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Determination of General and Specific Combining Ability Effects in a Diallel Cross of Spring Wheat

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Abstract: Combining ability of some polygenic traits was studied in a set of 5 × 5 diallel cross involving five varieties of bread wheat viz., Inqalab 91, Uqab 2000, Punjab 96, MH. 97 and Fsd. 85. Mean squares for GCA effects were highly significant for fertile tillers per plant, spike length, spikelets per spike and grains per spike, significant for plant height and flag leaf area and non-significant for 1000-grain weight and grain yield per plant. Mean squares for SCA effects were highly significant for all the traits except fertile tillers per plant which was non-significant while reciprocal effects were non-significant for all the traits except spike length and grain yield per plant which were highly significant. The magnitude of GCA variance was higher than SCA variance for flag leaf area, fertile tillers per plant, spike length, spikelets per spike and grains per spike suggesting additive genetic control of these traits. Whereas, plant height, 1000-grain weight and grain yield per plant indicated the preponderance of non-additive genetic effects with higher magnitude of SCA variance. The varieties Uqab 2000 and Fsd. 85 were the best general combiners for most of the traits and could be used in further breeding programmes. Cross combinations Inqalab 91 × Fsd. 85, Uqab 2000 × MH. 97, Punjab 96 × MH. 97 and Uqab 2000 × Fsd. 85 with high SCA effects could be exploited for further selection of high yielding progenies.

Key words: Wheat, Combining ability, Multigenic traits, Pakistan

INTRODUCTION

Much of the emphasis in wheat development has been placed in increasing productivity of the crop. This has been in response to the pressure on an adequate food supply caused by constantly increasing population in Pakistan. Since the introduction of short statured and fertilizer responsive varieties, wheat production has significantly improved in the country almost at the threshold of self-sufficiency. But unfortunately, for the last couple of years wheat production has become stagnant. Therefore, development of new wheat cultivars with high genetic potential for grain yield has become a permanent goal in all breeding programmes.

In order to achieve this target one should be aware of genetic make up and the nature of gene action involved in controlling plant responses to different environments. For any breeding programme aiming at hybridization, knowledge of better combiner parents is a pre-requisite. It is important to achieve genetic gain within limited resources and minimum time. The combining ability analysis developed by Griffing (1956) provides useful information regarding the selection of parents in terms of the performance of their hybrids. This analysis further elucidates the nature and the magnitude of various types of gene actions involved in the expression of quantitative characters which help in choosing the parents for hybridization programme. Various workers like Borghi and Perenzin (1994), Mishra *et al.* (1994), Bhutta *et al.* (1997), Mahmood and Chowdhry (2002) and Saeed *et al.* (2002) have reported general and specific combining ability effects for several wheat varieties. All their studies revealed that a large part of genetic variability for yield and its components was associated with general combining ability which is a measure of additive genetic variance but non-additive genetic variability due to specific combining ability was also equally important for yield components.

In present research work the best combining parent out of five widely grown native bread wheat varieties was assessed. The estimates thus obtained would help to exploit the parents for further breeding programme.

MATERIALS AND METHODS

The research work on combining ability studies was carried out in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental material consisted of 5 × 5 diallel cross involving five local varieties of bread wheat viz., Inqalab 91, Uqab 2000, Punjab 96, MH. 97 and Fsd. 85. The crossed seed obtained along with their parents was sown in the field in a triplicated randomized complete block design. The seeds were dibbled in rows keeping within and between row distances at 15 and 30 cm, respectively. Single row of 5 meters length served as an experimental unit. Three seeds per hill were sown to ensure the crop stand which were thinned to single

seedling per site after germination. Non-experimental plants were also raised at the borders to eliminate competition among marginal plants. At maturity ten guarded plants from each row were randomly selected and data were recorded for plant height (cm), flag leaf area (cm^2), number of fertile tillers per plant, spike length (cm), number of spikelets per spike, number of grains per spike, 1000-grain weight (g) and grain yield per plant (g).

Combining ability analysis was done according to procedure given by Griffing (1956), using Method I, Model II. Estimates of GCA, SCA and reciprocal effects and their variances were obtained.

RESULTS AND DISCUSSION

Plant height: Analysis of variance for combining ability revealed that mean squares due to GCA were significant and due to SCA were highly significant. While, reciprocal mean squares were non-significant (Table 1). Although general combining ability variance was greater than specific combining ability variance but calculations of variance components revealed that SCA effects were greater than GCA effects (Table 2), which displayed the preponderance of non-additive genetic effects for the control of plant height. These results are in agreement with the findings of Borghi and Perenzin (1994), Mishra *et al.* (1994) and Chowdhry *et al.* (1999). Whereas Chowdhry and Ahmad (1990) and Rajara and Maheshwari (1996) illustrated additive genetic effects in the control of this trait.

The estimates of general combining ability effects of parents and their corresponding standard errors are presented in Table 3. Highest positive general combining ability effects for plant height were exhibited by variety Uqab 2000 (3.941) followed by Fsd. 85 (1.807). Short stature plants are preferred because they do not lodge and are more responsive to fertilizers, therefore, negative combining ability effects are preferred for plant height in wheat. Three parents namely Punjab 96, Inqalab 91 and MH. 97 showed desirable negative GCA effects of -3.549,-1.238 and-0.962, respectively. Maximum positive SCA effects (Table 4) were found in cross combination Punjab 96 × MH. 97 (2.911) followed by Uqab 2000 × MH. 97 (2.833). While Inqalab 91 × Uqab 2000, Punjab 96 × Fsd.85, Inqalab 91 × Punjab 96 and MH. 97 × Fsd. 85 showed desirable negative SCA effects of -1.937, -1.352, -0.592 and -0.412, respectively.

The highest positive reciprocal effects (Table 5) were displayed by hybrid Punjab 96 × MH. 97 (0.478) followed by MH. 97 × Fsd. 85 (0.445). The poorest reciprocal effects were exhibited by Inqalab 91 × Punjab 96 and Inqalab 91 × Fsd. 85 with negative values of -0.910 and -0.425, respectively.

Flag leaf area: It is apparent from Table 1 that estimates of mean squares were significant for GCA effects, highly significant for SCA effects and non-significant for reciprocal effects. It was observed that variance of GCA effects was greater than the variance of SCA effects. Similar results were also obtained from the estimates of variance components (Table 2). These results indicate the involvement of additive genetic effects for the control of this trait. Similar conclusions have also been reported by Bhutta *et al.* (1997) and Mahmood and Chowdhry (2002). A perusal of Table 3 revealed that maximum GCA effects for flag leaf area were observed for Fsd. 85 (3.867) followed by Punjab 96 (1.315). Whereas, negative GCA effects were shown by varieties Inqalab 91 (-2.783) and MH. 97 (-3.552). Maximum SCA effects (Table 4) were observed for crosses Punjab 96 × Fsd. 85 and Inqalab 91 × MH. 97 with values of 4.141 and 3.623, respectively. While minimum SCA effects were indicated by cross combinations Inqalab 91 × Fsd. 85 and Inqalab 91 × Punjab 96 with values of -2.080 and -1.779, respectively.

Three crosses Uqab 2000 × Fsd. 85 (1.542), MH. 97 × Fsd. 85 (1.375) and Punjab 96 × MH. 97 (0.588) indicated positive reciprocal effects (Table 5). While negative reciprocal effects ranged from -0.047 (Inqalab 91 × MH. 97) to -1.297 (Uqab 2000 × MH. 97).

Number of fertile tillers per plant: Mean squares of GCA were greater than SCA mean squares and highly significant for number of tillers per plant (Table 1). However, mean squares for SCA and reciprocal effects were non-significant. The variance components (Table 2) also revealed the proportion of GCA variance suggesting the preponderance of additive genetic effects. These

Table 1: Combining ability analysis for some polygenic traits of spring wheat in a 5 x 5 diallel cross

		Mean Squares							
Source of variation	d.f	Plant height	Flag leaf area	Fertile tillers per plant	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Grain yield per plant
GCA	4	84.635*	95.957*	10.271**	5.907**	3.924**	290.72**	14.856ns	9.294ns
SCA	10	14.575**	16.710**	1.773ns	0.420**	0.436**	31.628**	12.413**	8.118**
Reciprocal	10	0.360ns	1.689ns	0.746ns	0.237**	0.180ns	8.995ns	1.770ns	5.501**
Error	48	0.566	4.127	0.902	0.063	0.111	5.495	0.982	0.378

ns = Non-significant * = Significant at 5% level of probability ** = Highly significant at 1% level of probability

results are in accordance with those of Khaliq *et al.* (1991) and Mahmood and Chowdhry (2002).

Highest positive GCA effects for fertile tillers per plant were recorded in the parent MH. 97 (1.783) which turn out to be the best general combiner for this trait (Table 3). Other four parents showed the negative GCA effects which were recorded maximum for Inqalab 91 (-0.651), the poorest general combiner.

Positive SCA effects were found maximum in Uqab 2000 × Punjab 96 (0.477) and Punjab 96 × MH. 97 (0.347) hybrids, which thus turned out to be the best specific combinations (Table 4). While, MH. 97 × Fsd. 85 (-1.126) and Inqalab 91 × MH. 97 (-1.189) were the poorest specific combinations with high negative values. Highest positive reciprocal effects (Table 5) were displayed by Inqalab 91 × Punjab 96 hybrid with value of 1.317. Whereas highest negative reciprocal effects were displayed by Uqab 2000 × Fsd. 85 (-0.850).

Spike length: A perusal of Table 1 displayed that GCA, SCA and reciprocal effects mean squares were highly significant ($P \leq 0.01$) for spike length. Mean squares due to GCA were greater than SCA mean squares. Similarly, the variance components also indicated that GCA variance was greater than SCA variance (Table 2). Thus, a predominant role of additive genetic effects was revealed for this trait. These results are in agreement with those of Tosun *et al.* (1995), Shahzad *et al.* (1998) and Iqbal and Chowdhry (2000).

The best general combiner for spike length was Uqab 2000 followed by Inqalab 91 with GCA effects of 0.671 and 0.660, respectively (Table 3). The poorest general combiner was MH. 97 with negative GCA effects of -1.146 followed by Fsd. 85 (-0.363). The cross combination Inqalab 91 × Fsd. 85 (0.843) indicated highest positive SCA effects (Table 4). Three crosses namely Inqalab 91 × Punjab 96, Inqalab 91 × Uqab 2000 and MH. 97 × Fsd 85 displayed negative SCA effects (-0.055, -0.133 and -0.224, respectively). The hybrid MH. 97 × Fsd. 85 was the poorest specific combiner.

A reference to Table 5 indicates that maximum positive reciprocal effects were observed in the hybrid Inqalab 91 × Fsd. 85 (0.550) followed by Inqalab 91 × MH. 97 (0.415). Whereas maximum negative reciprocal effects were exhibited by the cross combination Uqab 2000 × Fsd. 85 (-0.490).

Number of spikelets per spike: After partitioning the genotypic mean squares it was found that GCA and SCA mean squares were highly significant for number of spikelets per spike. Reciprocal effects were, however, non-significant in this case (Table 1). The presence of additive genetic effects was revealed due to greater GCA mean squares as well as higher GCA variance in the computation of variance components (Table 2). Tosun *et al.* (1995) and Bhutta *et al.* (1997) also reported similar findings for this character.

Combining ability effects (Table 3) depicted that maximum GCA effects were indicated by variety Uqab 2000 (0.703). While lowest GCA effects were displayed by variety MH. 97 (-1.003). The best specific performance (Table 4) was indicated by hybrid combinations Inqalab 91 × Fsd. 85 (0.513) and Punjab 96 × Fsd. 85 (0.440). Whereas, poorest SCA effects were exhibited by hybrids Inqalab 91 × Punjab 96 (-0.250) and MH. 97 × Fsd. 85 (-0.217).

The highest positive reciprocal effects (Table 5) were displayed by Uqab 2000 × MH. 97 (0.500) followed by hybrid Inqalab 91 × Fsd. 85 (0.383). While two cross combinations Uqab 2000 × Fsd. 85 and MH. 97 × Fsd. 85 indicated lowest reciprocal effects with values of -0.483 and -0.050, respectively.

Number of grains per spike: It is obvious from analysis of variance that mean squares due to GCA and SCA effects were highly significant. While, reciprocal effects mean squares were non-significant (Table 1). GCA mean squares were much greater than SCA mean squares. The variance components also depicted that GCA variance was greater than SCA variance indicating the presence of additive genetic effects for number of grains per spike (Table 2). These results contradicted the findings of Rajara and Maheshwari (1996), Shahzad *et al.* (1998) and Chowdhry *et al.* (1999) who reported non-additive genetic effects for this trait. Which may be due to differences in genetic material used and environmental conditions under which the experiment was conducted.

Out of five parents Uqab 2000 was the best combiner with maximum GCA effects (8.548) whereas MH. 97 (-6.372) was the poorest general combiner (Table 3). As far as SCA effects were concerned only one out of ten crosses showed negative effects (Table 4). The best cross combination for SCA effects was Inqalab 91 × Fsd. 85 which displayed the highest value of 7.025. Four crosses namely Punjab 96 × MH. 97, Uqab 2000 × Fsd. 85, Uqab 2000 × Punjab 96 and Punjab 96 × Fsd. 85 showed positive SCA effects with values of 1.425, 1.375, 1.222 and 1.175, respectively. The only hybrid which displayed negative SCA effects was Inqalab 91 × MH. 97.

The highest reciprocal effects (Table 5) were exhibited by hybrid Uqab 2000 × MH. 97 with a value of 3.067. While, the lowest reciprocal effects were shown by two cross combinations Uqab 2000 × Fsd. 85 and Inqalab 91 × Uqab 2000 with values of -4.950 and -1.217, respectively.

Table 2: Estimates of components of variation due to GCA, SCA and reciprocal effects for some polygenic traits of spring wheat in a 5 x 5 diallel cross

Source of Variation	Plant height	Flag leaf area	Fertile tillers per plant	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Grain yield per plant
GCA	7.073 (45.89)	7.985 (51.60)	0.854 (62.24)	0.550 (64.78)	0.350 (60.66)	26.033 (60.07)	0.299 (3.99)	0.155 (2.12)
SCA	8.339 (54.12)	7.489 (48.40)	0.518 (37.76)	0.212 (24.97)	0.193 (33.45)	15.555 (35.89)	6.804 (90.76)	4.607 (62.91)
Reciprocals	-0.103	-1.219	-0.078	0.087 (10.25)	0.034 (5.89)	1.750 (4.04)	0.394 (5.25)	2.561 (34.97)
Error	0.566	4.127	0.902	0.063	0.111	5.495	0.982	0.378

Values in the parenthesis indicate the percentage of variance components

Table 3: Estimates of general combining ability effects for some polygenic traits of spring wheat in a 5 x 5 diallel cross

Source of Variation	Plant height	Flag leaf area	Fertile tillers per plant	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Grain yield per plant
Inqalab 91	-1.238	-2.783	-0.651	0.660	-0.033	0.031	0.806	-0.547
Uqab 2000	3.941	1.154	-0.181	0.671	0.703	8.548	-0.231	1.583
Punjab 96	-3.549	1.315	-0.371	0.177	0.090	-1.402	-1.331	-0.587
MH. 97	-0.962	-3.552	1.783	-1.146	-1.003	-6.372	-0.884	-0.708
Fsd. 85	1.807	3.867	-0.580	-0.363	0.243	-0.805	1.639	0.260
$SE(g_i - g_j)$	0.337	0.909	0.425	0.113	0.149	1.048	0.443	0.275

Table 4: Estimates of specific combining ability effects for some polygenic traits of spring wheat in a 5 x 5 diallel cross

Source of Variation	Plant height	Flag leaf area	Fertile tillers per plant	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Grain yield per plant
Inqalab 91 x Uqab 2000	-1.937	-0.985	-0.159	-0.133	-0.080	0.305	-0.156	-1.528
Inqalab 91 x Punjab 96	-0.592	-1.779	0.081	-0.055	-0.250	0.405	0.044	0.437
Inqalab 91 x MH. 97	0.492	3.623	-1.189	0.008	0.143	-5.608	3.647	0.031
Inqalab 91 x Fsd. 85	2.240	-2.080	-0.009	0.843	0.513	7.025	0.074	2.772
Uqab 2000 x Punjab 96	1.183	0.197	0.477	0.198	0.363	1.222	-0.619	0.605
Uqab 2000 x MH. 97	2.833	-0.298	0.157	0.140	-0.160	0.225	2.184	2.381
Uqab 2000 x Fsd. 85	2.743	0.514	-0.713	0.195	0.377	1.375	0.861	0.502
Punjab 96 x MH. 97	2.911	2.630	0.347	0.141	0.320	1.425	0.184	1.792
Punjab 96 x Fsd.85	-1.352	4.141	-0.389	0.309	0.440	1.175	1.327	-0.037
MH. 97 x Fsd. 85	-0.412	0.231	-1.126	-0.224	-0.217	0.079	1.047	-0.069
SE ($S_{ij} - S_{ik}$)	0.673	1.817	0.850	0.225	0.298	2.097	0.886	0.550
SE ($S_{ij} - S_{kl}$)	0.583	1.574	0.736	0.195	0.258	1.816	0.768	0.476

Table 5: Estimates of reciprocal effects for some polygenic traits of spring wheat in a 5 x 5 diallel cross

Crosses	Plant height	Flag leaf area	Fertile tillers per plant	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Grain yield per plant
Inqalab 91 x Uqab 2000	0.058	-0.162	0.467	0.252	0.117	-1.217	-1.450	-0.268
Inqalab 91 x Punjab 96	-0.910	-0.152	1.317	0.388	0.200	1.600	-0.550	3.060
Inqalab 91 x MH. 97	0.190	-0.047	0.600	0.415	0.300	1.717	0.667	2.120
Inqalab 91 x Fsd. 85	-0.425	-0.737	-0.017	0.550	0.383	0.250	-1.283	-0.935
Uqab 2000 x Punjab 96	0.110	-0.915	-0.050	-0.113	0.117	0.633	0.017	0.132
Uqab 2000 x MH. 97	-0.400	-1.297	0.183	0.355	0.500	3.067	0.100	1.963
Uqab 2000 x Fsd. 85	0.220	1.542	-0.850	-0.490	-0.483	-4.950	-1.200	-2.632
Punjab 96 x MH. 97	0.478	0.588	0.383	0.145	0.300	1.317	-1.633	-0.752
Punjab 96 x Fsd.85	-0.325	-0.848	0.150	-0.273	0.133	1.367	0.467	0.783
MH. 97 x Fsd. 85	0.445	1.375	0.700	-0.153	-0.050	0.133	0.133	0.850
SE ($R_{ij} - R_{kl}$)	0.753	2.032	0.950	0.252	0.333	2.344	0.991	0.614

1000-grain weight: The results regarding the mean squares of GCA, SCA and reciprocal effects revealed that GCA and reciprocal effects were non-significant and only SCA effects were highly significant for 1000-grain weight (Table 1). Although mean square due to GCA effects were higher than mean squares due to SCA effects but prevalence of non-additive gene action was revealed after the computation of variance components. The SCA variance turn out to be much higher than the GCA variance (Table 2). These results are in accordance with those of Rajara and Maheshwari (1996).

It was revealed that Fsd. 85 proved to be the best combiner (Table 3) with highest GCA effects (1.639) followed by Inqalab 91 (0.806). The remaining three varieties showed poor performance for this trait by displaying negative GCA effects. In case of SCA effects (Table 4) the hybrid Inqalab 91 × MH. 97 showed excellent performance with the highest (3.647) SCA effects followed by the hybrid Uqab 2000 × MH. 97 (2.184). The lowest specific combiners were two cross combinations namely Uqab 2000 × Punjab 96 and Inqalab 91 × Uqab 2000 with negative values of -0.619 and -0.156, respectively.

It is apparent from Table 5 that 50% hybrids displayed positive reciprocal effects. The cross combination Inqalab 91 × MH. 97 manifested highest positive reciprocal effects (0.667) followed by the hybrid Punjab 96 × Fsd. 85 (0.467). The minimum reciprocal effects ranged from -0.550 (Inqalab 91 × Punjab 96) to -1.633 (Punjab 96 × MH 97).

Grain yield per plant: Non-significant mean squares due to GCA effects and highly significant mean squares due

to SCA and reciprocal effects were observed from the Table 1. The components of variance (Table 2) computed to observe the nature of inheritance for the trait depicted that SCA variance was much greater than GCA variance, giving the importance of non-additive genetic control for grain yield. The results are in conformity with those of already given by Yadav and Mishra (1992), Mishra *et al.* (1994) and Chowdhry *et al.* (1999).

A perusal of Table 3 displayed that maximum general combining ability effects (1.583) were found in case of variety Uqab 2000 followed by Fsd. 85 (0.260). The rest of the three varieties viz., Inqalab 91, Punjab 96 and MH. 97 showed negative GCA effects with values of -0.547, -0.587 and -0.708, respectively.

SCA effects presented in Table 4 revealed that the hybrid Inqalab 91 × Fsd. 85 (2.772) exhibited the maximum SCA effects for grain yield per plant followed by Uqab 2000 × MH. 97 (2.381). Three cross combinations Inqalab 91 × Uqab 2000, MH. 97 × Fsd. 85 and Punjab 96 × Fsd. 85 indicated negative SCA effects of -1.528, -0.069 and -0.037, respectively.

The cross combination Inqalab 91 × Punjab 96 displayed the highest reciprocal effects (3.060) followed by two other hybrids Inqalab 91 × MH. 97 and Uqab 2000 × MH. 97 with values of 2.120 and 1.963, respectively (Table 5). The weakest performance with highest negative reciprocal effects (-2.632) was displayed by hybrid Uqab 2000 × Fsd. 85. Three other hybrids namely Inqalab 91 × Uqab 2000, Punjab 96 × MH. 97 and Inqalab 91 × Fsd. 85 also exhibited negative effects with respective values of -0.268, -0.752 and -0.935.

The present studies envisage the importance of both additive and non-additive type of gene action. It is concluded that variety Uqab 2000 proved to be the best general combiner for spike length, number of spikelets per spike, number of grains per spike and grain yield per plant. While, Fsd. 85 was best general combiner for flag leaf area and 1000-grain weight, and second best combiner for number of spikelets per spike and grain yield per plant. The variety MH. 97 was best combiner for number of fertile tillers per plant. Regarding plant height Punjab 96 was the best general combiner with lowest negative value followed by Inqalab 91. Among the crosses Inqalab 91 × Fsd. 85 proved to be the best specific combiner for spike length, number of spikelets per spike, number of grains per spike and grain yield per plant. Inqalab 91 × MH. 97 was best specific combiner for 1000-grain weight and Uqab 2000 × Punjab 96 for number of fertile tillers per plant. The F_1 hybrid Inqalab 91 × Uqab 2000 having lowest negative value was the best specific combiner for plant height. While, the hybrid Punjab 96 × Fsd. 85 was best specific combiner for flag leaf area.

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