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Combining ability and heterosis for grain yield and its attributing traits in bread wheat (*Triticum aestivum* L.)

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Abstract

The present investigation was undertaken to study the combining ability and heterosis for grain yield and its components in F_1 generation of wheat through Line X Tester analysis. Experiment was conducted with 2 replications and 54 genotypes consisting 10 lines *viz.*, 33rdESWYT150, 20thHRWYT213, 20thHRWYT235, 45thIBWSN1021, 14thFHBSN6418, 36thSAWSN3065, PBW658, KB2013-03, KB2013, VW921 and 4 testers *viz.*, GW273, GW366, RVW 4106, SUJATA and their 40 crosses made in L X T mating fashion in randomized block design at experimental Research Farm, College of Agriculture, Gwalior, (M.P.) during 2014-2015. Genetic analysis revealed that GCA and SCA variances were significant for all characters, thereby, indicating all traits under the control of both additive and non-additive components inheritance. The predictability ratios were more than unity, inferring the predominance of additive gene action governing the traits. Good general combiners on the basis of GCA effects were 33rdESWYT150, PBW658, KB2013-03, KB2013 and VW921, GW273 and SUJATA. These parents involved in F_2 generations may yield superior transgressive recombinant and may exploit either through pedigree selection or progeny selection or mass selection. Segregating generations of good specific combination, 'KB2013-03 × SUJATA', 'PBW658 × SUJATA', 'KB2013 × GW273' and 'VW921 × SUJATA' consisting good general combining parent would be highly desirable for effective selection. The cross 33rdESWYT150 × RVW4106 followed by KB2013-03 × SUJATA and KB2013-03 × RVW4106 was recognized as best heterotic cross as well as high *per se* performance for grain yield and it exhibited highly significant positive heterosis over both the better and mid parent.

Keywords: combining ability, GCA, SCA, relative heterosis, heterobeltiosis

Introduction

Wheat is the principal food crop in most areas of the world and also occupies prominent position in Indian agriculture after rice. It is nutritionally important cereal essential for the food security, poverty alleviation and for livelihoods. It is widely cultivated as staple food crop among the cereals and is contributing about 30% to the food basket of the country. India is the second largest producer of wheat in the world with the production around 75 million tonnes during the last decade and it is a major contributor to the food security system in India, occupying nearly 30.37 million hectares, producing 90.78 million tonnes and productivity 29.89 q/ha and in Madhya Pradesh, grown in 5.56 million hectares with production of 13.37 million tonnes and productivity of 24.05 q/ha (Anonymous 2014-2015) [1]. The substantial improvement in production is utmost necessary not only to meet ever increasing food requirement for domestic consumption, but also for export to earn foreign exchange. To feed the growing population, the country's wheat requirement by 2030 has been estimated at 100 million metric tonnes and to achieve this target, wheat production has to be increased at the rate of <1per annum (Sharma *et al.*, 2011) [15] and this can be achieved through horizontal approach i.e. by increasing area under cultivation or through vertical approach i.e. varietal / hybrid improvement, which is one of the strongest tool to take a quantum jump in production and productivity under various agro- climatic conditions.*Triticum aestivum* (bread wheat) (2n=6x=42) is an allohexaploid produced from two separate naturally occurring hybridization events. The initial hybridization, that occurred between the two grass species *Triticum urartu* (2n=2x=14) (the A genome donor), and *Triticum speltoides* (2n=2x=14) (B genome donor). This new species would have been tetraploid wheat (2n=4x=28) viz., *Triticum turgidum* var. durum (Durum wheat). Hexaploid wheat arose as a result of a second hybridization between the new tetraploid and a third diploid species (2n=2x=14) viz., *Triticum tauschii* (D genome donor). Again, doubling chromosome must have occurred in order to produce a fertile individual. This new species would then have 42 chromosomes; i.e. six complete genomes each of 7 chromosomes.

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Objectives

1. To identify good combining parents to be use in future breeding programme.
2. To estimate genetic parameters i.e. heritability and genetic advances etc.
3. To determine general combining ability (GCA) as well as specific combining ability (SCA) for genotypes.
4. To estimate heterosis in the experimental hybrids for grain yield and contributing traits.
5. To find out causes of associations of components traits through path analysis affecting grain yield and their application in crop improvement.

Materials and Methods: The experimental material consisted 54 genotypes consisting 10 lines *viz.*, 33rdESWYT150, 20thHRWYT213, 20thHRWYT235, 45thIBWSN1021, 14thFHBSN6418, 36thSAWSN3065, PBW658, KB2013-03, KB2013, VW921 and 4 testers *viz.*, GW273, GW366, RVW 4106, SUJATA and their 40 crosses made in L X T mating fashion in randomized block design at experimental Research Farm, College of Agriculture, Gwalior, (M.P.) during 2014-2015. Observations were recorded on randomly selected 5 tagged plants for grain yield per plant and different yield contributing traits *viz.*, days to heading, days to maturity, plant height, tillers per plant, spike length, 1st internodes length, weight of spikes per plant, weight of grains per spike, grains per spike, test weight, canopy temperature index, biological yield and harvest index. The analysis was carried out by adopting Kempthorne (1957) [11] for estimation of variances components and combining ability effects. Heterosis over mid parents and better parents (Fonseca and Patterson, 1968) [6] were determined as per standard procedure. Significance of heterosis value was tested using‘t’ test.

Results and Discussion: Line × tester analysis techniques has been extensively used in almost all the major field crops to estimates GCA and SCA variances and effect and to understand In the present research work, variances due to both lines and testers were significant for days to heading, plant height, tillers per plant, spike length, weight of spikes per plant, grains per spike, test weight, grain yield per plant, canopy temperature index, biological yield and harvest index. However, lines were significant for days to maturity, 1st inter-node length, weight of grains per spike. Variances due to Line × tester were significant for all the 14 characters (Singh *et al.*, 2013 [16] and kapoor *et al*., 2011 [10] also reported similar results). In the present study both GCA and SCA variances were significant for most of the characters, thereby, indicating importance of both additive as well as non additive components of genetic variance in the control of these traits (table 1.1). Singh *et al*., (2013) [16] and Kumar *et al*., (2011) [13] also reported similar results.

Genetic components: Genetic component of variances is assessed through the estimates of GCA and SCA variances. The additive genetic variance is equal to GCA variance and dominance variance is equal to SCA variance. In the present research, the genetic component’s magnitudes showed that the additive components of variances were higher compared to dominance components of variances for all characters. The ratio of genetic components “σ^2gca / σ^2sca” also showed more than one, indicating predominance of additive variances for almost all characters (table 1.2). Present finding are in confirmation with Kandil *et al.*, (2016) [9], Khiabani *et al.*, (2015) [12], Ismail K.A.S. (2015) [7] and Awan *et al.*, (2005) [3], were recorded predominance of additive variances for all the traits.

Combining ability: Combining ability plays major role in the evaluation of inbred in terms of their breeding values; and this will help to decide efficient breeding method to be applied in segregating generation.

General combining ability effects: It is primarily a function of additive genetic variance; it helps in the selection of suitable good general combining parents for hybridization. Data presented in table 1.3 revealed that 5 lines viz., 33rdESWYT150, PBW 658, KB 2013-03, KB 2013 and VW921 reported significant and positive GCA effect for grain yield, test weight, weight of spike/plant, biological yield and harvest index, thereby, suggesting good general combiner for these traits. Tester ‘GW273’ was good general combiner for grain yield, test weight and biological yield, whereas, tester SUJATA registered significant and positive GCA effect for grain yield, days to heading, spike length and harvest index, thereby, suggested good general combiner for these traits. Lines 33rdESWYT150 was also reported significant and positive GCA effect for tillers/plant and weight of grains/plant. Line KB2013-03 also exhibited significant positive GCA effect for plant height, weight of grain/spike and grains/spike. Significant positive GCA effect was reported in KB2013 and VW921 for canopy temperature index. These genotypes can be used in the development of high yielding varieties through the pedigree selection and progeny selection or mass selection in later generations in promising segregating generations in wheat Present finding are in confirmation with Kandil *et al*., (2016) [9], Ismail K.A.S. (2015) [7], Kalhoro *et al.* (2015) [8], Aslam *et al.* (2014) [2], Singh *et al.* (2013) [16], Raj and Kandalkar (2013) [14], Kumar *et al.* (2011) [13] and Kapoor *et al.* (2011) [10].

Specific combining ability Effects: It is mainly a function of dominance variances; it helps in the identification of superior cross combination for commercial exploitation of heterosis. In self–pollinated crops like wheat, SCA effects are not much important as they are mostly related to non-additive gene effects excluding those of arising from complementary gene action or linkage effects they cannot be fixed in pure lines. Further superiority of the hybrids might not indicate their ability to yield transgressive segregates; rather SCA would provide satisfactory criteria. However, if a cross combination exhibiting high SCA as well as high *per se* performance having at least one parent as good general combiner for a specific trait, it is expected to throw desirable transgressive segregants in later generations. Data presented in table 1.4 revealed that 19 crosses showed significant and positive SCA effect, thereby, indicating good specific combinations for grain yield and other attributing traits. Crosses viz., KB2013-03 × SUJATA’, KB2013 × GW273’, PBW658 × SUJATA’ and ‘VW921 × SUJATA’ registered best good specific combiner for grain/yield because these crosses were the results of good x good general combiners and reported significant positive SCA effect. Crosses ‘33rdESWYT150 × GW366’, ‘33rdESWYT150 × RVW4106’, ‘2OthHRWYT213 × GW273’, ‘2OthHRWYT213 × SUJATA’, ‘20thHRWYT235 × SUJATA’, ‘45thIBWSN1021 × GW273’, ‘14thFHBSN6418 × SUJATA’, ‘KB2013-03 × GW366’, ‘KB2013 × RVW4106’ and ‘VW921 × GW366’ were the result of good x poor general combiner and also reported significant positive SCA effect for grain yield. Rest of the crosses *viz*., ‘45thIBWSN1021 × RVW4106’, ‘36thSAWSN3065 × RVW4106’, ‘36thSAWSN3065 ×GW366’, ‘14thFHBSN6418 × GW366’, ’45thIBWSN1021 × RVW4106’, ’20thHRWYT235 × GW366’ were result of poor x poor general combiner but exhibited significant positive SCA effect for grain/yield, thereby, suggesting good specific combiner for these traits. Present finding are in confirmation with Kandil *et al*., (2016) [9], Kalhoro *et al*. (2015) [8], Aslam *et al*. (2014) [2], Singh *et al*. (2013) [16], Raj and Kandalkar (2013) [14], Kumar *et al*. (2011) [13], Kapoor *et al*. (2011) [10] and Desale *et al*., (2014) [4].

Heterosis: The aim of estimation of heterosis in the present study has to spot out the best combination of parents giving high degree of useful heterosis and characterization of parents for their genotypic worth for future use in breeding programme. All characters had shown considerable amount of heterosis over better parent (Heterobeltiosis) and mid parent (relative heterosis). Present finding are in confirmation with Devi *et al.* (2013) [5]. The degree of heterosis however differed for different characters. Data presented in table 1.5 revealed that 4 cross *viz*., ‘KB2013 × RVW4106’, ‘33rdESWYT150 × RVW4106’, ‘KB2013-03 × SUJATA’ and ‘KB2013-03 × RVW4106’ recorded significant heterobeltiosis and relative heterosis in positive direction for grain yield, while another 3 cross ‘33rdESWYT150 × GW366’, ‘45thIBWSN1021 × RVW4106’ and ‘PBW658 × RVW4106’ recorded significant positive relative heterosis for grain yield. Devi *et al.* 2013 [5] also reported similar result. Cross ‘KB2013 × RVW4106’ was also reported significant positive heterobeltiosis and relative heterosis for weight of spike/plant and test weight. Cross ‘33rdESWYT150 × RVW4106’ also showed significant heterobeltiosis and relative heterosis in positive direction for tillers/plant, weight of spike/plant, test weight and biological yield. Cross ‘KB2013-03 × RVW4106’ was also reported significant positive heterobeltiosis and relative heterosis for days to maturity, test weight and biological yield. Cross ‘KB2013-03 × SUJATA’ showed significant positive relative heterosis for 1st inter-node length, weight of spike/plant, test weight, biological yield and harvest index, while significant positive heterobeltiosis was reported for test weight and canopy temperature index. Cross ‘33rdESWYT150 × GW366’ was also reported significant positive relative heterosis for weight of spike/plant, test weight, and biological yield. Cross ‘45thIBWSN1021 × RVW4106’ was also reported significant positive heterobeltiosis and relative heterosis for biological yield. Cross ‘PBW658 × RVW4106’ also showed significant positive relative heterosis for biological yield. Further it was noticed that both significant heterobeltiosis or / and relative heterosis were recorded for attributing traits without showing heterosis for grain yield.

Conclusion

Genotypes 33rdESWYT150, PBW658, KB2013-03, KB2013, VW921, GW273 and SUJATA were identified good general combiner for grain yield per plant and its components in wheat. Cross 33rd ESWYT 150 X GW 366, 33rd ESWYT 150 X RVW4106, 2OthHRWYT 213 X GW273, 2OthHRWYT 213 X SUJATA, 20thHRWYT 235 X GW366, 20thHRWYT 235 X SUJATA, 45thIBWSN1021 X GW273, 45thIBWSN1021 X RVW4106, 14thFHBSN6418 X GW366, 14thFHBSN6418 X SUJATA, 36thSAWSN3065 X GW366, 36thSAWSN3065 X RVW4106, PBW658 X SUJATA, KB2013-03 X GW366, KB2013-03 X SUJATA, KB2013 X GW273, KB2013 X RVW4106, VW921 X GW366, VW921 X SUJATA were identified good specific combiner for grain yield per plant and its components in wheat so it may be suitable for exploitation in future plant breeding programme. Additive variance played the major role in determining all of the characters. Some of the cross recorded significant heterosis for grain yield, thereby, indicating further scope of hybrid development in near future. The crosses KB2013-03 X SUJATA was desirable for selecting higher yielding and short duration plant, while cross KB2013 X RVW4106 was desirable for the selection of high yielding dwarf plant over the better parent. The crosses KB2013-03 X RVW4106, KB2013 X SUJATA and KB2013-03 X SUJATA were suitable for selection of high yielding and short duration plant over the mid parent. The cross ESWYT 150 X RVW4106 was desirable for selecting higher yielding and short duration plant over both better and mid parent.

Suggetions for further work

The following relevant suggestions could be drawn for further scope of improvement from the present study:

Good general combiners like 33rdESWYT150, PBW658, KB2013-03, KB2013 and VW921, GW273 and SUJATA could be used in the development of high yielding varieties through the simple / recurrent selection from promising segregating cross generations in wheat.

New recombinant promising single plants may be selected in F_2 generations of good cross 33rdESWYT150 X RVW4106, KB2013-03 X SUJATA and 33rdESWYT150 X GW 366 involving one of the good specific combining parents.

The cross 33rd ESWYT 150 X RVW4106 was found higher yielding and short duration plant over both better and mid parent. Thus it was very desirable for further breeding programme while selecting the genotype.

Table 1.1: Analysis of variance for combining ability for Grains yield and yield contributing characters in wheat

Sources	DF	Days to heading	Days to maturity	Plant height	Tillers/Plant	1st inter-node length	Spike length	Wt. of Spike/Plant
Lines	9	2.48**	4.47**	25.01**	0.91**	0.09**	0.76**	6.10**
Tester	3	3.90**	0.55	8.04**	0.27	0.01	0.90**	0.54*
L X T	27	2.14**	5.49**	80.51**	0.38**	0.08**	2.41**	3.58**
Error	53	0.40	0.49	0.66	0.08	0.01	0.01	0.17

Sources	DF	Grains weight/ Spike	Grains/Spike	Test weight	Grains yield/Plant	Canopy temperature index	Biological yield	Harvest index
Lines	9	0.08**	16.35**	48.25**	7.40**	0.0011**	8.66**	64.79**
Tester	3	0.01	26.96**	2.42**	0.42**	0.0004*	2.32**	3.69**
L X T	27	0.03**	79.12**	14.63**	2.29**	0.0010**	3.45**	15.93**
Error	53	0.01	1.06	0.18	0.02	0.0001	0.32	1.57

*, ** significant at 5 and 1 percent levels, respectively

Table 1.2: Genetic components for Grains yield and its attributes in wheat

	Days to heading	Days to maturity	Plant height	Tillers/Plant	1st inter-node length	Spike length	Wt. of Spike/Plant
Covariances							
Cov HS (Line)	0.04	-0.05	-2.77	0.03	0.00	-0.08	0.13
Cov HS (Tester)	0.09	-0.62	-9.06	-0.01	-0.01	-0.19	-0.38
Cov HS (Average)	0.01	-0.02	-0.45	0.00	0.00	-0.01	0.01
Cov FS	5.85	4.90	45.96	1.06	0.10	2.07	6.85
Genetic components							
σ2GCA (Lines)	0.01	-0.02	-0.45	0.00	0.00	-0.01	0.01
σ2GCA(Testers)	0.02	-0.06	-1.81	0.01	0.00	-0.05	0.03
σ2GCA (Parents)	11.77	-33.10	-526.51	-0.16	-0.50	-11.43	-17.24
σ2SCA	0.87	2.50	39.93	0.15	0.04	1.20	1.70
σ2GCA / σ2SCA	13.52	-13.26	-13.19	-1.06	-12.87	-9.54	-10.11
σ2 A	23.54	-66.19	-1053.02	-0.31	-1.00	-22.87	-34.48
σ2 D	0.87	2.50	39.93	0.15	0.04	1.20	1.70

Table: Continued…

	Grains weight/Spike	Grains/Spike	Test weight	Grains yield/Plant	Canopy temperature index	Biological yield	Harvest index
Covariances							
Cov HS (Line)	0.00	-3.14	1.68	0.26	0.0000	0.65	6.11
Cov HS (Tester)	0.00	-6.52	-1.53	-0.23	-0.0001	-0.06	-0.61
Cov HS (Average)	0.00	-0.46	0.17	0.03	0.0000	0.03	0.25
Cov FS	0.08	55.12	52.38	8.10	0.0014	10.79	67.04
Genetic components							
σ2GCA (Lines)	0.00	-0.46	0.17	0.03	0.00	0.03	0.25
σ2GCA(Testers)	0.00	-1.82	0.67	0.10	0.00	0.11	1.02
σ2GCA (Parents)	-0.09	-401.83	-45.77	-7.03	0.00	-2.09	-30.72
σ2SCA	0.01	39.03	7.23	1.13	0.00	1.56	7.18
σ2GCA / σ2SCA	-6.58	-10.29	-6.33	-6.20	-7.80	-1.34	-4.28
σ2 A	-0.18	-803.67	-91.54	-14.05	-0.01	-4.19	-61.45
σ2 D	0.01	39.03	7.23	1.13	0.00	1.56	7.18

Table 1.3: Parents showing significant GCA effects for grain yield along with GCA effects for other attributes

Parents	Lines/ Tester	Grain yield/plant(g)		Days to heading		Days to maturity		Plant height(cm)		Tillers/plant (cm)	
		Mean	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**
1. GW 273	T	17.91	0.17*	85.50	0.10	135.00	0.22	104.80	-0.05	8.30	0.08
2. SUJATA	T	17.33	0.07*	85.50	0.55**	137.00	-0.09	104.60	-0.09	8.30	-0.12
3. VW 921	L	16.56	0.75**	87.50	0.45**	135.00	-0.60**	103.90	2.83**	7.10	-0.01
4. PBW 658	L	16.46	0.47**	86.50	-1.05**	138.50	-0.47	104.70	-1.95**	7.00	-0.21**
5. 33rd ESWYT 150	L	16.23	1.51**	87.00	-0.05	139.00	-0.35	100.20	-1.85**	7.20	0.77**
6. KB 2013-03	L	16.11	0.72**	89.50	-0.05	136.50	-0.47	109.60	1.75**	6.90	0.04
7. KB 2013	L	14.98	0.68**	88.00	0.08	137.00	-0.60**	109.60	0.45	6.90	-0.51**

Table: Continued…

Parents	Lines/ Tester	1st inter-node length(cm)		Spike length(cm)		Spike weight/plant(g)		Grain weight/spike(g)		Grains /spike	
		Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	mean	GCA
1. GW 273	T	3.11	-0.02	10.75	-0.17**	24.46	0.16	2.26	0.00	68.10	-1.09
2. SUJATA	T	2.68	0.02	11.32	0.28**	23.78	0.12	2.11	0.02	70.80	1.52
3. VW 921	L	2.77	0.04	11.11	0.05	23.08	0.66**	2.04	0.06	66.50	-0.76
4. PBW 658	L	2.90	-0.09**	10.29	-0.15**	23.41	0.32**	2.12	0.04	60.80	0.54
5. 33rd ESWYT 150	L	3.02	-0.05	10.43	-0.61**	21.22	1.36**	2.00	0.13**	61.90	-2.11**
6. KB 2013-03	L	3.02	-0.10**	8.94	-0.23**	21.01	0.68**	2.07	0.07**	54.20	0.94**
7. KB 2013	L	2.91	-0.04	11.03	0.22**	20.09	0.58**	2.02	0.07**	67.30	-0.36

Table: Continued….

Parents	Lines/ Tester	Test weight(g)		Canopy temperature index		Biological yield(g)		Harvest index (%)	
		Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
1. GW 273	T	44.78	0.42**	0.41	-0.01**	32.70	0.43**	54.75	0.11
2. SUJATA	T	43.33	0.13	0.36	0.00	33.48	-0.15	51.75	0.56*
3. VW 921	L	41.54	1.99**	0.36	0.02**	35.04	-0.73**	47.27	2.79**
4. PBW 658	L	41.82	1.11**	0.35	-0.01**	35.76	0.96**	46.59	2.36**
5. 33rd ESWYT 150	L	40.79	3.73**	0.36	-0.01	39.40	2.18**	41.22	1.57**
6. KB 2013-03	L	40.49	2.02**	0.36	0.01	35.29	1.05**	45.65	3.28**
7. KB 2013	L	38.69	1.64**	0.37	0.01**	37.96	-0.92**	43.09	3.00**

*, ** significant at 5 and 1 percent levels, respectively

Table 1.4: Crosses showing significant SCA effects for grain yield and its attributes

SN	Crosses	Grain yield/plant(g)		Days to heading	Days to maturity	Plant height(cm)	Tillers/plant	1st inter-node length(cm)
		mean	SCA	SCA	SCA	SCA	SCA	SCA
1	33rd ESWYT 150 ×GW 366	17.87	0.59**	-0.50	-1.45**	2.73**	0.36	0.16**
2	33rd ESWYT 150 ×RVW 4106	18.06	0.72**	0.15	-1.10**	5.99**	0.56**	0.14**
3	20th HRWYT 213 ×GW 273	16.89	1.67**	-0.10	-0.10	1.85**	0.59**	-0.26**
4	20th HRWYT 213 ×SUJATA	15.44	0.23**	-0.05	-0.85	5.59**	0.19	0.09
5	20th HRWYT 235 ×GW 366	15.57	1.27**	-0.50	-1.70**	0.83	-0.16	-0.20**
6	20th HRWYT 235 ×SUJATA	14.80	0.29**	-0.05	0.15	1.62**	0.17	0.13
7	45th IBWSN 1021 ×GW 273	15.70	0.67**	2.52**	-0.10	6.75**	-0.31	0.24
8	45th IBWSN 1021 ×RVW 4106	15.87	1.09**	-1.23**	1.35**	1.86**	-0.24	-0.31**
9	14th FHBSN6 4188 ×GW ×366	15.79	0.54**	-0.63	0.92	2.98**	0.24	0.18**
10	14th FHBSN6 4188 ×SUJATA	15.87	0.41**	0.80	-1.72**	-0.03	-0.23	-0.24**
11	36th SAWSN 3065 ×GW 366	16.31	0.82**	0.63	-1.33**	0.15	0.14	0.05
12	36th SAWSN 3065 ×RVW 4106	16.06	0.51**	-0.73	-0.47	4.41**	0.16	0.00
13	PBW 658 ×SUJATA	16.89	0.42**	-0.55	0.03	7.62**	0.37	0.12*
14	KB 2013-03 ×GW366	17.16	0.66**	0.00	-0.83	4.63**	-0.81	-0.17**
15	KB 2013-03 × SUJATA	18.00	1.29**	0.95	0.97*	2.32**	-0.48**	0.21**
.16	KB 2013 × GW 273	17.27	0.49**	-0.73	-1.10**	5.47**	-0.63**	0.17**
17	KB 2013 × RVW 4106	17.42	0.90**	-0.48	-0.85	0.79	-0.27	-0.18**
18	VW 921 × RVW 4106	17.43	0.91**	0.00	1.30**	3.75**	0.04	0.13
19	VW 921 × SUJATA	17.01	0.27**	0.45	-0.85	-2.46**	-0.03	-0.20**

Table: Continued…

SN	Crosses	Spike length(cm)	Spikes weight/plant(g)	Grain weight/spike(g)	Grains/spike	Test weight(g)
		SCA	SCA	SCA	SCA	SCA
1	33rd ESWYT 150 ×GW 366	0.22**	0.84**	0.11*	-1.50**	1.56**
2	33rd ESWYT 150 ×RVW 4106	-0.70**	1.24**	-0.01	-3.56**	1.65**
3	20th HRWYT 213 ×GW 273	0.27**	1.96**	0.08	0.71	4.25**
4	20th HRWYT 213 ×SUJATA	-1.53**	-0.66**	0.05	-8.40**	0.80**
5	20th HRWYT 235 ×GW 366	0.59**	0.73**	0.17	-3.43**	3.50**
6	20th HRWYT 235 ×SUJATA	-0.78**	1.45**	-0.03	-3.10**	0.92**
7	45th IBWSN 1021 ×GW 273	-1.52**	1.79**	0.02	-8.78**	1.67**

Table: Continue…

SN	Crosses	Spike length(cm)	Spikes weight/plant(g)	Grain weight/spike(g)	Grains/spike	Test weight(g)
		SCA	**SCA**	**SCA**	**SCA**	**SCA**
8	45th IBWSN 1021 ×RVW 4106	-0.30**	0.65**	0.08	-2.57**	2.66**
9	14th FHBSN6 4188 ×GW ×366	-1.25**	0.74**	-0.03	-8.85**	1.33**
10	14th FHBSN6 4188 ×SUJATA	-0.19**	-0.03	0.06	-0.32	1.08**
11	36th SAWSN 3065 ×GW 366	-0.30**	0.75**	0.11*	0.70	2.14**
12	36th SAWSN 3065 ×RVW 4106	-1.17**	0.79**	0.05	-5.76**	1.13**
13	PBW 658 ×SUJATA	-1.58**	-0.48	-0.06	-10.62**	1.13**
14	KB 2013-03 ×GW366	0.24**	0.91**	0.10	1.25	1.39**
15	KB 2013-03 × SUJATA	-0.06	1.81**	0.14**	1.18	2.91**
.16	KB 2013 × GW 273	-1.40**	0.36	0.14**	-4.61**	1.15**
17	KB 2013 × RVW 4106	0.43	0.39	0.04	1.09	2.23**
18	VW 921 × RVW 4106	-1.44**	1.43**	0.09	-9.15**	2.10**
19	VW 921 × SUJATA	0.34**	0.27	0.08	-0.72	0.32

Table: Continue…

SN	Crosses	Canopy temperature index	Biological yield	Harvest index
		SCA	**SCA**	**SCA**
1	33rd ESWYT 150 ×GW 366	0.02**	0.14	1.19
2	33rd ESWYT 150 ×RVW 4106	-0.01	0.08	2.11**
3	20th HRWYT 213 ×GW 273	0.03**	-0.40	4.58**
4	20th HRWYT 213 ×SUJATA	0.01	0.77	-0.22
5	20th HRWYT 235 ×GW 366	0.01	1.10**	1.95
6	20th HRWYT 235 ×SUJATA	-0.01	1.31**	-0.66
7	45th IBWSN 1021 ×GW 273	-0.02	1.53**	0.17
8	45th IBWSN 1021 ×RVW 4106	0.00	1.49**	1.74

9	14th FHBSN6 4188 ×GW ×366	0.03**	0.60	0.66
10	14th FHBSN6 4188 ×SUJATA	-0.04**	1.97**	-1.06
11	36th SAWSN 3065 ×GW 366	-0.02**	-0.01	3.25**
12	36th SAWSN 3065 ×RVW 4106	0.00	0.54	-2.55**
13	PBW 658 ×SUJATA	-0.01	-0.07	0.94
14	KB 2013-03 ×GW366	0.00	0.80*	0.50
15	KB 2013-03 × SUJATA	0.00	-2.57**	6.44**
.16	KB 2013 × GW 273	0.00	-0.82**	1.93
17	KB 2013 × RVW 4106	0.02**	0.76	1.78
18	VW 921 × RVW 4106	-0.03**	-0.75	3.14**
19	VW 921 × SUJATA	0.00	1.48**	-1.17

*, ** significant at 5 and 1 percent levels, respectively

Table 1.5: Heterosis over better parent and mid parent for grain yield and its attributes

Crosses	**Grain yield/plant**		**Days to heading**		**Days to maturity**		**Plant height**		**Tillers/plant**		**1st inter-node length**		**Spike length**	
	BP	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**
‘KB2013 × RVW4106’	16.33**	16.88**	-2.84**	-1.44	-1.09**	-2.61**	-2.59**	-10.14**	-9.49	-6.87**	-12.78**	-9.60**	-1.09	9.43**
‘33rdESWYT150 × RVW4106’	11.24**	16.05**	-1.15	-0.29	-2.52**	-1.81**	0.05	4.28**	15.28**	18.57**	0.00	3.25**	-22.19**	-19.35**
‘KB2013-03 × SUJATA’	3.90**	7.67**	-2.31**	0.00	-1.08**	-0.91	-4.78**	-2.33**	-21.69**	-14.47**	1.38	7.37**	-9.98**	0.59
‘KB2013-03 × RVW4106’	3.20**	7.28**	-3.91**	-1.71	1.46**	1.65**	-15.69**	-15.48**	1.45	2.19	-0.99	2.22	-25.53**	-17.16**
33rdESWYT150 × GW366’	0.34	4.99**	-2.30**	-1.45	-2.88**	-1.82**	-3.43**	0.19	-1.19	6.41	-2.24	-0.49	-5.37**	2.07
‘45thIBWSN1021 × RVW4106’	-0.53	2.90**	-6.04**	-3.12**	-0.73	-0.55	-3.53**	-3.33**	-10.39**	-4.83	-10.07**	-7.62**	-9.63**	-9.30**
‘PBW658 × RVW4106’	-2.43**	2.47**	-1.16	-0.58	-2.53**	-2.00**	-4.36**	-2.41**	-7.14	-5.80	-1.38	-0.17	11.14**	-7.30**

	Weight of spike/plant		**Weight of grain/spike**		**Grain/spike**		**Test weight**		**Canopy temperature index**		**Biological yield**		**Harvest index**	
Crosses	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**	**BP**	**MP**
‘KB2013 × RVW4106’	4.31**	8.82**	4.21	5.65	-7.73	-6.84**	12.54**	13.52**	-21.92**	-19.72**	1.55	7.49	2.40	3.59
‘33rdESWYT150 × RVW4106’	11.80**	13.55**	6.27	7.07	-17.06**	-12.08	10.44**	14.33**	-21.13**	-20.00	4.00**	12.00**	-0.08	3.30
‘KB2013-03 × SUJATA’	3.36	9.76**	4.96	6.1	-5.51	7.04**	3.67**	7.18**	-16.90**	-16.08**	0.03	2.67	-1.53	4.64**
‘KB2013-03 × RVW4106’	1.28	3.40	-0.97	1.49	-18.22	-8.63**	5.46**	8.78**	-18.06**	-16.31**	8.39**	10.78**	-4.81	-3.16
33rdESWYT150 × GW366’	-1.13	5.47**	-3.95	2.46	-3.23	-2.20	0.54	4.96**	-21.79**	-18.12**	5.29**	14.44**	-19.86**	-9.28**
‘45thIBWSN1021 × RVW4106’	-1.07	0.50	0.76	0.76	-10.13**	-3.97	-0.55	1.80	-14.29**	-13.67**	8.73**	13.95**	-11.04**	-9.82**
‘PBW658 × RVW4106’	-4.04**	-0.85	-1.18	2.45	-3.21	2.63	-4.33	0.23	-26.09**	-26.09**	2.03	4.95**	-5.51*	-2.91

*, ** significant at 5 and 1 per cent level, respectively, MP: mid parent, BP: better parent

References

1. Anonymous. Progress Report of All India Coordinated Wheat and Barley Improvement Project, 2014-2015, IIW and BR, Karnal, India. 2015; 1(1):1.
2. Aslam R, Munawar M, Salam A. Genetic architecture of yield components accessed through line × tester analysis in wheat (*Triticum aestivum* L.). Universal J PL. Sci. 2014; 2(5):93-96.
3. Awan SI, Malik MF, Siddique M. Combining ability analysis in inter-varietal crosses for component traits in hexaploid wheat. J Agric. and social Sci. 2005; 1813-2235/316-317.
4. Desale CS, Mehta DR, Singh AP. Combining ability analysis in bread wheat. J of Wheat Res. 2014; 6(1):25-28.
5. Devi L, Swati, Goel P, Singh M, Jaiswal JP. Heterosis studies for yield and yield contributing traits in bread wheat (Triticum *aestivum* L.). The Bioscan, 2013; 8(3):905-909.
6. Fonseca S, Patterson FL. Hybrid vigor in seven parental diallel cross in common wheat (*Triticum aestivum* L.). Crop Sci. 1968; 8:85-88.
7. Ismail KAS. Heterosis and combining ability analysis for yield and its Components in Bread Wheat (*Triticum aestivum* L.). Int. J Curr. Microbiol. App. Sci. 2015; 4(8):1-9.
8. Kalhoro FA, Rajpar AA, Kalhoro SA, Mahar A, Ali A *et al.* Heterosis and combing ability in *F*1 population of hexaploid wheat (*Triticum Aestivum* L.). American J PL. Sci. 2015; 6:1011-1026.
9. Kandil AA, Sharief AE, Hasnaa SM, Gomaa. Estimation of general and specific combining ability in bread wheat (*Triticum aestivum* L.). Int. J Agri. R. 2016; 8(2):37-44.

10. Kapoor E, Mondal S, Dey T. Combining ability analysis for yield and yield contributing traits in winter and spring wheat combinations. J Wheat Res. 2011; 3(1):52-58.
11. Kempthrone O. An introduction to genetical statistics. John Wiley and Sons' Inc, New York, 1957.
12. Khiabani BN, Aharizad S, Mohammadi SA. Genetic analysis of grain yield and plant height in full diallel crosses of bread wheat. Biological Forum-An Int. J. 2015; 7(1):1164-1172.
13. Kumar A, Mishra VK, Vyas RP, Singh V. Heterosis and combining ability analysis in bread wheat (*Triticum aestivum* L.). J PL. Breeding and Crop Sci. 2011; 3(10):209-217.
14. Raj p, Kandalkar VS. Combining ability and heterosis analysis for grain yield and its components in wheat. J Wheat Res. 2013; 5(1):45-49.
15. Sharma I, Shoran J, Singh G, Tyagi BS. Wheat Improvement in India. Souvenir of 50th All India Wheat and Barley Res. Workers, Meet, 2011, 11.
16. Singh K, Singh UB, Sharma SN. Combining ability analysis for yield and its components in bread wheat (*Triticum aestivum* L.). J Wheat Res. 2013; 5(1):63-67.
17. Singh H, Sharma SN, Sain RS. Heterosis studies for yield and its components in bread wheat over environments. Hereditas, 2004; 141:106-114.