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Estimation of Combining Ability Effects for Plant Biomass, Grain Yield and Protein Content in Wheat (*Triticum aestivum* L.)

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ABSTRACT

In order to examine the genetic mechanisms for controlling biomass, protein content and grain yield, 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. Combining ability analysis of the data revealed that general combining ability effects were highly significant ($P \leq 0.01$) for biomass, protein content and grain yield. The general combining ability (GCA) variances were greater than specific combining ability (SCA) variances for biomass per plant and protein content, which showed the predominance of non-additive gene effects. SCA variance was greater than GCA variance for grain yield per plant that showed the predominance of additive gene effects. Among the eight parents, LU 26S and Chakwal 86 appeared to be the best general combiners for all the characters studied. Due to the preponderance effects of additive genes, it seems that single plant selection in segregating generations would be effective for improving the traits.

Key Words: Combining ability; *Triticum aestivum* L.; Biomass; Protein content; Grain yield; Non-additive and additive variance

INTRODUCTION

Wheat is a crucial food staple for a large part of humanity in the world. In Pakistan people eat bread as a main meal in breakfast, lunch and dinner and therefore, genetic improvement of wheat in respect of grain yield and quality has remained a prime objective in agricultural sector. Consequently, people of the region witnessed the Green Revolution in wheat production. However, most wheat varieties currently under cultivation in this country seem to have reached a state of decay with their pristine yielding abilities significantly diminished. These need to be either appropriately renovated and restored or discarded and replaced with newly evolved varieties possessing attractive agronomic attributes and the possibilities of matching economic returns in competitive farming. In the selective improvement of crop plants, quantitative characters like plant biomass, grain yield and quality figure prominently in breeding programmes.

For the estimation of combining ability effects for plant biomass, grain yield and protein content, 8 wheat varieties/lines once known for one or another good quality, namely, Pak 81, LU 26S, Inqilab 91, Rawal 87, Chakwal 86, Barani 83, Rohtas 90 and 5039, were selected. These genotypes were crossed in a diallel fashion and data collected were analysed according to the procedures given by Griffing (1956).

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. Prior to anthesis, the florets were emasculated. The emasculated spikes were enclosed separately in glassine bags. A day after emasculation pollinations were made by shaking ripe anthers. At maturity the seed was harvested from each female parent.

Assessment of diallel progenies. The seed of 56 F_1 hybrids and their 8 parents was 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 plant biomass, the selected plants were harvested from the ground level and above ground biomass per plant was recorded by weighing the whole plant including straw and grains. The grains obtained from a single plant were weighed using an electronic balance and average plant grain yield was determined for each genotype. The protein contents of three seed samples per family were determined by grinding the oven dried seed. The flour was analyzed for protein percentage according to the AOAC method (1984). The following formula was used to estimate the % protein.

$$\% \text{ Nitrogen} = \frac{Vol.\,of\;\; acid\; used \times 0.0014 \times 250}{Wt.\,of\;\; sample \times 25\; ml}$$

% Protein = 6.25 × N %

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

Good combining ability implies the capacity of a parent to produce superior progeny when combined with another parent. General combining ability (GCA) provides an assessment of the degree of mainly additive gene action, while specific combining ability (SCA) refers to the performance of two particular lines in a specific cross, and it thus reflects non-additive types of gene interactions. Statistically, 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. Results obtained from the analysis of the diallel cross data following combining ability approach (Griffing, 1956) are present here. Simple analysis of variance of biomass per plant, protein content and grain yield indicated significant differences ($P \leq 0.01$) in the characters studied (Table I). Further analysis of the data, following the combining ability technique (Griffing, 1956) revealed highly significant differences for mean squares due to general and specific combining ability for biomass per plant, protein content and grain yield and for reciprocal effects, were significant ($P \geq 0.01$) for all the characters.

Involvement of additive genetic effects was inferred due to greater GCA variance for biomass per plant (Table II). Importance of non-additive genetic effects for biomass per plant was also reported in other studies by Singh and Paroda (1988), Mishra *et al.* (1994) and Kumar *et al.* (2003). However, Sangwan *et al.* (1999) observed the importance of both additive and non-additive genetic effects for biomass per plant. The parents expressed different general combining ability effects for the accumulation of biomass per plant (Table III). The maximum positive GCA effects were shown by the genotype Chakwal 86 (2.298), which was the best general combiner for this trait. SCA effects were positive in 12 cross combinations. The best specific combination was Pak 81 × Rohtas 90 with the highest SCA effects of 2.056, while Pak 81 × Inqilab 91 hybrid with SCA effects of -1.875 was the poorest combiner. Twelve crosses showed positive reciprocal effects, which were the maximum in Inqilab 91 × Pak 81 hybrid (3.517).

The SCA variance (9.914) was larger than GCA variance (4.359) for grain yield per plant (Table II), which suggested the importance of non-additive genetic effects for the manifestation of grain yield per plant. Greater SCA variance for grain yield per plant in wheat was also reported by Kumar *et al.* (2003) and Sudesh *et al.* (2002). However, Wagoire (1998), Hamada *et al.* (2002) and Dhayal and Sastry (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.

The genotype 5039 exhibited the 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 (Table IV). 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.

For protein content GCA variance (0.204) was higher than SCA variance (0.092) signifying the importance of additive genetic effects in the inheritance of protein content (Table II). The importance of additive genetic effects was also reported by Kumar *et al.* (2003) and Joshi *et al.* (2003) for protein contents.

The highest GCA effects were found in LU 26S (0.447) and Rohtas 90 (0.427) and were proved as the best general combiners where as Rawal 87 was the poorest general combiner having a GCA effects value of -0.981.

Positive SCA effects were recorded in 19 out of 28 direct crosses, the highest positive SCA effects were recorded in hybrid Rohtas 90 × 5039 (0.461), whilst SCA effects were more negative (-0.553) in the hybrid LU 26S × Rawal 87 (Table V). Positive reciprocal effects were recorded in 10 cross combinations with maximum positive reciprocal effect in hybrid Rohtas 90 × Pak 81 (0.242). Two crosses Rawal 87 × LU 26S and Chakwal 86 × Barani 83

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

Source of variation	D.F.	Biomass/Plant	Grain yield	Protein content
Replication	2	3.96^{NS}	3.71^{NS}	1.71^{**}
Families	63	25.22^{**}	76.32^{**}	1.53^{**}
Error	126	4.55	4.85	0.27

** 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	Biomass/plant	Grain yield	Protein content
GCA	3.33	4.36	0.21
SCA	0.34	9.91	0.09
Reciprocal	0.73	7.08	-0.04
Error	1.52	1.62	0.09

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

Genotypes	LU26S	Pak 81	Barani83	Chak. 86	Rawal87	Rohtas90	Inqilab91	5039
LU26S	**1.214**	-0.141	1.103	-0.023	-1.219	-0.212	0.761	0.297
Pak81	-0.310	**-0.129**	-0.246	0.119	0.769	2.056	-1.875	-0.099
Barani 83	-0.060	0.615	**0.697**	-0.334	0.088	-0.374	-0.774	0.160
Chak. 86	-0.575	-0.330	-2.330	**2.298**	0.352	-0.303	-0.290	1.151
Rawal 87	-0.352	-1.153	1.012	-0.077	**-2.809**	-1.011	3.014	-0.729
Rohtas 90	-1.063	0.462	0.942	-0.050	0.302	**-2.374**	-0.536	0.838
Inqilab 91	0.415	3.517	-1.213	-0.145	2.438	-0.400	**-0.635**	-1.254
5039	1.427	-0.525	-0.350	0.098	0.375	-1.893	2.030	**1.737**

S.E. (g_i) = 0.288 S.E. (s_{ij}) = 0.770 S.E. (r_{ij}) = 0.871

Table IV. 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

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

Genotypes	LU26S	Pak 81	Barani83	Chak. 86	Rawal87	Rohtas90	Inqilab91	5039
LU26S	**0.447**	0.037	0.214	-0.002	-0.553	0.192	0.226	0.310
Pak81	0.035	**-0.132**	-0.073	-0.101	0.181	0.233	0.071	0.296
Barani 83	-0.047	-0.010	**-0.139**	-0.034	0.090	-0.006	0.012	0.000
Chak. 86	-0.050	-0.062	0	**-0.056**	-0.083	0.071	0.024	0.244
Rawal 87	0	0.002	0.035	-0.085	**-0.981**	0.170	-0.518	0.115
Rohtas 90	0.090	0.242	0.047	-0.063	-0.060	**0.427**	-0.165	0.461
Inqilab 91	-0.052	0.028	-0.020	-0.045	-0.023	0.008	**0.042**	0.105
5039	-0.083	-0.017	-0.005	-0.222	-0.060	0.055	0.117	**0.392**

S.E. (g_i) = 0.070 S.E. (s_{ij}) = 0.187 S.E. (r_{ij}) = 0.212

showed no reciprocal effects. The negative reciprocal effects were maximum (-0.085) in the hybrid Rawal 87 × Chakwal 86.

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