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COMBINING ABILITY ESTIMATES OF SOME YIELD AND QUALITY RELATED TRAITS IN SPRING WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

Combining ability effects and variances for yield and quality related traits were carried out in an 8x8 diallel cross of spring wheat. The general combining ability effects were significant for all the characters except days to maturity, whereas specific combining ability effects were significant for most of the characters except grain yield, flag leaf area, number of spikelets spike^{-1}, protein contents and lysine contents. The part of variance due to SCA was greater than GCA for most of the characters indicating the importance of non-additive gene action. The parental varieties, Chakwal 97 and Kohistan 97, proved as the best general combiners for grain yield plant^{-1}. Shahkar 95 proved to be better combiner for plant height, number of tillers m^{-2} and number of grains spike^{-1}. MH 97 was shown to be the best general combiner for protein contents. The cross Pothowar 93 x Kohistan 97 gave the highest SCA values for 1000 grain weight and protein contents. For grain yield plant^{-1} the cross Pak 81 x Kohistan 97 showed maximum SCA values.

Introduction

The main target of a plant breeder in a self-pollinated crop like wheat is to develop true breeding (homozygous) population with superior quantitative traits. This objective will be achieved only when proper choice of parents to get desirable recombinations through hybridization is considered. Most of the important characters are now known to be controlled by polygenes i.e., a number of genes with small individual additive effects. Environment also contributes appreciably to the expression of the total variation. It is hardly possible to measure the individual effect of genes. Therefore, average effects of genes involved in the expression of individual characters are considered. Among the various diallel techniques, combining ability analysis outlined by Griffing (1956) is being considered to be more useful to the wheat breeders. Earlier workers revealed that both general and specific combining abilities were involved for yield and yield components (Bhatt, 1971; Bitzer & Fu, 1972; Malik, 1978; Chen & Chen, 1987; Chaudhry *et al*., 1992; Hasnain *et al.,* 2006; Chowdhary *et al.,* 2007). They reported that additive genetic variance was responsible for a large part of total genetic variability for yield and yield components. Since there is sufficient work reported on different cultivars of wheat, however there is sporadic information on selected local cultivars. Therefore, present study was launched to carry out the mechanism of gene action controlling the yield and quality traits of selected wheat genotypes.

Materials and Methods

For studying the inheritance pattern of yield and quality related parameters, an 8x8 parent diallel was conducted. Eight genotypes (Pak-81, Pothowar 93, Parwaz 94, Shahkar

95, Suleiman 96, Chakwal 97, Kohistan 97, MH 97) selected on the basis of phenotypic diversity, were sown with two sowing dates in order to facilitate hybridization during November, 2003. The genotypes were crossed in all possible combinations. The seeds of 8x8 parent diallel (28 direct crosses and 28 indirect crosses) along with their parents were sown in the field during first week of November, 2004. Randomized Complete Block Design was followed in the experiment having three replications. Each treatment comprised a single row of 5-meter length in each replication. Inter row and interplant distances were kept at 30 cm and20 cm, respectively. All the necessary agronomic practices were followed as recommended for wheat crop. Basal fertilizer dose of NPK was applied @ 100-40-0 kg ha^{-1} to meet the nutritional requirements of the crop plants.

The data for days to heading, days to maturity, plant height (cm), grain filling period, number of tillers m^{-2}, flag leaf area (cm^{2}), spike length (cm), number of spikelets spike^{-1}, number of grains spike^{-1}, 1000-grain weight (g) and grain yield plant^{-1} (g) were recorded on 10 guarded plants selected randomly and averaged on plant^{-1} basis. While quality related traits i.e., protein contents, lysine contents, flour yield and gluten contents were determined by following the methods of Anon., (1983). The data were then subjected to simple analysis of variance technique (Steel & Torrie, 1980). Combining ability analysis Method 1, Model 1 as proposed by Griffing (1956) was used to study the nature of gene action controlling the particular parameters.

Results and Discussion

The analysis of variance for 8 parent diallel revealed highly significant differences among parents and hybrids for all the characters under study (Table 1). Results of analysis of variance (mean squares) from the combining ability analysis (Table 2) showed that all the characters revealed significant differences for gca. For sca most of the characters showed significant differences except flag leaf area, spikelets spike^{-1}, protein contents and lysine contents. Reciprocal effects were also significant for most of the characters except flag leaf area, spikelets spike^{-1} and lysine contents. Estimates of variances due to gca, indicated the predominance of additive gene action for flag leaf area, grain filling period, days to heading, grain yield plant^{-1}, protein contents and lysine contents. High sca variances for plant height, spike length, number of spikelets spike^{-1}, days to maturity, 1000 grain weight and gluten contents revealed the importance of non-additive gene action for these characters and hence delayed selection for the improvement of these characters is suggested in later generations where the genes are fixed and expressed fully. High reciprocal variances for number of grains spike^{-1}, number of tillers m^{-2} and flour yield suggested the importance of material contributing the parents in hybridization. Moreover,high contribution of reciprocal effect also restricts the bulking of hybrids sharing same parentage but reciprocally mated and hence, these should be handled separately for detection in later segregating generation.

Estimates of gca effects of the parents are shown in Table 3. It is quiet evident from the results that wheat varieties Chakwal 97 and Kohistan 97 proved as better general combiners for grain yield with GCA values 32.458 and 29.479, respectively. Chakwal 97 also proved as best combiner for traits like days to maturity, 1000 grain weight, number of spikelets spike^{-1} and gluten contents. Shahkar 95 proved to be better combiner for plant height, number of tillers m^{-2} and number of grains spike^{-1}. MH 97 was shown to be best general combiner for protein contents with maximum value of 0.311. The wheat variety Pak 81 was good general combiner for grain filling period and spike length while

Suleiman 96 was shown to be best general combiner for flag leaf area and flour yield with maximum values of 2.021 and 1.566, respectively. Kohistan 97 was shown to be best general combiner for lysine contents and days to heading with maximum values of 0.290 and 2.266. The comparison of values revealed that wheat varieties Pothowar 93 and Perwaz 94 were the poorest general combiners for most of the characters studied. These results suggest that six parental varieties Pak 81, Shahkar 95, Suleiman 96, Kohistan 97, Chakwal 97 and MH 97 can be further used as the source material in the development of segregating generation.

The estimates of specific combining ability effects of the crosses given in Table 4 revealed that the cross Pak 81 x Kohistan 97 showed the highest sca value for plant height (3.482). The cross Pothowar 93 x Kohistan 97 gave the highest values for 1000 grain weight (3.282) and protein contents (0.678). It is evident from the analysis that best sca effects for grain filling period, spike length and flour yield with values of 6.958, 2.379 and 3.522 respectively, were exhibited by the cross Pothowar 93 x Suleiman 96. These cross involved one poor general combiner while the other a better general combiner. It is obvious that a parent with low gca effects may have the potential to be exploited through hybridization with better general combiner. The cross Perwaz 94 x Shahkar 95 gave maximum sca value (3.227) for number of grains spike^{-1}. Similarly for days to maturity, the cross Pothowar 93 x Suleiman 96 showed highest sca value (5.677). The cross Pak 81 x Pothowar 93 revealed highest sca value (3.214) for days to heading followed by the cross Pak 81 x Suleiman 96 with sca value of 3.193. Highest sca value (20.422) for tillers^{m-2} was shown by the cross Parwaz 94 x Shahkar 95. For grain yield plant^{-1} the cross Pak 81 x Kohistan 97 gave maximum sca value (40.604). For flag leaf area, number of spikelets spike^{-1}, gluten contents and lysine contents the crosses Pak 81 x Perwaz 94, Perwaz 94 x MH 97, Suleiman 96 x Chakwal 97 and Shahkar 95 x Kohistan 97 gave the high sca values of 2.586, 1.627, 2.510 and 0.820 respectively.

Table 1. Analysis of variance of different quantitative traits in F_1 generation of 8x8 diallel cross of wheat.

Parameters	Genotypic mean squares	Replication mean squares	Error mean squares
Days to heading	71.57**	30.15	20.81
Days to maturity	255.06**	196.29	33.57
Plant height (cm)	106.81**	96.26	16.04
Number of tillers m^{-2}	3727.10**	1723.60	420.10
Flag leaf area (cm^2)	87.77**	34.60	15.99
Grain filling period (days)	288.44**	105.77	57.25
Spike length	2.18*	2.24	1.44
Number of spikelets spike^{-1}	15.59**	8.89	3.55
Number of grains spike^{-1}	50.73**	92.45	8.26
1000 grain weight (g)	25.62**	33.40	16.91
Grain yield plant^{-1} (g)	3506.10**	3173.80	448.10
Protein contents (%)	2.44**	11.46	1.13
Lysine contents (%)	1.24**	0.26	0.03
Flour yield (%)	18.49**	0.49	5.65
Gluten contents (%)	23.53**	72.15	11.70

**, * = Significant at 1% and 5% probability level, respectively

Table 2. Mean squares for combining ability in an eight-parent complete diallel of wheat.

Genetic parameters	df	Plant height	Flag leaf area	Grain filling period	Spike length	Spikelets per spike	Grains per spike	Days to heading
GCA	7	21.480**	7.710**	9641.437**	7110.805*	7.043*	66.838**	103.799**
SCA	28	32.858**	5.515	800.6597**	1004.489*	4.334	14.767**	12.482**
Reciprocal	28	12.677**	3.122	662.8949**	551.605**	3.110	17.532**	13.456**
Error	126	1.105	4.820	69.2216	104.292	2.806	1.217	3.822
GCA σ^2		-0.676	0.809	553.350	382.631	0.171	3.269	5.716
SCA σ^2		17.826	0.390	410.631	505.373	0.857	7.607	4.862
RECσ^2		5.786	-0.848	296.836	223.656	0.152	8.157	4.817

** = Significant at 1% and * = Significant at 5%

Table 2. (Cont'd.).

Genetic parameters	Days to maturity	Tillers m^{-2}	1000 grain weight	Grain yield per plant	Protein contents	Lysine contents	Flour yield	Gluten contents
GCA	103.799**	79.5249**	26.205**	2.555*	2.807**	27.613**	0.613**	12.842**
SCA	12.482**	21.280**	14.639**	0.548	0.466	5.600	0.364**	5.232**
Reciprocal	13.456**	27.892**	11.473**	0.746	1.138*	5.142	0.416**	5.430**
Error	3.822	9.659	5.516	0.864	0.709	3.900	0.012	1.883
GCA σ^2	-0.323	3.653	0.732	0.757	1.021	1.377	0.015	0.479
SCA σ^2	3.681	6.523	5.126	-0.177	-0.136	0.954	0.197	1.880
RECσ^2	4.817	9.116	2.978	-0.0589	0.214	0.621	0.20	1.773

Table 3. General combining ability effects in an 8x8 complete diallel of wheat.

S. No	Parents	Plant height	Flag leaf area	Grain filling period	Spike length	Spikelets per spike	Grains per spike	Days to heading
1.	Pak 81	-0.114	-1.682	5.229	0.322	-0.669	-0.992	-5.880
2.	Pothowar 93	0.499	-0.551	-0.396	0.217	-0.345	-2.279	-0.151
3.	Perwaz 94	0.384	-1.551	0.479	-0.058	0.251	1.398	-0.464
4.	Shahkar 95	1.140	0.008	-0.750	-0.243	0.122	2.767	0.203
5.	Suleiman 96	0.785	2.021	-1.500	-0.083	0.181	-2.017	1.370
6.	Chakwal 97	0.606	1.106	-0.479	0.041	0.988	-1.481	1.411
7.	Kohistan 97	-0.849	0.779	-1.875	-0.063	0.539	-0.077	2.266
8.	MH 97	-2.451	-0.131	-0.780	-0.132	-1.066	2.681	2.245
	SE[g(i)]	0.245	0.549	0.726	0.217	0.391	0.258	0.457
	SE[g(i)-(j)]	0.371	0.830	1.098	0.328	0.592	0.390	0.691

Table 3. (Cont'd.).

S. No	Days to maturity	Tillers m^{-2}	1000 grain weight	Grain yield per plant	Protein contents	Lysine contents	Flour yield	Gluten contents
1.	-0.052	-4.026	-0.371	-17.917	-0.117	-0.284	0.334	0.365
2.	0.240	3.641	0.550	-13.250	0.104	-0.110	-0.839	-0.844
3.	0.060	15.849	-1.265	-13.208	0.040	0.181	-0.884	-0.302
4.	-0.198	37.182	0.213	-22.375	0.125	0.128	-0.732	-0.344
5.	0.197	-0.589	0.667	4.021	-0.372	-0.065	1.566	0.240
6.	0.615	-49.250	0.776	32.458	0.144	-0.188	0.730	2.823
7.	0.323	6.495	-0.263	29.479	-0.236	0.290	-0.578	-1.719
8.	-1.531	-9.297	0.187	0.792	0.311	0.049	0.403	-0.219
	0.521	1.945	0.513	2.388	0.196	0.026	0.320	0.461
	0.787	2.941	0.776	3.610	0.297	0.039	0.485	0.698

Table 4. Specific combining ability effects in an 8x8 complete diallel of wheat.

S. No.	Crosses			Plant height	Flag leaf area	Grain filling period	Spike length	Spikelets per spike	Grains per spike	Days to heading	Days to maturity
1.	Pak-81	x	Pothowar 93	-1.281	-2.721	-3.104	0.303	-0.582	-2.271	3.214	-0.906
2.	Pak-81	x	Perwaz 94	-5.799	2.586	0.687	0.258	-1.697	-0.748	-0.307	0.073
3.	Pak-81	x	Shahkar 95	0.942	0.057	0.750	0.175	-2.359	2.367	2.359	1.131
4.	Pak-81	x	Suleiman 96	-1.181	-0.235	-5.167	-1.028	-0.610	0.700	3.193	-2.365
5.	Pak-81	x	Chakwal 97	-2.599	-1.002	3.646	-1.105	-1.094	-2.535	-2.016	1.719
6.	Pak-81	x	Kohistan 97	3.483	0.416	6.708	-0.318	-0.679	1.777	-5.370	1.177
7.	Pak-81	x	MH-97	-6.173	-2.411	-4.125	0.135	-0.335	0.969	1.484	-0.702
8.	Pothowar93	x	Perwaz 94	2.349	-2.993	-0.688	-0.194	-0.837	-3.360	1.464	-0.031
9.	Pothowar93	x	Shahkar 95	0.165	-4.216	-1.958	0.128	-0.651	1.337	-0.703	-3.427
10.	Pothowar93	x	Suleiman 96	-1.815	-1.439	6.958	2.379	0.108	2.704	-0.536	5.677
11.	Pothowar93	x	Chakwal 97	2.987	0.975	-3.063	0.062	0.572	0.485	1.255	-1.906
12.	Pothowar93	x	Kohistan 97	-9.751	0.908	0.500	-0.418	1.472	-3.869	-3.766	-0.281
13.	Pothowar93	x	MH-97	3.087	0.020	1.500	-0.751	-0.602	2.656	-2.578	0.573
14.	Perwaz 94	x	Shahkar 95	-0.601	1.744	2.000	0.355	0.596	3.227	0.943	3.240
15.	Perwaz 94	x	Suleiman 96	-1.241	1.800	-0.583	-0.122	0.565	1.744	-0.057	0.177
16.	Perwaz 94	x	Chakwal 97	-3.380	-5.680	4.896	0.164	-1.842	-5.025	0.401	3.760
17.	Perwaz 94	x	Kohistan 97	-1.206	-0.137	2.289	0.223	1.056	0.163	-1.236	1.836
18.	Perwaz 94	x	MH 97	-1.195	0.385	2.493	-0.494	1.627	0.181	-1.374	1.993
19.	Shahkar 95	x	Suleiman 96	-1.184	0.427	2.696	0.158	-0.349	0.199	-1.512	2.151
20.	Shahkar 95	x	Chakwal 97	-1.173	1.552	2.899	0.083	-0.409	0.217	-1.650	2.309
21.	Shahkar 95	x	Kohistan 97	-1.162	1.947	3.103	-0.143	-0.643	0.235	-1.788	2.467
22.	Shahkar 95	x	MH 97	-1.151	-0.582	3.306	0.016	0.795	0.253	-1.926	2.625
23.	Suleiman 96	x	Chakwal 97	-1.139	0.379	3.510	1.933	0.349	0.271	-2.064	2.783
24.	Suleiman 96	x	Kohistan 97	-1.128	1.356	3.713	0.368	-0.741	0.289	-2.202	2.940
25.	Suleiman 96	x	MH 97	-1.117	-1.893	3.917	0.417	0.347	0.307	-2.340	3.098
26.	Chakwal 97	x	Kohistan 97	-1.106	-1.744	4.120	-0.030	0.793	0.325	-2.478	3.256
27.	Chakwal 97	x	MH 97	-1.095	0.123	4.324	0.119	-0.410	0.343	-2.616	3.414
28.	Kohistan 97	x	MH 97	-1.084	1.075	4.527	0.291	-2.965	0.361	-2.754	3.572
	SE[g(i)]			0.910	2.050	2.710	0.813	1.460	0.965	1.710	1.940
	SE[g(i)-(j)]			0.657	1.460	1.940	0.581	1.040	0.689	1.220	1.390

Table 4. (Cont'd.).

S. No.	Crosses			Tillers m^{-2}	1000 grain weight	Grain yield per plant	Protein contents	Lysine contents	Flour yield	Gluten contents
1.	Pak-81	x	Pothowar 93	14.339	-0.276	-13.000	-0.562	0.490	-0.234	-1.948
2.	Pak-81	x	Perwaz 94	7.630	-0.104	-21.375	0.381	-0.679	0.736	1.844
3.	Pak-81	x	Shahkar 95	9.460	-0.672	-19.042	0.068	-0.076	-1.680	-0.781
4.	Pak-81	x	Suleiman 96	-12.599	0.234	24.396	0.568	-0.008	-1.072	-0.698
5.	Pak-81	x	Chakwal 97	-0.099	1.589	27.792	0.374	-0.201	1.136	2.385
6.	Pak-81	x	Kohistan 97	-8.182	2.854	40.604	0.016	-0.190	1.948	-0.073
7.	Pak-81	x	MH-97	-22.557	-2.548	-25.708	-0.882	0.623	-0.880	-1.906
8.	Pothowar93	x	Perwaz 94	10.964	-0.885	-5.375	-0.648	0.553	2.339	-1.281
9.	Pothowar93	x	Shahkar 95	8.297	-0.200	-23.708	-0.011	-0.532	0.415	1.427
10.	Pothowar93	x	Suleiman 96	9.568	-1.756	20.063	0.574	0.061	3.522	1.510
11.	Pothowar93	x	Chakwal 97	-34.599	1.920	28.458	-0.157	0.423	-0.651	-2.073
12.	Pothowar93	x	Kohistan 97	-16.016	3.282	-21.396	0.678	-0.479	-1.017	0.135
13.	Pothowar93	x	MH-97	-17.891	-1.964	-3.042	-0.080	-0.288	-0.309	-0.698
14.	Perwaz 94	x	Shahkar 95	20.422	1.666	1.083	-0.051	0.148	-2.000	1.219
15.	Perwaz 94	x	Suleiman 96	-1.474	1.630	-1.479	-0.224	-0.168	-0.440	-1.356
16.	Perwaz 94	x	Chakwal 97	-11.474	-1.024	-3.250	-0.110	0.155	0.649	-2.615
17.	Perwaz 94	x	Kohistan 97	-10.043	0.578	1.480	0.427	-0.135	-0.013	-1.073
18.	Perwaz 94	x	MH 97	-10.900	0.618	1.617	0.305	-0.166	0.211	2.094
19.	Shahkar 95	x	Suleiman 96	-11.756	0.659	1.754	0.204	-0.545	-0.941	-1.990
20.	Shahkar 95	x	Chakwal 97	-12.612	0.699	1.891	-0.602	0.473	1.814	-1.906
21.	Shahkar 95	x	Kohistan 97	-13.469	0.740	2.028	-0.438	0.820	2.070	0.969
22.	Shahkar 95	x	MH 97	-14.325	0.780	2.165	0.660	-0.578	1.734	1.802
23.	Suleiman 96	x	Chakwal 97	-15.182	0.821	2.303	-0.135	-0.152	-1.965	2.510
24.	Suleiman 96	x	Kohistan 97	-16.038	0.861	2.440	-0.561	0.553	-1.445	-0.281
25.	Suleiman 96	x	MH 97	-16.895	0.901	2.577	-0.109	-0.180	-0.824	-1.781
26.	Chakwal 97	x	Kohistan 97	-17.751	0.942	2.714	-0.291	-0.656	-0.059	0.469
27.	Chakwal 97	x	MH 97	-18.608	0.982	2.851	-0.147	0.107	-0.345	0.969
28.	Kohistan 97	x	MH 97	-19.464	1.023	2.988	-0.697	0.387	-1.648	-1.490
	SE[g(i)]			7.270	1.920	8.930	0.736	0.097	1.201	1.720
	SE[g(i)-(j)]			5.190	1.370	6.380	0.526	0.069	0.857	1.230

Table 5. Reciprocal effects in an 8x8 complete diallel of wheat.

S. No.	Crosses			Plant height	Flag leaf area	Grain filling period	Spike length	Spikelets per spike	Grains per spike	Days to heading	Days to maturity
1.	Pothowar 93	x	Pak-81	4.327	-0.593	4.333	0.927	1.567	1.467	-5.500	-1.167
2.	Perwaz 94	x	Pak-81	-1.270	5.127	3.000	-0.010	-0.388	4.333	-0.667	2.167
3.	Shahkar 95	x	Pak-81	0.410	-3.183	-3.167	-0.692	-0.213	6.450	2.000	-2.667
4.	Suleiman 96	x	Pak-81	0.372	6.768	-0.167	-0.502	1.412	-2.967	0.001	0.001
5.	Chakwal 97	x	Pak-81	-0.482	-0.353	7.000	-0.138	-0.945	2.700	-8.167	-1.167
6.	Kohistan 97	x	Pak-81	-0.342	-0.367	-1.000	0.902	-1.592	0.717	-0.333	-1.333
7.	MH-97	x	Pak-81	-6.182	-0.760	3.333	-0.878	0.913	3.067	-2.167	1.167
8.	Perwaz 94	x	Pothowar93	1.972	2.015	-1.000	-0.623	0.302	4.633	0.167	0.833
9.	Shahkar 95	x	Pothowar93	-0.753	0.892	0.167	0.643	0.175	1.700	-2.000	-1.833
10.	Suleiman 96	x	Pothowar93	0.328	2.135	2.667	0.065	1.530	1.317	0.001	2.667
11.	Chakwal 97	x	Pothowar93	4.172	0.333	-0.667	0.268	0.358	-2.833	-1.167	-1.833
12.	Kohistan 97	x	Pothowar93	7.558	0.963	6.500	0.800	-2.142	-0.717	-1.667	1.500
13.	MH-97	x	Pothowar93	-2.118	1.252	3.667	0.128	1.157	1.700	-1.833	1.833
14.	Shahkar 95	x	Perwaz 94	-0.705	-2.642	-0.667	1.132	0.398	0.333	0.667	-0.667
15.	Suleiman 96	x	Perwaz 94	-0.457	-1.007	-2.000	-0.115	0.927	-0.033	3.500	0.333
16.	Chakwal 97	x	Perwaz 94	-2.875	1.205	1.500	-1.012	-0.247	-3.567	-1.333	1.667
17.	Kohistan 97	x	Perwaz 94	0.153	-2.098	-4.500	-0.617	-2.648	-1.100	0.333	-4.167
18.	MH 97	x	Perwaz 94	-1.915	-2.057	6.667	-0.767	-0.085	2.850	-3.167	3.500
19.	Suleiman 96	x	Shahkar 95	-1.215	-3.863	-3.333	-0.193	1.203	2.817	1.667	-1.667
20.	Chakwal 97	x	Shahkar 95	-1.753	2.707	1.000	-0.972	1.740	4.583	-0.500	0.333
21.	Kohistan 97	x	Shahkar 95	0.602	-1.485	-3.000	-0.118	0.917	-4.600	2.500	-3.000
22.	MH 97	x	Shahkar 95	0.958	0.805	-2.500	-0.332	-0.790	-0.783	0.833	0.001
23.	Chakwal 97	x	Suleiman 96	-2.472	0.607	2.833	0.068	0.832	4.933	0.167	3.000
24.	Kohistan 97	x	Suleiman 96	-0.615	-3.043	3.667	0.153	-0.402	-1.883	0.333	0.167
25.	MH 97	x	Suleiman 96	-1.355	2.953	4.833	0.687	-1.552	-0.750	-2.167	1.500
26.	Kohistan 97	x	Chakwal 97	-1.560	1.768	-8.000	0.472	-2.757	-3.683	2.500	-5.000
27.	MH 97	x	Chakwal 97	0.030	-0.258	3.667	-0.005	-0.958	-0.150	0.001	0.667
28.	MH 97	x	Kohistan 97	-2.335	-0.680	2.500	0.780	0.557	-2.335	5.000	-0.833
	SE[g(i,j)]			1.280	2.870	3.800	1.180	2.050	1.350	2.390	2.720
	SE[g(i)-(j)]										

Table 5. (Cont'd.).

S. No.	Crosses			Tillers m^{-2}	1000 grain weight	Grain yield per plant	Protein contents	Lysine contents	Flour yield	Gluten contents
1.	Pothowar 93	x	Pak-81	-16.667	-1.357	-10.000	0.227	0.087	0.020	1.667
2.	Perwaz 94	x	Pak-81	14.167	-0.833	17.000	-0.153	0.092	-1.145	2.667
3.	Shahkar 95	x	Pak-81	-17.000	-2.050	9.833	0.482	0.095	0.632	2.667
4.	Suleiman 96	x	Pak-81	-12.833	0.260	-5.333	-0.442	-0.610	-2.195	-2.000
5.	Chakwal 97	x	Pak-81	1.000	-1.577	-22.167	-0.037	-0.313	1.827	1.667
6.	Kohistan 97	x	Pak-81	-5.000	1.780	-14.000	-1.248	0.297	2.197	-0.667
7.	MH-97	x	Pak-81	2.167	0.677	28.667	0.753	-0.345	2.720	1.000
8.	Perwaz 94	x	Pothowar93	6.500	-1.743	7.667	0.302	-0.452	-1.532	1.667
9.	Shahkar 95	x	Pothowar93	-4.833	-1.437	-7.500	0.607	0.043	1.147	1.000
10.	Suleiman 96	x	Pothowar93	-6.333	0.882	16.333	1.465	-0.383	-2.555	0.333
11.	Chakwal 97	x	Pothowar93	-0.167	-1.510	-13.500	-0.423	-0.178	-0.513	-2.000
12.	Kohistan 97	x	Pothowar93	-31.167	0.223	15.000	-0.918	0.395	-2.262	0.333
13.	MH-97	x	Pothowar93	-3.500	-0.500	-0.333	0.613	-0.682	-1.172	1.000
14.	Shahkar 95	x	Perwaz 94	-5.833	2.930	10.333	0.453	-0.918	-0.817	0.667
15.	Suleiman 96	x	Perwaz 94	-13.167	0.298	-13.833	-0.777	0.312	-2.472	-1.333
16.	Chakwal 97	x	Perwaz 94	-28.167	-0.057	34.167	-0.747	-0.012	-0.482	0.001
17.	Kohistan 97	x	Perwaz 94	-8.167	-0.727	26.500	-0.700	0.987	0.548	0.333
18.	MH 97	x	Perwaz 94	-40.167	0.278	3.833	-1.292	0.345	-2.677	-1.667
19.	Suleiman 96	x	Shahkar 95	-29.333	-0.138	19.833	0.627	-0.108	-1.903	0.001
20.	Chakwal 97	x	Shahkar 95	42.500	-0.143	27.833	0.473	-0.767	-2.305	2.000
21.	Kohistan 97	x	Shahkar 95	-11.500	-1.553	-10.667	-0.907	-0.115	-1.610	0.333
22.	MH 97	x	Shahkar 95	-10.833	-0.217	-18.667	0.648	-0.533	-1.882	2.333
23.	Chakwal 97	x	Suleiman 96	-16.167	-0.912	16.000	-0.347	-0.285	0.298	2.333
24.	Kohistan 97	x	Suleiman 96	-3.000	0.167	-11.833	-0.287	-0.785	1.747	0.333
25.	MH 97	x	Suleiman 96	-5.500	1.873	10.667	0.112	-0.235	-0.868	-0.333
26.	Kohistan 97	x	Chakwal 97	-15.333	-1.730	18.500	-0.983	0.287	0.623	-3.000
27.	MH 97	x	Chakwal 97	-2.333	1.808	-4.500	-1.197	0.362	2.112	-1.667
28.	MH 97	x	Kohistan 97	3.167	-0.145	-15.000	1.147	-0.470	0.006	0.001
	SE[g(i,j)]			10.180	2.680	12.500	1.030	0.136	1.680	2.410
	SE[g(i)-(j)]									

Regarding the estimates of reciprocal effects in the F_1, the cross Chakwal 97 x Perwaz 94 had the largest reciprocal effects (34.167) for grain yield. The cross Shahkar 95 x Pak 81 showed highest values for number of grains spike^{-1} (6.450). In case of days to heading the cross MH 97 x Kohistan 97 expressed highest value (5.000) of reciprocal effects. For days to maturity MH 97 x Perwaz 94 gave high value (3.500). The cross combination Chakwal 97 x Shahkar 95 produced largest reciprocal values for number of tillers m^{-2} and number of spikelets spike^{-1}. The hybrid Shahkar 95 x Perwaz 94 gave maximum reciprocal effects for spike length and 1000 grain weight. For grain filling period highest value was observed in Chakwal 97 x Pak 81. As regards flag leaf area the cross Suleiman 96 x Pak 81 exhibited highest value. The cross Suleiman 96 x Pothowar 93 gave largest value of reciprocal effects for protein contents. For lysine contents largest value of reciprocal effects were observed in Kohistan 97 x Perwaz 94. Whereas for flour yield and gluten contents the highest values of reciprocal effects were observed in the crosses MH 97 x Pak 81 and MH 97 x Shahkar 95.

The findings of the present study for these traits in which both additive and non-additive gene action played important role is in conformity with several of the earlier findings of Sattar (1992), Hassan *et al*., (1996), Sabour *et al*., (1996), Shahzad *et al.*, (1998), Subhani & Chaudhry, (2000), Hasnain *et al.*, (2006) and Chowdhary *et al*., (2007). It is concluded from the present study that the varieties Chakwal 97, MH 97, Kohistan 97, Pak 81, Pothowar 93 and Perwaz 94 have the potential to breed for high yield with equally good quality genotypes.

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