

# Assessment of Heritable Variation and Best Combining Genotypes for Grain Yield and Its Attributes in Bread Wheat

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## Abstract

Grain yield in wheat is the resultant of several plant attributes. It is very important to assess heritable variation involved in the inheritance of these attributes in addition to find the best combining genotypes. For this purpose, the present study involving 5 × 5 full diallel analysis was performed. Twenty F<sub>1</sub> hybrids along with their parents (9797, 9801, 9802, Chakwal-50 and Chakwal-86) were planted in field using randomized complete block design (RCBD) with three replications in the research area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during 2015-2016. Plant characters like plant height, flag leaf area, spike length, No. of fertile tillers per plant, No. of grains per spike, No. of spikelets per spike, 1000 grain weight and grain yield per plant were studied in this experiment. Mean squares due to general combining ability (GCA) were highly significant for all the traits except for spike length for which GCA effects were significant. Mean squares due to specific combining ability (SCA) and reciprocal combining ability (RCA) were highly significant for all the characters studied. GCA variance was higher than the SCA variance for spike length and No. of grains per spike exhibiting the predominant role of additive genetic variation in the inheritance of these traits. However, for the characters like plant height, flag leaf area, No. of fertile tillers per plant, No. of spikelets per spike, 1000 grain weight and grain yield per plant, the value of SCA variance was higher than the value of GCA variance showing non additive gene action for these

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traits. The variety Chakwal-50 proved to be the best general combiner for plant height, spike length, No. of spikelets per spike, No. of grains per spike and grain yield per plant. The cross, 9802 × Chakwal-86 was the best specific combination for grain yield and most of the yield attributes. The good general and specific combiners are important breeding resources for the initiation of future wheat breeding programmes aimed at enhancement of grain yield in bread wheat.

## Keywords

Wheat, Combining Ability, Yield, Diallel, Additive Genetic Variation

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## 1. Introduction

Wheat (*Triticum aestivum* L.) is a cereal crop originated in Middle East. It is a self pollinated crop belonging to Poaceae family. Bread wheat is hexaploid species and has three genomes namely A, B and D [1]. Genetic study of wheat is complex because of its large genome size. Wheat supply 20% of total calories consumed by human daily. The genetic studies of wheat enabled breeders to develop high yielding, good quality and disease resistant varieties. It has vital position in Pakistan agricultural policies and in international trade wheat share is more than other crops combined. Contribution of wheat to GDP is 1.9% and 9.6% to value added in agriculture. During 2016-2017, it was cultivated on 9052 thousand hectares and total production was 25.75 million tonnes and yield was 2752 kg/ha [2]. Grain is a good source of carbohydrates, vitamins and minerals. Amount of protein in wheat is more than other cereals and thus a main source of vegetable protein worldwide. Consumption of wheat is increasing by 2% worldwide per year, to fill this increasing demand there is a need to develop high yielding and disease resistant varieties. Genetic studies of wheat provided the information useful in developing wheat varieties with high yield and improved quality [3].

Combining ability studies invented by [4] depict the ability of the parents to transmit their useful characters to next generation and assess the performance of genotypes in cross combinations [5]. Diallel analysis gives information about the inheritance and gene action that enables the plant breeder to do selection in earlier or later generations. Mean performance of a line in cross combinations is evaluated by general combining ability (GCA) and GCA is linked to the percentage of additive type of gene action [6]. SCA is the estimation of the performance of progeny derived from a specific cross in relation to what would be expected based on the average performance of the genotypes involved.

Keeping in view of the above situation the research study was carried out with the following objectives;

- 1) To assess performance of five bread wheat genotypes and their F<sub>1</sub>s to recognize the best performing genotypes,

2) To study the GCA and SCA to discover the best general combiners and hybrid combinations for yield and its related components.

## 2. Materials and Methods

The present research to estimate the combining ability effects for wheat yield and its related traits was carried out in the experimental area of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad (UAF) during 2014-2016. The experimental material was comprised of five different lines/varieties of spring wheat, namely 9797, 9801, 9802, Chakwal-50 and Chakwal-86. During 2014-2015 the genotypes were planted and crossed in all possible combinations according to full diallel crossing scheme. Prior to anthesis the florets on a spike of the female parents were emasculated by clipping back the glumes and removing anthers with fine pointed tweezers. To avoid self-pollination any flower with mature anthers was excluded. The emasculated spikes were enclosed separately in butter paper bags. A day after emasculating pollinations were made by shaking ripe anthers from the male parent plant on to the mature stigma. The spikes, in which crosses were made, were covered again with butter paper bags for about one week to prevent any other cross fertilization. At maturity the crossed seed was harvested from each female parent and parental lines. Seeds of twenty  $F_1$  crosses along with their parents were sown in the experimental area on November 22, 2015 in a triplicate randomized complete block design. The entries were assigned at random to experimental units in each block. The interplant and inter row distances were 15 cm and 30 cm, respectively. Two seeds per hole were sown with the help of dibbler and after germination thinning was done to have a single healthy seedling per hole. Standard cultural practices, irrigation, fertilizer and hoeing were provided to all treatments.

At maturity, 10 guarded plants were selected randomly from each row of each replication and data were recorded for traits like plant height, flag leaf area, spike length, No. of fertile tillers per plant, No. of grains per spike, No. of spikelets per spike, 1000 grain weight and grain yield per plant. Analysis of variance for combining ability was carried using Griffing approach [4] (Method I Model II). Estimates of GCA, SCA and reciprocal effects and their variances were also calculated by Griffing approach [4].

## 3. Results and Discussion

The results pertaining to the heritable variation and inheritance pattern of grain yield and its various attributes are given below.

### 3.1. Plant Height

In wheat negative combining ability effects are desirable for plant height. Analysis of variance for combining ability revealed that mean squares for GCA, SCA, and RCA effects were highly significant (**Table 1**). Although mean squares of

**Table 1.** Analysis of variance for combining ability in a 5 × 5 diallel cross of wheat.

SOV	D.F	Plant height	Flag leaf area	Spike length	Fertile tillers per plant	Grains per spike	Spikelets per spike	1000 grain weight	Grain yield per plant
GCA	4	46.82**	22.26**	1.76*	5.91**	50.74**	2.27**	9.24**	4.64**
SCA	10	28.55**	23.86**	1.51**	2.91**	51.94**	4.23**	15.79**	9.33**
RCA	10	58.55**	5.59**	1.85**	4.82**	82.38**	2.83**	12.84**	7.94**
Error	48	8.83	1.57	0.49	0.43	0.81	0.59	0.82	4.11

\* = Significant at  $P \leq 0.05$ ; \*\* = Highly Significant at  $P \leq 0.01$ .

GCA (46.82) were greater than SCA mean squares (28.55) but estimates of components of variance (Table 2) showed that SCA variance (11.74) was greater than GCA variance (1.92) which displayed that non-additive genetics effects were involved in controlling this trait. These results are in agreements with findings of [7] [8] [9] [10] that the plant height is controlled by non-additive type of genetic mechanism.

The estimates of GCA effects of parents were in the range of  $-2.21$  to  $2.95$  for the plant height (Table 3). The highest positive GCA effects were exhibited by the parent 9797 with the value of  $2.95$  and the highest negative effects for this trait were depicted by parent Chakwal-50 having the value of  $-2.21$  followed by 9802 ( $-2.04$ ). The negative GCA values are preferred for introducing dwarfing genes in high yielding varieties. SCA effects are shown in Table 4. The cross namely  $9801 \times 9802$  had the highest positive SCA value ( $4.33$ ) followed by  $9802 \times$  Chakwal-50 ( $3.52$ ). Cross, Chakwal-50  $\times$  Chakwal-86 ( $-5.75$ ) exhibited the highest negative SCA effects followed by  $9797 \times 9801$  ( $-3.86$ ) exhibiting that the hybrids of these crosses will give more desirable segregates and will be helpful in hybrid wheat development programmes. The lowest reciprocal effects for plant height were exhibited by Chakwal-50  $\times$  9797 ( $-9.76$ ) followed by Chakwal-86  $\times$  9802 ( $-6.35$ ). The highest positive reciprocal effects were depicted by Chakwal-86  $\times$  9797 ( $8.96$ ) followed by Chakwal-86  $\times$  9801 ( $6.89$ ) (Table 5).

### 3.2. Flag Leaf Area

Combining ability analysis showed that mean squares due to GCA, SCA and RCA effects were highly significant for flag leaf area (Table 1). Mean square values for SCA were greater than GCA mean squares. Similarly variance of SCA

**Table 2.** Estimation of components of variation for combining abilities of some polygenic traits in a 5 × 5 diallel crosses of wheat.

Components of variation	Plant height	Flag leaf area	Spike length	Fertile tillers per plant	Grains per spike	Spikelets per spike	1000 grain weight	Grain yield per plant
Vg	1.92	-5.35	0.61	0.31	30.43	-0.18	-0.58	-0.43
Vs	11.74	13.26	0.02	1.48	0.12	2.17	8.91	5.31
Vr	24.86	2.00	0.68	2.19	40.78	1.12	6.01	3.76

**Table 3.** Estimates of general combining ability effects for some polygenic traits of wheat in a 5 × 5 diallel cross of wheat.

Parents	Plant height	Flag leaf area	Spike length	Fertile tillers per plant	Grains per spike	Spikelets per spike	1000 grain weight	Grain yield per plant
9797	2.95	1.13	0.31	0.88	-1.03	-0.66	0.40	0.94
9801	0.43	-1.02	-0.07	-0.89	-2.22	0.14	-0.49	0.11
9802	-2.04	-0.98	-0.67	0.01	2.35	0.31	1.15	-0.98
Chakwal-50	-2.21	-1.19	0.32	0.63	2.50	0.51	-0.63	1.23
Chakwal-86	0.86	2.05	0.14	-0.63	-1.59	-0.29	-0.79	0.04

**Table 4.** Estimates of specific combining ability effects for some yield and yield related traits in a 5 × 5 full diallel cross of wheat.

Crosses	Plant height	Flag leaf area	Spike length	Fertile tillers per plant	Grains per spike	Spikelets per spike	1000 grain weight	Grain yield per plant
9797 × 9801	-3.86	2.81	0.46	0.52	3.18	1.57	-1.03	-1.90
9797 × 9802	-0.92	-2.21	-0.78	-1.44	0.48	-2.27	-0.98	2.18
9797 × Chakwal-50	2.29	-0.86	-0.75	-0.41	-4.41	0.05	-0.22	-1.20
9797 × Chakwal-86	1.73	1.88	-0.09	0.98	-2.45	0.19	0.41	-2.60
9801 × 9802	4.33	1.35	-1.25	-1.49	-1.00	-0.11	1.78	-0.96
9801 × Chakwal-50	1.98	2.74	0.29	-0.54	0.08	1.76	1.27	1.18
9801 × Chakwal-86	-1.98	-2.59	0.64	1.16	8.20	-0.05	-4.73	1.16
9802 × Chakwal-50	3.52	-4.74	0.13	1.00	-2.76	-1.36	2.52	1.98
9802 × Chakwal-86	-1.98	0.26	1.2	1.55	8.43	1.45	3.33	2.48
Chakwal-50 × Chakwal-86	-5.75	4.66	0.07	-1.28	5.32	-2.11	-0.64	-0.10

**Table 5.** Estimates of reciprocal effects for some yield and yield related traits in a 5 × 5 full diallel cross of wheat.

Crosses	Plant height	Flag leaf area	Spike length	Fertile tillers per plant	Grains per spike	Spikelets per spike	1000 grain weight	Grain yield per plant
9801 × 9797	2.41	-0.73	0.35	-1.66	-3.63	-1.44	-0.51	-1.58
9802 × 9797	-0.84	2.69	-0.73	-2.33	-12.67	1.53	-3.46	2.22
9802 × 9801	1.29	-2.08	-0.36	-1.62	-1.01	-1.77	-0.09	-0.43
Chakwal-50 × 9797	-9.75	-1.51	-0.93	1.69	-0.38	-0.37	1.61	-4.06
Chakwal-50 × 9801	3.96	1.11	-0.27	2.43	2.33	-1.58	3.91	1.86
Chakwal-50 × 9802	-1.09	-1.41	0.08	0.84	-12.58	0.23	1.88	0.35
Chakwal-86 × 9797	8.96	-1.02	2.12	-0.76	6.68	-1.66	4.88	2.13
Chakwal-86 × 9801	6.89	-0.10	1.34	1.25	-5.04	-0.02	-1.78	0.16
Chakwal-86 × 9802	-6.36	3.03	-0.99	0.58	-1.45	-1.08	0.51	-1.81
Chakwal-86 × Chakwal-50	-2.03	-0.07	0.40	-1.13	-0.97	0.01	1.79	2.02

effects (**Table 2**) was greater than variance of GCA effects indicating the predominance of nonadditive gene action. The above results are in agreement with the findings of [11] [12] [13] who reported nonadditive gene action for flag leaf area. However, [7] [14] reported additive gene action for governing flag leaf area.

The estimates of GCA (**Table 3**) revealed that parent Chakwal-86 (2.05) exhibited the highest positive GCA effects for flag leaf area followed by 9797 (1.13) remaining three parents had negative GCA effects. Chakwal-50 was the poorest general combiner with highest negative GCA effects (-1.19). The cross namely Chakwal-50 × Chakwal-86 exhibited the highest positive SCA effects (**Table 4**) which were 4.66 followed by 9797 × 9801 (2.80) while the cross 9801 × Chakwal-50 showed the highest negative SCA effects which were -4.74 followed by 9801 × Chakwal-86 (-2.59). Two crosses Chakwal-86 × 9802 and 9802 × 9797 manifested positive reciprocal effects of 3.03 and 2.69 respectively and remaining crosses manifested negative reciprocal effects ranging from -2.08 (9802 × 9801) to -1.51 (Chakwal-50 × 9797) (**Table 5**). The above discussion revealed that the best general combiner for the flag leaf area was Chakwal-86 and the best specific combiner for this trait was Chakwal-50 × Chakwal-86.

### 3.3. Spike Length

ANOVA for combining ability depicted that the mean squares for general combining ability were significant. While the mean squares due to SCA effects and RCA effects were highly significant (**Table 1**). Mean squares of GCA (1.76) were higher than mean squares of SCA (1.51) indicating the importance of additive type of gene action for spike length and mean squares of RCA were 1.85. Calculation of variance components also confirmed additive type of gene action for spike length (**Table 2**). These results are in agreements with the findings of [9] [15].

Estimates of GCA effects are given in **Table 3**. Results revealed that the good general combiners for spike length were Chakwal-50 and 9797 with GCA effects of 0.32 and 0.31 respectively. Genotypes 9802 (-0.67) and 9801 (-0.07) exhibited the high negative GCA values thus proved poor combiners for spike length. Estimates for the SCA effects (**Table 4**) were studied and the value 1.20 was the highest positive value for this trait which was exhibited by the cross namely 9802 × Chakwal-86 followed by 9801 × Chakwal-86 (0.64). Negative SCA effects of -1.25, -0.78, -0.75 and -0.09 were exhibited by the crosses namely, 9801 × 9802, 9797 × 9802, 9797 × Chakwal-50 and 9797 × Chakwal-86 respectively. Highest positive reciprocal effects were shown by cross Chakwal-86 × 9797 with 2.12 value followed by Chakwal-86 × 9801 (1.34) and highest negative reciprocal effects (-0.99) were exhibited by a cross named as Chakwal-86 × 9802 (**Table 5**).

### 3.4. Fertile Tillers per Plant

ANOVA for combining ability depicted the highly significant mean squares due to GCA (13.8), SCA (6.80) and RCA effects (4.82) (**Table 1**). Although the mean squares of GCA were higher than the mean squares of SCA for No. of tillers per plant but computation of variance components showed that SCA variance was higher than the variance of GCA denoting the non-additive gene action for fertile tillers per plant (**Table 2**). These results are in accordance with the results of [14] [16] [17]. The contrary results were reported by [18] [19].

For this trait the estimates GCA effects revealed that parent namely 9797 exhibited the highest positive GCA value which was 0.88 followed by Chakwal-50 (0.63) and the genotype 9801 exhibited the highest negative value -0.89 followed by Chakwal-86 (-0.63) (**Table 3**). Three crosses namely 9802 × Chakwal-86, 9801 × Chakwal-86 and 9802 × Chakwal-50 were good specific combiners for fertile tillers per plant with the positive SCA effects (1.55, 1.16 and 1.00 respectively). Weakest specific combination for this trait was the hybrid 9801 × 9802 (-1.49) followed by 9797 × 9802 (-1.44) (**Table 4**). In case of reciprocal effects (**Table 5**) maximum value was shown by cross Chakwal-50 × 9801 (2.43) followed by Chakwal-50 × 9797 (1.69) and Chakwal-86 × 9801 (1.25). The cross 9802 × 9797 exhibited poorest performance with highest negative reciprocal effects (-2.33). Four other crosses namely 9801 × 9797, 9802 × 9801, Chakwal-86 × Chakwal-50 and Chakwal-86 × 9797 also displayed negative reciprocal effects of -1.66, 1.62, -1.13 and -0.76 respectively. Parent, 9797 was the best general combiner and cross 9802 × Chakwal-86 was the best specific combination for fertile tillers per plant.

### 3.5. No. of Grains per Spike

Analysis of variance for combining ability showed that there were highly significant means squares for GCA, SCA and RCA (**Table 1**). These results exhibited that the mean square value for GCA ruled over SCA mean square indicating predominant additive type of gene action for this trait. Higher GCA variance than variance of SCA also confirmed the presence additive genetic effects (**Table 2**). The similar findings, which indicated additive type of gene action, were obtained by [9] [20].

Estimates of general combining ability effects (**Table 3**) revealed that parent Chakwal-50 (2.49) possessed highest positive GCA effects followed by 9802 (2.35) and highest negative value was -2.21 possessed by genotype 9801 followed by -1.59 (Chakwal-86). Estimates for the SCA effects (**Table 4**) depicted that crosses 9802 × Chakwal-86 and 9801 × Chakwal-86 showed excellent performance for grains per spike with high positive SCA effects (8.43 and 8.20 respectively) followed by Chakwal-50 × Chakwal-86 (5.32). The highest negative value was shown by 9797 × Chakwal-50 (-4.41) thus it was the weakest specific combiner. Three other crosses also displayed negative SCA effects of -2.76 (9802 × Chakwal-50), -2.45 (9797 × Chakwal-86) and -1.00 (9801 × 9802). Highest positive reciprocal combining ability effects were shown by cross Chakwal-86 × 9797 (6.67) followed by Chakwal-50 × 9797 (2.33) and high negative reciprocal effects of -12.67 and -12.58 were exhibited by crosses named as 9802 × 9797 and Chakwal-50 × 9802 respectively (**Table 5**). Parent, Chakwal-50 proved to be best general combiner and cross, namely 9802 × Chakwal-86 was the best specific combination for No. of grains/spike.

### 3.6. No. of Spikelets per Spike

The analysis of variance for combining ability revealed that mean squares due to

GCA (2.26), SCA (4.23) and RCA (2.83) were highly significant. Mean squares due to SCA (4.23) were greater than GCA mean squares (2.26) and reciprocal combining ability (2.83) mean squares (**Table 1**). Similarly estimates of variance components depicted that SCA variance was higher than GCA variance (**Table 2**). Thus indicating predominant role of non additive gene action for No. of spikelets/spike. These results are in agreement with the findings of [10] [21] [22]. The different results which showed additive gene action for spikelets/spike were reported by [20] [23].

Estimates of GCA effects (**Table 3**) revealed that three parents namely Chakwal-50, 9802 and 9801 exhibited the positive GCA effects of 0.51, 0.31 and 0.14 respectively. Chakwal-50 proved to be the good general combiner as it exhibited the highest value for GCA effects. The highest negative GCA effects were possessed by 9797 (−0.66) followed by Chakwal-86 (−0.29). The maximum SCA effects were exhibited by the cross 9801 × Chakwal-50 (1.76) followed by 9797 × 9801 (1.57) and 9802 × Chakwal-86 (1.45) for this character. Thus cross 9802 × Chakwal-50 was the best specific combination (**Table 4**). Two crosses 9797 × 9802 and Chakwal-50 × Chakwal-86 were poor specific combiners for spikelets/spike possessing high negative SCA effects of −2.27 and −2.11 respectively. For the reciprocal combining ability the cross 9802 × 9797 (1.53) has the maximum positive value and cross 9802 × 9801 (−1.77) has highest negative value (**Table 5**).

### 3.7. 1000 Grain Weight

ANOVA for combining ability revealed that mean squares due to GCA (9.23), SCA (15.79) and RCA (12.84) effects were highly significant for 1000 grain weight (**Table 1**). The mean squares due to SCA were greater than GCA mean squares. Thus, indicated the presence of non additive type of gene action. For 1000 grain weight the estimates of genetic components of variance due to general, specific and reciprocal combining ability were studied and the estimates were −0.58 (Vg), 8.91 (Vs) and 6.01 (Vr) as given in **Table 2**. Computation of variance components also exhibited the pronounced role of non additive gene action in controlling the inheritance of 1000 grain weight. The similar conclusion that indicated non additive effects were obtained by [9] [24].

The genotype, 9802 exhibited the maximum positive GCA effects with 1.51 value followed by 9797 (0.40) and highest negative GCA effects were exhibited by Chakwal-86 (−0.79) pursued by Chakwal-50 (−0.63) (**Table 3**). Estimates of SCA effects showed that the cross 9802 × Chakwal-86 exhibited the highest positive SCA effects with the value of 3.33 and cross 9801 × Chakwal-86 showed the maximum negative value which was −4.74 (**Table 4**). The highest positive reciprocal effects were depicted by the cross Chakwal-86 × 9797 (4.88) while highest negative reciprocal effects (−3.46) were displayed by 9802 × 9797 (**Table 5**).

### 3.8. Grain Yield per Plant

ANOVA for combining ability (**Table 1**) exhibited highly significant mean

squares due to GCA (4.64), SCA (9.33) and RCA (7.94). The mean squares due to SCA were greater than GCA mean squares. Thus, indicated the presence of non additive type of gene action for grain yield/plant. Computation of variance components also exhibited the pronounced role of non additive gene action in controlling the inheritance of grain yield/plant (**Table 2**). The similar conclusion that indicated non additive effects were obtained by [8] [25]. These results differed from the findings of [23] who found additive gene action for grain yield/plant.

Four parents showed positive GCA effects of which the genotype, Chakwal-50 was the best general combiner for grain yield/plant with highest positive GCA effects of 1.23 followed by 9797 (0.94) and one parent (9802) manifested negative GCA effects of  $-0.98$  (**Table 3**). Estimates of specific combining ability showed that the crosses, 9802  $\times$  Chakwal-86 and 9797  $\times$  9802 exhibited the high positive SCA effects (2.48 and 2.18 respectively). Hybrid, 9797  $\times$  Chakwal-86 was the poorest specific combiner having highest negative value ( $-2.60$ ) followed by 9797  $\times$  9801 ( $-1.90$ ) (**Table 4**). The high positive reciprocal effects were depicted by the crosses namely 9802  $\times$  9797 (2.22), Chakwal-86  $\times$  9797 (2.13) and Chakwal-86  $\times$  Chakwal-50 (2.02). Four parents showed negative reciprocal effects of  $-4.06$ ,  $-1.81$ ,  $-1.58$  and  $-0.43$  (Chakwal-50  $\times$  9797, Chakwal-86  $\times$  9802, 9801  $\times$  9797 and 9802  $\times$  9801 respectively) (**Table 5**).

#### 4. Conclusion

Parent Chakwal-50 proved to be the best general combiner for plant height, spike length, No. of spikelets per spike, No. of grains per spike and grain yield per plant. 9802 was the best general combiner for 1000 grain weight. 9797 showed high GCA effects for fertile tillers per plant while for flag leaf area Chakwal-86 was the good general combiner. So, it is concluded that Chakwal-50 may be used in breeding programmes to develop high yielding wheat varieties. 9802  $\times$  Chakwal-86 was the best specific combination for grain yield per plant and most of the yield related traits and this specific combination can be used in developing hybrid varieties.

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