	0.61**	45.66	-0.10**	-0.12**	10.49	-0.51**	-0.45**	11.68
K9423	0.05**	0.08**	2.32	0.08	0.36	40.66	0.33**	0.25**	12.41	-0.67**	-0.74**	10.13
SE(gi)	0.01	0.01		0.17	0.20		0.01	0.01		0.10	0.08	
SE(gi-ji)	0.02	0.02		0.26	0.30		0.02	0.01		0.14	0.12	

\* Significant at 5% level; \*\* significant at 1% level

**Table.3** Estimation of sca and corresponding mean performance for 13 characters in a 10 parents diallel cross in F<sub>1</sub> and F<sub>2</sub> generations of wheat

Cross combinations	Days to 75% flowering				Plant height				Reproductive tiller/ plant				Spikelets/spike			
	F <sub>1</sub>		F <sub>2</sub>		F <sub>1</sub>		F <sub>1</sub>		F <sub>1</sub>		F <sub>2</sub>		F <sub>1</sub>		F <sub>2</sub>	
	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	Sca	mean
K9533XK0424	1.06	72.67	0.76	71.67	4.78**	92.33	3.37	90.67	-0.34	8.33	0.76	71.67	0.71	20.33	-0.33	19.67
X PBW343	-4.21**	73.00	-4.93**	72.33	7.23**	96.00	0.40	89.33	0.52	9.00	-4.93**	72.33	0.55	20.33	0.06	21.00
XK0402	1.62**	74.33	2.04**	74.33	1.09	88.33	5.98**	95.67	-0.26	8.67	2.04**	74.33	-2.25**	18.33	-3.06**	17.67
XK9351	2.59**	74.67	2.79**	74.67	0.03	89.00	2.01	91.67	0.35	9.00	2.79**	74.67	1.27	21.67	1.39	22.33
XNW 2036	-1.51**	74.33	-1.41*	74.33	-2.747	86.33	1.37	91.33	0.24	8.67	-1.41*	74.33	0.99	21.00	-0.56	19.67
XK0607	-3.29**	72.67	-2.68**	73.00	4.48*	98.33	-0.63	93.33	0.05	8.33	-2.68**	73.00	-1.39	18.33	1.89*	22.33
XHD2888	-0.18	74.33	-0.49	73.67	-6.54**	85.00	-6.60**	84.00	0.99	9.67	-0.49	73.67	-2.14**	17.67	-1.56	18.33
X8027	1.26*	76.67	1.40*	76.33	-1.65	89.67	0.04	91.33	-0.59	8.33	1.40*	76.33	-2.39**	17.67	0.22	21.00
X9423	1.90**	72.33	1.95**	76.67	3.50*	92.67	3.29	92.33	-1.01	7.33	1.95**	76.67	-0.22	19.67	-1.17	19.67
K0424XPBW343	-5.18**	71.67	-4.46**	72.33	3.75*	88.00	3.07	87.67	0.49	9.33	-4.46**	72.33	0.16	20.33	1.50	22.33
XK0402	-0.01	72.33	0.18	72.00	-5.04**	77.67	-1.68	83.67	-0.62	8.67	0.18	72.00	0.68	21.67	-0.28	20.33
XK9351	-0.71	71.00	-0.41	71.00	3.89*	88.33	-0.65	84.67	0.66	9.67	-0.41	71.00	-5.11***	15.67	-3.17**	17.67
XNW 2036	-1.82**	73.67	-1.60**	73.67	2.42	87.00	1.71	87.33	-0.12	8.67	-1.60**	73.67	1.27	21.67	-0.44	19.67

XK0607	-0.93	74.67	0.88	74.33	7.01**	96.33	2.37	92.00	-0.65	8.00	0.88	74.33	-0.44	19.67	-1.33	19.00
XHD2888	2.51**	76.67	1.98**	75.67	-0.35	86.67	3.40	89.67	-0.04	9.00	1.98**	75.67	2.13**	22.33	1.89*	21.67
X8027	4.29**	79.33	2.54**	77.00	-3.46	83.33	-6.96**	80.00	1.05	10.33	2.54**	77.00	-0.11	20.33	-0.33	20.33
X9423	-2.07**	72.67	-1.24*	73.00	-2.96	81.67	-0.04	84.67	0.96	9.67	-1.24*	73.00	0.05	20.33	2.94***	23.67
PBW343X K0402	3.70**	81.67	3.15**	81.33	-0.27	83.67	1.68	88.67	0.91	10.00	3.15**	81.33	1.18	22.33	0.78	22.33
XK9351	2.01**	79.33	2.57**	80.33	2.01	87.67	0.37	87.33	-0.15	8.67	2.57**	80.33	-3.28**	17.67	-2.11*	19.67
XNW 2036	-0.76	80.33	-0.63	81.00	3.20	89.00	3.73	91.00	-0.26	8.33	-0.63	81.00	-2.22**	18.33	-1.39	19.67
XKK607	3.12**	84.33	4.09**	85.67	-5.54**	85.00	-3.27	88.00	-1.12	7.33	4.09**	85.67	1.38	21.67	-0.28	21.00
XHD2888	-0.43	79.33	-0.38	79.67	-1.24	87.00	-2.57	85.33	1.16*	10.00	-0.38	79.67	1.96*	22.33	1.61*	22.33
X8027	-0.31	80.33	0.18	81.00	-6.35**	81.67	-0.93	87.67	-1.09	8.00	0.18	81.00	-2.28**	18.33	-1.94*	19.67
X9423	-1.68**	78.67	-1.93**	78.67	0.81	86.67	-0.68	85.67	0.83	9.33	-1.93**	78.67	-0.11	20.33	2.00*	23.67
K0402XK9351	0.51	73.33	-0.13	72.67	-1.46	82.67	0.29	88.00	-0.92	8.33	-0.13	72.67	-1.42	20.33	0.11	21.67
XNW 2036	-3.93**	72.67	-3.66**	73.00	-0.60	83.67	1.32	89.33	0.96	10.00	-3.66**	73.00	-0.36	21.00	0.83	21.67
XK0607	-4.71**	72.00	-4.93**	71.67	-2.68	86.33	-5.35*	86.67	1.77**	10.67	-4.93**	71.67	1.24	22.33	0.61	21.67
XHD2888	-3.59**	71.67	-3.41**	71.67	-4.04*	82.67	0.35	89.00	0.05	9.33	-3.41**	71.67	-0.50	20.67	-0.83	19.67
XK8027	-3.48**	72.67	-4.18**	71.67	5.84**	92.33	3.32	92.67	0.80	10.33	-4.18**	71.67	0.91	22.33	0.94	22.33
X9423	-2.51**	73.33	-2.63**	73.00	4.67*	89.00	2.23	89.33	-0.29	8.67	-2.63**	73.00	1.07	22.33	0.22	21.67
K9351 XNW 2036	-2.29**	73.67	-2.24**	74.00	3.34	89.33	1.01	89.00	0.24	9.00	-2.24**	74.00	1.16	22.33	0.61	21.67
XK0607	-2.07**	74.00	-2.18**	74.00	-2.40	88.33	-2.65	89.33	1.62**	7.00	-2.18**	74.00	1.43	22.33	1.06	22.33
XHD2888	-2.29**	72.33	-1.99**	72.67	-0.77	87.67	-3.29	85.33	-0.34	8.67	-1.99**	72.67	0.68	21.67	0.28	21.00
XK8027	-0.84	74.67	-0.77	74.67	-6.54**	81.67	-2.65	86.67	0.41	9.67	-0.77	74.67	2.43**	23.67	0.72	22.33
X9423	-1.87**	73.33	-2.21***	73.00	-5.04**	81.00	2.93	90.00	0.66	9.33	-2.21**	73.00	1.27	22.33	0.00	21.67
NW2036XK0607	0.81	80.67	1.29*	81.33	-9.21**	81.67	-2.96	89.33	-0.40	8.00	1.29*	81.33	-0.83	19.67	-0.22	20.33
XHD2888	2.26	80.6	2.48**	81.00	-4.90**	83.67	-4.27*	84.67	-1.12	7.67	2.48**	81.00	-0.92	19.67	-0.33	19.67
XK8027	3.70**	83.00	2.37**	81.67	-6.02**	82.33	-6.63**	83.00	-0.70	8.33	2.37**	81.67	0.82	21.67	0.78	21.67
X9423	2.34**	81.33	1.59**	80.67	4.14*	90.33	-0.71	86.67	0.21	8.67	1.59**	80.67	0.99	21.67	0.72	21.67
K0607X HD2888	2.48**	81.00	1.87**	80.33	-1.65	91.67	-0.93	92.00	0.02	8.67	1.87**	80.33	1.35	21.67	0.11	20.33
X8027	1.92**	81.33	2.43**	81.67	-1.77	91.33	-0.29	93.33	1.10	10.00	2.43**	81.67	-0.89	19.67	-0.11	21.00
X9423	2.56***	81.67	1.65**	80.67	5.06**	96.00	2.96	94.33	0.69	9.00	1.65**	80.67	-0.72	19.67	0.50	21.67
HD2888XK8027	-1.29*	76.67	-1.05	76.67	-7.79**	83.00	-6.60**	83.67	-0.62	8.67	-1.05	76.67	1.68*	22.33	1.78*	22.33
XK9423	-0.65	77.00	-0.49	77.00	1.29	87.33	-3.68	84.33	1.30*	10.00	-0.49	77.00	-0.14	20.33	-0.28	20.33
K8027XK9423	-2.21**	76.33	-1.27*	77.00	-1.07	87.33	-4.71*	84.00	0.71	9.67	-1.27*	77.00	-0.39	20.33	-1.17	20.33
SE(ij) <sub>±</sub>	1.19		1.16		3.50		4.41		1.12		1.16		1.54		1.59	
SE(Sij-Sik) <sub>±</sub> 5%	1.75		1.17		5.51		6.08		1.65		1.17		2.26		2.34	

Continued

Cross combinations	Spike length				Grains / spike				Days to maturity				1000- seed weight			
	F <sub>1</sub>		F <sub>2</sub>		F <sub>1</sub>		F <sub>1</sub>		F <sub>1</sub>		F <sub>2</sub>		F <sub>1</sub>		F <sub>2</sub>	
	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	Sca	mean
K9533XK0424	-0.76**	8.27	-0.32	8.77	2.78	49.00	2.52	49.00	4.18**	118.67	3.83**	118.33	-0.01	39.33	2.39**	42.33
X PBW343	0.42	9.47	0.93**	10.40	-0.77	47.67	-0.76	49.33	3.89**	117.67	-3.01**	118.33	0.66	40.33	1.89*	42.67
XK0402	-0.81**	8.37	-1.03**	8.20	-1.82	44.67	-2.01	46.00	-1.31*	117.33	-1.84**	118.00	0.22	40.33	0.42	41.33
XK9351	0.84**	10.17	0.98**	10.47	-2.13	44.67	2.96*	50.33	1.60**	118.00	1.66**	118.33	-2.50**	37.67	-0.53	40.00
XNW 2036	-0.65*	8.73	-0.58	8.73	-3.88**	44.00	-0.95	46.67	1.55*	119.67	1.49*	119.33	0.30	40.33	-1.33	39.33
XK0607	1.08**	10.23	1.22**	10.43	0.50	47.00	0.83	46.33	-0.86	119.00	-0.79	119.00	0.52	41.00	0.36	41.33

XHD2888	1.34**	10.67	-0.35	8.80	-3.96**	41.33	-2.26	44.00	-2.00**	117.00	-2.56**	117.33	1.22	40.67	0.28	40.67
X8027	-0.89**	8.47	0.05	9.60	-1.68	46.00	-1.79	45.33	-0.47	119.00	-1.04	119.00	2.33**	42.33	0.39	41.33
X9423	-0.36	8.57	-0.53*	8.60	2.45	48.67	-4.81**	41.67	-1.22*	117.33	-0.79	118.33	0.97	41.33	1.03	41.67
K0424XPBW343	-0.36	8.67	0.16	9.37	0.42	48.67	2.30	51.33	-4.92**	114.67	-4.04**	115.67	1.19	40.00	2.39**	42.33
XK0402	-0.21	8.77	0.16	9.13	-1.63	44.67	2.71	49.67	-2.00**	114.67	-1.87**	116.33	-0.91	38.33	-0.42	39.67
XK9351	-1.33**	7.80	-0.67**	8.57	-3.27*	43.33	-2.98*	43.33	-0.08	114.33	-0.37	114.67	2.02**	41.33	0.97	40.67
XNW 2036	0.54*	9.73	0.34	9.40	-1.02	46.67	-3.56*	43.00	-1.47*	114.67	-0.20	116.00	1.83**	41.00	2.17*	42.00
XK0607	0.51	9.43	-0.45*	8.50	0.70	47.00	-4.45**	40.00	-2.22**	115.67	-2.15**	116.00	2.72**	42.33	0.89	41.00
XHD2888	1.46**	10.50	0.64**	9.53	2.89*	48.00	2.46	47.67	-0.30	117.33	-1.59*	116.67	0.08	38.67	-0.22	39.33
X8027	0.66*	9.83	0.00	9.30	-0.82	46.67	-0.73	45.33	0.82	118.33	0.60	119.00	-0.14	39.00	-0.78	39.33
X9423	-0.37	8.37	0.26	9.13	1.31	47.33	1.91	47.33	1.74**	118.33	2.85**	120.33	-3.16**	36.33	-2.47**	37.33
PBW343X K0402	0.45	9.63	0.06	9.40	-1.18	47.33	1.10	51.67	-0.75	123.00	-1.70**	123.33	-0.91	38.67	-2.25*	38.67
XK9351	-0.69*	8.63	-0.21	9.40	2.50	51.33	1.08	51.00	2.82**	124.33	2.80**	124.67	-1.97**	37.67	-2.86**	37.67
XNW 2036	0.18	9.57	-0.13	9.30	2.09	52.00	0.16	50.33	1.10	124.33	0.63	123.67	-0.50	39.00	-2.33**	38.33
XKK607	-0.21	8.90	-0.56*	8.77	0.81	49.33	2.94*	51.00	0.35	125.33	-0.65	124.33	-0.61	39.33	3.36**	44.33
XHD2888	0.36	9.60	0.10	9.37	-1.32	46.00	0.19	49.00	0.21	124.33	0.24	125.33	1.08	40.00	1.28	41.67
X8027	-0.49	8.87	-0.10	9.57	-0.04	49.67	-0.01	49.67	0.07	124.67	0.44	125.67	0.85	40.33	1.39	42.33
X9423	0.29	9.23	0.25	9.50	-2.90*	45.33	-3.04*	46.00	0.99	124.67	1.02	125.33	-0.83	39.00	-0.64	40.00
K0402XK9351	-0.17	9.10	-0.24	9.13	-0.21	46.67	-1.84	46.00	5.41**	124.00	4.63**	125.00	0.58	40.67	3.00**	43.67
XNW 2036	-0.07	9.27	0.07	9.27	2.03	50.00	0.24	48.33	3.02**	123.33	2.80**	124.33	-0.28	39.67	-0.47	40.33
XK0607	0.97**	10.03	0.91**	10.00	3.75*	50.33	2.69	48.67	0.60	122.67	1.52*	125.00	1.27	41.67	0.22	41.33
XHD2888	-0.01	9.17	0.71	9.20	-1.04	44.33	0.27	47.00	-3.53**	117.67	0.41	124.00	-0.03	39.33	0.81	41.33
XK8027	0.32	9.63	0.63**	10.07	-4.10**	43.67	-2.59	45.00	-4.33**	117.33	-1.73**	122.00	-2.91**	37.00	-0.75	40.33
X9423	0.07	8.97	0.27	8.73	2.70	49.00	1.71	48.67	-2.08**	118.67	-1.81**	121.00	1.05	41.33	-0.44	40.33
K9351 XNW 2036	-0.08	9.40	-0.26	9.20	2.39	50.67	2.21	49.67	0.60	118.67	0.63	119.00	-0.66	39.33	1.25	41.67
XK0607	0.88**	10.10	0.91**	10.27	-0.21	46.67	-0.67	44.67	-4.47**	115.33	-1.31*	119.00	-1.11	39.33	-3.06**	37.67
XHD2888	-0.10	9.23	0.08	9.37	-3.35*	42.33	0.58	46.67	-2.61**	116.33	-2.09**	118.33	1.24	40.67	-1.14	39.00
XK8027	1.13**	10.60	0.54*	10.23	0.59	48.67	-3.29*	43.67	-2.42**	117.00	-3.23**	117.33	-1.30	38.67	1.31	42.00
X9423	-0.50	8.53	-0.74**	8.53	-1.93	44.67	-3.65*	42.67	-1.50*	117.00	-1.65**	118.00	0.66	41.00	-1.72	38.67
NW2036XK0607	-0.50	8.77	-0.15	9.03	-6.63**	41.33	-5.26**	40.33	-3.19**	118.33	-3.15**	118.33	1.69*	42.00	2.47**	43.33
XHD2888	-0.59*	8.80	-0.25	8.87	1.89	48.67	-3.67*	42.67	-1.67**	119.00	-2.26**	119.33	1.38*	40.67	1.06	41.33
XK8027	0.24	9.77	-0.02	9.50	-0.49	48.67	0.80	48.00	-1.81**	119.33	-2.40**	119.33	0.83	40.67	-1.17	39.67
X9423	1.17**	10.27	0.67**	9.77	-0.68	46.00	1.44	48.00	-1.89**	118.33	-1.81**	119.00	-1.53*	38.67	2.81**	43.33
K0607X HD2888	-0.78**	8.33	-0.45*	8.57	0.28	45.67	0.10	44.33	1.91**	124.33	-0.54	123.00	-1.05	38.67	1.75*	42.33
X8027	-0.74**	8.50	-0.39	9.03	2.89*	50.67	-0.76	44.33	1.43*	124.33	1.33*	125.00	1.05	41.33	2.19*	43.33
X9423	-0.08	8.73	0.24	9.23	0.36	46.67	0.88	45.33	3.68**	125.67	3.24**	126.00	1.69*	42.33	-1.17	39.67
HD2888XK8027	0.73**	10.10	0.95**	10.30	0.42	47.00	-2.17	43.67	1.63**	123.67	4.55**	128.33	-0.91	38.33	0.11	40.67
XK9423	0.18	9.13	1.20**	10.13	3.23*	48.33	5.13**	50.33	2.21**	123.33	4.46**	127.33	-0.94	38.67	0.75	41.00
K8027XK9423	0.02	9.10	-0.14	9.20	-0.15	47.33	2.60	48.67	4.07**	125.67	3.33**	126.33	1.83**	42.00	1.53	42.33
SE(ij) <sub>±</sub>	0.54		0.44		2.88		2.90		1.16		1.21		1.36		1.73	
SE(Sij-Sik) <sub>±</sub> 5%	0.39		0.64		4.24		4.26		1.71		1.78		2.00		2.55	
Cross combinations	Seed Hardness				Ear density				Duration of reproductive phase				Protein content			
	F <sub>1</sub>		F <sub>2</sub>		F <sub>1</sub>		F <sub>1</sub>		F <sub>1</sub>		F <sub>2</sub>		F <sub>1</sub>		F <sub>2</sub>	
	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	sca	mean	Sca	mean
K9533XK0424	-0.29**	17.33	-0.15	17.50	0.26**	2.46	-0.02	2.20	3.12**	46.00	3.25**	46.67	-0.28**	11.26	-0.32**	11.24
X PBW343	-0.51**	17.60	-0.49**	17.50	0.07	2.24	-0.18**	2.01	0.40	44.67	1.89**	46.00	-0.28**	11.31	-0.40**	11.27
XK0402	0.07	17.57	-0.02	17.50	-0.05	2.19	-0.07	2.15	-3.12**	42.67	-3.94**	43.67	0.04	11.25	0.14**	11.34



XK9351	0.06	18.10	-0.79**	17.33	-0.06	2.13	-0.05	2.13	-1.04	43.33	-0.80	44.00	0.58**	11.35	0.53**	11.44
XNW 2036	0.47**	18.47	-0.47**	17.63	0.25**	2.40	0.08	2.25	3.06**	45.33	2.86**	45.00	-0.07	11.16	0.14**	11.42
XK0607	-0.22*	17.37	-0.03	17.57	-0.39**	1.79	-0.06	2.15	3.62**	47.00	2.33**	46.00	-0.08	11.19	-0.02	11.19
XHD2888	-0.69**	17.33	-0.46**	17.40	-0.46**	1.71	-0.09	2.08	-1.90**	42.67	-2.13**	43.67	0.06	11.27	0.13**	11.48
X8027	-0.83**	17.37	-0.14	17.87	-0.06	2.08	0.01	2.18	-2.01**	42.00	-1.27	44.00	0.08	11.26	0.17**	11.38
X9423	0.78**	18.53	0.90**	18.40	0.01	2.26	0.00	2.22	-3.76**	40.33	-3.35**	41.67	-0.19**	11.43	-0.26**	11.33
K0424XPBW343	0.27*	18.23	-0.69**	17.63	0.08	2.34	0.09	2.38	0.37	43.00	0.55	43.33	-0.03	11.90	0.01	11.89
XK0402	-0.01	17.33	-0.29	17.37	0.14*	2.48	-0.08	2.22	-1.82**	42.33	-1.94**	44.33	0.03	11.58	-0.21**	11.18
XK9351	-0.34**	17.53	0.26	18.53	-0.27**	2.00	-0.21**	2.06	0.59	43.33	0.19	43.67	0.34**	11.45	0.49**	11.61
XNW 2036	-0.37**	17.47	0.45*	18.70	-0.01	2.22	-0.02	2.22	0.37	41.00	0.86	41.67	0.05	11.63	-0.17**	11.31
XK0607	0.19	17.63	-0.13	17.60	-0.18**	2.08	-0.06	2.23	-1.40*	40.33	-0.66	41.67	0.13*	11.75	0.04	11.46
XHD2888	-0.14	17.73	-0.13	17.87	-0.13*	2.12	0.01	2.27	-2.26**	40.67	-3.47**	41.00	-0.32**	11.23	-0.21**	11.33
X8027	-0.51**	17.53	-0.61**	17.53	-0.17**	2.06	-0.06	2.18	-3.04**	39.33	-1.60*	42.33	-0.10*	11.41	-0.16**	11.24
X9423	-0.40**	17.20	0.29	17.93	0.10	2.42	0.22**	2.58	3.20**	45.67	3.64**	47.33	-0.49**	11.46	-0.36**	11.43
PBW343X K0402	0.74**	18.57	1.04**	19.23	0.01	2.31	0.08	2.38	-4.21**	41.33	-4.97**	42.00	0.03	11.63	0.17**	11.68
XK9351	-0.19	18.17	0.50**	19.30	-0.20**	2.04	-0.16**	2.09	0.87	45.00	0.50	44.67	0.77**	11.93	0.57**	11.79
XNW 2036	-0.05	18.27	-0.37*	18.40	-0.29**	1.90	-0.12*	2.11	1.98**	44.00	1.16	42.67	-0.34**	11.28	-0.34**	11.24
XKK607	0.51**	18.43	0.72**	19.00	0.19**	2.43	0.10	2.39	-2.46**	40.67	-4.02**	39.00	-0.51**	11.15	-0.18**	11.34
XHD2888	-0.19	18.17	0.22	18.77	0.16**	2.39	0.14*	2.38	0.67	45.00	0.50	45.67	-0.06	11.31	-0.22**	11.43
X8027	-0.30**	18.23	0.21	18.90	-0.13*	2.06	-0.17	2.05	-0.43	43.33	0.36	45.00	-0.04	11.52	0.04	11.56
X9423	0.15	18.23	0.09	18.27	-0.09	2.19	0.13*	2.49	2.15**	46.00	2.28**	46.67	-0.11*	11.89	-0.23**	11.67
K0402XK9351	-0.44**	17.30	0.73**	18.87	-0.10	2.23	-0.05	2.22	5.01**	50.67	4.66**	52.33	0.54**	11.31	0.57**	11.32
XNW 2036	0.05	17.77	-0.47**	17.63	-0.02	2.26	0.07	2.33	7.12**	50.67	7.01**	52.00	0.32**	11.56	0.17**	11.28
XK0607	0.22*	17.53	-0.01	17.60	-0.10	2.22	-0.14*	2.16	3.67**	48.33	6.80**	53.33	0.23**	11.52	0.14**	11.19
XHD2888	-0.57**	17.17	-0.33	17.53	-0.13*	2.18	-0.12*	2.13	0.81	46.67	3.66**	52.33	0.29**	11.50	0.15**	11.34
XK8027	-0.38**	17.53	-0.67	17.33	0.03	2.32	-0.03	2.21	-0.62	44.67	2.19**	50.33	0.41**	11.59	0.42**	11.47
X9423	-0.20	17.27	0.13	17.63	0.11	2.49	0.10	2.48	-0.04	45.33	0.11	48.00	0.02	11.64	0.03	11.46
K9351 XNW 2036	0.05	18.30	-0.44*	18.27	0.14*	2.37	0.12*	2.35	2.54**	44.67	2.80**	45.00	-0.33**	10.45	0.60**	11.43
XK0607	0.35**	18.20	-0.30	17.90	-0.05	2.21	-0.08	2.17	-1.90**	41.33	1.28	45.00	-0.51**	10.32	-0.41**	10.35
XHD2888	0.22*	18.50	0.35*	18.83	0.09	2.34	0.01	2.23	-0.43	44.00	-0.19	45.67	-0.37**	10.39	-0.63**	10.27
XK8027	-0.02	18.43	0.25	18.87	0.01	2.23	-0.03	2.18	-1.54*	42.33	-2.66**	42.67	-0.30**	10.44	-0.68**	10.07
X9423	0.26*	18.27	0.29	18.40	0.29**	2.61	0.20*	2.53	0.37	44.33	-0.08	45.00	-0.63**	10.54	-0.68**	10.46
NW2036XK0607	-0.37**	17.43	0.31	18.50	0.02	2.24	-0.01	2.25	03.46**	37.67	-4.38**	36.67	0.01	11.31	-0.86**	10.27
XHD2888	-0.90**	17.33	-0.01	18.43	0.02	2.23	0.01	2.21	-3.98**	38.33	-4.85**	38.33	-0.12**	11.11	0.07	11.34
XK8027	-0.85**	17.57	-0.19	18.40	0.04	2.22	0.07	2.27	-5.43**	36.33	-4.99**	37.67	0.09*	11.30	0.13**	11.25
X9423	-0.20	17.77	-0.01	18.07	-0.16**	2.11	-0.09	2.22	-4.84**	37.00	-4.08**	38.33	0.02	11.67	-0.25**	11.25
K0607X HD2888	-0.43**	17.40	-0.01	17.93	0.35**	2.60	0.12*	2.37	-0.09	43.33	-2.05**	42.67	-0.06	11.22	0.31**	11.52
X8027	-0.38**	17.63	0.17	18.27	0.08	2.31	0.08	2.32	0.12	43.00	-0.85	43.33	0.20**	11.45	0.12**	11.19
X9423	0.01	17.57	-0.28	17.30	-0.06	2.25	-0.01	2.34	1.04	44.00	1.39*	45.33	0.07	11.76	-0.20**	11.25
HD2888XK8027	1.01**	19.47	-0.75**	17.63	-0.01	2.19	-0.03	2.16	2.92**	47.00	5.33**	51.67	0.28**	11.47	0.23**	11.43
XK9423	1.13**	19.13	0.41*	18.27	-0.07	2.22	-0.25**	2.07	2.17**	46.33	5.58**	51.67	-0.13**	11.49	-0.06	11.52
K8027XK9423	1.12**	19.30	0.31	18.30	-0.04	2.23	-0.10	2.20	5.73**	49.33	3.70**	49.33	0.70**	12.29	0.85**	12.29
SE(ij)±	0.21		0.35		0.11		0.11		1.20		1.37		0.09		0.08	
SE(Sij-Sik)± 5%	0.32		0.51		0.16		0.17		1.76		2.02		0.13		0.11	

\* Significant at 5% level; \*\* significant at 1% level

Continued

Cross combinations	Yield/plant			
	F <sub>1</sub>		F <sub>2</sub>	
	sca	mean	Sca	Mean
K9533XK0424	0.05	11.67	-0.09	11.67
X PBW343	-0.42	12.07	-0.68*	11.80
XK0402	0.10	12.40	-0.18	12.15
XK9351	-0.64	11.54	-0.56	11.61
XNW 2036	1.61**	13.63	0.90**	12.90
XK0607	-0.71*	11.80	-0.54	11.90
XHD2888	-0.05	11.60	0.06	11.88
X8027	-0.51	10.90	-0.65*	10.87
X9423	-0.05	11.20	-0.01	11.22
K0424XPBW343	-0.55	11.62	-0.16	12.03
XK0402	0.52	12.50	0.49	12.53
XK9351	-0.36	11.50	-0.53	11.35
XNW 2036	0.53	12.23	0.43	12.13
XK0607	1.20**	13.40	0.88**	13.03
XHD2888	-0.77*	10.57	-0.52	11.00
X8027	-1.00**	10.10	-0.89**	10.33
X9423	0.211	11.16	0.13	11.07
PBW343X K0402	0.10	12.97	0.08	12.85
XK9351	-0.08	12.67	-0.09	12.52
XNW 2036	-0.11	12.47	-0.17	12.25
XKK607	0.65	13.73	0.52	13.40
XHD2888	0.41	12.63	0.14	12.40
X8027	-0.85	11.13	-0.82**	11.13
X9423	-0.02	11.80	0.03	11.70
K0402XK9351	0.24	12.80	0.21	12.67
XNW 2036	0.51	12.90	0.26	12.53
XK0607	0.48	13.37	0.64*	13.37
XHD2888	0.10	12.13	0.03	12.13
XK8027	0.21	12.00	0.68*	12.48
X9423	0.46	12.10	0.22	11.73
K9351 XNW 2036	0.12	12.40	0.28	12.40
XK0607	-0.10	12.67	-0.75*	11.82
XHD2888	0.68*	12.60	0.74*	12.68
XK8027	0.28	11.97	0.25	11.90
X9423	0.14	11.67	0.46	11.82
NW2036XK0607	0.02	12.63	0.24	12.63
XHD2888	0.25	12.00	0.40	12.17
XK8027	-0.11	11.40	-0.06	11.40
X9423	-0.45	10.90	-0.27	10.90
K0607X HD2888	0.52	12.77	0.55	12.77
X8027	-0.27	11.73	-0.18	11.73
X9423	0.01	11.87	0.04	11.67
HD2888XK8027	0.18	11.33	-0.12	11.17
XK9423	0.07	11.07	0.06	11.07
K8027XK9423	0.54	11.30	0.43	11.13
SE(ij)±	0.67		0.56	
SE(Sij-Sik)± 5%	0.99		0.83	

Significant at 5% level; \*\* significant at 1% level

**Table.4** Best general combiners on the basis of *per se* performance and *gca* effect for 13 characters in a 10 parent diallel cross in wheat

Characters	<i>Per se</i> performance	<i>gca</i>		Common parent
		F <sub>1</sub>	F <sub>2</sub>	
Days to 75% flowering	K9533, K0424, K9351	K0402, K9351, K9533	K9351	K9351
Plant height	PBW343, K0424, K9423, K0402	Nw2036, PBW343, K0424, K9423	K0424, PBW343	K0424, PBW343
Reproductive tillers/plant	K8027, HD2888, K0402, K0424	K0424, K0402, HD2888	K9423, K0402, K8027	K0402, HD2888
Spikelets/spike	K9351, K9533, PBW343, K8027	K0402, K9351, K8027	K9351, K9423, K8027	K8027, K9351
Spike length	K9351, NW2036, PBW343, K8027	NW2036, K8027, K9351	K9351, K8027, PBW343	K9351, K8027
Grains/spike	NW2036, K8027, K9533, PBW343	PBW343, NW2036, K8027	K8027, K9351, PBW343	PBW343, K8027
Days to maturity	K0424, K9351, K9423, K9533	K0424, K9351, K9533	K0424, K9533, K9351	K0424, K9533
1000-seed weight	K9351, K0402, K9423, PBW343	K0607, K9423, K9533	K8027, K0607, K0402	K9423
Seed hardness	NW2036, K8027, K9533, HD2888	K8027, PBW343, HD2888	PBW343, K9351, W2036, K8027	K8027
Ear density	K0402, K0424, K9351, K9533	K0402, K9351, K0424	K0424, K0402	K0402, K0424
Duration of reproductive phase	HD2888, K8027, K9533, PBW343	K9533, K0402, HD2888	K0402, HD2822, K8027	HD2888
Protein content	K9423, PBW343, K0424, K0607	K9423, PBW343, K0424	PBW343, K9423, K0424	K9423, K0424, PBW343
Yield/plant	PBW343, K9351, K9533, K0607	PBW343, K0607, K0402	PBW343, K0607, K0402	PBW343, K0607

In wheat, parents having good general combining ability have been reported by Desai *et al.*, (2005); Bikram and Ahmed, (2008); Ajmal *et al.*, (2011) and Ankita *et al.*, (2012). These parents may be used for simultaneous improvement in grain yield and quality attributes through an inter-mating population involving all possible combinations among themselves (Table 2).

**Specific combining ability (*sca*) effects**

The *sca* effects representing dominance and epistatic component of genetic variability would not contribute much for improvement of self-pollinated crops except where commercial exploitation of heterosis is feasible.

The crosses involving good general combiners and showing high *sca* effects may be utilized for further breeding purposes. Desirable transgressive segregants are expected to be produced by making a large number of crosses Jinks and Jones (1958) also suggested that the superiority of many hybrids may not be indicated by their ability to produce transgressive segregants due to non-fixable gene action would be important for grain yield.

In respect of grain yield per plant; the positive and significant values of *sca* were associated with four combinations with high *per se* performance like PBW343/K0607, K9533/NW2036, K0424/K0607 and K0402/ K0607; out of these in F<sub>1</sub> K9533/NW2036, K0424/K0607, K9351/ HD2888 and PBW343/K0607 were best with good specific combinations Table 4. All the three possible combinations namely, high x high, high x low and low x low were observed between the parents of high and low *gca* effects. Relatively higher estimates of *sca* effects were recorded in those crosses which involved diverse parents (Table 3).

The category of contribution for high x low *gca* effects played an important role in the expression of positive and significant *sca* effects. These crosses showing high *sca* effects with at least one good general combiner could produce desirable transgressive segregants in subsequent generations: Singh (1981), Singh *et al.*, (1990), Shahid *et al.*, (2005) and Zahid *et al.*, (2011) also came to the same results. For better utilization of these crosses, the *inter se* crossing of F<sub>1</sub> hybrids in all possible combinations for multiple parents is put into a common gene pool, which will lead to

realization of better recombinants and also help in breaking up of the genetic barriers, if present (Jensen 1970). Later, Redden and Jensen (1974) demonstrated significant gain in seed weight through mass selection with concurrent random mating and suggested that this technique could be a useful breeding procedure for wheat.

The cross combinations possessing low x low effects in both the-generations such types of hybrids might be due to non-additive gene effects and could not be easily exploited in further segregating generations.

Hence these crosses could be used in production of multiline variety combining other desirable attributes of economic value.

The relative ranking of the parents on the basis of per se performance and gca effect in both the generations K9351 for days to 75% flowering, K0424 and PBW343 for plant height, K0402 and HD2888 for number of reproductive tillers per plant, K8027 and K9351 for number of spikelets per spike and spike length, PBW343 and K87027 for number of grain per spike, K0424 and K9351 for days to maturity, k9423 for 1000-seed weight, K8027 for seed hardness, K0402 and K0424 for ear density, HD2888 for duration of reproductive phase, K9423, K0424 and PBW343 for protein content and PBW343 and K0607 for yield per plant. These parents could be exploited further in breeding programme for simultaneously improved in grain yield and quality attributes. The sca effect for grain yield per plant was significant and considerable good specific combiner were four crosses in F1 and four crosses in F2 generations. These crosses had involved all the three possible combination between high and low gca effects. The cross combinations involving parents K0402, K8027, K9533, and HD2888 were expected to have fixable, additive or additive x additive gene effects.

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