
Genetic Analysis of Various Agronomic Traits in Some Intra and Inter-Specific Crosses of Wheat

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Abstract: Six wheat genotypes (4 hexaploid and 2 tetraploid) against plant height, days to heading, days to anthesis, days to maturity, grain filling period, grains per spike and 1000 grain weight characters were studied for combining ability and heterosis through 6 × 6 half diallel fashion. This experiment was conducted at Regional Agricultural Research Institute Bahawalpur during 2016-17. Results of mean square of general combining ability (GCA) and specific combining ability (SCA) was found significant for all studied characters except for plant height and grains per spike against SCA. Ratio of GCA/SCA showed the involvement of additive gene action in the inheritance of all under studied traits. Durum-1 was found best parent among all other parents against 1000 grain weight and days to heading. Miraj-08 was good general combiner as it reflected maximum grain yield per plant. Best specific combining ability and heterosis was exhibited by cross combination Ass-11 × Chakwal-50, Glaxy-13 × Chakwal-50 and Chakwal-50 × Miraj-08 against plant height, grain per spike and yield character. Results indicated that selection of best general combiner would be helpful in increasing yield through hybridization and superior hybrids may develop by the selection of superior best specific combiners.

Keywords: *Triticum aestivum*, General Combining Ability, Specific Combining Ability, Heterosis, Half Diallel Analysis

1. Introduction

Wheat is considered as important staple food and strategic crop worldwide with 27% contribution in world's cereal production. It is first ever plant grown by the human beings and due to its wider adaption and resistance to biotic and abiotic stresses it is now widely cultivated throughout the world [8].

Wheat is most important food grain crop of Pakistan. Worldwide Pakistan ranked 6th in wheat with production 25.4 million tonnes on area 9260 thousand hectares [3].

The contribution of wheat in agriculture and total GDP of Pakistan is about 9.9% and 2% (Anonymous, 2016-17). The average wheat production has increased in Pakistan but its yield is still low when compared to many other countries. Population of Pakistan is increasing geometrically which has been a great challenge for agriculture scientists. Yield potential of recent wheat varieties is not increasing in parallel to overcome demand of population in Pakistan. To meet the challenge of increasing population there is a dire need to

develop high yielding varieties of wheat through different breeding methods which are adaptable to different climatic condition of the country. Breeder should develop few crosses, instead of maintaining many crosses, from parents having high genetic potential. Selection of best performing parents for hybridization is based on the production of desirable segregants when a specific line combine with other lines [7]. Heterosis play important role in combining ability of parents and can be included in breeding programme [14].

Combining ability analysis is important way to select parents with desirable characters along with information regarding nature and magnitude of controlling quantitative traits [9]. Better parents are selected on the basis of general combining ability while specific combining ability is associated with the selection of superior hybrids [1]. In GCA additive genetic effect is involved while SCA is due to non-additive genetic effect i.e dominance or epistasis. Information related to mechanism of genetic controlling different plant characters in parents may help in improving the genetic makeup of plant to maintain and improve crop production.

Diallel approach is a powerful tool for evaluating combining ability and heterosis in addition to analyse the genes nature involving in the inheritance of grain yield and its contributing traits [11]. Parental lines can be tested in all possible combinations through diallel crosses [6]. Selection of parents with desirable characteristics showing good GCA and SCA effects for yield and its trait components are essential [4].

The objectives of present study were to estimate the combining ability of some local bread and durum wheat genotypes and to assess the heterotic potential of intra and inter-specific crosses of wheat. Another important objective was to generate diversification in wheat germplasm to be used as base line for development of highly stable wheat varieties under changing climatic conditions.

2. Material and Methods

Six genotypes of *Triticum aestivum* were crossed in half diallel fashion at Regional Agricultural Research Institute Bahawalpur during 2015-16. Spikes of female were hand emasculated for crossing and covered by butter paper bag so that contamination of foreign pollen may not occur. Pollen of selected male parent was applied on the receptive ovaries of the emasculated spikes of the female parents. Sufficient number of spikes was emasculated for each of the 6 parents and pollinated to obtain maximum seed of 15 direct crosses which were to be planted in the following year. At harvesting F_0 seeds of each cross were threshed separately and stored.

In the next year (2016-17) the F_0 seeds of 15 crosses with six parents were sown in the field in randomized complete block design (RCBD) with three repeats. Sowing was done with manual dibbler maintaining plant to plant distance 15 cm and row to row distance 30 cm respectively. In each hole two seeds were sown and later thinned to one seedling per hole after 10-12 days of germination. Standard agronomic practices were performed from sowing to maturity of crop.

At reproductive stage ten guarded plants were randomly selected from each experimental unit to record data for various traits including days to heading, days to anthesis, grain filling period, days to maturity, plant height (cm), grains per spike, 1000-grain weight (g) and grain yield per plant (g). Combining ability analysis and heterotic effect of F_1 hybrid was carried out by method given by Griffing [5].

3. Results and Discussion

3.1. Mean Performance

Means of parents and their cross combination were given in table 1. Broad range of expression was shown by parents for various plant characters especially for plant height ranging 88 cm to 102 cm. Among six parents, minimum plant height (88 cm) was observed in parent Durum-2 followed by Durum-1 (90 cm). Genotype Ass-11 exhibited maximum plant height 102 cm. Minimum days (94) against days to heading were recorded in Duram-2 while Chakwal-50 showed maximum days in heading i.e 102. Genotype Duram-2 took 100 days to anthesis while maximum days were recorded in Glaxy-13 (109). Early maturity (139 days) was observed in Miraj-08 followed by Duram-1 in which 142 days were recorded for maturity. Glaxy-13 showed maximum days i.e 148 to mature. Genotype Miraj-08 exhibited minimum days (36) against grain filling character and maximum days (43) for grain filling was recorded in Duram-2. Maximum no of grain per spike shown by Ass-11 which was 54 followed by Chakwal-50 in which 50 grain/spike was recorded. Ass-11 and Duram-1 showed maximum weight (42 g) against 1000 grain weight and minimum weight was observed in Chakwal-50 which was 39 g. Highest grain yield/plant (35 g) was observed in variety Glaxy-13 followed by Miraj-08 which exhibited 34 g yield/plant while Duram-1 and Duram-2 showed minimum yield/plant 31 g among all parents.

Mean values of 15 crosses were presented in table 1. Cross combination Durum-1 x Durum-2 performed better against plant height trait with minimum value 90 cm followed by cross Miraj-08 x Durum-1 having plant height 92 cm. Better performance with minimum value (94) for days to heading was performed by cross Ass-11 x Miraj-08 and maximum value was recorded for Ass-11 x Chakwal-50. Glaxy-13 x Durum-2 took 99 days for anthesis while maximum days i.e 109 was recorded for Glaxy-13 x Ass-1. Early maturity (140 days) was recorded in cross Miraj-08 x Durum-1 and cross combination Miraj-08 x Durum-2 took minimum days (32) for grain filling while maximum days was exhibited by Glaxy-13 x Durum-2 which was 45 days. Highest grains (50) in a spike was found in cross Ass-11 x Durum-2 followed by Chakwal-50 x Durum-2 (49). Weight of 1000-grain is a vital yield component and is more or less stable character of wheat. Cross combination Durum-1 x Durum-2 and Chakwal-50 x Miraj-09 exhibited maximum 1000 grain weight 44 g and yield per plant 37 g.

Table 1. Mean values of parents and crosses for yield related traits in wheat.

	Plant height	Days to heading	Days to anthesis	Days to maturity	Grain filling period	Grains per spike	1000-grain weight	Grain yield per plant
Parents								
Galaxy-13	101	101	109	148	39	46	39	35
Aas-11	102	101	108	144	37	54	42	33
Chakwal-50	98	102	107	146	39	50	39	33
Mairaj-08	93	95	103	139	36	46	40	34
Durum-1	90	96	102	142	39	44	42	31
Durum-2	88	94	100	143	43	49	38	31
Crosses								
Galaxy-13 × Aas-11	102	100	109	146	37	49	39	36
Galaxy-13 × Chakwal-50	100	99	106	145	38	48	38	36
Galaxy-13 × Mairaj-08	97	96	102	141	39	46	40	34
Galaxy-13 × Durum-1	96	100	105	144	39	45	39	33
Galaxy-13 × Durum-2	96	95	99	145	45	47	37	34
Aas-11 × Chakwal-50	99	102	109	144	35	50	40	35
Aas-11 × Mairaj-08	100	94	101	142	41	49	41	37
Aas-11 × Durum-1	101	100	107	142	36	48	40	33
Aas-11 × Durum-2	101	101	108	144	36	50	38	32
Chakwal-50 × Mairaj-08	97	96	101	142	41	46	43	37
Chakwal-50 × Durum-1	94	102	108	144	36	45	41	33
Chakwal-50 × Durum-2	94	98	105	145	40	49	37	32
Mairaj-08 × Durum-1	92	99	106	140	34	44	41	36
Mairaj-08 × Durum-2	93	102	108	140	32	47	38	34
Durum-1 × Durum-2	90	95	101	141	40	46	44	32

3.2. Combining Ability

3.2.1. Analysis of Variance (ANOVA)

Plant breeders rely on the availability of genetic diversity for the improvement of any plant trait. Significant differences (Table 2) of wheat varieties and their hybrids indicated the presence of genetic variation between genotypes and crosses. Highly significant or significant mean squares due to male, female and their interaction showed the involvement of both additive and non-additive i.e dominance and epistasis gene action in the expression of studied traits. [2] also found significant differences among wheat varieties

against days to heading, weight of 1000 grain and grain yield per plant. General combining ability (GCA) of parents was observed higher than specific combining ability (SCA) of crosses for all traits like plant height, days to heading, days to anthesis, days to maturity, grain filling period, grains per spike, 1000 grain weight and grain yield per plant. High GCA reflected the prominent role of additive type of gene action in the inheritance of studied traits although significant mean squares for specific combining ability of crosses were also observed against characters except plant height and grains per spike. Similar findings have also been observed in wheat by [12].

Table 2. Mean square values corresponding to diallel analysis for various characters in bread wheat.

SOV	d.f.	Plant height	Days to heading	Days to anthesis	Days to maturity	Grain filling period	Grains per spike	1000-grain weight	Grain yield per plant
Replication	2	3.1027 ^{NS}	5.9141 ^{NS}	15.0714 ^{NS}	10.3542**	0.4449 ^{NS}	27.4464**	1.1594 ^{NS}	1.0173 ^{NS}
Genotype	20	6.4949**	25.1385**	34.0833**	15.7354**	29.530**	17.7208**	10.5207**	11.0493**
Error	40	52.6531	16.0521	9.0798	1.0490	9.0111	4.9110	3.5420	3.0325
GCA	5	61.20**	11.53**	15.33**	18.75**	10.15*	22.03**	6.75**	8.29**
SCA	15	2.99	1.97**	10.03**	0.74*	9.73**	0.53	2.42*	2.14*
Error	40	2.16	7.32	3.02	0.34	3.00	1.63	1.18	1.01
GCA/SCA		20.46	5.85	1.52	25.33	1.04	41.56	2.78	3.87

3.2.2. General Combining Ability

The general combining ability gives information about better performing parents based on their hybrid performance to exploit heterosis breeding. Among parents, genotype Durum-2 was best general combiner against plant height and days to anthesis with minimum negative value 2.93 and 1.74. Durum-1 exhibited maximum 1000 grain weight (1.14). Minimum days to heading (1.38), days to maturity (2.38) and maximum grain yield per plant (1.06) was shown by Mairaj-08. Ass-11 showed best performance against grain filling

period character with minimum negative value 1.22 and exhibited maximum no of grains per spike 2.61. Parents with maximum GCA effects were the best general combiners as valuable genes were present in them for the improvement of traits and such parents may be preferred for selection and hybrid development [10].

3.2.3. Specific Combining Ability

Among fifteen hybrids, best specific combining ability against plant height was exhibited by cross combination Ass-11 x Chakwal-50 with minimum negative value 1.91cm.

Minimum days to heading (4.14) and days to anthesis (4.68) was recorded in Ass-11 x Miraj-08. The hybrid Galaxy-13 x Chakwal-50 was found to be best specific combiner against days to maturity and grains per spike with minimum negative value 1.61 and maximum positive value 0.58. Minimum days in grain filling period was recorded in cross Miraj-08 x Durum-2 as it showed minimum negative SCA value 7.10. High yield per plant (2.26g) was observed in cross combination Chakwal-50 x Miraj-08 (Table 3). Selection of

such crosses with high specific combining ability would be fruitful in the development of superior hybrid through heterosis breeding. It is not a rule that hybrid should be produced by parents with best general combiners sometimes hybrid may be developed by the combination of either parent showing poor GCA (Patel et al., 1997) e.g Ass-11 x Chakwal-50 for plant height, Ass-11 x Miraj-08 for days to anthesis, Galaxy-13 x Chakwal-50 for days to maturity and Durum-1 x Durum-2 for 1000 grain weight respectively in this study.

Table 3. Estimates of GCA effects of parents and SCA effects of crosses for yield related characters of wheat.

	Plant height	Days to heading	Days to anthesis	Days to maturity	Grain filling period	Grains per spike	1000-grain weight	Grain yield per plant
GCA for parents								
Galaxy-13	2.36 **	0.17	0.81	1.87 **	1.07	-0.68	-0.90 *	0.85 *
Aas-11	3.82 **	1.08 *	1.72 **	0.50 *	-1.22 *	2.61 **	0.47	0.35
Chakwal-50	0.69	1.58 **	0.97	1.17 **	0.19	0.61	-0.07	0.22
Mairaj-08	-1.18 *	-1.38 **	-1.36 *	-2.38 **	-1.01	-1.06 *	0.60	1.06 **
Durum-1	-2.76 **	-0.21	-0.40	-0.96 **	-0.56	-2.14 **	1.14 **	-0.99 **
Durum-2	-2.93 **	-1.25 **	-1.74 **	-0.21	1.53 **	0.65	-1.24 **	-1.49 **
SCA for crosses								
Galaxy-13 x Aas-11	-0.91	-0.01 ns	1.82 *	0.39	-1.43	-0.42	-0.08	1.35 **
Galaxy-13 x Chakwal-50	0.21	-1.51 *	-0.43	-1.61 **	-1.18	0.58	-0.54	1.14 *
Galaxy-13 x Mairaj-08	-0.58	-1.22 *	-2.10 **	-1.40 **	0.69	-0.09	0.80	-1.70 **
Galaxy-13 x Durum-1	0.34	1.28 *	-0.05	0.18	0.23	0.33	-1.41 **	-0.99 *
Galaxy-13 x Durum-2	0.51	-2.35 **	-4.72 **	-0.24	4.48 **	-0.13	-0.70	1.18 **
Aas-11 x Chakwal-50	-1.91 **	1.24 *	1.32	-0.57 *	-1.89 *	-0.71	0.09	0.64
Aas-11 x Mairaj-08	0.96	-4.14 **	-4.68 **	0.30	4.98 **	-0.05	0.09	1.80 **
Aas-11 x Durum-1	3.21 **	0.36	0.36	-0.45	-0.81	0.04	-1.12 *	0.18
Aas-11 x Durum-2	3.38 **	2.40 **	3.36 **	0.80 **	-2.56 **	-0.76	-1.41 **	-0.99 *
Chakwal-50 x Mairaj-08	1.42 *	-2.30 **	-3.26 **	0.30	3.57 **	-1.05	2.63 **	2.26 **
Chakwal-50 x Durum-1	0.01	1.86 **	2.45 **	0.22	-2.23 **	-1.30 *	0.09	-0.36
Chakwal-50 x Durum-2	-0.16	-0.76	0.45	0.80 **	0.36	-0.09	-1.54 **	-0.53
Mairaj-08 x Durum-1	-0.79	2.49 **	2.78 **	0.43	-2.35 **	-0.30	-0.58	1.80 **
Mairaj-08 x Durum-2	1.05	6.53 **	6.45 **	-0.65 *	-7.10 **	0.24	-0.87	0.30
Durum-1 x Durum-2	-0.37	-1.97 **	-1.85 *	-1.07 **	0.77	0.33	3.92 **	0.35

3.2.4. Heterosis

Means of eight characters of fifteen F₁ hybrids were compared with values of mid parent (relative heterosis), better parent (heterobeltosis) and over standard parent (table 4).

Short stature and early maturing plants of wheat are required to improve plant height and yield improving characters, hence negative heterosis is favourable for plant height, days to heading, days to anthesis, days to maturity and grain filling period. Heterosis for plant height was non-significant in all crosses. Maximum heterosis over Mid parent was exhibited by cross combinations Ass-11 x Chakwal-50 (-0.835cm), Ass-11 x Miraj-08 (-3.918), Galaxy-13 x Durum-2 (-4.944), Galaxy-13 x Chakwal-50 (-1.699), Miraj-08 x Durum-2 (-20.50g), Durum-1 x Durum-2 (10.084g), and Chakwal-50 x Miraj-08 (12.562) against plant height, days to heading, days to anthesis, days to maturity, grain filling period, 1000 grain weight and yield/plant.

Highly significant negative heterobeltosis was found in Galaxy-13 x Durum-2 (-9.146) against days to heading and plant height (-4.934 cm) while Chakwal-50 x Miraj-08

showed positive heterotic effect i.e 7.500g and 10.891g for thousand grain weight and yield/plant relative to better parent heterosis. Minimum day to heading (-6.623) and days to maturity (-4.719) was exhibited by Ass-11 x Miraj-08 and Galaxy-13 x Miraj-08. Minimum heterobeltosis for grain filling period was shown by hybrid Miraj-08 x Durum-2 (-26.923).

Significant positive results 8.695 and 6.666g relative to standard heterosis were recorded for cross combination Ass-11 x Chakwal-50 and Chakwal-50 x Miraj-08 for grain/spike and yield/plant. Durum-1 x Durum-2 reflected short stature (-10.855cm) and Ass-11 x Miraj-08 required minimum days to heading (-6.623). Early maturing characters like days to anthesis(-9.146) was observed by hybrid Galaxy-13 x durum-2 while minimum days for grain filling (-18.803) period and days to maturity (-5.617) were shown by Miraj-08 x Durum-2. These hybrids contained valuable genes from both parents and thus grain yield and yield contributing traits can be increased by exploring hybrids which exhibited maximum heterosis and heterobeltosis under studied traits [13].

Table 4. Heterotic effects of F1 hybrids over mid parents (MPH) and better parents (BPH) and standard heterosis (STH).

Crosses		Plant height	Days to heading	Days to anthesis	Days to maturity	Grain filling period	Grains per spike	1000-grain weight	Grain yield per plant
Galaxy-13 × Aas-11	MPH	0.164	-0.993	0.923	-0.114	-3.083	-2.000	-2.880	6.8627*
	BPH	0.000	-0.993	0.000	-1.573*	-5.982	-9.259*	-6.349	3.810
	STH	0.329	-0.993	0.000	-1.573*	-5.982	6.521	0.855	3.810
Galaxy-13 × Chakwal-50	MPH	0.000	-2.791	-1.543	-1.699**	-2.127	0.000	-2.127	6.4039*
	BPH	-1.645	-3.583	-2.743	-2.472**	-2.542	-4.000	-2.542	2.857
	STH	-1.645	-1.987	-2.743	-2.472**	-1.709	4.347	-1.709	2.857
Galaxy-13 × Mairaj-08	MPH	-0.172	-1.874	-3.459*	-1.624**	3.539	0.000	2.109	-0.971
	BPH	-4.276	-4.636	-6.402*	-4.719**	0.000	0.000	0.833	-2.857
	STH	-4.276	-4.636	-6.402*	-4.719**	0.000	0.000	3.418	-2.857
Galaxy-13 × Durum-1	MPH	0.873	1.356	-0.472	-0.460	-0.425	0.000	-4.132	-1.507
	BPH	-4.934	-0.993	-3.658	-2.696**	-0.847	-2.173	-7.200	-6.667
	STH	-4.934	-0.993	-3.658	-2.696**	0.000	-2.173	-0.854	-6.667
Galaxy-13 × Durum-2	MPH	1.582	-2.397	-4.944*	-0.686	10.121*	-1.052	-3.478	4.569
	BPH	-4.934	-5.629	-9.146**	-2.471**	4.615	-4.081	-5.128	-1.905
	STH	-4.934	-5.629	-9.146**	-2.471**	16.239*	2.173	-5.128	-1.905
Aas-11 × Chakwal-50	MPH	-0.835	0.821	1.869	-0.459	-7.017	-3.846	-0.819	6.5989*
	BPH	-2.623	0.000	1.552	-1.141	-10.169	-7.407*	-3.968	6.061
	STH	-2.303	1.656	-0.304	-2.696**	-9.401	8.695*	3.418	0.000
Aas-11 × Mairaj-08	MPH	2.740	-3.918	-4.126*	0.117	12.328*	-2.000	0.000	11**
	BPH	-1.639	-6.623	-6.211*	-1.620*	11.818	-9.259*	-2.380	9.9009*
	STH	-1.316	-6.623	-7.926**	-4.494**	5.128	6.521	5.128	5.714
Aas-11 × Durum-1	MPH	5.226	1.356	1.748	-0.350	-6.140	-2.040	-3.585	3.627
	BPH	-0.984	-0.993	-0.621	-1.157	-9.322	-11.11**	-3.968	1.010
	STH	-0.658	-0.993	-2.439	-4.044**	-8.547	4.347	3.418	-4.762
Aas-11 × Durum-2	MPH	5.965	3.425	4.669*	0.580	-10*	-2.912	-5.439	-0.523
	BPH	-0.984	0.000	0.931	0.231	-16.92**	-7.407*	-10.31*	-4.040
	STH	-0.658	0.000	-0.914	-2.696**	-7.692	8.695*	-3.418	-9.523*
Chakwal-50 × Mairaj-08	MPH	1.920	-2.365	-3.184	-0.116	8.370	-4.166	8.403**	12.562**
	BPH	-0.680	-5.863	-5.00*	-2.511**	4.237	-8*	7.500	10.891*
	STH	-3.947	-4.305	-7.317**	-4.044**	5.128	0.000	10.256*	6.666
Chakwal-50 × Durum-1	MPH	0.533	2.521	3.349	-0.115	-9.322*	-4.255	1.235	2.083
	BPH	-3.742	-0.651	1.250	-1.598*	-9.322	-10*	-1.600	0.000
	STH	-6.908	0.993	-1.219	-3.146**	-8.547	-2.173	5.128	-6.666
Chakwal-50 × Durum-2	MPH	0.894	-0.170	1.453	0.346	-2.419	-1.010	-3.896	1.052
	BPH	-4.082	-4.235	-1.875	-0.684	-6.923	-2.000	-1.769	-2.040
	STH	-7.237	-2.649	-4.268	-2.247**	3.418	6.521	-5.128	-8.571*
Mairaj-08 × Durum-1	MPH	0.365	4.014	3.414	0.000	-9.251	-2.222	0.408	9.743**
	BPH	-1.434	3.472	3.246	-0.941	-12.711	-4.347	-1.600	5.940
	STH	-9.539	-1.325	-3.048	-5.393**	-11.965	-4.347	5.128	1.904
Mairaj-08 × Durum-2	MPH	2.941	8.289242*	7.084**	-0.709	-20.50**	-1.052	-1.287	4.663
	BPH	0.358	7.719298*	5.519*	-2.097**	-26.923**	-4.081	-4.166	0.000
	STH	-7.895	1.656	-0.914	-5.617**	-18.803**	2.173	-1.709	-3.809
Durum-1 × Durum-2	MPH	1.498	0.000	0.000	-0.936*	-3.226	-1.075	10.084**	2.150
	BPH	0.743	-1.042	-1.302	-1.398*	-7.692	-6.122	4.800	1.063
	STH	-10.855	-5.629	-7.621*	-4.943**	2.564	0.000	11.965**	-9.523*

4. Conclusion

Our results indicated the presence of both additive and non additive (dominant or epistasis) gene action in the inheritance of studied traits. General combining ability (GCA) of parents was observed higher than specific combining ability (SCA) of crosses for all traits like plant height, days to heading, days to anthesis, days to maturity, grain filling period, grains per spike, 1000 grain weight and grain yield per plant. Durum-1 was found best parent among all other parents against 1000

grain weight and days to heading. Miraj-08 was good general combiner as it reflected maximum grain yield per plant. These parents contain valuable genes for improvement of characters and may be preferred for selection and hybridization program. Best specific combining ability and heterosis was exhibited by cross combination Ass-11× Chakwal-50, Galaxy-13 × Chakwal-50 and Chakwal-50 × Miraj-08 against plant height, grain per spike and yield character. Selection of such crosses would be beneficial for the development of superior hybrids through heterosis breeding.

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