Int.J.Curr.Microbiol.App.Sci (2017) *6*(3): 24-39

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 3 (2017) pp. 24-39**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.603.003

Combining Ability Analysis for Yield and its Components in Bread Wheat (*Triticum aestivum* L.) under Abiotic Stress

Jaydev Kumar[1]*, S.K. Singh[1], Lokendra Singh[1], Mukul Kumar[2], Meera Srivastava[4], Jagbir Singh[4] and Arun Kumar[3]

[1]Department of Genetics and Plant Breeding, C.S. Azad University of Agriculture and Technology, Kanpur 208 002, India
[2]Department of Botany and Plant Physiology, Mandan Bharti Agriculture College, Agwanpur, Saharsa, Bihar 852 201, India
[3]Department of Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar-263 145 (Uttarakhand), India
[4]Economic Botanical Research Farm, C.S. Azad University of Agriculture and Technology, Nawabganj, Kanpur 208 002, India
**Corresponding author*

Keywords

Bread wheat, Combining ability, Gene effects, Yield components.

Article Info

Accepted:
08 February 2017
Available Online:
10 March 2017

A B S T R A C T

Combining ability analysis for yield and its component under late sown condition in bread wheat involved ten diverse parents and their 45 F_1s and their F_2s indicated significance differences among the parents for gca and crosses for sca for all characters under studied. The GCA and SCA components of variances in both generations showed significant for all traits indicating additive and non additive gene action controlled the pattern of inheritance for the concern traits over the both generations. Based on the general combining ability effects and *per se* performance, parent K 0307 and K 0911 emerged as good general combiners for grain yield and average to high combiners for almost of the yield component characters in late sown condition, it means these genotypes probably possessed the desirable genes for heat temperature during reproductive phase. Whereas K 0307 showed also good general combiner as their gca effect as well as *per se* performance for number of spikelets, number of grains per spike, grain weight per spike, spike length, 1000 grain weight while K 0911 exhibited good general combiner for protein content based on per se performance and GCA effect in both generations. On the basis on *per se* performance and sca effects, DBW 14 x K 0424 and K 9533 x K 0307 possessed good super combinations for grain yield and its related components whereas, K 0607 x K 0307 exhibited good cross combination for protein content based on their *per se* performance in both generations. The good cross combinations were the product of high x high, high x low or low x low general combiners. Hybridization scheme for wheat improvement, such as multiple crossing or bi-parental mating could be useful in further manipulation of genes for economic purposes.

Introduction

With rice and maize, wheat is essential for human cultivation. With more than 215 million hectares planted annually, wheat is the most widely cultivated cereal in the world. It is the most important source of dietary protein and provides around 20% of the global calories for human consumption. With around 130 million tonnes, annual global wheat trade is higher than that of maize and rice combined. More than 60% of wheat is produced in emerging and developing countries; both China and India together produce nearly twice as much as wheat as the USA and Russia combined.

Among the major staples, wheat is the only crop adapted to low temperatures that can be grown during the cool season and drought tolerant crop among cereals. But unfortunately it is also the most sensitive to high night and day temperatures. Wheat yield model indicate that a 1^0c temperature increase reduces yield potential of wheat 10% in some part of world. Expert from the Inter-governmental Penal on Climate Change (IPCC) report that an average temperature increase of 1.5-6^0C by the end of this country is likely and the World Bank estimate that we are barreling down a path to heat up by 4^0c if the problem of climate change is not tackled aggressively now. The world leading wheat belts, wheat yield in 2050 could decline down to 27% compared to 2000 by scientist project 2050. So wheat production needs to be increase by around 60% by 2050 to meet the demand of a growing population with a challenging diet, the challenges of wheat breeders termed. So, breeder interests to development of new wheat varieties expressed their better response under heat regions.

For advancement in the yield of wheat requires certain information regarding the nature of combining ability of parents available for use in the hybridization programme of some quantitative traits have economic importance. Information of general and specific combining ability effects is very important in making the next phase of a breeding programme for heat tolerance. Many workers have reported GCA and SCA effects for yield and its component in wheat (Dubey *et al.*, 2001; Wahid *et al.*, 2007; Kapoor *et al.*, 2011; Ankita *et al.*, 2012). Through, diallel cross analysis a number of parental lines can be tested in all possible combinations. Thus the main objective of the present study was to identify the best combiners and their crosses on the basis of their general and specific combining ability for yield and its components under late sown condition.

Materials and Methods

Ten diverse parents of bread wheat (*Triticum aestivum* L.) *i.e.*, K 9533, K 9162, K 1114, DBW 14, K 0607, K 0424, K 0911, K 0307, NW 2036 and K 9423 were selected on the basis of a broad range of diversity for major yield and its component characters under heat tolerance condition. The experiment was conducted during Rabi 2014-15 at Crop Research Farm (Nawabganj) of C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. The experimental materials was comprised of 100 genotypes including 10 parents and their resulting 45 F_1s and 45 F_2s in a randomized complete block design with three replication under late sown condition. In each replication parents and their F_1s and F_2s were randomly assigned to experimental unit/plots. Each plot comprised single row of 4 m with spacing of 20 cm between rows. Seed was planted at 5 cm apart. All recommended cultural practices were applied to raise a good crop. Five competitive plants in parents and their F_1's and ten plants in F_2's progenies were selected randomly from each replication for recording observation on eleven yield and its component traits *viz.*, number of effective tillers per plant, number of spikelets per spike, number of grains per spike, grain weight per spike (g), spike length (cm), biological yield per plant (g), harvest index (%), 1000 grain weight (g), spike density, protein content (%) and grain yield per plant (g). The mean of each plot was used for statistical analysis. The combining analysis was computed according to Griffings, 1956.

Results and Discussions

Analysis of variance for combining ability revealed that the variance due to general combining ability (*gca)* and specific combining ability (*sca*) were highly significant for all the characters under studied over both generations given in table 1(a) and 1(b). Thus the both kind of gene effects pictured important in controlling the pattern of inheritance of all the characters under studied. The $(gca/sca)^{0.5}$ variance ratio was below unity in both generations for all the characters indicating the preponderance of additive gene effects present in both generations for all traits under studied. The similar findings were reported by Vanpariya *et al.,* (2006) for different characters. Due to differences in the experimental and condition which evaluation is done some differences in the reports *i.e.,* grain yield and some others components governed by both additive and non additive gene effects. Though, variances of specific combining ability were most pronounced than variances of general combining ability for all characters under studied. The prepotencies of non additive genetic variance for difference characters indicating that the best cross combinations could be selected on the basis on *sca* for further substantial.

On the basis on general combining ability effects and *per se* performance (table 2 and table 4), it showed that among parents, Parents K 0307 was best general combiner for number of spikelets per spike, number of grains per spike, grain weight per spike (g), spike length (cm), 1000 grain weight (g), and grain yield per plant (g) while, parent K 0911 was good general combiner for protein content (%) and grain yield per plant and K 9423, K 0307 for high biological yield per plant over both generations. Although, on the basis on general combining ability effects, parents K 0607 for spike length (cm), 1000 grain weight (g), protein content (%), K 1114 for lowest biological yield per plant (g), harvest index (%), DBW 14 and K 9423 for spike density, and NW 2036 for protein content (%) were identified good general combiners over both generations. Therefore, these parents have good potential and can be utilized in synthesizing a dynamic population with most desirable genes accumulated. Apparently, thus, there is still further scope for improving upon the combining ability for component traits, as none of the higher combiner for grain yield was a higher combiner or at least an average combiner for all the desirable traits. In bread 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). It was observed that top parents on the basis of high *per se* performance also have high general combining ability effects. Since, gca effects are attributed to additive and additive x additive gene effects, the above mentioned parents for *gca* effects have good potential for respective traits and may be used in multiple crossing breeding programme to isolate a imaginable population with desired gene manipulated of grain yield. It seems practicable, that the *gca* rank for grain yield is related to the useful yield components, it is therefore, recommended the breeder should breed for superior combining ability for the component traits with a ultimate objective to improve the overall *gca* for grain yield in bread wheat. The good parents having desirable *gca* effects for grain yield per plant in different generations revealed that the *gca* effects and *per se* performance were positively correlated in most of the best parents but few cases is not allow such conditions.

Table.1(a) Analysis of variance for combining ability in a 10 parent- diallel cross (parents and their F1s) among 11th characters in bread wheat

Source of variation	*d.f*	No. of effective tillers per plant	No. of spikelets per spike	No. of grains per spike	Grain weight per spike (g)	Spike length (cm)	Biological yield per plant (g)	Harvest index (%)	1000 grain weight (g)	Spike density	Protein content (%)	Grain yield per plant (g)
GCA	9	0.68**	1.45**	53.29**	0.12**	1.11**	17.68**	20.11**	7.93**	0.01419**	3.95**	6.47**
SCA	45	0.82**	2.34**	43.58**	0.13**	0.51**	17.33**	36.14**	4.34**	0.01155**	1.42**	7.77**
Error	108	0.05	0.26	6.82	0.006	0.013	0.18	1.34	0.12	0.00209	0.02	0.12
σ^2 g		0.05248	0.09929	3.97245	0.00948	0.09087	1.45800	1.56330	0.65087	0.00101	0.32843	0.52970
σ^2 s		0.77202	2.08119	36.76074	0.12375	0.49893	17.14829	34.79825	4.22376	0.00946	1.41359	7.65193
$(\sigma^2 g/ \sigma^2 s)^{0.5}$		0.2607	0.2184	0.3245	0.2768	0.4267	0.2915	0.2119	0.3925	0.3265	0.4820	0.2630

Table.1(b) Analysis of variance for combining ability in a 10 parent- diallel cross (parents and their F2s) among 11th characters in bread wheat

Source of variation	*d.f.*	No. of effective tiller per plant	No. of spikelets per spike	No. of grains per spike	Grain weight per Spike (g)	Spike length (cm)	Biological yield per Plant (g)	Harvest index (%)	1000 grain weight (g)	Spike density	Protein content (%)	Grain yield per plant (g)
GCA	9	0.52**	0.75**	32.36**	0.09**	0.96**	6.58**	19.01**	5.02**	0.01582	1.64**	1.33**
SCA	45	0.38**	0.90**	34.76**	0.06**	0.35**	8.12**	15.83**	3.00**	0.01039	0.73**	1.89**
Error	108	0.04	0.07	7.33	0.009	0.03	0.43	3.85	0.17	0.00147	0.04	0.18
σ^2 g		0.04088	0.05650	2.08586	0.00676	0.07754	0.51274	1.26338	0.40444	0.00120	0.13383	0.09595
σ^2 s		0.35166	0.83120	27.42676	0.05583	0.32426	7.69504	11.97968	2.82960	0.00892	0.70206	1.71779
$(\sigma^2 g/ \sigma^2 s)^{0.5}$		0.3409	0.2607	0.2757	0.3348	0.4890	0.2581	0.3247	0.3780	0.3661	0.4366	0.2363

Note: * significant at p=0.05 and ** significant at p=0.01

Table.2 Estimates of mean performance and their GCA effect of 10 diallel parents for 11th characters in bread wheat

	Number of effective tillers per plant			**Number of spikelets per spike**			**Number of grains per spike**			**Grain weight per spike (g)**			**Spike length (cm)**		
	GCA effect		**Mean**	**GCA effect**		**Mean**	**GCA effect**		**Mean**	**GCA effect**		**Mean**	**GCA effect**		**Mean**
	F_1	**F_2**		**F_1**	**F_2**		**F_1**	**F_2**		**F_1**	**F_2**		**F_1**	**F_2**	
K 9533	0.12	0.07	4.20	0.15	0.16*	19.13	-0.03	-0.21	49.13	0.13	-0.10**	1.92	0.26**	-0.12**	11.27
K 9162	-0.37**	0.17**	4.93	-1.39	-0.27**	19.80	-0.03	-1.64**	49.90	0.07	-0.038	2.02	-0.03	0.14**	11.77
K 1114	-0.58**	0.29**	5.06	-2.86**	-0.37**	19.06	-0.11**	-2.24**	50.53	0.28**	-0.08**	2.14	0.23	-0.46**	10.10
DBW 14	0.38**	-0.21**	3.86	-0.60	0.32**	19.93	-0.08**	-0.74	51.83	-0.18**	0.03	2.03	-1.45**	-0.03	11.00
K 0607	0.11	0.04	4.20	2.13**	0.01	19.53	-0.01	-1.10	52.60	0.18	-0.02	2.23	0.53**	0.16**	11.73
K 0424	-0.429**	0.27**	3.60	-2.33**	-0.24**	18.46	-0.02	1.25	48.00	-0.35**	0.03	1.79	-1.51**	0.01	12.00
K 0911	0.16	0.23**	4.40	0.69	0.26**	19.53	-0.02	0.64	53.46	0.021**	-0.01	2.13	0.96**	-0.01	11.93
K 0307	0.46**	0.02	4.53	4.36**	0.24**	20.26	0.26**	3.28**	57.86	0.19**	0.16**	2.55	2.53**	0.58**	13.50
NW 2036	0.11	-0.32**	3.33	-0.14	0.08	20.80	0.03	1.29	56.20	-0.39**	0.14**	2.54	-0.78**	0.05	12.50
K 9423	0.02	-0.02	4.73	-0.02	-0.19*	19.33	0.01	-0.55	48.60	0.03	-0.04	1.97	-0.73**	-0.32**	10.10
SE±(Gi)	**0.06**	**0.053**		**0.14**	**0.076**		**0.71**	**0.74**		**0.022**	**0.026**		**0.031**	**0.048**	
SE±(Gi-Gj)	**0.08**	**0.079**		**0.20**	**0.113**		**1.06**	**1.10**		**0.032**	**0.039**		**0.046**	**0.072**	

Parents	**Biological yield per plant (g)**			**Harvest index (%)**			**1000 grain weight (g)**			**Spike density**			**Protein content (%)**			**Grain yield per plant (g)**		
	GCA effect		**Mean**	**GCA effect**		**Mean**	**GCA effect**		**Mean**	**GCA effect**		**Mean**	**GCA effect**		**Mean**	**GCA effect**		**Mean**
	F_1	**F_2**		**F_1**	**F_2**		**F_1**	**F_2**		**F_1**	**F_2**		**F_1**	**F_2**		**F_1**	**F_2**	
K 9533	-1.74**	0.82**	19.36	-1.30**	-2.52**	43.24	0.05	-1.13**	39.52	0.000	0.03**	1.70	-1.8**	0.91**	11.36	-0.29**	-0.16**	8.37
K 9162	-0.27	0.47*	19.60	0.03	-0.92	51.58	-0.11**	0.18	40.64	-0.02	-0.04**	1.68	-0.42**	-0.10	12.95	-0.08	0.02	10.11
K 1114	-0.88**	-0.74**	20.71	0.31**	1.83**	53.03	-0.51**	-0.40**	42.84	0.02	0.03**	1.78	-0.20**	-0.09	11.25	-0.07	0.04	10.97
DBW 14	-0.33	-0.71**	19.04	-1.09**	0.13	43.40	-0.18**	0.41**	39.44	0.059**	0.03**	1.81	-0.05	-0.11*	10.29	-0.73**	-0.29*	8.25
K 0607	0.47	-0.23	20.22	0.15	0.07	49.25	0.34**	0.36**	43.31	-0.4**	-0.02*	1.66	0.27**	0.28**	11.83	0.29**	-0.08	9.96
K 0424	0.56	-1.19**	16.03	-0.23**	0.23	46.31	-0.02	-0.19	38.87	-0.03**	-0.02*	1.54	0.47**	0.16**	12.25	-0.52**	-0.48**	7.41
K 0911	0.01	0.38*	19.12	0.06	1.46*	52.79	0.04	0.04	41.07	0.01	0.02*	1.65	0.59**	0.36**	11.93	0.43**	0.43**	10.08
K 0307	2.38**	1.03**	23.18	1.55**	0.81	52.55	0.60**	0.79**	44.39	-0.04**	-0.06**	1.51	0.2**	0.29**	12.55	1.76**	0.65**	12.18
NW 2036	-1.65**	-0.27	18.64	0.67**	-0.23	43.31	-0.02	1.09**	43.05	0.02	0.01	1.69	0.19**	0.18**	11.20	-0.76**	-0.14	8.07
K 9423	1.45**	0.44*	20.75	-0.15	-0.88	45.05	-0.18**	-0.34**	40.16	0.03**	0.03**	1.91	0.32**	-0.06	11.44	-0.01	0.004	9.35
SE±(Gi)	**0.11**	**0.18**		**0.31**	**0.53**		**0.095**	**0.113**		**0.012**	**0.010**		**0.031**	**0.051**		**0.096**	**0.11**	
SE±(Gi-Gj)	**0.17**	**0.26**		**0.47**	**0.80**		**0.142**	**0.169**		**0.018**	**0.015**		**0.046**	**0.077**		**0.143**	**0.17**	

Table.3 Estimates of specific combining effects and corresponding mean performance of 45F1s and 45F2s for 11th characters in bread wheat

Crosses	No. of effective tillers per plant				No. of spikelets per spike			
	F_1		F_2		F_1		F_2	
	SCA effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean
1.K 9533 x K 9162	0.04	5.00	0.14	4.80	1.46**	21.00	0.25	19.67
2.K 9533 x K 1114	0.16	5.33	-0.52**	4.27	2.67**	22.00	1.56**	20.87
3. K 9533 x DBW 14	-0.44*	4.27	-0.35	3.93	-0.63	19.67	-0.74**	19.27
4.K 9533 x K 0607	0.86**	5.93	0.74**	5.27	0.59	20.60	0.18	19.87
5.K 9533 x K 0424	-0.28	4.27	-0.68**	3.53	-3.75**	15.73	0.22	19.67
6.K 9533 x K 0911	-0.16	4.93	0.35	5.07	1.19*	21.27	0.53*	20.47
7. K 9533 x K 0307	0.91**	6.00	0.83**	5.33	0.62	21.00	0.15	20.07
8. K 9533 x NW 2036	-0.30	4.20	-0.57**	3.60	-0.09	19.93	-0.37	19.40
9. K 9533 x K 9423	0.60**	5.47	0.79**	5.27	-0.27	19.67	-0.35	19.13
10. K 9162 x K 1114	-0.90**	4.33	-0.94**	3.93	-1.30**	17.53	-0.54*	18.33
11.K 9162 x DBW 14	-0.43*	4.33	-0.57**	3.80	-2.80**	17.00	-2.17**	17.40
12. K 9162 x K 0607	0.07	5.20	0.38*	5.00	0.28	19.80	0.41	19.67
13. K 9162 x K 0424	0.60**	5.20	0.10	4.40	0.81	19.80	0.12	19.13
14. K 9162 x K 0911	-0.23	4.93	-0.21	4.60	-0.58	19.00	-0.11	19.40
15. K9162 x K 0307	0.59**	5.73	0.54**	5.13	0.05	19.93	-0.42	19.07
16. K 9162 x NW 2036	-0.89**	3.67	-0.53**	3.73	-0.73	18.80	0.26	19.60
17. K 9162 x K 9423	1.34**	6.27	0.70**	5.27	1.29**	20.73	0.55*	19.60
18. K 1114 x DBW 14	-0.64**	4.33	-0.36*	4.13	-0.06	19.53	0.87**	20.33
19. K 1114 x K 0607	-0.94**	4.40	0.25	5.00	-3.51**	15.80	1.85**	21.00
20. K 1114 x K 0424	0.86**	5.67	-0.10	4.33	3.69**	22.47	-1.77**	17.13
21. K 1114 x K 0 911	2.64**	8.00	1.93**	6.87	0.56	19.93	0.40	19.80
22. K 1114 x K 0307	-0.75**	4.60	-0.39*	4.33	-0.88	18.80	0.02	19.40
23. K 1114 x NW 2036	2.04**	6.80	0.94**	5.33	-0.05	19.27	-0.23	19.00
24. K 1114 x K 9423	-1.73**	3.40	-0.96**	3.73	0.03	19.27	-0.75**	18.20
25. DBW 14 x K 0607	0.93**	5.80	0.76**	5.00	1.79**	22.07	0.09	19.93
26. DBW 14 x K 0424	1.92**	6.27	1.08**	5.00	2.32**	22.07	1.13**	20.73
27. DBW 14 x K 0911	-0.63**	4.27	-0.43*	4.00	-0.54	19.80	-0.70**	19.40
28. DBW 14 x K 0307	-0.09	4.80	-0.22	4.00	0.36	21.00	0.86**	20.93
29. DBW 14 x NW 2036	0.04	4.33	0.78**	4.67	0.71	21.00	0.94**	20.87
30. DBW 14 x K 9423	0.60**	5.27	-0.45*	3.73	0.13	20.33	0.16	19.80
31. K 0607 x K 0424	0.56**	5.27	0.09	4.27	0.74	20.20	1.78**	21.07
32. K 0607 x K 0911	-0.20	5.07	-0.61**	4.07	2.27**	22.33	-0.25	19.53
33. K 0607 x K 0307	0.55**	5.80	-0.67**	3.80	-0.03	20.33	-1.10**	18.67
34. K 0607 x NW 2036	0.47*	5.13	0.07	4.20	-1.60**	18.40	-2.88**	16.73
35. K 0607 x K 9423	-0.23	4.80	-0.43*	4.00	0.41	20.33	-0.06	19.27
36. K 0424 x K 0911	-1.07**	3.67	0.10	4.47	-2.93**	16.60	-0.01	19.53
37. K 0424 x K 0307	-0.39	4.33	-0.22	3.93	-0.83	19.00	-0.65*	18.87
38. K 0424 x NW 2036	-0.67**	3.47	0.32	4.13	-0.47	19.00	-0.37	19.00
39. K 0424 x K 9423	-0.37	4.13	-0.18	3.93	1.35**	20.73	0.71**	19.80
40. K 0911 x K 0307	0.39	5.67	-0.59**	4.07	0.58	21.00	-0.08	19.93
41. K 0911 x NW 2036	0.84**	5.53	0.01	4.33	1.60**	21.67	0.74**	20.60
42. K 0911 x K 9423	0.21	5.27	0.38*	5.00	-0.98*	19.00	0.49	20.07
43. K 0307 x NW 2036	0.25	4.93	0.49**	4.60	0.50	20.87	0.76**	20.60
44. K 0307 x K 9423	0.02	5.07	0.05	4.47	0.52	20.80	-0.09	19.47
45. NW 2036 x K 9423	-0.26	4.20	-0.61**	3.47	-1.46**	18.47	-1.07**	18.33
SE±(Sij)	0.20		0.17		0.47		0.25	
SE±(Sij-Sik)	0.29		0.26		0.69		0.37	

Table.3 continued

Crosses	No. of grains per spike				Grain weight per spike (g)			
	F_1		F_2		F_1		F_2	
	SCA effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean
1.K 9533 x K 9162	3.64	55.13	-3.03	43.40	0.13	2.22	-0.11	1.71
2.K 9533 x K 1114	2.54	52.57	1.63	47.47	0.11	2.12	-0.15	1.63
3. K 9533 x DBW 14	-3.05	49.23	-6.20*	41.13	-0.12	1.92	-0.17	1.66
4.K 9533 x K 0607	1.45	56.47	2.30	49.27	0.23**	2.33	0.00	1.84
5.K 9533 x K 0424	0.11	50.67	-2.13	47.20	-0.12	1.98	-0.13	1.75
6.K 9533 x K 0911	3.89	57.47	1.55	50.27	0.21**	2.31	0.12	1.97
7. K 9533 x K 0307	5.35*	62.60	6.44*	57.80	0.31**	2.69	0.25**	2.27
8. K 9533 x NW 2036	-3.61	49.13	-6.70*	42.67	-0.26**	1.88	-0.28**	1.72
9. K 9533 x K 9423	-2.53	50.33	3.61	51.13	-0.17*	1.96	0.15	1.96
10. K 9162 x K 1114	-3.48	45.00	-4.54	39.87	-0.18*	1.83	-0.09	1.75
11.K 9162 x DBW 14	-5.20*	45.53	1.10	47.00	-0.29**	1.75	-0.09	1.80
12. K 9162 x K 0607	-4.20	49.27	0.13	45.67	-0.01	2.10	0.08	1.99
13. K 9162 x K 0424	7.25**	56.27	-1.23	46.67	0.14	2.24	-0.04	1.91
14. K 9162 x K 0911	-1.77	50.27	1.78	49.07	-0.09	2.01	0.07	1.99
15. K9162 x K 0307	-0.97	54.73	-5.26*	44.67	0.11	2.49	-0.26**	1.82
16. K 9162 x NW 2036	-8.46**	42.73	0.00	47.93	-0.42**	1.73	0.02	2.08
17. K 9162 x K 9423	13.28**	64.60	1.24	47.33	0.73**	2.86	0.13	2.01
18. K 1114 x DBW 14	3.26	52.53	-1.24	44.07	0.13	2.09	0.01	1.85
19. K 1114 x K 0607	14.73**	66.73	-4.41	40.53	-0.58**	1.45	-0.15	1.70
20. K 1114 x K 0424	-8.61**	38.93	6.77**	54.07	0.76**	2.78	0.01	1.92
21. K 1114 x K 0 911	-4.70	45.87	-7.76**	38.93	-0.29**	1.73	-0.34**	1.53
22. K 1114 x K 0307	-5.04*	49.20	1.13	50.47	-0.29**	2.01	0.08	2.12
23. K 1114 x NW 2036	1.74	51.47	-2.68	44.67	0.29**	2.36	-0.04	1.98
24. K 1114 x K 9423	-7.46**	42.40	-2.37	43.13	-0.38**	1.67	-0.03	1.79
25. DBW 14 x K 0607	0.81	55.07	6.23*	52.67	0.00	2.06	0.12	2.02
26. DBW 14 x K 0424	14.80**	64.60	6.21*	55.00	0.85**	2.90	0.51**	2.46
27. DBW 14 x K 0911	-11.43**	41.40	-10.92**	37.27	-0.34**	1.71	-0.46**	1.46
28. DBW 14 x K 0307	-4.29	52.20	-8.23**	42.60	-0.38**	1.96	-0.28**	1.81
29. DBW 14 x NW 2036	-3.92	48.07	0.70	49.53	-0.10	2.00	0.05	2.12
30. DBW 14 x K 9423	8.42**	60.53	2.27	49.27	0.16*	2.24	0.03	1.91
31. K 0607 x K 0424	-3.53	49.00	4.04	52.47	-0.20**	1.92	0.28**	2.25
32. K 0607 x K 0911	9.78**	65.33	4.68	52.50	0.78**	2.90	0.29**	2.23
33. K 0607 x K 0307	0.38	59.60	-4.33	46.13	-0.02	2.38	-0.20*	1.90
34. K 0607 x NW 2036	0.35	55.07	-10.61**	37.87	-0.13	2.04	-0.57**	1.51
35. K 0607 x K 9423	-10.98**	43.87	-11.10**	35.53	-0.27**	1.88	-0.46**	1.43
36. K 0424 x K 0911	-9.63**	41.47	-5.85*	44.33	-0.81**	1.30	-0.30**	1.68
37. K 0424 x K 0307	-0.43	54.33	-0.82	52.00	-0.10	2.29	0.00	2.15
38. K 0424 x NW 2036	-1.66	48.60	-0.83	50.00	0.02	2.18	0.09	2.22
39. K 0424 x K 9423	1.88	52.27	-0.59	48.40	0.11	2.25	0.02	1.96
40. K 0911 x K 0307	5.14*	62.93	-6.35*	45.87	0.33**	2.72	-0.30**	1.82
41. K 0911 x NW 2036	11.05**	64.33	2.98	53.20	0.27**	2.43	0.14	2.24
42. K 0911 x K 9423	-1.01	52.40	12.09**	60.47	-0.08	2.06	0.43**	2.34
43. K 0307 x NW 2036	-1.28	55.67	12.93**	65.80	-0.23**	2.21	0.25**	2.51
44. K 0307 x K 9423	8.32**	65.40	-1.55	49.47	0.51**	2.92	-0.11	1.96
45. NW 2036 x K 9423	-1.71	50.87	-6.43*	42.60	-0.12	2.06	-0.27**	1.78
SE±(Sij)	2.40		2.49		0.074		0.088	
SE±(Sij-Sik)	3.50		3.66		0.108		0.129	

Crosses	Spike length (cm)				Biological yield per plant (g)			
	F_1		F_2		F_1		F_2	
	SCA effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean
1.K 9533 x K 9162	0.12	11.83	0.04	11.60	1.54**	24.71	-0.06	20.94
2.K 9533 x K 1114	1.36**	12.67	1.01**	11.97	3.54**	26.97	-1.25*	18.53
3. K 9533 x DBW 14	-0.50**	11.13	0.86**	12.23	-3.27**	18.49	-3.09**	16.72
4.K 9533 x K 0607	0.01	12.17	-1.21**	10.37	4.48**	28.21	3.23**	23.53
5.K 9533 x K 0424	-0.56**	11.23	0.58**	12.00	-0.93*	20.77	-3.07**	16.25
6.K 9533 x K 0911	0.28*	12.13	-0.91**	10.50	0.46	24.62	-1.01	19.90
7. K 9533 x K 0307	0.61**	13.03	0.17	12.17	3.49**	29.23	7.05**	28.60
8. K 9533 x NW 2036	0.34**	12.13	0.23	11.70	-0.64	21.78	-1.17	19.08
9. K 9533 x K 9423	-0.46**	11.17	-0.72**	10.37	-0.48	21.99	3.33**	24.30
10. K 9162 x K 1114	-0.86**	10.30	0.21	11.43	-2.45**	20.69	-2.53**	16.90
11.K 9162 x DBW 14	-0.18	11.30	0.06	11.70	-2.70**	18.76	-0.88	18.58
12. K 9162 x K 0607	0.32**	12.33	0.16	12.00	-1.55**	21.89	0.69	20.64
13. K 9162 x K 0424	0.15	11.80	-0.48**	11.20	1.24**	22.65	0.46	19.43
14. K 9162 x K 0911	-0.48**	11.23	-0.14	11.53	-0.89*	22.98	1.94**	22.50
15. K9162 x K 0307	0.79**	13.07	0.44*	12.70	2.99**	28.43	0.53	21.73
16. K 9162 x NW 2036	-1.02**	10.63	-0.77**	10.97	0.76	22.89	-2.71**	17.19
17. K 9162 x K 9423	0.75**	12.23	0.58**	11.93	7.62**	29.80	4.65**	25.26
18. K 1114 x DBW 14	0.96**	12.03	0.50**	11.53	-2.13**	19.59	-0.29	17.95
19. K 1114 x K 0607	-1.13**	10.47	0.76**	12.00	-8.04**	15.65	-1.60*	17.12
20. K 1114 x K 0424	1.13**	12.37	-0.81**	10.27	6.80**	28.46	0.29	18.05
21. K 1114 x K 0 911	-0.27*	11.03	0.03	11.10	4.59**	28.72	0.89	20.23
22. K 1114 x K 0307	-0.66**	11.20	-0.79**	10.87	-1.94**	23.76	-1.56*	18.43
23. K 1114 x NW 2036	-0.04	11.20	-0.10	11.03	7.71**	30.10	3.56**	22.25
24. K 1114 x K 9423	0.80**	11.87	0.22	10.97	-2.71**	19.73	-2.53**	16.87
25. DBW 14 x K 0607	0.84**	12.77	0.28	11.93	2.61**	24.63	2.30**	21.06
26. DBW 14 x K 0424	0.20	11.77	0.10	11.60	11.83**	31.81	4.90**	22.69
27. DBW 14 x K 0911	-0.66**	10.97	-0.56**	10.93	-1.43**	21.02	-2.26**	17.11
28. DBW 14 x K 0307	0.48**	12.67	0.02	12.10	-1.84**	22.19	-3.68**	16.34
29. DBW 14 x NW 2036	-0.67**	10.90	-0.48**	11.07	-1.38**	19.33	3.06**	21.78
30. DBW 14 x K 9423	0.33**	11.73	0.13	11.30	0.32	21.08	-1.62*	17.81
31. K 0607 x K 0424	-0.16	11.93	0.24	11.93	1.68**	23.65	3.36**	21.63
32. K 0607 x K 0911	0.78**	12.93	0.38*	12.07	5.82**	30.25	0.97	20.82
33. K 0607 x K 0307	-0.05	12.67	-0.68**	11.60	2.32**	28.32	-3.79**	16.71
34. K 0607 x NW 2036	0.38**	12.47	0.18	11.93	2.22**	24.90	-4.61**	14.59
35. K 0607 x K 9423	0.44**	12.37	0.13	11.50	-2.00**	20.73	-2.52**	17.40
36. K 0424 x K 0911	-0.29**	11.50	-0.50**	11.03	-5.64**	16.76	-2.15**	16.74
37. K 0424 x K 0307	-1.35**	11.00	-0.75**	11.37	-1.53**	22.44	-0.41	19.12
38. K 0424 x NW 2036	-0.70**	11.03	-0.36*	11.23	-2.86**	17.79	0.98	19.21
39. K 0424 x K 9423	1.04**	12.60	1.06**	12.27	-2.80**	17.91	-1.80**	17.15
40. K 0911 x K 0307	-0.62**	11.80	-0.14	11.97	4.13**	30.57	-2.94**	18.18
41. K 0911 x NW 2036	0.74**	12.53	0.28	11.87	2.99**	26.11	2.23**	22.05
42. K 0911 x K 9423	0.34**	11.97	0.73**	11.93	1.44**	24.60	5.03**	25.56
43. K 0307 x NW 2036	-0.09	12.27	-0.01	12.17	-0.68	24.02	3.27**	23.73
44. K 0307 x K 9423	-0.15	12.03	0.14	11.93	2.72**	27.46	-1.30*	19.88
45. NW 2036 x K 9423	-0.50**	11.07	-0.70**	10.57	-2.66**	18.77	-3.57**	16.30
SE±(Sij)	0.105		0.164		0.39		0.60	
SE±(Sij-Sik)	0.154		0.241		0.58		0.89	

Crosses	Harvest index (%)				1000 grain weight (g)			
	F_1		F_2		F_1		F_2	
	SCA effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean
1.K 9533 x K 9162	0.91	45.85	-2.72	40.34	-0.23	39.90	-0.91*	39.58
2.K 9533 x K 1114	-3.32**	41.01	-1.74	44.07	-0.23	40.18	-0.12	39.78
3. K 9533 x DBW 14	1.48	46.36	1.70	45.81	0.25	39.26	1.55**	41.44
4.K 9533 x K 0607	0.80	46.49	-1.99	42.07	0.02	40.28	-1.15**	39.51
5.K 9533 x K 0424	-4.13**	41.64	1.49	45.70	-1.60**	38.28	-1.33**	38.78
6.K 9533 x K 0911	3.58**	48.80	5.61**	51.04	0.56	40.73	1.89**	42.23
7. K 9533 x K 0307	6.46**	54.06	-3.24	41.55	1.69**	43.35	0.85*	41.95
8. K 9533 x NW 2036	-5.60**	37.96	-1.75	41.99	-1.61**	39.17	-0.55	40.84
9. K 9533 x K 9423	0.30	46.97	-0.92	42.17	-0.28	39.68	-0.95*	39.00
10. K 9162 x K 1114	-4.49**	41.31	-3.06	44.34	-1.41**	40.33	0.12	41.34
11.K 9162 x DBW 14	-4.14**	42.20	-2.24	43.47	-1.44**	38.90	-0.77*	40.44
12. K 9162 x K 0607	3.25**	50.40	3.29	48.94	2.46**	44.05	2.10**	44.09
13. K 9162 x K 0424	5.16**	52.40	-0.17	45.63	-1.10**	40.11	-0.43	41.00
14. K 9162 x K 0911	-0.58	46.11	-6.87**	40.16	-0.01	41.49	0.29	41.95
15. K9162 x K 0307	2.38*	51.45	-2.50	43.89	1.30**	44.29	0.28	42.69
16. K 9162 x NW 2036	-20.04**	24.99	2.49	47.82	-0.61	41.50	-1.05**	41.66
17. K 9162 x K 9423	7.20**	55.33	-2.08	42.61	2.69**	43.98	2.72**	44.00
18. K 1114 x DBW 14	-0.16	45.58	-6.20**	42.27	-0.37	40.26	-0.49	40.13
19. K 1114 x K 0607	-4.08**	42.47	-2.61	45.80	-2.31**	39.56	0.72	42.11
20. K 1114 x K 0424	8.83**	55.46	-2.82	45.75	1.16**	42.65	-3.89**	36.95
21. K 1114 x K 0 911	1.23	47.31	2.09	51.88	-1.45**	40.33	-1.14**	39.94
22. K 1114 x K 0307	-6.20**	42.26	0.64	49.78	0.79*	44.06	0.03	41.86
23. K 1114 x NW 2036	7.17**	51.58	-2.26	45.84	3.52**	45.90	2.00**	44.12
24. K 1114 x K 9423	-14.69**	32.83	10.22**	57.67	-1.31**	40.26	-1.66**	39.03
25. DBW 14 x K 0607	2.81*	49.90	2.32	49.03	-1.35**	39.12	-0.85*	40.54
26. DBW 14 x K 0424	6.39**	53.57	2.64	49.51	4.31**	44.40	2.12**	42.96
27. DBW 14 x K 0911	-9.34**	37.29	9.29**	57.38	2.03**	42.40	-1.85**	39.22
28. DBW 14 x K 0307	-1.75	47.25	2.97	50.41	-4.20**	37.67	1.34**	43.16
29. DBW 14 x NW 2036	1.80	46.76	0.49	46.89	1.88**	42.87	1.05**	43.17
30. DBW 14 x K 9423	8.67**	56.74	-4.23*	41.52	-1.54**	38.63	0.25	40.93
31. K 0607 x K 0424	-2.47*	45.51	1.12	47.92	0.15	41.48	1.03**	42.64
32. K 0607 x K 0911	-0.79	46.64	-4.42*	43.61	3.30**	44.92	1.68**	43.52
33. K 0607 x K 0307	-3.77**	46.05	-0.45	46.93	0.98**	44.09	-2.27**	40.32
34. K 0607 x NW 2036	2.18*	47.95	3.05	49.39	-5.14**	37.09	-2.62**	40.27
35. K 0607 x K 9423	-0.62	48.26	-5.50**	40.19	-1.31**	40.11	-0.94*	40.51
36. K 0424 x K 0911	-9.06**	38.46	-0.04	48.15	-3.44**	37.80	-1.43**	39.86
37. K 0424 x K 0307	-3.64**	46.26	-1.78	45.76	-1.28**	41.45	2.54**	44.58
38. K 0424 x NW 2036	1.62	47.48	0.77	47.26	3.55**	45.40	3.41**	45.74
39. K 0424 x K 9423	0.81	49.77	0.09	45.94	2.41**	43.44	2.35**	43.25
40. K 0911 x K 0307	-0.42	48.94	-6.93**	41.83	1.06**	44.08	-1.38**	40.90
41. K 0911 x NW 2036	4.25**	49.56	-3.53	44.19	-0.02	42.11	1.05**	43.62
42. K 0911 x K 9423	-0.49	47.92	-1.96	45.11	-1.12**	40.21	1.79**	42.93
43. K 0307 x NW 2036	3.07**	50.75	2.43	49.50	-2.33**	41.30	-1.97**	41.36
44. K 0307 x K 9423	2.23*	53.02	0.01	46.44	2.23**	45.05	-2.17**	39.72
45. NW 2036 x K 9423	6.22**	52.97	3.73*	49.11	0.14	42.07	-0.21	41.98
SE±(Sij)	1.06		1.80		0.32		0.38	
SE±(Sij-Sik)	1.57		2.65		0.47		0.56	

Crosses	Spike density				Protein content (%)			
	F_1		F_2		F_1		F_2	
	SCA effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean	*SCA* effect	Mean
1.K 9533 x K 9162	0.11*	1.77	0.01	1.70	1.10**	11.77	0.75**	11.60
2.K 9533 x K 1114	0.03	1.74	-0.02	1.75	1.12**	12.00	1.28**	12.13
3. K 9533 x DBW 14	0.02	1.77	-0.19**	1.57	-0.40**	10.63	0.36*	11.20
4.K 9533 x K 0607	0.05	1.69	0.21**	1.92	-1.19**	10.17	-0.66**	10.57
5.K 9533 x K 0424	-0.25**	1.39	-0.07	1.64	-1.30**	10.27	-0.85**	10.27
6.K 9533 x K 0911	0.06	1.75	0.20**	1.95	-0.84**	10.83	-1.28**	10.03
7. K 9533 x K 0307	-0.03	1.61	-0.02	1.65	-0.59**	10.70	-1.27**	9.97
8. K 9533 x NW 2036	-0.06	1.64	-0.08*	1.66	-1.02**	10.27	0.00	11.13
9. K 9533 x K 9423	0.04	1.76	0.08*	1.85	-0.20	11.21	-1.01**	9.87
10. K 9162 x K 1114	0.02	1.71	-0.08*	1.61	-0.47**	11.37	0.00	11.67
11.K 9162 x DBW 14	-0.22**	1.50	-0.20**	1.49	-0.66**	11.33	0.18	11.83
12. K 9162 x K 0607	-0.02	1.61	0.01	1.64	-0.62**	11.70	-1.08**	10.97
13. K 9162 x K 0424	0.05	1.68	0.08*	1.71	-0.99**	11.53	0.74**	12.67
14. K 9162 x K 0911	0.02	1.70	0.01	1.68	-0.64**	12.00	-1.29**	10.83
15. K9162 x K 0307	-0.10*	1.53	-0.09*	1.50	0.02	12.27	-0.52**	11.53
16. K 9162 x NW 2036	0.08	1.77	0.13**	1.78	0.75**	13.00	-0.28	11.67
17. K 9162 x K 9423	-0.01	1.69	-0.04	1.64	-1.13**	11.23	-1.10**	10.60
18. K 1114 x DBW 14	-0.14**	1.62	0.00	1.76	-0.44**	11.77	-0.32	11.33
19. K 1114 x K 0607	-0.15**	1.51	0.04	1.75	-2.26**	10.27	-0.75**	11.30
20. K 1114 x K 0424	0.14**	1.81	-0.04	1.67	-0.30**	12.43	-0.50**	11.43
21. K 1114 x K 0 911	0.09*	1.81	0.03	1.79	0.98**	13.83	1.54**	13.67
22. K 1114 x K 0307	0.01	1.68	0.12**	1.79	0.77**	13.23	-0.42*	11.63
23. K 1114 x NW 2036	0.00	1.72	-0.01	1.72	1.18**	13.63	0.09	12.03
24. K 1114 x K 9423	-0.12**	1.62	-0.10**	1.66	1.02**	13.60	-0.10	11.60
25. DBW 14 x K 0607	0.03	1.73	-0.03	1.67	1.34**	14.03	0.53**	12.57
26. DBW 14 x K 0424	0.17**	1.88	0.09*	1.79	1.54**	14.43	0.22	12.13
27. DBW 14 x K 0911	0.05	1.80	0.02	1.78	0.66**	13.67	1.09**	13.20
28. DBW 14 x K 0307	-0.05	1.66	0.06	1.73	-0.69**	11.93	-0.38*	11.67
29. DBW 14 x NW 2036	0.17**	1.93	0.16**	1.89	1.15**	13.77	0.90**	12.83
30. DBW 14 x K 9423	-0.04	1.74	-0.01	1.75	1.66**	14.40	0.11	11.80
31. K 0607 x K 0424	0.09*	1.69	0.11**	1.76	0.01	13.23	0.19	12.50
32. K 0607 x K 0911	0.08	1.73	-0.08*	1.62	1.73**	15.06	-0.01	12.50
33. K 0607 x K 0307	0.01	1.61	0.00	1.61	1.94**	14.89	1.93**	14.37
34. K 0607 x NW 2036	-0.18**	1.48	-0.27**	1.40	0.53**	13.47	0.41*	12.73
35. K 0607 x K 9423	-0.03	1.65	-0.03	1.68	0.89**	13.95	0.65**	12.73
36. K 0424 x K 0911	-0.21**	1.44	0.07	1.77	0.67**	14.21	-0.02	12.37
37. K 0424 x K 0307	0.12**	1.73	0.05	1.66	0.79**	13.94	-0.82**	11.50
38. K 0424 x NW 2036	0.06	1.72	0.02	1.69	0.43**	13.57	0.19	12.40
39. K 0424 x K 9423	-0.03	1.65	-0.09*	1.61	1.30**	14.56	0.54**	12.50
40. K 0911 x K 0307	0.13**	1.78	0.00	1.67	0.02	13.28	0.95**	13.47
41. K 0911 x NW 2036	0.02	1.73	0.01	1.74	0.38**	13.63	-0.01	12.40
42. K 0911 x K 9423	-0.14**	1.59	-0.07*	1.68	0.48**	13.86	0.34	12.50
43. K 0307 x NW 2036	0.04	1.70	0.05	1.69	-0.49**	12.38	-0.04	12.30
44. K 0307 x K 9423	0.05	1.73	-0.04	1.63	-1.13**	11.86	0.35	12.43
45. NW 2036 x K 9423	-0.06	1.67	0.00	1.73	0.43**	13.41	0.79**	12.77
SE±(Sij)	0.042		0.035		0.10		0.17	
SE±(Sij-Sik)	0.061		0.051		0.15		0.25	

Crosses	Grain yield per plant (g)			
	F_1		F_2	
	SCA effect	Mean	*SCA* effect	Mean
1.K 9533 x K 9162	0.85*	11.33	-0.55	8.44
2.K 9533 x K 1114	0.56	11.05	-0.85*	8.16
3. K 9533 x DBW 14	-1.26**	8.57	-1.03*	7.65
4.K 9533 x K 0607	2.26**	13.12	0.97*	9.86
5.K 9533 x K 0424	-1.41**	8.64	-1.10**	7.38
6.K 9533 x K 0911	1.05**	12.04	0.70	10.11
7. K 9533 x K 0307	3.48**	15.80	2.25**	11.88
8. K 9533 x NW 2036	-1.53**	8.27	-0.79	8.03
9. K 9533 x K 9423	-0.21	10.33	1.28**	10.26
10. K 9162 x K 1114	-2.15**	8.55	-1.68**	7.51
11.K 9162 x DBW 14	-2.11**	7.92	-0.85*	8.01
12. K 9162 x K 0607	-0.03	11.03	0.95*	10.02
13. K 9162 x K 0424	1.63**	11.88	0.17	8.84
14. K 9162 x K 0911	-0.61	10.59	-0.54	9.04
15. K9162 x K 0307	2.11**	14.63	-0.28	9.53
16. K 9162 x NW 2036	-4.29**	5.71	-0.71	8.29
17. K 9162 x K 9423	5.73**	16.49	1.61**	10.77
18. K 1114 x DBW 14	-1.14**	8.90	-1.29**	7.59
19. K 1114 x K 0607	-4.42**	6.65	-1.23**	7.86
20. K 1114 x K 0424	5.52**	15.78	-0.45	8.24
21. K 1114 x K 0 911	2.38**	13.59	0.89*	10.50
22. K 1114 x K 0307	-2.50**	10.05	-0.64	9.19
23. K 1114 x NW 2036	5.52**	15.53	1.16**	10.18
24. K 1114 x K 9423	-4.29**	6.47	0.56	9.73
25. DBW 14 x K 0607	1.88**	12.29	1.55**	10.31
26. DBW 14 x K 0424	7.44**	17.04	2.86**	11.21
27. DBW 14 x K 0911	-2.70**	7.84	0.54	9.82
28. DBW 14 x K 0307	-1.39**	10.49	-1.27**	8.23
29. DBW 14 x NW 2036	-0.33	9.02	1.53**	10.22
30. DBW 14 x K 9423	1.86**	11.96	-1.45**	7.39
31. K 0607 x K 0424	0.14	10.76	1.80**	10.37
32. K 0607 x K 0911	2.54**	14.11	-0.40	9.08
33. K 0607 x K 0307	0.13	13.03	-1.86**	7.85
34. K 0607 x NW 2036	1.57**	11.95	-1.71**	7.19
35. K 0607 x K 9423	-1.13**	10.00	-2.05**	7.00
36. K 0424 x K 0911	-4.30**	6.46	-1.02*	8.06
37. K 0424 x K 0307	-1.68**	10.41	-0.56	8.75
38. K 0424 x NW 2036	-1.12**	8.45	0.59	9.08
39. K 0424 x K 9423	-1.40**	8.92	-0.78	7.87
40. K 0911 x K 0307	1.90**	14.94	-2.62**	7.60
41. K 0911 x NW 2036	2.42**	12.94	0.33	9.74
42. K 0911 x K 9423	0.56	11.82	1.96**	11.53
43. K 0307 x NW 2036	0.36	12.21	2.10**	11.74
44. K 0307 x K 9423	1.96**	14.56	-0.58	9.21
45. NW 2036 x K 9423	-0.13	9.94	-0.98*	8.01
SE±(Sij)	0.32		0.39	
SE±(Sij-Sik)	0.47		0.57	

Table.4 Ranking of the desirable parents on the basis of per se performance and gca effects for 11th characters in bread wheat

Character	**Desirable parent on the basis of *per se* performance**	**Good general combiner**		**Common parent in F_1 and F_2**	**Common parent on the basis of *per se* and gca effect in F_1 and F_2**
		F_1	F_2		
Number of effective tillers per plant	K 1114 K 9162 K 9423 K 0307 K 0911	K 0307** DBW 14**	K 1114** K 0424** K 0911** K 9162	Nil	Nil
Number of spikelets per spike	NW 2036 K 0307 DBW 14 K 9162 K 0607	K 0307** K 0607**	DBW 14** K 0911** K 0307** K 9533*	K 0307	K 0307
Number of grains per spike	K 0307 NW 2036 K 0911 K 0607 DBW 14	K 0307**	K 0307**	K 0307	K 0307
Grains weight per spike (g)	K 0307 NW 2036 K 0607 K 0911 K 1114	K 1114** K 0911** K 0307**	K 0307** NW 2036**	K 0307	K 0307
Spike length (cm)	K 0307 NW 2036 K 0424 K 9162 K 0607	K 0307** K 0911** K 0607** K 9533**	K 0307** K 0607** K 9162**	K 0307 K 0607	K 0307 K 0607
Biological yield per plant (g)	K 0307 K 9423 K 1114 K 0607 K 9162	K 0307** K 9423**	K 9533** K 9162** K 0911** K 0307** K 9423**	K 0307 K 9423	K 307 K 9423
Harvest index (%)	K 1114 K 0911 K 0307 K 9162 K0607	K 0307** NW 2036** K 1114**	K 1114** K 0911*	K 1114	K 1114
1000 grain weight (g)	K 0307 K 0607 NW 2036 K 1114 K 0911	K 0307** K 0607**	NW 2036** K 0307** DBW 14** K 0607**	K 0307 K 0607	K 0307 K 0607
Spike density	K 9423 DBW 14 K 1114 K 9533 NW 2036	DBW 14** K 9423**	K 9533** K 1114** DBW 14** K 9423** K 0911*	DBW 14 K 9423	DBW 14 K 9423
Protein content (%)	K 9162 K 0307 K 0424 K 0911 K 9423	K 0911** K 0424** K 9423** K 0607** NW 2036**	K 9533** K 0 911** K 0307** K 0607** NW 2036**	K 0911 K 0607 NW 2036	K 0911
Grain yield per plant (g)	K 0307 K 1114 K 9162 K 0911 K 0607	K 0307** K 0911** K 0607**	K 0307** K 0911**	K 0307 K 0911	K 0307 K 0911

*significant at 5% and ** significant at 1%.

Table.5 Ranking of the crosses in respect to their superiority for specific combining ability, per se performance and general combining effects of the parents for 11th characters in bread wheat

Character	Good specific combiner	gca effect of parent	Superior crosses on the basis of *per se* performance
F_1s **Number of effective tillers per plant**	**K 1114 x K 0911**** **K 1114 x NW 2036**** **DBW 14 x K 0424**** **K 9162 x K 9423**** DBW 14 x K 0607**	L x A L x A H x L L x A H x A	**K 1114 x K 0911** **K 1114 x NW 2036** **K 9162 x K 9423** **DBW 14 x K 0424** K 9533 x K 0307
Number of spikelets per spike	**K 1114 x K 0424**** **K 9533 x K 1114**** **DBW 14 x K 0424**** **K 0607 x K 0911**** **DBW 14 x K 0607****	L x L A x L A x L H x A A x H	**K 1114 x K 0424** **K 0607 x K 0911** **DBW 14 x K 0607** **DBW 14 x K 0424** **K 9533 x K 1114**
Number of grains per spike	**DBW 14 x K 0424**** K 1114 x K 0607** **K 9162 x K 9423**** K 0911 x NW 2036** **K 0607 x K 0911****	L x A L x A A x A A x A A x A	K 1114 x K 0607 K 0307 x K 9423 **K 0607 x K 0911** **K 9162 x K 9423** **DBW 14 x K 0424**
Grain weight per spike (g)	**DBW 14 x K 0424**** **K 0607 x K 0911**** **K 1114 x K 0424**** **K 9162 x K 9423**** **K 0307 x K 9423****	L x L A x H H x L A x A H x A	**K 0307 x K 9423** **DBW 14 x K 0424** **K 0607 x K 0911** **K 9162 x K 9423** **K 1114 x K 0424**
Spike length (cm)	K 9533 x K 1114** K 1114 x K 0424** K 0424 x K 9423** K 1114 x DBW 14** **DBW 14 x K 0607****	H x A A x L L x L A x L L x H	K 9162 x K 0307 K 9533 x K 0307 K 0607 x K 0911 **DBW 14 x K 0607** K 0607 x K 0307
Biological yield per plant (g)	**DBW14 x K 0424**** **K 1114 x NW 2036**** **K 9162 x K 9423**** K 1114 x K 0424** **K 0607 x K 0911****	A x A L x L A x H L x A A x A	**DBW 14 x K 0424** K 0911 x K 0307 **K 0607 x K 0911** **K 1114 x NW 2036** **K 9162 x K 9423**
Harvest index (%)	**K 1114 x K 0424**** **DBW 14 x K 9423**** **K 9162 x K 9423**** K 1114 x NW 2036** **K 9533 x K 0307****	H x L L x A A x A H x H L x H	**DBW 14 x K 9423** **K 1114 x K 0424** **K 9162 x K 9423** **K 9533 x K 0307** DBW 14 x K 0424
1000 grain weight (g)	**DBW 14 x K 0424**** **K 0424 x NW 2036**** **K 1114 x NW 2036**** **K 0607 x K 0911**** K 9162 x K 9423**	L x A A x A L x A H x A L x L	**K 1114 x NW 2036** **K 0424 x NW 2036** K 0307 x K 9423 **K 0607 x K 0911** **DBW 14 x K 0424**
Spike density	**DBW 14 x K 0424**** **DBW 14 x NW 2036**** **K 1114 x K 0424**** K 0911 x K 0307** K 0424 x K 0307**	H x L L x A A x L A x L L x L	**DBW 14 x NW 2036** **DBW 14 x K 0424** **K 1114 x K 0424** K 1114 x K 0911 DBW 14 x K 0911
Protein content (%)	**K 0607 x K 0307**** **K 0607 x K 0911**** **DBW 14 x K 9423**** **DBW 14 x K 0424**** DBW 14 x K 0607**	H x H H x H A x H A x H A x H	**K 0607 x K 0911** **K 0607 x K 0307** K 0424 x K 9423 **DBW 14 x K 0424** **DBW 14 x K 9423**
Grain yield per plant (g)	**DBW 14 x K 0424**** **K 9162 x K 9423**** **K 1114 x K 0424**** **K 1114 x NW 2036**** **K 9533 x K 0307****	L x L A x A A x L A x L L x H	**DBW 14 x K 0424** **K 9162 x K 9423** **K 9533 x K 0307** **K 1114 x K 0424** **K 1114 x NW 2036**

Table.5 continued

Character	**Good specific combiner**	**gca effect of parent**	**Superior crosses on the basis of *per se* performance**
F_2s **Number of effective tillers per plant**	**K 1114 x K 0911**** DBW 14 x K 0424** **K 1114 NW 2036**** **K 9533 x K 0307**** **K 9533 x K 9423****	H x H L x H H x H A x A A x A	**K 1114 x K 0911** **K 9533 x K 0307** **K 1114 x NW 2036** K 9533 x K 0607 **K 9533 x K 9423**
Number of spikelets per spike	**K 1114 x K 0607**** **K 0607 x K 0424**** **K 9533 x K 1114**** DBW 14 x K 0424** **DBW 14 x NW 2036****	L x A A x L H x L H x L H x A	**K 0607 x K 0424** **K 1114 x K 0607** DBW 14 x K 0307 **DBW 14 x NW 2036** **K 9533 x K 1114**
Number of grains per spike	**K 0307 x NW 2036**** **K 0911 x K 9423**** **K 1114 x K 0424**** **K 9533 x K 0307**** DBW 14 x K 0607**	H x A A x A L x A A x H A x A	**K 0307 x NW 2036** **K 0911 x K 9423** **K 9533 x K 0307** DBW 14 x K 0424 **K 1114 x K 0424**
Grain weight per spike (g)	**DBW 14 x K 0424**** **K 0911 x K 9423**** K 0607 x K 0911** **K 0607 x K 0424**** **K 9533 x K 0307****	A x A A x A A x A A x A L x H	K 0307 x NW 2036 **DBW 14 x K 0424** **K 0911 x K 9423** **K 9533 x K 0307** **K 0607 x K 0424**
Spike length (cm)	**K 0424 x K 9423**** K 9533 x K 1114** **K 9533 x DBW 14**** K 1114 x K 0607** K 0911 x K 9423**	A x L L x L L x A L x H A x L	K 9162 x K 0307 **K 0424 x K 9423** **K 9533 x DBW 14** K 9533 x K 0307 K 0307 x NW 2036
Biological yield per plant (g)	**K 9533 x K 0307**** **K 0911 x K 9423**** DBW 14 x K 0424** **K 9162 x K 9423**** K 1114 x NW 2036**	H x H H x H L x L H x H L x A	**K 9533 x K 0307** **K 0911 x K 9423** **K 9162 x K 9423** K 9533 x K 9423 K 0911 x K 9423
Harvest index (%)	**K 1114 x K 9423**** **DBW 14 x K 0911**** **K 9533 x K 0911**** NW 2036 x K 9423** K 9162 x K 0607(NS)	H x A A x H L x H A x A A x A	**K 1114 x K 9423** **DBW 14 x K 0911** K 1114 x K 0911 **K 9533 x K 0911** DBW 14 x K 0307
1000 grain weight (g)	**K 0424 x NW 2036**** **K 9162 x K 9423**** **K 0424 x K 0307**** K 0424 x K 9423** DBW 14 x K 0424**	A x H A x L A x H A x A H x A	**K 0424 x NW 2036** **K 0424 x K 0307** K 1114 x NW 2036 K 9162 x K 0607 **K 9162 x K 9423**
Spike density	**K 9533 x K 0607**** **K 9533 x K 0911**** **DBW 14 x NW 2036**** K 9162 x NW 2036** K 1114 x K 0307**	H x L H x H H x A L x A H x L	**K 9533 x K 0911** **K 9533 x K 0607** **DBW 14 x NW 2036** K 9533 x K 9423 K 1114 x K 0307
Protein content (%)	**K 0607 x K 0307**** **K 1114 x K 0911**** K 9533 x K 1114** **DBW 14 x K 0911**** **K 0911 x K 0307****	H x H A x H H x A L x H H x H	**K 0607 x K 0307** **K 1114 x K 0911** **K 0911 x K 0307** **DBW 14 x K 0911** DBW 14 x NW 2036
Grain yield per plant (g)	**DBW 14 x K 0424**** **K 9533 x K 0307**** **K 0307 x NW 2036**** **K 0911 x K 9423**** K 0607 x K 0424**	L x L L x H H x A H x A A x L	**K 9533 x K 0307** **K 0307 x NW 2036** **K 0911 x K 9423** **DBW 14 x K 0424** K 9162 x K 9423

*significant at 5% and ** significant at 1%. L =Low estimate; A =Average estimate and H =High estimate.

In present investigation, parent K 307 was identified good general combiner for grain yield and its component traits and K 0911 had also good general combining ability for grain yield and other quality traits over both generations in late condition, it means both parents possessed the desirable gene having good responsibility for produced good grain yield per plant of wheat and its quality traits under high temperature during grain filing period. Biological yield was the traits identified for selection with heat stress (Shah, 1998). The increase in productivity under late sown condition depends on the biomass attained by a genotype at the time of anthesis. The selection for high biomass yield should bring about positive improvement in grain yield and its associated characters. Thus the selection for biomass yield is one of the ways to improve the productivity in bread wheat.

For object to synthesize a dynamic population with most of the favorable gene accelerated by using of good general combiners for several characters, multiple crossing programme. Apart of conventional breeding approaches resting slowly upon additive or additive x additive type gene action, population improvement appears to be hopeful alternatives. Diallel selective mating system sounds to be good technique, which delays quick fixation of genes complexes, permits break down of linkage, general fostering of combination and concentration of desirable genes or gene groups into central gene pool by a series of multiple crosses. The *sca* represents the dominance and epistatic interaction, which can be related with heterosis. However, in self-pollinated crops like wheat, the additive x additive type of interaction component is fixable in later generations. Breeder's interest, therefore, vests in obtaining transgressive segregants through crosses and producing more potent homozygous lines. The superiority of hybrids might not indicate their ability to yield transgressive segregants, rather *sca* would provide satisfactory criteria (Jinks and Jones, 1958).

The estimate of specific combining ability (*sca*) revealed that out of 45 crosses, 18 crosses in F_1s and 13 cross combinations in F_2s were identified good specific combiners for grain yield per plant (Table 3). In comparable study of top 5 crosses of each F_1 and F_2 generations, only two cross combinations revealed that good positive and significant *sca* effects. The highest positive and significant *sca* effects as well as their *per se* performance was exhibited by cross DBW 14 x K 0424 and K 9533 x K 0307 in both generation for grain yield per plant. Whereas, other cross combination *viz.*, K 9162 x K 9423, K 1114 x K 0424, K 1114 x NW 2036 in F_1s and K 0307 x NW 2036, K 0911 x K 9423 K 0607 x K 0424 in F_2s were identified good specific combiner for grain yield per plant on basis of *sca* effects. Cross combination K 0607 x K 0307 was found good specific combiner for protein content over both generation on the basis of *sca* effects as well as their *per se* performance (table 5). Crosses K 1114 x K 0911, K 1114 x NW 2036 and DBW 14 for number of effective tillers per plant, K 9533 x K 1114 and DBW 14 x K 0424 for number of spikelets per spike, DBW 14 x K 0424 and K 0607 x K 0911 for grain weight per spike, K 9533 x K 1114 for spike length, DBW 14 x K 0424, K 1114 x NW 2036, K 9162 x K 9423 for high biological yield per plant, DBW 14 x K 0424 for 1000 grain weight were also identified for super *sca* effects over both generations. As generally, these cross combinations were showed good yielding capacity, in most of the crosses, one of the parents involved was good combiner indicating they produced desirable segregants.

All the best cross combinations for grain yield per plant also showed an average to high *sca* effects for most of the yielding components. It is response to production of new materials in future breeding programme for recombining of desirable alleles of genes in the genotypes.
All the important crosses involving parents with high x average, average x average and average x poor general combiners indicated that non-additive type of gene actions, which are unfixable in nature, were involved in selected cross combinations. The results of high *sca* effect due to high x higher reflect additive x additive types of gene action and superiority of

favorable genes contributed by both parents, while high x average or lox x low combiners indicate the interaction of additive dominance and dominance x dominance types of gene action, respectively. In such condition will be arisen in study materials, bi-parental progeny selection suggested by (Andrus, 1963) may be used to get some good transgressive segregants from crosses involving high x high and high x poor combiners.

Acknowledgement

We are extremely thanks to Department of Genetics and Plant Breeding of C.S. Azad University of Agriculture and Technology, Kanpur for valuable suggestions and assistance provided during the course of investigation.

References

Ajmal, S., Khalid, I. and Rehman, A.U. 2011. Genetic analysis for yield and some yield traits in bread wheat (*Triticum aestivum* L.). *J. Agri. Res.*, 49(4): 447-454.

Andrus, C.F. 1963. Plant breeding systems. *Euphytica*, 12:205-228.

Ankita, S., Anil, K., Ekhlaque, A., Swati and Jaiswal, J.P. 2012. Combining ability and gene action studies for grain yield, its components and quality traits in bread wheat (*T. aestivum* L. em Thell.). *Electronic J. Plant Breeding*, 3(4): 964-972.

Ashadusjaman, M., Shamsuddoha, M., Alam, M.L. and Begum, M.O. 2012. Combining ability and gene action for different root characters in spring wheat. *J. Environ. Sci. Resour.*, 5(2): 73-76.

Bikram, S. and Ahmad, B.A. 2008. Combining behavior of elite synthetic hexaploid wheat with staple wheat cultivar. *J. Res. SKUAST-J.*, 7(2): 218-224.

Desai, S.A., Lohithaswa, H.C., Hanchinal, R.R., Patie, B.N., Kalappanavar, I.K. and Math, K.K. 2005. Combining ability for quantitative traits in bread wheat (*Triticum aestivum* L.). *Indian J. Genetics and Plant Breeding*, 65: 311-312.

Dubey, L.K., Sastry, E.V.D. and Sinha, K. 2001. Heterosis for yield and yield components in bread wheat (*Triticum aestivum* L.) under saline and normal environments. *Annals of Arid Zone*, 40: 57-60.

Griffings, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Australian J. Biol. Sci.*, 9: 463-493.

Jensen, N.F. 1970. A diallel selective mating system for cereal breeding. *Crop Sci.*, 10: 629-635.

Jinks, J.L. and Jones, R.M. 1958. Estimation of heterosis. *Genetics*, 43: 223-234.

Kapoor, E., Mandal, S.K. and Dey, T. 2011. Combining ability analysis for yield and yield contributing traits in winter and spring wheat combinations. *J. Wheat Res.*, 3(1): 52-58.

Shah, M.A. 1998. Genetic studies for grain and temperature attributes in wheat (*Triticum aestivum* L.). *The Indian J. Genetics and Plant Breeding*, 61: 209-212.

Vanpariya, L.G., Chovatia, V.P. and Mehta, D.R. 2006. Combining ability studies in bread wheat (*Triticum aestivum* L.). *National J. of Pl. Improvement*, 8(2): 132-137.

Wahid, A., Gelani, S., Ashraf, M. and Foolad, M. 2007. Heat tolerance in plant. An overview. *Environ. Exp. Bot.*, 61: 199-223.

How to cite this article:

Jaydev Kumar, S.K. Singh, Lokendra Singh, Mukul Kumar, Meera Srivastava, Jagbir Singh and Arun Kumar. 2017. Combining ability analysis for yield and its components in bread wheat (*Triticum aestivum* L.) under abiotic stress. *Int.J.Curr.Microbiol.App.Sci.* 6(3): 24-39.
doi: https://doi.org/10.20546/ijcmas.2017.603.003