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RESEARCH ARTICLE

Study of combining ability analysis in half diallel crosses of spring wheat (*Triticum aestivum* L.).

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Abstract

Combining ability analysis were performed in a 10 x 10 haif diallel cross of ten bread wheat genotypes for yield and its contributing traits. The experiment was conducted in 2011-2012 and 2012-2013 at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Modipuram, Meerut, UP. The results revealed that non-additive genetic variance play a predominant role in the inheritance of most of the traits. The best combinations mostly involved high x low and low x low general combiner for the characters under study. There was very rare case in which high x high general combiner were involved for best combinations. On the basis of gca and sca effects, two parents (i.e. PBW 373 and RAJ 3765) and 17 cross combinations (i.e. five best crosses namely, K 9423 x NW 1014, Unnat Halna x HUW 560, K 9423 x Unnat Halna, K 9162 x NW 1014, K 7903 x HUW 560), were found good general and specific combiners for higher grain yield and also for other yield contributing traits, respectively. These crosses may be used in heterosis breeding programme for developing new wheat genotype with broad genetic base by multiple crossing programmes. Therefore, crosses involving high x low general combiners in respect of different characters in the present study may be utilized for obtaining trasgressive segregants in the next generation resulting from dominance gene interaction.

INTRODUCTION

Among the major crops, wheat is one of the most critical for warranting human nourishment, it is the most widely crop grown globally and is the primary source of protein for the world population (Braun *et al.*, 2010). India is considered to be the second largest producer of wheat (Sharma *et al*., 2013, Anonymous, 2014) and occupies second position after China. The geometrical increase in India's population has been a challenge for agricultural scientists. To fulfill the projected demand of the world population for food grains, it is essential that production and productivity of wheat must be increased. However, this may not be easily achieved as there is mounting evidence that genetic gains in yield have recently been much lower than what it would be required Reynolds *et al.*,(2012). Future wheat breeding needs to be extremely efficient as the land allocated to wheat is unlikely to increase significantly, and the use of inputs cannot increase at similar rates as they have in the last half-century Hall and Richards, (2013).The selection of genetically superior parents is an important step in the development of high yielding varieties which is possible only by the study of combining ability. The understanding of various characters and identification of superior parents are important prerequisites for launching effective and efficient breeding programme. Selection of suitable parents on the basis of phenotypic performance alone is not an effective method, since phenotypically superior lines may be gives poor cross combination for yield. Therefore, it is essential that parents should be selected on the basis of their genetic value**.** The general combining ability effects were due to additive gene action and specific combining ability effects were due to non-additive gene effects which are important to selects the best parents for hybridization to produce superior cross combination and to launch a successful wheat-breeding programme. The performance of parents may not necessarily reveal it to be good or poor combiners. Therefore gathering information nature of gene effects and their expression in term of combining ability is necessary. At the same time, it also elucidates the nature of gene action involved in the inheritance of the characters. The parents which are genetically superior and diverse in the traits of interest are utilized for varietal development programme. Many researchers gives reviews, which revealed that both general and specific combining abilities were involved in the improvement of yield and its contributing traits in wheat (Murphy *et al*., 2008, Singh *et al.,* 2012 and Singh *et al.,* 2014).In systematic breeding programme, selection of parents with desirable characteristics having good general combining ability effects for grain yield and its components, high heterosis and high estimates of specific combining ability effects are essential. These parameters will help in formulating an efficient and effective breeding procedure to bring about rapid and suitable improvement in this crop. The general and specific combining ability effects are very effective genetic parameters in deciding, the next phase of breeding programme. Diallel analysis also provides a unique opportunity to test a number of lines in all possible combinations. The main objective of the present study was to obtained the information on the extent of combining ability for grain yield and its related traits in the selection process and greater the response to selection, a diallel cross of bread wheat was employed for determination of best combiner and their crosses.

MATERIALS AND METHODS

Ten genotypes of bread wheat namely, Raj 3765, K 9162, PBW 373, K 9423, K 7903, Unnat Halna, NW 1014, HUW 560, NW 1076 and UP 2425 were sown at Crop Research Centre during *rabi* 2011-2012 for attempting crossing programme in a 10 x 10 diallel fashion excluding reciprocals. In the next crop season *rabi* 2012-2013, experimental material consisted of 55 genotypes (10 parents and 45 F_1s) were sown in a randomized block design with three replication. Each of the parental lines and crosses were sown by dibbling seeds in two row plot of 2 meter length at spacing of 10 cm between plant to plant and row to row spacing was 23 cm. Uniform standard agronomical practices were applied to the whole experiment from sowing to till harvest of crop. At maturity, for recording observations, five competitive plants from each replication of crosses and parents were selected and tagged for recording data for various yield and its attributing traits except days to 50 per cent flowering and days to maturity which was recorded on line basis. The data were recorded for 13 quantitative traits namely; days to 50% flowering, days to maturity, plant height (cm), number of productive tillers per plant, flag leaf area (cm^2), spike length (cm), number of spikelets per spike, number of grains per spike, 1000-grains weight (g), biological yield per plant (g), grain yield per plant (g), and harvest index (%).For flag leaf area (cm2), length and the maximum width of flag leaf was measured and the area was calculated using the following formula suggested by Muller (1991) as Flag leaf area = leaf length × maximum leaf width ×correction factor (0.74). The mean values were used for the analysis of variance to test the significance for each character as per methodology advocated by Panse and Sukhatme (1967). The estimates of general and specific combining ability were calculated according to the method of griffing (1956) model 1 (fixed effect) and method 2 (parents and one set of F_1s without reciprocals) which is a fixed effect model. Estimates of combining ability were computed according to Kempthorne (1957) and average degree of dominance by Kempthorne and Curnow (1961).

Results and discussion

Analysis of variance for combing ability

Study of combining ability analysis provides useful information about the nature and magnitude of gene action and selection of suitable parents and specific cross combinations to prepare an effective breeding programme and to utilize them in further breeding programme for the improvement of yield potential of a crop. Combining ability give the information about genetic value of parental line to produce superior hybrid. The general combining ability give the information about additive and additive x additive gene action, whereas specific combining ability about the non-allelic interaction and dominance gene action.

The analysis of variance for combining ability (Table 2) revealed that general and specific combining ability variances were found highly significant in F_{1s}cross combination for 13 characters namely, days to 50 % flowering, days to maturity, plant height, peduncle length, flag leaf area, productive tillers per plant, spike length, spikelets per spike, grains per spike, biological yield per plant, harvest index, 1000 grain weight and grain yield per plant indicating the importance of additive and non-additive gene actions in the inheritance of these characters. In the same way, the result were also reported by Singh *et al.,* (2012), Farshadfar *et al.,* (2013) and Dholariya *et al.,* (2014).The variance due to δ^2g was higher than δ^2s for spike length which indicated predominance of additive gene action as the ratio of δ^2g/δ^2s was more than unity while rest of the traits predominance of non-additive gene action. The average degree of dominance $(\delta^2s/\delta^2g)^{0.5}$ for spike length showed partial dominance while rest of the traits showed over dominance. The same result on the preponderance of non-additive gene action was reported by several researchers for yield and its contributing traits. Non additive type of gene action were reported by Singh *et al.* (2012),for productive tillers per plant, spikelets per spike, grains per spike, biological yield per plant, 1000 grain weight and grain yield per plant, Dholariya *et al.*,(2014) for Days to flowering**,** days to maturity, Ali *et al*., (2014) for plant height**,** flag leaf area, peduncle length, Desale and Mehta, (2013)for harvest index whereas additive gene action for spike length were reported by Singh *et al.,* (2012), Padhar *et al.,* (2013) and Dholariya *et al.*,(2014).

General combining ability effects:

The information regarding general combining ability effects of the parents is of prime importance because it helps in successful prediction of genetic potentiality which would give desirable individuals in subsequent segregating population. In the present investigation, it was observed that none of the parents was found as good general combiner for all the 13 characters under study because the combining ability of the parents was not consistent for all the yield components**.** The magnitude and direction of combining ability effects provides the guidelines for the utilization of parents in any breeding programme. Based on significant gca effects in desirable direction, we selected a number of good general combiners out of 10 parents for a single character (Table 3). The performance of parents in respect to general combining ability is as out of ten parents, the parents NW 1014 and K 7903 for days to 50 % flowering; parents NW 1014, UP 2425, HUW 560 and K 9162 for days to maturity and parents PBW 373, UNNAT-HALNA, UP 2425, K 7903 and NW 1076 for plant height showing good favorable GCA effects. The parents UNNAT-HALNA, NW 1014, UP 2425 and NW 1076 for peduncle length; K 9423, K 7903, UNNAT-HALNA, NW 1076 and UP 2425 for flag leaf area; K 9423, NW 1076, UP 2425 and HUW 560 for productive tillers per plant; K 7903, NW 1076, K 9423 and HUW 560 for spike length; K 7903, K 9423, NW 1076 and HUW 560 for number of spikelets per spike; K 7903 for number of grains per spike; RAJ 3765, K 9162 and NW 1076 for biological yield per plant; PBW 373, K 9423, HUW 560 and NW 1076 for harvest index; K 9162, NW 1076, UP 2425 and K 9423 for 1000 grain weight, and PBW 373 and RAJ 3765 for grain yield per plant were found good general combiners. It is clear from above study that some parents are good general combiners for more than one trait indicating the presence of additive gene action and additive x additive interaction effects and shall be included in the breeding programme for the accumulation of favorable alleles in a single genetic background. Therefore these parents can be used for crossing programme to have the superior recombinants for respective traits. Similar result on gca effects were also given by Singh *et al.*,(2012), Farshadfar *et al.,* (2013), Desale and Mehta, (2013), Yao *et al.* (2014), Singh *et al*., (2014), Khiabani *et al.,* (2015), and Kumar *et al.,* (2015).

Specific combining ability effects:

In the present study, it was noticed that there were significant sca effects in desirable direction for almost all the characters under study. Hence these specific combiners can be used in breeding programme for overall improvement. Out of 45 cross combinations, 23 for days to 50 % flowering; 14 for days to maturity; 19 for plant height; 13 for peduncle length; 16 for flag leaf area; 7 for number of productive tillers per plant; 4 for spike length; 9 for number of spikelets per spike; 3 for number of grains per spike; 18 for biological yield per plant; 18 for harvest index; 14 for 1000 grain weight and 17 for grain yield per plant exhibited significant sca effects in desirable direction.

Specific combining ability effects is associated with interaction effects which may be due to dominance and epistatic components of variation which are non-fixable in nature, it would be worth full for commercial exploitation of heterosis. Among the 45 cross combinations, 17 crosses namely, K 9423 x NW 1014, Unnat Halna x HUW 560, K 9423 x Unnat Halna, K 9162 x NW 1014, K 7903 x HUW 560, PBW 373 x UP 2425, Raj 3765 x NW 1076, K 9423 x K 7903, NW 1014 x HUW 560, Raj 3765 x Unnat Halna, K 7903 x NW 1014, K 9162 x K 7903, K 9162 x NW 1076, Raj 3765 x NW 1014, K 9423 x HUW 560, K 9162 x Unnat Halna, HUW 560 x NW 1076 which exhibited significant specific combining ability effects in desirable direction for grain yield per plant and also showed significant sca effects for some other yield contributing traits (table 4). Similar results on grain yield and its contributing traits were reported by Singh *et al.*, (2012 and Desale and Mehta, (2013).In present study, best specific combiner mostly involved low x low and high x low general combiners for the characters under study. There was rare case in which high x high general combiners were involved for best combination (table 4). Thus it is evident that high specific combiners are not always obtained between high x high general combiners but may occur between low x low or high x low general combiners. The results in the same way were also reported by Singh *et al.,* (2012) and Padhar *et al.,* (2013). These crosses may be used in heterosis breeding programme for developing new genotype having broad genetic base by multiple crossing programme. Therefore, crosses involving high x low general combiners in respect of different characters in the present study may be utilized for obtaining trasgressive segregants in the next generation resulting from dominance gene interaction.

The cross combinations, which exhibited high sca effects in desirable direction for grain yield per plant, also showed significant sca effects for some other two or more yield contributing traits such as the cross K 9423 x NW 1014 exhibited the significant sca effects in desirable direction for five traits; Unnat Halna x HUW 560 for four traits; K 9423 x Unnat Halna for four traits; K 9162 x NW 1014 for seven traits; K 7903 x HUW 560 for five traits; PBW 373 x UP 2425 for four traits; Raj

3765 x NW 1076 for two traits; K 9423 x K 7903 for five traits; NW 1014 x HUW 560 for five traits; Raj 3765 x Unnat Halna for six traits; K 7903 x NW 1014 for six traits; K 9162 x K 7903 for four traits; K 9162 x NW 1076 for six traits; Raj 3765 x NW 1014 for five traits; K 9423 x HUW 560 for four traits; K 9162 x Unnat Halna for two traits and HUW 560 x NW 1076 for four traits. Similar result has been reported by Padhar *et al*,.(2013), Yao *et al.* (2014), Singh *et al*., (2014), Khiabani *et al.*, (2015) and Kumar *et al.*, (2015).The cross combinations showing high sca and involving both or at least one good general combiners, suggesting dominance type of gene action. Thus identification of specific parental combination of producing the higher transgressive effects can be of greater value for the development of high yielding of wheat genotypes.

Thus based on gca effects, the genotypes PBW 373 and RAJ 3765 can be used for the improvement of yield and its contributing traits through hybridization. The cross combinations namely, K 9423 x NW 1014, Unnat Halna x HUW 560, K 9423 x Unnat Halna, K 9162 x NW 1014, K 7903 x HUW 560, PBW 373 x UP 2425, Raj 3765 x NW 1076, K 9423 x K 7903, NW 1014 x HUW 560, Raj 3765 x Unnat Halna, K 7903 x NW 1014, K 9162 x K 7903, K 9162 x NW 1076, Raj 3765 x NW 1014, K 9423 x HUW 560, K 9162 x Unnat Halna, HUW 560 x NW 1076 which had highly significant sca effects for grain yield and most of the yield contributing traits may be exploited for the development of single cross hybrids and also through the population improvement programme for the development of high yielding varieties. Similar result was also reported by Singh *et al.*, (2012),Dholariya *et al.*,(2014),Yao *et al.* (2014), Singh *et al*., (2014), Khiabani *et al.*, (2015), and Kumar *et al.*, (2015).Since these crosses were the product of low x medium, low x low, medium x medium high x medium, high x low, general combiners and significant sca effects which is due to non-additive gene action and response of dominance and dominance x dominance type of gene effect. A number of cross combinations were identified for multiple traits based on sca effects and can be further used for obtaining transgressive segregants.

Conclusion:

The results revealed that non-additive genetic variance play a predominant role in the inheritance of most of the traits. The best combinations mostly involved high x low and low x low general combiners for the characters under study. On the basis of gca and sca effects, two parents (i.e. PBW 373 and RAJ 3765) and 17 cross combinations (i.e. five best crosses namely, K 9423 x NW 1014, Unnat Halna x HUW 560, K 9423 x Unnat Halna, K 9162 x NW 1014, K 7903 x HUW 560, were found good general and specific combiners for higher grain yield and also for some other yield contributing traits, respectively. These crosses may be used in heterosis breeding programme for developing new wheat genotype with broad genetic base by multiple crossing programmes. Therefore, crosses involving high x low general combiners in respect of different characters in the present study may be utilized for obtaining trasgressive segregants in the next generation resulting from dominance gene interaction.

Table 1: Pedigree and origin of the parental lines are given in the following table:

Genotype	Species	Parentage	Centre developed
Raj 3765	*T. aestivum*	HD 2402/VL639	R.A.U. Rajasthan
K 9162	*T. aestivum*	K 7827/HD 2204	C.S.A.U. Kanpur
PBW 373	*T. aestivum*	ND/VG1944//KAL/BB/3/YACO`S'/4/VEE#5`S'	P.A.U. Ludhiana
K 9423	*T. aestivum*	HP 1533/Kalyan Sona/UP 262	C.S.A.U. Kanpur
K 7903	*T. aestivum*	HP 1982/K 816	C.S.A.U. Kanpur
Unnat Halna	*T. aestivum*	--------------------------------	C.S.A.U. Kanpur
NW 1014	*T. aestivum*	HAHN`S'	N.D.U.A.T. Faizabad
HUW 560	*T. aestivum*	----------------------	B.H.U. Banaras
NW 1076	*T. aestivum*	OPATA/KILL	N.D.U.A.T. Faizabad
UP 2425	*T. aestivum*	HD 2320/UP 2263	G.B.P.U.A.T. Pantnagar

Table 2: Analysis of variance for combining ability along with components of genetic variance and degree of dominance for 13 traits bread wheat.

	Mean Sum of Square													
SOV	DF	DTF	DTM	PH	PL	FLA	PT	SL	SPS	GPS	TGW	HI	BY	GY
Gca	9	5.11**	2.78**	48.64**	17.16**	129.69**	0.53**	0.93**	7.68**	20.16**	6.19**	29.35**	33.51**	1.90**
Sca	45	15.25**	4.93**	19.44**	5.83**	23.48**	0.08**	0.13**	2.83**	16.47**	4.13**	21.46**	34.95**	6.94**
Error	108	0.53	0.27	1.48	0.33	1.49	0.02	0.06	0.75	6.07	0.73	0.51	2.49	0.57
$\delta^2 g$	-	0.38	0.20	3.93	1.40	10.68	0.04	0.07	0.57	1.17	0.45	2.40	2.58	0.11
$\delta^2 s$	-	14.71	4.66	17.96	5.50	21.98	0.05	0.06	2.08	10.40	3.40	20.95	32.46	6.36
$\delta^2 g/ \delta^2 s$	-	0.02	0.04	0.21	0.25	0.48	0.71	1.07	0.27	0.11	0.13	0.12	0.08	0.02
$(\delta^2 g/ \delta^2 s)^{1/2}$	-	6.21	4.72	2.13	1.98	1.43	1.17	0.96	1.89	2.97	2.73	2.95	3.54	7.57

Table 3: Estimates of general combining ability effects of parents for 13 traits in bread wheat (*Triticum aestivum* L).

Character	DTF	DTM	PH	PL	FLA	PT	SL	SPS	GPS	TW	BY	HI	GY
Parent	GCA	GCA	GCA	GCA	GCA	GCA	GCA	GCA	GCA	GCA	GCA	GCA	GCA
Raj 3765	0.45*	0.73**	-0.33	-0.96**	-0.93**	-0.22**	-0.05	-1.10**	-1.23	-0.82**	3.39**	-2.23**	0.46*
K 9162	0.06	-0.38**	0.10	-0.78**	-5.14**	-0.29**	-0.14*	0.23	1.16	0.72**	1.57**	-1.16**	0.04
PBW 373	0.06	0.76**	-2.40**	-2.05**	-5.82**	-0.09*	0.05	-0.27	0.11	-0.58*	-1.35**	2.73**	0.47*
K 9423	-0.36	-0.13	3.15**	0.25	3.83**	0.29**	0.20**	0.70**	0.89	0.51*	-2.46**	1.91**	-0.13
K 7903	-0.74**	-0.11	-1.21**	0.02	3.37**	-0.02	0.34**	1.00**	1.38*	-0.03	-0.49	-1.64**	-0.90**
Unnat Halna	1.34**	0.39**	-1.62**	2.21**	2.57**	-0.23**	-0.34**	-1.31**	-2.87**	-1.40**	-0.56	-0.14	-0.26
NW 1014	-0.77**	-0.66**	3.36**	0.89**	1.63**	-0.06	-0.56**	-0.59*	-0.58	0.09	1.18**	-0.91**	0.09
HUW 560	0.59**	-0.30*	1.40**	-0.80**	-0.22	0.12**	0.18*	0.64**	0.64	0.24	-1.08*	0.79**	-0.11
NW 1076	-0.24	0.06	-0.85*	0.47**	-0.12	0.28**	0.23**	0.69**	0.70	0.69*	-0.39	0.65**	0.22
UP 2425	-0.38	-0.36*	-1.60**	0.75**	0.83*	0.17**	0.09	0.01	-021	0.57*	0.19	0.00	0.12
SE (Gi)	0.45**	0.32**	0.75**	0.36**	0.76**	0.10**	0.16**	0.54**	1.53**	0.53**	0.98**	0.44**	0.47**
SE (Gi-Gj)	0.68**	0.48**	1.12**	0.53**	1.13**	0.15**	0.24**	0.80**	2.28**	0.79**	1.46**	0.66**	0.70**

Table 4: The estimates of sca effects in 45 F_1s cross combination for 13 traits in spring wheat (*Triticum aestivum* L.).

Character	DTF	DTM	PH	PL	FLA	PT	SL	SPS	GPS	TW	BY	HI	GY
F_1s crosses	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA
A x B	-3.05**	1.36**	9.85**	1.71**	1.83	-0.03	-0.21	1.29	2.19	-1.28	3.37*	-3.72**	-0.35
A x C	4.62**	-0.78	0.72	1.98**	10.67**	0.07	0.05	1.00	1.90	2.42**	4.28**	-3.70**	0.44
A x D	-1.63*	1.78**	-1.77	-0.34	2.49*	-0.07	0.49*	-0.18	-1.35	-0.54	-2.22	-1.01	-1.40
A x E	5.09**	-3.25**	3.53**	-0.15	-2.29*	-0.11	0.26	1.76*	4.97*	2.00*	2.97*	0.08	1.32
A x F	4.34**	-2.42**	-2.19	0.50	2.02	0.55**	0.12	2.18*	1.69	3.59**	-0.12	3.88**	2.00**
A x G	-2.55**	0.30	-2.55*	-4.26**	-4.98**	0.60**	0.21	1.39	2.78	-0.87	8.34**	-3.35**	1.67*
A x H	-5.24**	2.28**	-5.75**	-3.06**	-0.89	-0.11	0.00	-0.82	1.75	-1.88	-4.74**	3.86**	-0.22
A x I	-0.41	3.25**	0.60	-3.13**	-7.83**	-.13	-0.29	-1.28	-0.67	-0.62	-4.28**	8.85**	2.30**
A x J	-4.94**	0.33	-2.35*	3.48**	-1.78	-0.29	0.18	-1.86*	-2.25	1.89*	1.04	1.29	1.26
B x C	-3.66**	2.66**	-3.72**	1.73**	3.89**	0.48**	0.44	0.52	0.97	2.38**	6.88**	-6.14**	0.47
B x D	3.42**	-1.45**	-2.43*	-0.19	-6.60**	-0.37*	-0.26	1.31	3.14	2..35**	-2.55	2.59**	0.13
B x F	6.14**	-2.47**	2.73*	2.97**	-5.71**	0.07	-0.45	0.15	3.64	1.11	7.63**	-2.82**	1.87*
B x G	2.39**	0.69	-1.65	-0.96	-3.30**	0.25	0.28	1.36	2.77	-0.96	-2.24	5.05**	1.57*
B x H	-4.16**	3.41**	-5.61**	-1.64**	2.87*	0.38*	0.27	-0.25	-0.41	1.68*	3.95**	1.29	2.77**
B x I	3.48**	-2.28**	2.98*	-0.12	-4.55**	0.07	0.18	1.13	2.08	-0.20	0.22	-0.46	0.17
B x J	-4.36**	-1.31**	-1.40	-0.09	3.52**	-0.29	0.49*	0.35	0.30	1.39	6.72**	-2.84**	1.73*
B x K	-2.88**	-3.56**	-3.71**	-3.54**	-0.63	-0.12	0.65**	0.19	-0.83	0.34	-7.63**	7.35**	-0.12
C x D	3.42**	0.08	-3.04**	1.11*	-4.19**	0.03	0.16	-1.18	1.08	-3.03**	2.47	-0.30	1.28
C x E	-4.52**	1.72**	-3.51**	-1.76**	-6.49**	0.03	-0.30	1.34	-0.72	-0.13	-1.53	1.86**	0.36
C x F	-5.27**	-2.45**	2.97*	-3.50**	-2.85*	-0.08	0.13	-0.13	0.15	3.54**	-1.99	-1.10	-1.19
C x G	4.51**	1.94**	-1.52	-0.61	-1.88	-0.22	0.02	0.46	0.00	-2.14**	-5.78**	0.80	-2.40**
C x H	5.81**	-3.09**	4.48**	2.75**	-3.03**	0.20	-0.07	1.91*	1.23	2.98**	2.48	-1.95**	0.59
C x I	-3.69**	1.55**	-2.80*	-1.85**	-1.20	-0.06	0.61*	-0.94	2.63	-0.16	-1.77	1.76*	0.18
C x J	2.78**	3.97**	8.58**	0.23	-2.98*	-0.02	-0.07	1.62*	5.13*	-1.22	10.86**	-5.76**	2.38**
D x E	-3.11**	0.61	-3.26**	-2.82**	-1.18	0.02	0.30	1.34	1.82	0.77	3.36*	1.44*	2.23**
D x F	-2.86**	2.11**	-6.38**	-0.48	-2.71*	0.14	-0.04	-1.30	1.63	-2.15**	-1.10	8.75**	3.32**

Conti……..

Table 4: The estimates of sca effects in 45 F_1s cross combination for 13 traits in spring wheat (*Triticum aestivum* L.).

Character	DTF	DTM	PH	PL	FLA	PT	SL	SPS	GPS	TW	BY	HI	GY
F_1s crosses	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA	SCA
D x G	3.59**	-1.17*	6.73**	-2.53**	9.96**	0.10	0.30	0.78	2.38	2.20**	7.34**	0.77	4.01**
D x H	-5.44**	2.14**	-5.37**	-2.01**	-5.99**	-0.01	0.15	1.15	3.50	1.08	-0.70	4.69**	1.66*
D x I	-2.61**	0.11	-4.82**	1.82**	6.14**	0.36	0.08	2.79**	1.86	1.95*	1.27	-1.25	-0.05
D x J	5.53**	-0.81	2.97*	0.67	9.23**	0.34*	-0.06	0.27	1.89	0.68	4.83**	-6.48**	-0.97
E x F	-3.80**	0.75	-1.91	1.52**	1.25	0.07	-0.57*	-1.14	0.16	-1.14	-5.76**	4.28**	-0.82
E x G	-3.02**	-2.20**	-3.80**	-2.70**	2.79*	0.10	-0.48	-0.19	0.52	0.66	5.71**	-1.17	1.97**
E x H	-3.72**	3.11**	3.76**	0.72	2.84*	0.25	0.46	-0.04	0.28	2.03*	-1.91	7.74**	2.64**
E x I	1.78*	-0.59	-0.55	0.09	8.17**	0.06	0.13	2.14*	0.97	1.64*	6.25**	-3.10**	1.17
E x J	-1.41*	1.16*	-2.80*	0.44	-0.18	0.07	0.47	-0.63	1.07	-1.50	-5.13**	2.85**	-1.07
F x G	-1.44*	2.64**	-0.49	-0.16	-1.87	0.09	0.37	0.06	1.62	-1.40	-1.21	3.65**	1.30
F x H	-0.80	-0.39	-1.86	-1.53**	2.71*	0.28	0.12	0.54	2.75	2.93**	9.11**	-1.75*	3.39**
F x I	6.37**	-3.09**	7.89**	4.46**	3.21**	-0.05	0.00	-0.84	-1.68	0.59	2.02	-0.07	0.93
F x J	-1.16	3.00**	-2.19	-4.22**	7.49**	-0.11	0.27	2.35**	4.62*	-1.46	-3.05*	1.31	-0.76
G x H	2.64**	-3.00**	1.52	-0.52	6.42**	0.07	-0.15	2.27**	2.92	-068	7.60**	-2.88**	2.12**
G x I	-2.86	0.97	-2.83*	4.58**	-2.35*	-0.03	0.12	-0.33	0.28	1.36	-4.73**	6.04**	0.57
G x J	3.95**	-1.61**	-2.95*	2.93**	-2.03	0.22	0.11	0.11	2.52	1.36	-6.64**	2.23**	-1.94**
H x I	1.78*	-0.72	-4.27**	1.87**	-0.11	0.20	-0.12	1.05	1.71	-0.33	8.17**	-4.38**	1.56*
H x J	4.92**	2.69**	5.48**	-0.38	2.35*	-0.13	-0.28	0.03	4.19	-0.22	4.20**	-3.63**	0.22
I x J	-2.58**	0.00	-1.80	-3.68**	-3.92**	0.54**	-002	1.66*	1.85	0.32	-0.20	1.71	0.77
SE (Sij)	1.36	0.97	2.26	1.07	2.27	0.30	0.48	1.61	4.57	1.59	2.93	1.33	1.41
SE (Sij-Sik)	2.00	1.43	3.32	1.57	3.33	0.44	0.71	2.37	6.72	2.34	4.31	1.95	2.07

* Significant at 5 % probability level, ** Significant at 1% probability level

DTF- Days to 50 % Flowering, DTM- Days to Maturity, PH- Plant Height, PL- Peduncle Length, FLA- Flag Leaf Area, PT -Productive Tillers, SL- Spike Length, SPS- Spikelets Per Spike, GPS- Grains Per Spike, BY- Biological Yield, GY- Grain Yield, HI- Harvest Index, TGW -Thousand Grain Weight,

REFFERENCES:

Ali, A., Ahsan, I., Shoaib, L., Rana, I. A., Abdul, Q., Seema, M., Etrat, N., Muhammad, K. A., Arslan, A., Syed, A. M., and Waqas, M. (2014). Combining ability studies for yield components in wheat (*Triticum aestivum*). *Journal of Food, Agriculture & Environment,* 12 **(2)**: 383 – 386.

Anonymous, (2014). Progress Report of all India Coordinated Wheat and Barley Improvement Project. 2012-13. Project Director's Report, Directorate of Wheat Research, Karnal, India, p 104.

Braun, H. J., Atlin, G., and Payne, T. (2010). Multi-location testing as a tool to identify plant response to global climate change. In: Reynolds, M.P. (Ed.), Climate Change and Crop Production. CABI, Wallingford, UK, pp. 115–138.

Desale, C. S. and Mehta, D. R. (2013). Heterosis and combining ability analysis for grain yield and quality traits in bread wheat (*Triticum aestivum* L.). *Electronic Journal of Plant Breeding*, **4 (3):**1205-1213.

Dholariya, N. D., Akabari, V. R., Patel J. V. and Chovatia V. P. (2014). Combining ability and gene action study for grain yield and its attributing traits in bread wheat. *Electronic Journal of Plant Breeding,* **5 (3):** 402-407.

Farshadfar, E., Rafiee, F. and Hasheminasab, H. (2013). Evaluation of genetic parameters of agronomic and morpho-physiological indicators of drought tolerance in bread wheat (*Triticum aestivum* L.) using diallel mating design. *Australian Journal of Crop Science*, **7 (2):** 268-275.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Science,* **9**: 463-493.

Hall, A. J. and Richards, R. A. (2013). Prognosis for genetic improvement of yield potential and water-limited yield of major grain crops. *Field Crops Research*, 143: 18–33.

Hayman, B. I. (1954a). The theory of analysis of diallel crosses II. *Genetics*, **43:** 789-809.

Sharma, I., Singh, G., Tyagi, B. S. and Sharma, P. K. (2013). Wheat Improvement in India: Achievements & Future challenges. Souvenir 52ndAll India Wheat and Barley Research Workers Meet, Kanpur, India, pp 1-54.

Kempthorne, O. (1957).An Introduction to Genetical Statistics, (Ed.), *J. Wiley and Sons, Champman and Hall,* London.

Kempthorne, O. and Curnow, R. N. (1961). The partial diallel cross. *Biometrics*, **17:** 229-250.

Khiabani, B. N., Aharizad, S. and Mohammadi, S. A. 2015.Genetic Analysis of Grain Yield and Plant Height in full diallel Crosses of Bread Wheat. *Biological Forum – An International Journal*, 7 (1): 1164-1172.

Kumar, D., Kerkhi, S. A, Singh, G. and Singh, J. B. 2015. Estimates of genetic parameters for grain yield, agro-morphological traits and quality attributes in bread wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences,* **85** (5): 622-7.

Muller, J. (1991). Determining leaf surface area by mean of linear measurements in wheat and triticale (brief report). ArchivFuchtungsforschung, 21 (2): 121-23.

Murphy, K., Balow, K., Lyon, S. R. and Jones, S. S. (2008). Response to selection, combining ability and heritability of coleoptile length in winter wheat. *Euphytica,* **164 (3):** 709-718.

Padhar, P. R., Chovatia, V. P., Jivani, L. L. and Dobariya, K. L. (2013). Combining ability analysis over environments in diallel crosses in bread wheat (*Triticum aestivum* L.). *International Journal of Agricultural Sciences*, **9 (1):** 49-53.

Panse, V. G. and Sukhatme, P. V. (1967). Statistical Methods of agricultural Workers.2nd Edition, I.C.A.R Publ.New Delhi. pp. 381.

Reynolds, M., Foulkes, J., Furbank, R., Griffiths, S., King, J., Murchie, E., Parry, M. and Slafer, G., (2012). Achieving yield gains in wheat. *Plant Cell and Environment*, 35: 1799–1823.

Singh, M. K., Sharma, P. K., Tyagi, B. S. and Singh, G. (2014) .Combining ability analysis for yield and protein content in bread wheat (*Triticum aestivum* L.). *Indian Journal of Agricultural Sciences,* **84** (3): 328–36

Singh, V., Krishna, R., Singh, S. and Vikram, P. (2012). Combining ability and heterosis analysis for yield traits in bread wheat (*Triticum aestivum*).*Indian Journal of Agricultural Sciences*, **82 (11):** 916-21.

Yao, J. b., Ma, H. X., Yang, X., Yao, G. U. and Zhou, M. (2014). Inheritance of grain yield and its correlation with yield component in bread wheat (*Triticum aestivum* L). *African journal of biotechnology*, 13 (12): 1379-1385.