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Combining Ability for Yield and its Components in Bread Wheat (*Triticum aestivum* L.)

JEHANZEB FAROOQ[1], IMRAN HABIB, AKHTAR SAEED, NAUSHERWAN NOBEL NAWAB, IHSAN KHALIQ AND GHULAM ABBAS
Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad–38040, Pakistan
[1]Corresponding author's e-mail: jehanzeb1763@hotmail.com

ABSTRACT

Combining ability of some metric traits was studied in a 5 × 5 diallel cross of wheat involving three varieties (PBW-222, LU26S & Uqab-2000) and two lines (8961 & 8952). The above mentioned lines/varieties were planted during the year 2002 - 03. Mean squares for general combining ability (GCA) were significant for plant height, fertile tillers per plant, spike length, spikelets per spike, grains per spike and flag leaf area. Specific combining ability (SCA) mean squares were highly significant for all traits. Reciprocal effects were significant for plant height, flag leaf area, tillers per plant, spikelets per spike and grains per spike but were non-significant for spike length, 1000-grain weight and grain yield per plant. The magnitude of GCA variance was higher than the SCA variance indicating additive gene effects for flag leaf area, spike length, spikelets per spike and grains per spike. While high SCA variance for plant height, tillers per plant, 1000-grain weight and grain yield per plant confirmed the presence of non-additive genetic effects. The cross LU26S × Uqab-2000 showed high values of SCA effects for fertile tillers per plant, spike length, spikelets per spike, grains per spike and grain yield per spike. The variety Uqab-2000 proved to be the best general combiner for most of the traits and could be used in wheat breeding programs.

Key Words: GCA; SCA; Additive effects; Diallel

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the major staple food source for a large part of world population including Pakistan. In Pakistan, wheat is grown on 8.141 million hectares with an average yield of 2.28 tons per hectare. This is far lesser than that of the most wheat producing countries of the world. The production of wheat can be increased either by greater area under cultivation or by increasing per hectare yield. It is not feasible to increase area under wheat due to other competing crops and shortage of irrigation water. Therefore, the only alternate left is to increase per hectare yield. This is possible through the use of advanced crop management techniques and introducing high yielding varieties that are better adapted to wide range of environments and stresses.

Various researchers have reported general and specific combining ability effects for several wheat varieties/lines (Borghi & Perenzin, 1994; Mishra *et al.*, 1994; Bhutta *et al.*, 1997; Mahmood & Chowdhry, 2002; Saeed *et al*., 2002; Chowdhry *et al.*, 2005). All these studies revealed that a large part of genetic variability for yield and its components was equally associated with general and specific combining ability, which is a measure of additive and non-additive genetic variance, respectively indicating the usefulness of both additive and non-additive genetic variability for yield components. In present research work the best combining parent out of five widely grown native bread wheat varieties and promising high yielding lines was assessed. The estimates thus obtained would help to exploit the parents for further breeding program.

MATERIALS AND METHODS

The research work was carried out in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental material comprised five varieties/lines of bread wheat viz., PBW-222, LU26S, Uqab-2000, 8952 and 8961. These genotypes were crossed in diallel fashion during crop season 2002 - 03. Resulting F_1 progeny including parents were field sown on November 8, 2003 using randomized complete block design in three repeats. A single line of 5 m length having approximately 30 plants served as an experimental treatment to evaluate their performance as compared to their parents.

The seeds were dibble-sown keeping plant to plant and line to line distances of 15 and 30 cm, respectively. Two seeds per hole were planted to ensure proper plant population growth. All other agronomic practices like, irrigation, fertilizer application, weeding, etc., were carried out uniformly. Non-experimental plants were also raised at the borders to eliminate competition among marginal plants. At maturity ten guarded plants from each treatment were selected at random and data were recorded for plant height (cm), flag leaf area (cm^2), fertile tillers per plant, spike length (cm), spikelets per spike, 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.

RESULT AND DISCUSSION

Plant height. Analysis of variance for combining ability revealed that mean squares due to GCA, SCA and reciprocal effects were highly significant (Table I). Although general combining ability mean square was greater than specific combining ability mean square but calculations of variance components revealed that SCA effects (5.711) were greater than GCA effects (Table II), which indicated the preponderance of non-additive genetic effects for plant height. These results are in agreement with the findings of Borghi and Perenzin (1994), Mishra *et al.* (1994) and Chowdhry *et al.* (2005). However, (Chowdhry & Ahmed, 1990; Rajara & Maheshwari, 1996) illustrated additive genetic effects in the control of this trait.

Estimates of GCA effects of parents and their corresponding standard errors (S.E) are given in Table III. Highest positive GCA effect was exhibited by line 8952 (4.208) followed by 8961 (3.466). PBW-222 showed the desirable negative GCA effect of -12.080. Short stature behavior is preferred, because these plants do not lodge and are more fertilizer responsive; therefore, negative combining ability effects are preferred for plant height in case of wheat. Maximum positive SCA effects (Table IV) were observed in cross combination Uqab-2000 × 8952 (2.987) followed by PBW-222 × 8961 (1.897). While PBW-222 × Uqab-2000, 8961 × 8952, LU26S × 8952, PBW-222 × 8952, LU26S × 8961 and PBW-222 × LU26S showed desirable negative SCA effects of -2.423, -2.341, -2.262, -1.222, -0.785 and -0.638, respectively.

The highest positive reciprocal effects (Table V) were displayed by LU26S × Uqab-2000 (2.513) followed by PBW-222 × 8952 (1.098). The lowest reciprocal effects were exhibited by 8961 × 8952 (-3.781) and Uqab-2000 × 8952 (-2.181).

Flag leaf area. Estimates of mean squares were significant for GCA and reciprocal effects whereas, highly significant for SCA effects (Table I). It was observed that variance of GCA effects was greater than that of SCA effects. Similar results were obtained from the estimates of variance components (Table II). These results indicate the importance of additive genetic effects for the control of flag leaf area (Mahmood & Chowdhry, 1994; Bhutta *et al.*, 1997). Maximum GCA effects for flag leaf area were shown by Uqab-2000 (2.067) followed by PBW-222 (1.970), while high negative GCA effects were shown by variety LU26S (-2.478) and line 8961 (-1.244) in this study (Table III). Maximum SCA effects (Table IV) were observed for crosses PBW-222 × 8952 and LU26S × Uqab-2000 with values of 3.285 and 2.538, respectively, while maximum negative SCA effects were indicated by cross combination PBW-222 × LU26S (-1.506) and LU26S × 8961 (-1.088). Four crosses 8961 × 8952 (2.578), LU26S × 8961 (2.16), PBW-222 × 8961 (2.068) and LU26S × Uqab-2000 (0.026) indicated positive reciprocal effects (Table V), whereas negative reciprocal effects ranged from -0.353 (PBW-222 × LU26S) to -3.865 (Uqab 2000 × 8952).

Number of fertile tillers per plant. Mean squares of GCA were lower than SCA mean squares and highly significant for number of fertile tillers per plant (Table I). Mean squares for SCA and reciprocal effects were also highly significant. The variance components (Table II) revealed the proportion of SCA variance suggesting the preponderance of non-additive genetic effects. Importance of non-additive genetic effects for fertile tillers per plant was also reported by Li *et al*. (1991) and Senapati *et al.* (1994). Highest positive GCA effects for fertile tillers per plant were recorded in the parent PBW-222 (0.342) thus turned out to be the best general combiner for this trait (Table III) followed by 8961 (0.259). Other three parents i.e. Uqab-2000 (-0.331), 8952 (-0.195) and LU26S (-0.075) showed negative GCA effects.

Positive SCA effects were maximum in LU26S × Uqab-2000 (0.261) and Uqab-2000 × 8952 (0.231) hybrids (Table IV), which turned out to be the best specific combinations. While, LU26S × 8952 (-1.142), PBW-222 × LU26S (-0.779) and Uqab-2000 × 8961 (-0.622) were the poorest specific combiners with highest negative values. Highest positive reciprocal effects (Table V) were shown by LU26S × 8952(0.750) followed by 8961 × 8952 (0.550), whereas highest negative reciprocal effects were associated with Uqab-2000 × 8952 (-0.833).

Spike length. GCA, SCA effects were highly significant and reciprocal effects were significant for spike length. Mean squares due to GCA were greater than SCA mean squares (Table I). Similarly, the variance components also indicated that GCA variance was higher than SCA variance (Table II) indicating a predominant role of additive genetic effects for this trait (Tosun *et al.*, 1995; Shahzad *et al.*, 1998; Iqbal & Chowdhry, 2000; Kashif & Khaliq, 2003). The best general combiner for spike length (Table III) was Uqab-2000 (0.623). Remaining four parents showed negative values. The poorest general combiner was LU26S with negative GCA effects of (-0.007) followed by 8952 (-0.016). The cross combination LU26S × Uqab-2000 (0.627) indicated highest positive SCA effects (Table IV) followed by PBW-222 × 8961 (0.530). Four crosses namely Uqab-2000 × 8952, PBW-222 × LU 26S, PBW-222 × Uqab-2000 and LU26S × 8961 displayed negative SCA effects (-0.084, -0.176, -0.250 & -0.563, respectively). The hybrid Uqab-2000 × 8952 was the poorest specific combiner. A reference to Table V indicates that maximum positive reciprocal effects were observed in the hybrid Uqab-2000 × 8961 (0.217) followed by 8961 × 8952 (0.188), while maximum negative reciprocal effects were exhibited by PBW-222 × Uqab-2000 (-0.510).

Spikelets per spike. The genotypic mean variance showed that GCA, SCA and reciprocal, mean squares were highly significant for number of spikelets per spike (Table I). The

Table I. Combining ability analysis (mean squares) for certain traits using five wheat genotypes in a five diallel cross

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	163.622**	39.872*	0.842**	1.476**	7.288**	38.13**	32.560**	10.664**
SCA	10	8.053**	10.028**	2.097**	0.255**	0.412**	14.268**	10.211**	8.075**
Reciprocal	10	6.391**	9.473*	0.494**	0.130^{ns}	0.195*	3.920**	3.408^{ns}	2.493^{ns}
Error	48	6.845	0.432	0.251	0.067	0.080	1.200	0.786	0.709

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

Table II. Analysis of variance of combining ability in a 5 × 5 diallel cross of wheat

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	3.030	5.584	-0.116	0.122	0.689	22.449	2.280	0.294
	(22.85)	(50.43)		(46.21)	(73.06)	(71.07)	(24.78)	(5.28)
SCA	5.711	3.435	1.099	0.111	0.197	7.778	5.610	4.384
	(43.07)	(31.02)	(90.08)	(42.05)	(20.50)	(24.62)	(60.97)	(78.72)
Reciprocals	4.520	2.054	0.121	0.031	0.057	1.360	1.311	0.891
	(34.08)	(18.55)	(9.92)	(11.74)	(6.44)	(4.31)	(14.25)	(16.00)
Error	0.432	2.281	0..251	0.067	0.080	1.200	0.785	0.709

Values in the parenthesis indicate the percentage of variance components.

Table III. Estimates of general combining ability effects for some polygenic traits of wheat in a 5 × 5 diallel cross wheat

Varieties	Plant height	Flag leaf area	Fertile tillers per plant	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Grain yield per plant
PBW-222	-12.080	1.970	0.342	-0.405	-0.751	-2.371	-2.463	-1.130
LU26S	1.982	-2.478	-0.075	-0.007	-0.464	-1.948	2.047	0.172
UQAB-2000	2.424	2.067	-0.331	0.623	1.319	8.692	-1.173	1.643
8961	3.466	-1.244	0.259	-0.194	-0.494	-2.788	0.543	-0.451
8952	4.208	-0.314	-0.195	-0.016	0.389	-1.585	1.047	-0.234
SE($g_i - g_j$)	0.675	0.294	0.224	0.116	0.127	0.470	0.396	0.377

Table IV: Estimates of specific combining ability effects for certain characters in a diallel cross using five wheat genotypes.

Table IV. Estimates of specific combining ability effects for certain characters in a diallel cross using five wheat genotypes

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
PBW-222 × LU26S	-0.638	-1.506	-0.779	-0.176	-0.016	0.158	2.640	-0.272
PBW-222 × Uqab 2000	-2.423	0.620	-0.439	-0.250	-0.749	-3.615	1.043	-1.578
PBW-222 × 8961	1.897	1.939	-0.329	0.530	0.514	3.448	1.093	1.367
PBW-222 × 8952	-1.222	3.285	-0.242	0.177	0.214	0.561	1.723	1.899
LU26S × Uqab 2000	0.922	2.538	0.261	0.627	0.781	5.361	1.317	3.093
LU26S × 8961	-0.785	-1.088	-0.462	-0.563	-0.556	-3.425	-0.567	-1.619
LU26S × 8952	-2.262	0.573	-1.142	0.098	-0.006	-0.629	-1.470	-2.864
Uqab 2000 × 8961	0.329	1.224	-0.622	0.022	0.361	-1.265	0.037	-1.290
Uqab 2000 × 8952	2.987	-0.844	0.231	-0.084	0.011	0.198	1.217	0.815
8961 × 8952	-2.341	0.528	-0.509	0.090	-0.176	1.128	-1.717	-1.287
SE ($S_{ij} - S_{ik}$)	1.351	0.588	0.448	0.233	0.254	0.980	0.793	0.753
SE ($S_{ij} - S_{kl}$)	1.170	0.509	0.388	0.202	0.220	0.849	0.687	0.652

additive genetic effects occurred due to much greater GCA mean squares as well as higher GCA variance in the computation of variance components (Table II), which is in line with previous studies (Tosun *et al.*, 1995; Bhutta *et al.*, 1997). GCA effects (Table III) were maximally exhibited by Uqab-2000 (1.319), while minimally by variety LU26S (-0.464). The best specific performance (Table IV) was indicated by the hybrids PBW-222 × 8961 (0.514) and Uqab-2000 × 8952 (0.361), whereas poorest SCA effects were exhibited by hybrids PBW-222 × Uqab-2000 (-0.749) followed by cross LU26S × 8961 (-0.556). The highest positive reciprocal effects (Table V) were displayed by cross LU 26S × Uqab-2000 (0.433) followed by hybrid Uqab-2000 × 8961 (0.217), while lower by crosses Uqab-2000 × 8952 (-0.650) followed by PBW-222 × Uqab-2000 (-0.483), 8961 × 8952 (-0.183) and PBW-222 × 8952 (-0.510), respectively.

Grains per spike. The mean squares due to GCA, SCA and

Table V. Estimates of reciprocal effects for certain characters in a diallel cross using five wheat genotypes

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
LU26S × PBW-222	-0.858	-0.353	-0.217	-0.028	0.000	-0.267	0.750	0.275
Uqab 2000× PBW-222	-1.150	-0.621	0.267	-0.510	-0.483	-0.933	1.600	0.707
8961× PBW-222	-0.188	2.068	0.367	-0.043	0.067	-1.050	1.133	0.450
8952× PBW-222	1.098	-2.785	0.367	-0.145	-0.050	-0.333	1.633	1.730
Uqab 2000× LU26S	2.513	0.026	-0.217	0.185	0.433	2.100	-1.383	-1.100
8961× LU26S	-1.355	-1.681	-0.283	-0.257	0.183	-0.933	-0.350	-0.850
8952× LU26S	-0.267	2.160	0.750	0.100	0.117	1.100	-1.017	1.005
8961× Uqab 2000	-1.171	-2.387	-0.633	0.217	0.217	1.767	1.667	0.610
8952× Uqab 2000	-2.181	-3.865	-0.833	-0.421	-0.650	-2.100	-0.617	-2.305
8952× 8961	-3.781	2.587	0.550	0.188	-0.183	1.850	-1.933	0.261
SE ($R_{ij} - R_{kl}$)	1.510	0.658	0.501	0.260	0.284	1.096	0.887	0.842

reciprocal effects were highly significant (Table I). GCA mean squares were much greater than SCA mean squares. The variance components also depicted that GCA variance was greater than that of SCA indicating the preponderance of additive genetic effects for number of grains per spike (Table II), which contrasts the earlier findings, which reported non-additive genetic effects for this trait (Rajara & Maheshwari, 1996; Shahzad *et al.*, 1998; Chowdhry *et al.*, 1999). This difference in results may be due to difference in genetic material used and environmental conditions under, which the experiment was conducted. Out of 5 parents Uqab-2000 was the best combiner with positive GCA effects (8.629), whereas 8961 (-2.788) was the poorest general combiner (Table III). Regarding SCA effects (Table IV) hybrid LU26S × Uqab-2000 (5.361) followed by cross combination PBW-222 × 8961 (3.448) were the best specific combiners. PBW-222 × Uqab-2000 was the poorest specific combiner (-3.615) followed by the cross LU26S × 8961 (-3.425). The highest reciprocal effects (Table V) were exhibited by cross combination LU26S × Uqab-2000 (2.100), whereas the lowest reciprocal effects were shown by two crosses Uqab-2000 × 8952 and PBW-222 × 8961 with values of -2.100 and -1.050, respectively.

1000-grain weight. GCA and SCA effects were highly significant but reciprocal effects were non-significant for 1000-grain weight (Table I). Although mean squares due to GCA effects were higher than mean squares of SCA effects but prevalence of non-additive gene action was revealed after the computation of variance components. The SCA variance turned out to be higher than GCA variance (Table II). The results are in accordance with those of Rajara and Maheshwari (1996). It was revealed that LU26S proved to be the best combiner (Table III) with higher GCA effects (2.047) followed by 8952 (1.047) however, variety PBW-222 showed the poorest GCA with a value of -2.463. In case of SCA effects (Table IV) the hybrid PBW-222 × LU26S performed well with the highest (2.640) SCA effects followed by the hybrid PBW-222 × 8952 (1.723). Lowest specific combiners were 8961 × 8952 and LU26S × 8952 with negative values of -1.717 and -1.470, respectively. Table V showed that 50% hybrids displayed positive reciprocal effects. The cross Uqab-2000 × 8961 manifested highest positive reciprocal effects (1.667), closely followed by hybrid PBW-222 × 8952 (1.633). The minimum reciprocal effects ranged from -1.383 (LU26S × Uqab-2000) to -1.933 (8961 × 8952).

Grain yield per plant. Highly significant mean squares were observed for GCA and SCA effects, whereas for reciprocal effects non-significant mean squares were found (Table I). In line with the previous findings the components of variance revealed that SCA variance was much greater GCA variance (Table II), giving the importance of non-additive genetic control for grain yield (Mishra *et al.*, 1994; Chowdhry *et al.*, 1999). Maximum GCA effects (1.643) were found in case of Uqab-2000 followed by LU26S (Table III). Other three genotypes PBW-222, 8961 and 8952 showed negative GCA effects with values of -1.130, -0.451 and -0.234, respectively. LU26S × Uqab-2000 (Table IV) revealed maximum SCA effects (3.093) followed by hybrid PBW-222 × 8952 (1.899). The cross combinations LU26S × 8952 and LU26S × 8961 indicated negative SCA effects of -2.864 and -1.619, respectively. General combining ability effects presented in Table V revealed that the hybrid PBW-222 × 8952 (1.730) exhibited the maximum GCA effects for grain yield per plant followed by LU26S × 8952 (1.005). The weakest performance with highest negative reciprocal effects (-2.305) was displayed by hybrid Uqab-2000 × 8952 followed by LU26S × Uqab-2000 (-1.100).

CONCLUSION

In essence Uqab-2000 could be used for improvement in flag leaf area, spike length, Spikelets per spike, grain per spike and grain yield per plant. The variety LU26S could be used to improve grain yield per plant and 1000-grain weight. Likewise, PBW-222 could be used for the production of short stature cultivars, better flag leaf area and more fertile tillers per plant. Line 8952 holds promise for incorporating improved 1000-grain weight and spikelet per spike.

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