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Analysis of Combining Ability for Spike Characteristics in Wheat (*Triticum aestivum* L.)

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ABSTRACT

Eight parent lines of wheat (*Triticum aestivum* L.), Pak 81, LU 26S, Barani 83, Rawal 87, Rohtas 90, Chakwal 86, Inqilab 91 and 5039, were crossed in all possible combinations to examine combining ability effects for spike characteristics and grain yield. General combining ability effects were significant ($P \leq 0.01$) for spike length, number of spikelets per spike, number of grains per spike, spike density and grain yield. The specific combining ability (SCA) variances were greater than general combining ability (GCA) variances, which showed the predominance of non-additive gene effects. Among the eight parents, Rohtas 90, Barani 83 appeared to be the best general combiner for all the spike characters and LU 26S for grain yield per plant. It may be concluded that the wheat lines with high GCA would provide a better for improving the spike characteristics and grain yield.

Key Words: Combining ability; *Triticum aestivum* L.; Spike length; Spikelets/spike; Grains/spike; Spike density; Grain yield; Non-additive variance

INTRODUCTION

Being a staple food, an increase in wheat production is very much desirable to feed the world population at large and in Pakistan in particular. The option for increasing wheat production by expanding area under its cultivation has already been exploited to almost to its maximum and therefore increase per unit area production through genetic improvement of wheat plant is greatly needed. The inflorescence in wheat is spike and therefore would have a direct bearing on grain yield in the crop. Any improvement of spike characteristics through selection and breeding would help improve the per plant productivity. The breeding efforts get strength from the combining ability estimates for a set of particular genotypes. Combining ability analysis (Griffing, 1956) is a biometrical method, which identifies the parents having the best combining ability and effects of genes governing the inheritance of characters and therefore the same method was followed here to collect information on spike characteristics and grain yield.

MATERIALS AND METHODS

Development of plant material. The crossing material consisting of 8 wheat genotypes, Pak 81, LU 26S, Inqilab 91, Rawal 87, Chakwal 86, Barani 83, Rohtas 90 and 5039, was raised in a well-prepared field. The florets were emasculated and were enclosed separately in glassine bags. Next day after emasculation, pollination was made by shaking ripe anthers. At maturity the seed was harvested from each female parent.

Assessment of diallel progenies. The eight parental lines along with their 56 hybrids were sown in a field using a randomized complete block design in three replications. Each entry consisted of a single row of five-meter length, with intra-row and inter-row spacing of 15 and 25 cm, respectively. At maturity 10 plants from each replication were randomly selected and data were recorded for the following spike characteristics and grain yield.

Length of each spike on mother shoot of the selected plants was measured in centimeters from the base of the spike to the tip excluding awns and number of spikelets on the spike on the mother shoot of the selected plants was counted and average number of spikelets per spike was determined for each family.

The spike density was calculated as:

$$\text{Spike density} = \frac{\textit{Spikelets per spike}}{\textit{Spike length}}$$

The spikes were threshed manually and grains were counted from the spike on the mother shoot to determine the number of grains per spike.

The ten selected plants were threshed separately. The grains obtained from a single plant were weighed using an electronic balance and average plant grain yield determined for each genotype.

Statistical procedures. The 8 × 8 diallel data were subjected to ordinary analysis of variance in order to determine genotypic differences. Data were further analyzed according to Griffing (1956) Method I, Model II.

RESULTS AND DISCUSSION

The combining ability estimates help in the identification of promising parents and desirable combinations for the improvement of plant traits through selection and breeding. The estimates of general combining ability (GCA) and specific combining ability identifies the relative importance of additive and additive causes of variation. The GCA is the sum of the total effects of additive and additive × additive variances and SCA is the total effects of dominance and dominance × dominance variances. The Line × Tester analysis (Kempthorne, 1957) and diallel analysis (Griffing, 1956) are the two main techniques used for the estimation of combining ability, the diallel analysis approach for the estimation of combining ability (Griffing, 1956) is however more popular.

In the present studies the analysis of the diallel cross data was carried out following combining ability approach of Griffing, (1956). Simple analysis of variance of number of spikelets per spike, number of grains per spike, spike density and grain yield indicated significant differences ($P \leq 0.01$) in the characters studied (Table I). The breeding of the characters, which are controlled by non-additive gene action are not easy because inheritance of these characters was complex (Rehman *et al.,* 2003).

Importance of non-additive genetic effects for spike length depicted from the data (Table II) have also been reported by Li *et al.* (1991), Khan and Ali (1998), while Kumar *et al.* (2003) observed additive genetic effects for spike length, whereas Zubair *et al.* (1987), Mishra *et al.* (1996) found that both additive and non-additive genetic effects were important in spike length.

The estimation of general combining ability, specific combining ability and reciprocal effects are presented in Table III. Chakwal 86 had the highest positive GCA effects (0.803) for longest spike and Rohtas 90 had the highest negative GCA value of -0.955. Barani 83 had the lowest negative GCA value. Sixteen of the direct cross combinations showed positive SCA effects. Among them, Pak 81 × Inqilab 91 was the best specific cross SCA = 1.230, while Inqilab 91 × 5039 was the poorest specific cross SCA = -1.146. Reciprocal effects were positive only in 8 crosses and were highest in hybrid 5039 × Barani 83 (1.038).

The results suggested non-additive gene action for controlling number of spikelets per spike (Table II). These findings are in agreement with observations of Rehman *et al.* (2002), who reported non-additive genetic control for this trait. Khan and Ali (1998) and Hamada *et al.* (2002) reported additive genetic effects for spikelets per spike. Zubair *et al.* (1987) found the importance of both additive and non-additive genetic control for this trait.

The estimation of the general combining ability over all the parents, specific combining ability and reciprocal effects is given in Table VI. The parents have shown differences in GCA effects for spikelets per spike and parents Barani 83 (0.551). Rawal 87 (0.500), Pak 81 (0.381) and Chakwal 86 (0.313), had relative high GCA effect for maximum spikelets per spike. The parent Barani 83 with highest positive GCA effects was the best combiner, whilst

Table I. Mean squares from analysis of variance of plant characters in 64 families of *Triticum aestivum* L.

Source of variation	D.F.	Spike Length	Spikelets/ spike	Grains/ spike	Spike density	Grain yield
Replication	2	1.83**	6.72**	12.87**	0.01 NS	3.71 NS
Families	63	2.96**	3.63**	16.76**	0.07**	76.32**
Error	126	0.14	1.15	2.66	0.01	4.85

** Significant at $P \leq 0.01$, NS non-significant

Table II. Estimates of variances from combining ability analysis of plant characters of 64 families of *Triticum aestivum* L.

Source of variation	Spike Length	Spikelets/ Spike	Grains/ spike	Spike density	Grain yield
GCA	0.28	0.18	1.57	0.006	4.36
SCA	0.37	0.32	0.45	0.008	9.91
Reciprocal	0.09	0.21	1.65	0.004	7.08
Error	0.05	0.38	0.89	0.002	1.62

LU 26S possessing highest negative GCA effects (-0.679) was the poorest general combiner. Sixteen direct cross hybrids had the positive SCA effects, of which, Barani 83 × 5039 was the best specific cross with highest positive SCA effects (0.891), whilst Barani 83 × Rohtas 90 was the poorest specific cross with highest negative SCA effects (-1.009). Reciprocal effects were positive in 50% of the crosses and were highest in hybrid 5039 × Barani 83 (1.038).

The predominance of non-additive genetic control for the spike density (Table II) was due to greater SCA variance. Combining ability effects (Table V) showed that only three parents, Pak 81 (0.098), Barani 83 (0.064) and Rohtas 90 (0.119) were the best general combiner, while 5039 (GCA = -0.091) was the poorest general combiner for spike density. Positive SCA effects were recorded in 9 cross combinations and were maximum in Inqilab 91 × 5039 (0.231). The poorest specific cross was Barani 83 × Chakwal 86 as it had the most negative SCA effects (-0.108). Reciprocal effects were positive in 18 crosses and ranged from 0.004 (Barani 83 × Pak 81) to 0.123 (Inqilab 91 × Rohtas 90).

GCA variance (1.571) was greater than SCA variance (0.447) for number of grains per spike (Table II), which suggested that additive genetic effects were more prominent in controlling the genetics of grains per spike. Presents results are also in agreement with Ali and Khan (1998) and Hamada *et al.* (2002) for grains per spike. However results of this study differ with Kumar *et al.* (2003) and Dhayal and Sastry (2003), who reported non-additive genetic effects for number of grains per spike. Evidence of both additive and non-additive genetic effects has been reported by Mishra *et al.* (1996) and Sangwan and Chaudhry (1999). Rohtas 90 was the best general combiner (Table VI) for grains per spike with maximum positive GCA effects (1.704) followed by Barani 83 (1.571) whilst 5039 showed highest (GCA = -1.533) was the poorest general combiner for this character.

Table III. General combining ability (diagonal), Specific combining ability (above diagonal) and reciprocal (below diagonal) effects of 8 wheat genotypes and their crosses for spike length

Genotypes	LU26S	Pak 81	Barani83	Chak. 86	Rawal87	Rohtas90	Inqilab91	5039
LU26S	**-0.228**	0.251	-0.718	0.576	-0.076	0.401	-0.180	0.172
Pak81	-0.100	**-0.472**	-0.074	0.136	-0.349	0.095	1.230	0.416
Barani 83	0.433	-0.167	**-0.170**	0.551	0.266	-0.391	0.161	0.614
Chak. 86	-0.400	-0.150	-0.400	**0.803**	-0.441	-0.064	-0.211	-0.393
Rawal 87	-0.500	-0150	0.300	-0.033	**0.455**	-0.016	0.736	0.539
Rohtas 90	-0.033	0.117	-0.167	-0.233	0.167	**-0.955**	0.480	0.199
Inqilab 91	0.500	-0.467	0.100	0.033	0.300	-0.767	**0.159**	-1.146
5039	-0.033	-0.100	-0.330	-0.433	-0.317	-0.533	-0.500	**0.407**

S.E. (g_i) = 0.050 S.E. (s_{ij}) = 0.133 S.E. (r_{ij}) = 0.151

Table IV. General combining ability (diagonal), Specific combining ability (above diagonal) and reciprocal (below diagonal) effects of 8 wheat genotypes and their crosses for number of spikelets per spike

Genotypes	LU26S	Pak 81	Barani83	Chak. 86	Rawal87	Rohtas90	Inqilab91	5039
LU26S	**-0.679**	0.720	0.509	0.334	-0.595	0.499	0.452	-0.029
Pak81	-0.588	**0.381**	-0.261	-0.226	0.137	-0.139	0.097	-0.069
Barani 83	-0.237	-0.263	**0.551**	-0.579	-0.126	-1.009	0.196	0.891
Chak. 86	-0.757	-0.133	0.777	**0.313**	-0.866	0.044	0.271	0.091
Rawal 87	-1.302	-0.093	1.000	-0.722	**0.500**	0.611	0.769	-0.154
Rohtas 90	-0.155	0.033	0.327	1.025	0.758	**-0.158**	0.423	-0.119
Inqilab 91	-0.667	0.412	-0.727	0.530	-0.748	0.192	**-0.429**	0.564
5039	-0.228	0.465	1.038	0.223	0.945	-0.237	0.455	**-0.479**

S.E. (g_i) = 0.145 S.E. (s_{ij}) = 0.388 S.E. (r_{ij}) = 0.438

Table V. General combining ability (diagonal), Specific combining ability (above diagonal) and reciprocal (below diagonal) effects of 8 wheat genotypes and their crosses for spike density

Genotypes	LU26S	Pak 81	Barani83	Chak. 86	Rawal87	Rohtas90	Inqilab91	5039
LU26S	**-0.027**	0.011	0.145	-0.039	-0.037	-0.020	0.061	-0.023
Pak81	-0.031	**0.098**	-0.021	-0.049	0.045	-0.029	-0.155	-0.073
Barani 83	-0.088	0.004	**0.064**	-0.108	-0.051	-0.024	-0.011	-0.016
Chak. 86	-0.010	0.008	0.098	**-0.082**	-0.006	0.001	0.049	0.060
Rawal 87	-0.037	0.014	0.036	-0.047	**-0.025**	0.040	-0.026	-0.064
Rohtas 90	-0.007	-0.016	0.055	0.111	0.035	**0.119**	-0.031	-0.048
Inqilab 91	-0.117	0.082	-0.068	0.034	-0.085	0.123	**-0.057**	0.231
5039	0.021	0.047	0.113	0.067	0.099	0.053	0.109	**-0.091**

S.E. (g_i) = 0.011 S.E. (s_{ij}) = 0.029 S.E. (r_{ij}) = 0.033

Table VI. General combining ability (diagonal), Specific combining ability (above diagonal) and reciprocal (below diagonal) effects of 8 wheat genotypes and their crosses for grains per spike

Genotypes	LU26S	Pak 81	Barani83	Chak. 86	Rawal87	Rohtas90	Inqilab91	5039
LU26S	**-0.790**	1.934	-0.686	-1.468	-1.272	0.172	-0.105	1.293
Pak81	-0.978	**-0.861**	-0.011	-1.550	-1.011	0.625	-0.237	-0.977
Barani 83	0.087	-0.007	**1.571**	-0.0002	0.766	0.355	0.764	-0.026
Chak. 86	-1.622	1.625	-1.363	**0.358**	1.414	0.446	0.975	0.797
Rawal 87	2.052	3.248	-0.357	0.708	**-1.322**	-0.259	-0.294	-0.450
Rohtas 90	0.662	0.713	-2.325	1.150	0.788	**1.704**	-0.983	-0.331
Inqilab 91	0.690	1.210	0.460	0.125	-3E-18	-2.863	**0.873**	0.228
5039	-0.415	0.723	-0.493	0.070	-3.627	-1.482	0.487	**-1.533**

S.E. (g_i) = 0.220 S.E. (s_{ij}) = 0.588 S.E. (r_{ij}) = 0.665

Highest positive SCA effects (1.934) were recorded in the cross LU 26S × Pak 81, while these effects were negative and highest (-1.550) in the cross Pak 81 × Chakwal 86. A total of 16 crosses showed positive reciprocal effects with highest value (3.248) observed in in Rawal 87 × Pak 81 hybrid.

The SCA variance was larger than GCA variance for grain yield per plant (Table II). This suggested the importance of non-additive genetic effects for the manifestation of grain yield per plant. Greater SCA variance for grain yield per plant was also reported by Mishra *et al.* (1994) and Senapati *et al.* (2000), Kumar *et al.* (2003) and Sudesh *et al.* (2002). On the other hand, Larik *et al.* (1995) found significant GCA variance for grain yield. However, Ali and Khan (1998), Wagoire (1998), Mahmood and Chowdhry (2002), Hamada *et al.* (2002), Dhayal and Sastry

Table VII. General combining ability (diagonal), Specific combining ability (above diagonal) and reciprocal (below diagonal) effects of 8 wheat genotypes and their crosses for grain yield per plant

Genotypes	LU26S	Pak 81	Barani83	Chak. 86	Rawal87	Rohtas90	Inqilab91	5039
LU26S	**2.734**	4.108	-1.793	2.366	0.934	-3.118	-0.637	-0.230
Pak81	-0.580	**-0.222**	-0.202	-1.918	-0.005	0.928	1.159	-0.634
Barani 83	-0.875	-1.020	**-1.816**	1.826	-0.501	1.838	2.423	2.446
Chak. 86	0.350	2.330	-0.220	**0.890**	4.578	-0.964	1.157	-2.436
Rawal 87	2.420	2.945	-3.555	3.360	**-2.388**	-3.246	2.795	2.667
Rohtas 90	1.850	-2.030	-1.955	-4.700	0.450	**-3.236**	3.138	5.221
Inqilab 91	1.100	0.160	1.810	-1.670	-4.530	-4.445	**0.823**	-2.239
5039	3.580	-2.590	-0.345	-5.830	-3.165	-4.500	-3.100	**3.216**

S.E. (g_i) = 0.297 S.E. (s_{ij}) = 0.795 S.E. (r_{ij}) = 0.899

(2003) reported additive genetic effects, while Bebyakin and korobova (1989) and Saad (1999) showed importance of both additive and non-additive genetic effects for grain yield per plant.

Estimates of general, specific combining ability and reciprocal effects are presented in Table VII. Genotype 5039 exhibited highest SCA effects of 3.216 making it the best general combiner, while genotype Rohtas 90 was the poorest general combiner with GCA effects of -3.236. Among the 15 direct crosses producing positive SCA effects, the hybrids Rohtas 90 × 5039, LU 26S × Pak 81 with a values of 5.221 and 4.108, respectively were the best specific crosses. While highest negative SCA effects (-3.246) were in found in the hybrid Rawal 87 × Rohtas 90. Positive reciprocal effects were recorded in only 11 crosses and the hybrid 5039 × Chakwal 86 had the most negative reciprocal effects of -5.830.

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