Electronic Journal of Plant Breeding, 9 (3) : 899 - 907 (Sep 2018) DOI: 10.5958/0975-928X.2018.00112.6
ISSN 0975-928X

Research Article

Study of combining ability for yield and its contributing traits in bread wheat [*Triticum aestivum* (L.)]

H.G. Barot[1], M.S.Patel[2] and * D. J. Joshi[3]
[1]H.G. Barot, Extension Officer, District Pancahayt, Surat, Gujarat
[2]M.S.Patel, Associate Research Scientist, Centre for Crop Improvement, S.D. Agricultural University, Sardarkrushinagar-385 506
[*3]D. J. Joshi, Agricultural Officer, O/o Directorate of Research, S.D. Agricultural University, Sardarkrushinagar- 385 506,
E-Mail: joshi.dhaval.296@gmail.com

(Received:19 Apr 2018; Revised:25 Jul 2018; Accepted:17 Aug 2018)

Abstract
An experiment on combining ability for yield and its contributing traits in wheat [*Triticum aestivum* (L.)]" was carried out through Line x Tester analysis at Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Experimental materials comprising twelve parents, thirty-two crosses and one tester, GW 496 as standard check were planted in a randomized block design with two replications during *rabi* 2012-13 season. The analysis of variance for experimental design revealed that highly significant differences were existed among genotypes, parents and hybrids for most of traits. The analysis of variance for combining ability revealed specific combining ability variances for m x f interaction were highly significant for plant height, number of effective tillers per plant and grain yield per spike. The magnitude of general combining ability variances was higher than the specific combining ability variances for all the characters which indicated preponderance of additive gene action in the inheritance of these traits. This was further supported by high magnitude of $\sigma^2_{gca} / \sigma^2_{sca}$ ratios. On the basis of general combining ability (gca) effects none of the parent was good general combiners for all the characters. Among female GW 11 and male GW 322 was found to be good general combiner for grain yield per plant, harvest index and protein content, respectively. Six males showed significant general combining ability effects of which, GW 190 (4.85) and GW 322 (3.13) showed significant positive general combining ability effects for grain yield potential. In case of GW 503 (1.00) exhibited significant positive general combining ability effect for grain yield per plant. The results of specific combining ability effects of different cross revealed that none of the crosses showed significant and negative specific combining ability effects for days to 50 per cent heading, days to maturity and plant height and significant and positive specific combining ability effect were observed for number of effective tillers per plant, length of main spike and grain yield per spike. In case of SCA hybrids viz., GW 11 x GW 273 (0.42), GW 11 x GW 190 (0.35) and GW 173 x GW 438 (0.34) exhibited significant positive specific combining ability effects. Therefore, these crosses are revealed as good general combiner and can be utilized in breeding for improvement in yield and its contributing traits in wheat crop.

Key words
Line, Tester, Combining ability, GCA, SCA, gene action

Introduction

Wheat (*Triticum astevium L.*) is second imperative staple food crop in India next to rice. It is widely cultivated food crop that is known for its remarkable adaptation to a wide range of environment. *Triticum* spp. originated from Middle–East region of Asia and is a member of family *Poaceae.* It covers about 32 per cent of the total acreage under cereals in the world. The bread wheat (hexaploid 2n=42), the macaroni wheat (*Triticum durum*) having (Tetraploid 2n=28) is mostly growing in the central and the southern states and also in the North–West while, emmer wheat (*Triticum diccocum*) having (Tetraploid 2n=28) is confined to southern states of India and some part of Gujarat. India being largest producer of wheat, covers about 302.27 lakh hectares area with total production of 93.50 million tonnes and yield 3039 kg/ha (Annual Report., 2016-17), among the wheat growing states, Gujarat ranks seventh in the total production and fourth in productivity (3.1 t/ha) next to Punjab, Haryana and Rajasthan. The area under wheat crop in Gujarat is about 15.8 million hectares with the production of 50.13 lakh tonnes and productivity of 3156 kg/ha (Anon., 2010-11), which indicates the vast scope for the improvement of yield potential. *Aestivum* wheat has narrow genetic base, in this endeavour, new methods and techniques have been suggested to broaden the genetic base to evolve the elite genetic stock to maintain upward trend in the yield level.

Concept of combining ability as a measure of gene action was proposed by Sprague and Tatum (1942) working in maize. According to them the general combining ability (gca) is the comparative ability of the line to combine with other lines. Specific

Electronic Journal of Plant Breeding, 9 (3) : 899 - 907 (Sep 2018) DOI: 10.5958/0975-928X.2018.00049.2
ISSN 0975-928X

combining ability (sca) was defined as the deviation in the performance of specific cross from the performance expected on the basis of general combining ability effects of parents involved in the crosses. Combining ability analysis is a simple and convenient method for estimation of genetic parameters and it provides comprehensive information about different components of variation in the parental population in single generation and assists the breeder in the choice of promising parents and the breeding method.

Line x Tester analysis is widely used for selection of elite breeding material as well as breeding procedure both in terms of general and specific combining ability perspectives. There is need to improve the yield potential of wheat varieties as the genetic potential of present day cultivars of wheat appears to be fast reaching plateau and short span of cool season due to global warming. To accomplish this, the breeding programme can efficiently be planned with prior knowledge of the genetic make-up of complex quantitative characters like yield and its components.

The success of breeding procedure is determined by the useful gene combinations organized in the form of good combining lines and isolation of valuable germplasm. Some lines produce outstanding progenies on crossing with others, while others may look equally desirable, but may not produce good progenies on crossing. The lines, which perform well in combination, are eventually of great importance to the plant breeders. Hence, investigation on general and specific combining ability would yield very useful information. Accordingly, a good knowledge of gene action involved in the inheritance of quantitative characters of economic importance is required in order to frame an efficient breeding plan leading to rapid improvement.

Materials and Methods

Combining ability studies for yield contributing traits in bread wheat (*Triticum aestivum* L.) was carried out at Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The experimental material comprised of 44 entries including four lines as females, eight testers as males and their thirty-two crosses and one tester, GW 496 was selected as standard check. The experiment was laid out in a randomized block design with two replications during *rabi* 2012-13. Each entry was planted in a single row of 3.5 m length keeping a distance of 23 cm between rows and 10 cm between plants within the row. Fertilizer was applied at the rate of 120-60-00 NPK kg ha^{-1}. Five competitive plants were randomly selected to record the observations on eleven characters and mean values were subjected to statistical analysis. Observations were recorded on five randomized selected plants of each genotype in each replication for various characters except days to flowering and days to maturity, which were recorded on plot basis. The mean values were finally subjected to statistical analysis. The data obtained for each character were analyzed by the usual standard statistical procedure (Panse and Sukhatme, 1978) to provide comparisons, the treatment sums of squares were partitioned in to parents vs. hybrids, females vs. males, among hybrids, among parents, among male parents and among female parents. Combining ability analysis was computed as per the procedure developed by Kempthorne (1957).

Results and Discussion

The analysis of variance (Table 1) for various characters revealed that considerable genetic variation existed among the parents and hybrids for all the traits under study.

The analysis of variance for combining ability and the estimates of variance components (Table 2) indicated that the mean squares due to lines were highly significant for all characters except days to 50 per cent heading and 100- grain weight indicated significant contribution of lines towards general combining ability variance components for all the traits. The mean sum of squares due to testers was also highly significant for all the characters, suggesting larger contribution of testers towards gca variance component for all the characters. The mean sum of squares due to line x tester interaction were significant for plant height, number of effective tillers and grain yield per spike, revealed the significant contribution of hybrids for specific combining ability variance components. The magnitude of gca variance were higher than the sca variance for all the characters, which indicated preponderance of additive gene action in the inheritance of these traits. Therefore, selection for these traits in early generations would be effective for developing the varieties in wheat breeding programme. This was further supported by high magnitude of σ^2_{gca} / σ^2_{sca} ratios. Preponderance of additive variance in the expression for these traits in wheat have also been reported by Joshi *et al.* (2004).

General and specific combining ability effects were estimated for parents and crosses, respectively. The summary of general combining ability effects of the parents (Table 3) revealed that none of the parent was found to be good general combiner for all the characters. These results are akin to the findings of Dhadhal and Dobariya (2006).

The combining ability effects of female (gi) and males (gj) as well as specific combining ability effects of crosses (sij) for all the characters were also estimated (Table 3 & 4).

In the case of days to 50 per cent heading out of eight male parents, the parent GW 496 (-5.18) and GW 190 (-1.68) were good general combining parents, as they recorded highly significant negative general combining ability effects, while in case of specific combining ability effects it was ranged from -2.43 (GW 503 x GW 366) to 3.68 (GW 173 x GW 366).

Estimation of gca effects revealed that five males showed significant general combining ability effects in days to maturity. Out of which, three males *viz*., GW 366 (-2.23), GW 496 (-1.73) and GW 438 (-1.73) recorded significant negative general combining ability effects and thus were adjudged as good combiner for the trait. Whereas, the female GW 173 recorded -0.42 days significant negative gca effect. The sca effects for the hybrids ranged from -1.20 (GW 173 x GW 366) to 1.60 (GW 503 x GW 366).

For plant height, male GW 496 (-5.93) was found to be good combiner. The cross (GW 11 x GW 496) shows highest height 4.18 of sca effects.

In the case of number of effective tillers, male parents GW 322 (2.97), GW 273 (1.77), GW 190 (0.73) and GW 366 (0.67) were good general combiner as they recorded significant positive gca effects. While for specific combining ability effects, thirteen hybrids attributed towards significant specific combining ability effects for this trait. Among them, six hybrids *viz*., GW 173 x GW 273 (2.09), GW 173 x GW 322 (1.89), GW 173 x GW 190 (1.63), GW 11 x GW 366 (1.35), GW 11 x GW 439 (1.20) and GW 11 x GW 438 (1.11) showed significant positive sca effects for this trait. Therefore these hybrids were adjudged as best hybrids in consequences of yield contributing traits.

The testers GW 273 (0.83), GW 190 (0.49) and GW 496 (0.47) had general combining ability effects in positive direction for Length of main spike. The line GW 503 exhibited highly significant positive 0.37 amount of gca effect. While GW 503 x GW 273 (0.84) exhibited significant positive sca effect for this trait.

In case of grain yield per plant, among six males showed GW 190 (4.85) and GW 322 (3.13) showed significant positive general combining ability effects for the trait thus were adjudged superior for the trait. In case of line GW 503 (1.00) exhibited significant positive gca effect for grain yield per plant. The cross (GW 11 x GW 273) recorded 1.10 higher range of sca effects.

For Spikelets per spike five males exhibited highly significant general combining ability effect for which two males viz., GW 322 (1.53) and GW 273 (1.20) possessed significant positive gca effects. Therefore, these are good combiner for this trait. The sca effects were effects ranged from -0.52 (Lok 1 x GW 496) to 0.72 (GW 503 x GW 496). None of the cross exhibited significant positive and negative sca effects.

The Males GW 438 (0.64) and GW 190 (0.33) showed highly significant positive gca effects indicating its good combining ability for Grain yield per spike. The lines GW 11 (0.34) and GW 503 (0.16) showed significant positive general combining ability effects indicating its good combining ability for grain yield per spike. The specific combining ability values of the hybrids ranged from -0.40 (GW 173 x GW 190) to 0.42 (GW 11 x GW 273) for this trait. The crosses GW 11 x GW 273 (0.42), GW 11 x GW 190 (0.35) and GW 173 x GW 438 (0.34) exhibited significant higher positive sca effects for this component trait and revealed as best crosses for yield contributing traits.

In the case of 100-grain weight, three males showed significant gca effects, of which two males *viz.*, GW 322 (0.35) and GW 496 (0.29) exhibited significant positive general combining ability effects. The range of sca effects was recorded from -0.18 (GW 503 x GW 438) to 0.21 (GW 11 x GW 438).

For Harvest index five males exhibited significant gca effects in which two males viz., GW 322 (6.73) and GW 273 (4.36) possessed significant positive gca effects. Three lines viz. GW 11, GW 503 and Lok 1 exhibited significant gca effects. The sca effects ranged from -1.7 (GW 11 x GW 273) to 1.85 (GW 503 x GW 438).

In the case of Protein content five males exhibited significant gca effects for this trait, of which two males *viz*., GW 322 (0.56) and GW 496 (0.33) possessed significant positive gca effects. Two lines viz., GW 11 and Lok 1 exhibited significant general combining ability effects. Where, GW 11 (0.28) exhibited significant positive general combining ability effect. With respect to sca effects of crosses, none of the hybrid exhibited significant positive sca effects for this component. The range of sca effects was observed from -0.42 (GW 11 x GW 366) to 0.36 (GW 503 x GW 273).

An overall appraisal of general combining ability effects revealed that among the females, GW 503 was found to be good general combiner for length of main spike, grain yield per plant and spikelets per spike, Lok 1 for plant height and 100-grain weight, GW 173 for days to maturity and number of effective tillers per plant, GW 11 for plant height, grain yield per plant, grain yield per spike, harvest index and protein content. Among the males, GW 496 for days to 50 per cent heading, days to maturity, plant height, length of main spike, 100-grain weight and protein content , GW 190 for days to 50 per cent heading, number of effective tillers, length of main spike, grain yield per plant and grain yield per spike, GW 273 for number of effective tillers, length of main spike, spikelets per spike and harvest index, GW 322 for number of effective tillers, grain yield per plant, spikelets per spike, 100-grain weight, harvest index and protein content, GW 366 for days to maturity and number of effective tillers, GW 438 for grain yield per spike and GW 438 for plant height. It also observed in view of most of the characters that parents which exhibited high *per se* performance also displayed good general combining ability effects. Hence, *per se* performance may be used effectively for the selection of parents. Similar result of positive association of *per se* performance and general combining ability and its use for selection of the parents were also reported by Ashutosh Kumar *et al*. (2011).In general, the line GW 11 and tester GW 322 was good general combiner for grain yield and most of the yield contributing traits. So, it was considered as a good source gene for increasing grain yield as well as protein content in wheat. Hence, these parents can be a source of favourable genes for enhancing grain yield and protein content in hybrid wheat breeding programme. Based on general combining ability effects, the parents were classified as good, average and poor combiners for different traits. The character wise categorization of parents has been presented in (Table 5).

The results of specific combining ability effects (Table 4) of different cross revealed that none of the crosses showed consistently significant and desirable specific combining ability effects for all the characters. None of the crosses expressed significant and negative specific combining ability effects for days to 50 per cent heading, days to maturity and plant height and significant and positive specific combining ability effect were observed for number of effective tillers per plant, length of main spike and grain yield per spike. In general all characters the cross showing positive and negative combining ability effect, involved either good x good, good x average, good x poor, average x average, average x poor and poor x poor combining parents. Hence, information of general combining ability effects of the parents need not be supplemented by that of specific combining ability effects in crosses performance marked negative specific combining ability effects in crosses between good x good and good x average combiners could be attributed to lack of co-adaptation between favourable alleles of the parents involved, whereas marked positive specific combining ability effects in cross between poor x poor, average x poor and average x average. Combiners could be ascribed to better complementation between favourable alleles of the involved parents

References

Anonymous, 2010-11. Statistics of distribute area, production and yield of important food and food crops in Gujarat State for year 2010-11. Directorate of Agriculture, Gujarat State, Gandhinagar.

Annual Report, 2016-17. Area, production and yield of major food crops of India for year 2016-17, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, Krishi Bhawan, New Delhi.

Ashutosh, Kumar., Mishra, V.K., Vyas, R.P. and Singh, V. 2011. Heterosis and Combining ability analysis bread wheat (*Triticum aestivum* L.). *J. Pl. Breed. and Crop Sci.,* **3** (10) : 209-217.

Dhadhal, B.A. and Dobariya, K.L. 2006. Combining ability analysis over environment for grain yield and its components in bread wheat (*T. aestivum* L.). *Natl. J. Pl. Improv*., **8** (2) : 172-173.

Joshi, S.K., Sharma, S.N. and Sain, R.S. 2004. Non-allelic interactions for yield and its components in hexaploid wheat (*T. aestivum* L. Em. Thell.). *Indian J. Genet*., **64** : 63-64.

Kempthorne, O. 1957. An introduction to Genetics statistics, John Wiley and Sons, New York.

Panse, V.G. and Sukhatme, P.V. 1978. Statistical Methods for Agricultural Workers, *Indian Council of Agric. Res*., New Delhi.

Sprague, G.F. and Tatum, L.A. 1942. General versus specific combining ability in single crosses in corn. *Agron. J*., **34** : 923-932.

Sprague, G.F., Rusell, W.A., Penny, L.H. and Hanson, W.D. 1962. Epistatic gene action and grain yield in maize. *Crop Sci*., **21** : 205-208.

Electronic Journal of Plant Breeding, 9 (3) : 899 - 907 (Sep 2018) DOI: 10.5958/0975-928X.2018.00112.6
ISSN 0975-928X

Table .1 Analysis of variance (Mean square) for parents and hybrids for seed yield and its component characters in wheat

Source of variation	d.f.	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike	100-grain weight	Harvest index	Protein content
Replication	1	0.28	0.011	3.68	1.47	0.62	0.03	0.05	0.08	0.25	1.13	0.14
Genotype	43	27.15**	11.51**	52.69**	9.71**	1.78**	22.76**	3.40**	0.51**	0.18*	37.81**	0.42**
Parents	11	61.67**	22.59**	103.68**	5.60**	3.85**	35.37**	6.97**	0.59**	0.31**	58.18**	0.78**
Female	3	19.45*	9.33	222.45**	0.11	4.95**	16.85**	5.84**	0.44**	0.39*	43.98**	1.14**
Male	7	28.57**	13.39*	50.84**	7.39**	3.93**	47.16**	4.02**	0.70**	0.32**	66.36**	0.74**
Female vs. Male	1	420.08**	126.75**	117.18**	9.54**	0.05	8.41*	31.04**	0.29*	0.004	43.51**	0.005
Parents vs. Hybrid	1	47.28**	21.48*	83.52*	35.15**	0.00	6.95*	1.11	1.29**	0.06	12.81*	0.004
Hybrids	31	14.25**	7.26	33.60*	10.35**	1.11**	18.79**	2.21**	0.46**	0.14	31.40**	0.30**
Error	43	4.88	5.05	15.63	0.48	0.21	1.41	0.92	0.05	0.09	2.73	0.06

* and** indicates significant at P = 0.05 and P = 0.01 levels, respectively.

Electronic Journal of Plant Breeding, 9 (3) : 899 - 907 (Sep 2018) DOI: 10.5958/0975-928X.2018.00049.2
ISSN 0975-928X

Table .2 Analysis of variance (mean square) for combining ability, and estimates of components of variance for various characters in wheat

Source of variation	d.f.	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike	100-grain weight	Harvest index	Protein content
Replication	1	1.56	0.76	7.56*	1.59	0.50	1.82	0.003	0.26**	0.49*	0.15	0.003
Crosses	31	14.25**	7.26*	33.60*	10.35**	1.11**	18.79**	2.21**	0.46**	0.14	31.40**	0.30**
Females (Line)	3	5.75	3.43**	60.08**	16.53**	1.77*	39.08**	4.00**	1.51**	0.08	35.60**	0.75**
Males (Tester)	7	46.96**	26.33**	102.78**	29.05**	3.06**	64.60**	7.43**	0.99**	0.51**	118.95**	0.77**
Females x Males	21	4.55	1.45	6.76**	3.23**	0.36	0.62	0.21	0.13**	0.02	1.61	0.08
Error	31	4.53	3.63	15.43	0.49	0.21	1.34	0.79	0.03	0.08	2.93	0.07
COMPONENTS OF VARIANCES												
σ^2 Females		0.07	0.12	3.33**	0.83**	0.08*	2.40**	0.23**	0.08**	0.003	2.12**	0.04**
σ^2 Males		5.30**	3.11**	12.00**	3.22**	0.33**	7.99**	0.90**	0.10**	0.06**	14.66**	0.08**
σ^2_{gca}		1.81**	1.11**	6.22**	1.62**	0.17**	4.26**	0.45**	0.09**	0.02**	6.30**	0.05**
σ^2_{sca}		-0.16	-1.80	-4.43	1.37**	0.07	-0.39	-0.35	0.04**	-0.03	-0.56	0.01
$\sigma^2_{gca}/\sigma^2_{sca}$		1.05	5.28	1.55	1.18	2.25	1.05	1.63	2.18	2.00	1.05	5.20

* and** indicates significant at P = 0.05 and P = 0.01 levels, respectively.

Electronic Journal of Plant Breeding, 9 (3) : 899 - 907 (Sep 2018) DOI: 10.5958/0975-928X.2018.00049.2
ISSN 0975-928X

Table. 3 Estimation of general combining ability (gca) effects of parents for various characters in wheat

Source of variation	Days to 50 % heading	Daysto maturity	Plant height	No.of effective tillers	Length of main spike	Grain yieldper plant	Spikelets per spike	Grain yieldper spike	100-grain weight	Harvest index	Protein content
FEMALE PARENTS (Lines) :											
GW 503	0.68	0.26	0.68**	-0.39*	0.37**	1.00**	0.61*	0.16**	-0.09**	-0.95*	-0.09
LOK 1	-0.56	-0.35	-0.81**	0.14	-0.23	-2.31**	-0.59*	-0.32**	0.05**	-1.43**	-0.21**
GW 173	-0.43	-0.42**	-2.18	1.32**	-0.32**	0.41	-0.11	-0.18**	-0.02	0.54	0.02
GW 11	0.32	0.51**	-2.31**	-1.08**	0.18	0.89**	0.09	0.34**	0.05	1.84**	0.28**
S.E. (g_i)±	0.78	0.79	1.39	0.24	0.16	0.42	0.34	0.07	0.10	0.58	0.09
MALE PARENTS (Testers) :											
GW 496	-5.18**	-1.73*	-5.93**	-0.41	0.47**	0.50	-0.49	0.11	0.29*	-1.03	0.33**
GW 190	-1.68*	0.02	-2.68	0.73**	0.49**	4.85**	0.48	0.33**	0.03	0.73	-0.28**
GW 273	1.31	1.76*	-0.93	1.77**	0.83**	-0.10	1.20**	-0.35**	-0.30**	4.36**	-0.22**
GW 322	1.31	2.64**	1.31	2.97**	0.23	3.13**	1.53**	-0.26**	0.35**	6.73**	0.56**
GW 366	0.06	-2.23**	3.18*	0.67**	-0.40*	-1.15**	-0.89*	-0.34**	0.05	-2.67**	-0.02
GW 439	1.56	-0.10	-2.43	-1.92**	-0.73**	-3.79**	-0.71*	-0.04	0.06	-1.02	0.07
GW 428	0.31	1.39	4.31**	-1.14**	-0.88**	-2.50**	-0.19	-0.08	-0.18	-2.04**	-0.28**
GW 438	2.31**	-1.73*	3.18*	-2.68**	-0.01	-0.93*	-0.92*	0.64**	-0.31	-5.06**	-0.16
S.E. (g_j)±	1.10	1.12	1.97	0.34	0.23	0.59	0.48	0.11	0.15	0.82	0.12

* and** indicates significant at P = 0.05 and P = 0.01 levels, respectively.

Electronic Journal of Plant Breeding, 9 (3) : 899 - 907 (Sep 2018) DOI: 10.5958/0975-928X.2018.00049.2
ISSN 0975-928X

Table .4 The estimates of specific combining ability (sca) for various characters in wheat

No	Crosses	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike	100-grain weight	Harvest index	Protein content
1	GW 503 x GW 496	0.81	0.10	1.31	-0.74	0.55	0.18	0.72	0.28	0.006	-0.52	-0.10
2	GW 503 x GW 190	0.31	-0.64	-0.93	-0.14	-0.02	0.33	0.08	0.01	0.11	-0.29	-0.07
3	GW 503 x GW 273	0.31	-0.39	1.31	-0.18	0.84*	-1.20	0.07	-0.17	0.10	0.08	0.36
4	GW 503 x GW 322	-0.68	-0.26	-0.43	-0.38	-0.15	0.65	0.23	0.02	0.09	0.20	-0.22
5	GW 503 x GW 366	-2.43	1.60	0.18	-0.08	0.23	0.24	-0.02	0.05	-0.15	-0.43	0.01
6	GW 503 x GW 439	2.06	1.48	0.81	0.51	-0.29	-0.01	-0.36	-0.07	0.08	-0.48	0.06
7	GW 503 x GW 428	-0.68	-1.01	-1.43	0.74	-0.44	0.19	-0.42	-0.11	-0.06	-0.40	0.02
8	GW 503 x GW 438	0.31	-0.89	-0.81	0.28	-0.70*	-0.38	-0.30	-0.02	-0.18	1.85	-0.05
9	Lok 1 x GW 496	0.06	-0.76	-2.68	0.46	0.16	0.00	-0.52	-0.10	0.05	0.46	-0.08
10	Lok 1 x GW 190	-0.43	0.48	1.06	-0.18	0.23	0.15	0.09	0.03	-0.08	0.48	0.04
11	Lok 1 x GW 273	-1.43	-0.26	-1.68	-0.22	-0.70*	-0.38	-0.07	0.005	-0.14	0.56	0.03
12	Lok 1 x GW 322	1.56	-0.64	0.56	0.38	-0.50	0.02	-0.05	-0.01	-0.006	-0.81	-0.008
13	Lok 1 x GW 366	-1.18	0.73	1.18	0.03	0.03	0.46	0.33	0.10	-0.006	0.49	-0.22
14	Lok 1 x GW 439	0.31	0.10	-0.68	-0.52	0.21	-0.3	-0.30	0.06	0.08	-0.15	0.28
15	Lok 1 x GW 428	0.56	0.60	1.06	0.005	0.26	-0.03	0.33	0.005	0.13	0.47	-0.05
16	Lok 1 x GW 438	0.56	-0.26	1.18	0.04	0.29	0.08	0.20	-0.09	-0.03	-1.51	0.01
17	GW 173 x GW 496	-2.06	0.29	-2.81	-0.21	-0.45	0.02	0.005	-0.04	-0.11	-0.02	-0.12
18	GW 173 x GW 190	0.43	0.04	-1.56	1.63**	-0.02	0.42	0.01	-0.40*	0.04	0.40	-0.002
19	GW 173 x GW 273	1.43	0.29	0.18	2.09**	0.08	0.48	-0.09	-0.26	-0.06	1.08	-0.26
20	GW 173 x GW 322	-1.56	0.42	0.43	1.89**	0.53	-0.8	-0.23	-0.31	0.01	0.70	0.09
21	GW 173 x GW 366	3.68*	-1.20	0.56	-1.30*	-0.27	-0.66	-0.09	0.15	0.16	-0.38	0.33
22	GW 173 x GW 439	-1.81	-0.82	-0.31	-1.20*	-0.10	0.32	0.21	0.26	-0.04	-0.03	0.08
23	GW 173 x GW 428	0.43	0.17	1.93	-1.47**	-0.05	-0.11	0.30	0.25	0.006	-0.75	-0.05
24	GW 173 x GW 438	-0.56	0.79	1.56	-1.43**	0.28	0.31	-0.12	0.34*	-0.006	-0.99	-0.07
25	GW 11 x GW 496	1.18	0.35	4.18	0.49	-0.26	-0.20	-0.20	-0.13	0.05	0.08	0.31
26	GW 11 x GW 190	-0.31	0.10	1.43	-1.30*	-0.18	-0.90	-0.19	0.35*	-0.08	-0.59	0.03
27	GW 11 x GW 273	-0.31	0.35	0.18	-1.69**	-0.22	1.10	0.09	0.42 *	0.10	-1.72	-0.12
28	GW 11 x GW 322	0.68	0.48	-0.56	-1.89**	0.12	0.11	0.05	0.29	-0.10	-0.09	0.13
29	GW 11 x GW 366	-0.06	-1.14	-1.93	1.35**	0.01	-0.04	-0.20	-0.31	-0.006	0.31	-0.12
30	GW 11 x GW 439	-0.56	-0.76	0.18	1.20*	0.18	-0.006	0.45	-0.25	-0.11	0.66	-0.42*
31	GW 11 x GW 428	-0.31	0.23	-1.56	0.73	0.23	-0.04	-0.20	-0.14	-0.06	0.69	0.08
32	GW 11 x GW 438	-0.31	0.35	-1.93	1.11*	0.12	-0.02	0.21	-0.22	0.21	0.65	0.11
	S.E. (s_{ij}) ±	2.21	2.24	3.95	0.69	0.46	1.18	0.96	0.22	0.30	1.65	0.25

* and** indicates significant at P = 0.05 and P = 0.01 levels, respectively.

Electronic Journal of Plant Breeding, 9 (3) : 899 - 907 (Sep 2018) DOI: 10.5958/0975-928X.2018.00049.2
ISSN 0975-928X

Table.5 Summary table showing general combining ability effects of parents for various characters in wheat

Parents	Days to 50 % heading	Days to maturity	Plant height	No. of effective tillers	Length of main spike	Grain yield per plant	Spikelets per spike	Grain yield per spike	100-grain weight	Harvest index	Protein content
LINES (FEMALES) :											
GW 503	A	A	P	P	G*	G*	G*	G*	P	P	A
LOK 1	A	A	G*	A	A	P	P	P	G*	P	P
GW 173	A	G*	A	G*	P	A	A	P	A	A	A
GW 11	A	P	G*	P	A	G*	A	G*	A	G*	G*
TESTERS (MALES) :											
GW 496	G*	G*	G*	A	G*	A	A	A	G*	A	G*
GW 190	G*	A	A	G*	G*	G*	A	G*	A	A	P
GW 273	A	P	A	G*	G*	A	G*	P	P	G*	P
GW 322	A	P	A	G*	A	G*	G*	P	G*	G*	G*
GW 366	A	G*	P	G*	P	P	P	P	A	P	A
GW 439	A	A	A	P	P	P	P	A	A	A	A
GW 428	A	G*	P	P	P	P	A	A	A	P	P
GW 438	P	A	P	P	A	P	P	G*	A	P	A

G = Good parents having significant gca effects in desired direction,
A = Average parent having either positive or negative but non-significant gca effect, and
P = Poor parents having gca effect in the undesired direction.