**COMBINING ABILITY ANALYSIS FOR YIELD AND ITS COMPONENTS IN BREAD WHEAT (*Triticum aestivum* L. em. Thell.)**

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**Abstract**

Combining ability was analyzed using a half diallel of nine parents in bread wheat (*Triticum aestivum* L. em. Thell.). Combining ability analysis, revealed the importance of both additive as well as non-additive genetic variances for control of various traits. However, the ratio of σ2gca/ σ2sca revealed preponderance of non-additive gene actions in almost all the traits. Parents GW 404, MP 4010 and GW 366 were the good general combiners, whereas crosses GW 366 x GW 11, Raj 4037 x GW 496 and GW 322 x GW 404 were found to be best specific combiners for grain yield per plant and some of the yield contributing traits. However on the basis of *per se* performance and significant sca effects for grain yield per plant and some of its important components, hybrids GW 366 x GW 11, GW 322 x GW 404 and HI 1544 x MP 4010 were considered to be most promising for further exploitation in breeding programmes.

**Key words**: *wheat, general combining ability, specific combining ability*

**Introduction:**

Wheat was one of the first domesticated food crops and for 8000 years has been the basic staple food of the major civilizations of Europe, West Asia and North Africa. Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans. Its production leads all crops, including rice, maize and potatoes.

It is the leading grain crop of the temperate climates of the world, and is grown on 222 million hectares in the world (FAO, 2011). In India it stands at second position just after rice which contributes nearly one third of total food grain production. At global level, India ranks second largest wheat producing nation with 13.4 per cent global wheat production after China which contributes 17.7 per cent to the world wheat production. The other wheat producing countries are Russian Federation, United States of America and Canada and these five countries together contribute more than half of the global wheat production. To fulfill the increasing food demand of the world population, wheat production and productivity must be increased (USDA, 2012).

The increase in yield potential has always been of fundamental importance in wheat breeding programmes. Genetic analysis of wheat yield improvement had shown that grain yield is determined by component traits, and is a highly complex character (Adams, 1967; Blum, 1988). The analysis showed that genes for yield per se do not exist (Grafius, 1959). Therefore, knowledge about combining ability is important in selecting suitable parents for hybridization, understanding of inheritance of quantitative traits and also in identifying the promising crosses, are of paramount importance in formulating an efficient breeding programme. Keeping in view, present investigation was carried out to obtain more precise estimates of combining ability for grain yield and its contributing traits in bread wheat (*Triticum* *aestivum* L. em. Thell.).

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**Materials and methods:**

The present investigation aimed to gather information on the genetic basis of yield and its contributing traits in nine diverse genotypes of bread wheat (*Triticum aestivum* L. em. Thell.) *viz.* PBW 343, GW 322, GW 366, Raj 4037, GW 496, GW 11, HI 1544, MP 4010 and GW 404 selected from the germplasm maintained at Wheat Research Station, Vijapur, Gujarat. on the basis of a broad range of genetic diversity for major yield components. These selected genotypes were planted at Agricultural Research Station, Ladol, Gujarat, for hybridization in diallel fashion excluding reciprocals. The experiment was laid out in a randomized block design with three replications. The experiment plot comprised two rows each of 2.5 meter length. Row to row and plant to plant spacing was maintained at 22.5 cm and 10 cm. Recommended uniform agronomical practices were followed for raising the crop in all the three environments. Observations were recorded on twenty randomly selected competitive plants of each parent and F1’s in every replication for following traits *viz*., days to heading, days to maturity, plant height (cm), tillers per plant, flag leaf area(cm2), peduncle length (cm), spike length (cm), number of spikelets per spike, number of grains per spike, grain yield per spike (g), 1000-grain weight (g), biological yield per plant (g), harvest index (%) and grain yield per plant(g). In case of maturity traits (days to heading & days to maturity), the data was recorded on the whole plot basis. The mean of each plot used for statistical analysis. The data were first subjected to the usual analysis followed for a randomized block design for individual environment as suggested by Panse and Sukhatme, 1985. The combining ability analysis was done following Griffing’s method 2,Model I (1956).

**Results and discussion:**

Significant differences were observed among the treatments (parents and their F1s) revealing existence of variability for all the traits. Analysis of variance for combining ability (Table 1) revealed that mean squares due to GCA as well as SCA were significant for all the traits, indicating the importance of both additive and non-additive gene effects in the inheritance of characters. However, the ratio of σ2gca/ σ2sca was recorded below unity showed preponderance of non-additive type of gene actions for all the characters. Similar results were earlier reported by Menon and Sharma (1994), Kathiria and Sharma (1996), Esmail (2002), and Gothwal (2006).

Table 1. ANOVA for combining ability for various characters in F1 in wheat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Character |  | Source of variation | |  |
|  | GCA | SCA | Error | GCA/SCA |
|  | (df = 8) | (df = 36) | (df =88) | Variance |
| Days to heading | 15.82\*\* | 2.82\*\* | 0.94 | 0.66 |
| Days to maturity | 10.04\*\* | 1.84\*\* | 0.60 | 0.64 |
| Plant height | 44.04\*\* | 11.60\*\* | 1.67 | 0.36 |
| Tillers per plant | 3.13\*\* | 0.49\*\* | 0.03 | 0.56 |
| Flag leaf area | 28.52\*\* | 24.22\*\* | 0.99 | 0.10 |
| Peduncle length | 15.52\*\* | 6.74\*\* | 0.89 | 0.21 |
| Spike length | 2.26\*\* | 1.58\*\* | 0.17 | 0.12 |
| Number of spikelets spike-1 | 2.15\*\* | 1.79\*\* | 0.36 | 0.10 |
| Number of grains spike-1 | 82.62\*\* | 63.88\*\* | 1.12 | 0.11 |
| Grain yield spike-1 | 0.31\*\* | 0.12\*\* | 0.01 | 0.22 |
| 1000- grain weight | 29.11\*\* | 10.05\*\* | 0.58 | 0.25 |
| Biological yield plant-1 | 146.21\*\* | 50.94\*\* | 0.68 | 0.24 |
| Harvest index | 23.01\*\* | 7.07\*\* | 1.41 | 0.32 |
| Grain yield per plant | 26.71\*\* | 6.27\*\* | 0.10 | 0.36 |

*\*, \*\* Significant at 5 per cent & 1 per cent levels, respectively.*

The estimates of GCA effects for grain yield per plant & other contributing traits are presented in Table 2. The parent classified as good, average and poor combiners on the basis of estimates of combining ability effects for various characters. It was observed that none of the parents was good general combiner for all the characters.

However, the parent GW 404 was found to be good general combiners for grain yield per plant and most of the yield attributing traits viz., days to heading, number of tillers per plant, flag leaf area per plant, number of grains per plant, grain yield per spike, 1000- grain wt., biological yield per plant and harvest index; MP 4010 for days to maturity, plant height and tillers per plant, flag leaf area per plant, 1000- grain wt., biological yield per plant; Raj 4037 for grain yield per plant, number of grains per spike, grain yield per spike, spike length, biological yield per plant and grain yield per spike; GW 366 for 1000- grain wt., biological yield per plant and grain yield per plant;

PBW 343 for grain yield per plant, biological yield per plant, 1000- grain wt. and grain yield per spike were found to be good general combiners. In general it is evident from the table that the parents which were good general combiners for grain yield per plant were also good general combiners for some of its yield contributing traits like days to heading, days to maturity, plant height, tillers per plant, flag leaf area, spike length, number of grains per spike,1000-grain weight and biological yield per plant. From the result it is observed that the use of parent MP 4010, Raj 4037 and GW 404 in future breeding programme would be more useful for augmenting genes for high grain yield in bread wheat, as they are found to be good general combiners for grain yield per plant and some of the important yield components. It was interesting to note that parent Raj 4063 exhibited superior performance for grain yield per plant.

**Table 2. Estimates of GCA effects for grain yield per plant & other contributing traits in normal environments**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parent | Days to heading | Days to maturity | Plant height | Tiller per plant | Flag leaf area | Spike length |
|  |  |  |  |  |  |  |
| PBW 343 | 1.02 \*\*\* | 1.87 \*\*\* | 2.07\*\* | 0.09 | -0.60\* | 0.02 |
| GW 322 | 0.19 | -1.35 \*\*\* | 1.25\*\* | -0.34\*\* | -1.19\*\* | 0.03 |
| GW 366 | -1.01 \*\*\* | -0.43 \* | -1.62\*\* | 0.23\*\* | 0.28 | -0.63\*\* |
| Raj 4037 | 0.38 | -0.41 | 1.39\*\* | -0.30\*\* | 0.87\*\* | 0.72\*\* |
| GW 496 | 1.44 \*\*\* | 0.29 | -0.70\* | -0.64\*\* | 1.03\*\* | 0.24\* |
| GW 11 | 0.69 \* | -0.02 | 0.03 | -0.27\*\* | -3.20\*\* | -0.56\*\* |
| HI 1544 | 0.86 \*\* | 0.34 | 1.23\*\* | -0.33\*\* | -0.56\* | -0.24\* |
| MP 4010 | -1.56 \*\*\* | -1.13 \*\*\* | -4.20\*\* | 0.44\*\* | 2.14\*\* | -0.03 |
| GW 404 | -1.98 \*\*\* | 0.54 \* | -0.92\*\* | 1.14\*\* | 1.58\*\* | 0.58\*\* |
| SE (gi)+ | 0.265 | 0.213 | 0.354 | 0.048 | 0.273 | 0.114 |
| SE (gi-gj)+ | 0.395 | 0.317 | 0.527 | 0.071 | 0.408 | 0.169 |
|  |  |  |  |  |  |  |
| Parent | Number of grains | Grain yield per | 1000- grain | Biological yield | Harvest index | Grain yield per |
|  | per spike | spike | wt. | per plant |  | Plant |
| PBW 343 | -0.85\*\* | 0.07\*\* | 2.07\*\* | 1.54\*\* | -1.15\*\* | 0.30\*\* |
| GW 322 | -1.76\*\* | -0.07\*\* | -0.3 | -1.61\*\* | -1.61\*\* | -1.02\*\* |
| GW 366 | -0.91\*\* | 0.01 | 1.36\*\* | 2.23\*\* | -1.47\*\* | 0.31\*\* |
| Raj 4037 | 5.74\*\* | 0.24\*\* | 0.36 | 0.69\*\* | -0.04 | 0.26\*\* |
| GW 496 | -0.1 | -0.11\*\* | -1.89\*\* | 3.45\*\* | -0.12 | -1.36\*\* |
| GW 11 | -3.22\*\* | -0.19\*\* | -1.26\*\* | -4.10\*\* | -0.05 | -1.47\*\* |
| HI 1544 | -1.66\*\* | -0.17\*\* | -2.17\*\* | -4.05\*\* | 0.75\* | -1.21\*\* |
| MP 4010 | -0.84\*\* | -0.04 | 0.89\*\* | 0.48\* | 0.5 | 0.27\*\* |
| GW 404 | 3.22\*\* | 0.29\*\* | 1.95\*\* | 7.28\*\* | 3.22\*\* | 3.63\*\* |
| SE (gi)+ | 0.29 | 0.019 | 0.209 | 0.225 | 0.325 | 0.087 |
| SE (gi-gj)+ | 0.432 | 0.029 | 0.311 | 0.335 | 0.485 | 0.130 |

Best parent having desirable GCA effects for grain yield per plant are presented in Table 2. It was revealed that the GCA effect and per se performance were positively correlated in most of the best parents. Though, such pattern was not prevailed in all the cases. Perusal of Table 2 revealed that the parents, who showed desirable, GCA effects for grain yield per plant, also exhibited desirable GCA effects for one or more yield attributing traits. The parents GW 404, GW 366 and Raj 4037 emerged as good general combiners for grain yield and some associated traits. Earlier, Kathiria and Sharma (1996), Rajora and Maheshwari (1996), Singh (1998), Rajora (1999), Punia (2003), Joshi *et al*. (2003a), Desai *et al*. (2005) and Singh and Chaudhary (2008) providedsimilar information on combining ability in wheat. In all such cases where GCA effect was more pronounced for particular trait indicating preponderance of additive gene action, so these genotypes should be involved in crosses to improve the specific trait in future breeding programme.

In self-pollinated crops like wheat, SCA effects are not much important as they are mostly related to non-additive gene effects excepting those arising from complementary gene action or linkage effects they can not be fixed in the pure line or the end product inbred line. Jinks and Jones (1958) emphasized that the superiority of the hybrids might not indicate their ability to yield transgressive segregants, rather SCA would provide satisfactory criteria. However, if a cross combination exhibiting high SCA as well as high *per se* performance having at least one parent as good general combiner for a specific trait, it is expected to throw desirable transgressive segregants in later generations (Kathiria and Sharma, 1996). An overall appraisal of specific combining ability effects revealed that some crosses had significant SCA effects for a few specific characters across the environments with varied magnitudes. For e.g., GW 322 x GW 366 for flag leaf area, number of grains/ spike, grain yield/ plant and biological yield per plant; GW 366 x GW 11 for flag leaf area, grain yield per plant and biological yield x plant; GW 366 x HI 1544 for number of grains per spike and grain yield per spike; Raj 4037 x GW 496 for number of spikelets per spike, number of grains per spike, grain yield per spike, biological yield per plant, and grain yield per plant; GW 11 x GW 404 for number of spikelets per spike, number of grains per spike and 1000 - grain weight; HI 1544 x MP 4010 for plant height and number of grains per spike; GW 496 x GW 11 for 1000 - grain weight; GW 496 x GW 404 for number of grains per spike; Raj 4037 x GW 11 for tillers per plant; HI 1544 x MP 4010 and MP 4010 x GW 404 for plant height. The crosses GW 366 x GW 11, Raj 4037 x GW 496 and GW 322 x GW 404 emerged as good specific cross combinations for grain yield per plant. The parents GW 366, Raj 4037, MP 4010 and GW 404 involved in these crosses were good general combiners for grain yield and one or two yield contributing traits

The information regarding three best performing parents, best general combiners, best performing hybrids (Table 3) revealed that parent with good per se performance were in general, good specific combinations for different traits. In many cases, it was observed that at least one good general combining parent was involved in heterotic hybrids having desirable sca effects. This suggests that information on gca effects of the parents should be considered along with sca effects and per se performance of hybrid for predicting the value of any hybrid.

**Table 3. Best three parents, F1s selected on the basis of their *per se* performance, GCA and SCA effects for various characters in wheat**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Character |  |  | Per se performance |  | GCA | SCA |
|  | Parents | | F1 | |  |  |
| Days to | GW 322 | | GW 11 x GW 404 | | GW 404 | PBW 343 x GW 11 |
| Heading | MP 4010 | | GW 366 x MP 4010 | | MP 4010 | GW 11 x GW 404 |
|  | GW 404 | | MP 4010 x GW 404 | | GW 366 | Raj 4037 x GW 496 |
| Days to | GW 322 | | GW 322 x MP 4010 | | GW 322 | PBW 343 x GW 11 |
| Maturity | GW 366 | | Raj 4037 x MP 4010 | | MP 4010 | Raj 4037 x GW 404 |
|  | MP 4010 | | HI 1544 x MP 4010 | | GW 366 | GW 11 x HI 1544 |
| Plant height | MP 4010 | | MP 4010 x GW 404 | | MP 4010 | MP 4010 x GW 404 |
|  | GW 366 | | GW 496 x GW 404 | | GW 366 | GW 11 x HI 1544 |
|  | GW 496 | | GW 366 x MP 4010 | | GW 404 | GW 496 x GW 404 |
| Tillers | GW 404 | | GW 11 x GW 404 | | GW 404 | GW 322 x GW 366 |
| per plant | MP 4010 | | GW 322 x GW 404 | | MP 4010 | GW 322 x GW 404 |
|  | HI 1544 | | GW 366 x GW 404 | | GW 366 | GW 366 x GW 11 |
| Flag leaf area | MP 4010 | | GW 11 x GW 404 | | MP 4010 | GW 11 x GW 404 |
|  | GW 11 | | GW 496 x MP 4010 | | GW 404 | GW 322 x GW 366 |
|  | GW 404 | | GW 322 x GW 366 | | GW 496 | GW 496 x MP 4010 |
| Spike length | GW 11 | | GW 322 x MP 4010 | | Raj 4037 | GW 322 x MP 4010 |
|  | GW 404 | | Raj 4037 x GW 496 | | GW 404 | HI 1544 x MP 4010 |
|  | GW 496 | | Raj 4037 XGW 404 | | GW 496 | Raj 4037 x GW 496 |
| No. of grains | Raj 4037 | | Raj 4037 x GW 496 | | Raj 4037 | Raj 4037 x GW 496 |
| per spike | GW 404 | | HI 1544 x MP 4010 | | GW 404 | HI 1544 x MP 4010 |
|  | GW 366 | | PBW 343 x Raj 4037 | | - | PBW 343 x HI 1544 |
| Grain yield | Raj 4037 | | Raj 4037 x GW 496 | | GW 404 | Raj 4037 x GW 496 |
| per spike | GW 366 | | GW 322 x GW 404 | | Raj 4037 | PBW 343 x HI 1544 |
|  | GW 404 | | Raj 4037 x GW 404 | | PBW 343 | HI 1544 x MP 4010 |
| 1000- Grain weight | MP 4010 | | GW 496 x GW 404 | | PBW 343 | GW 496 x GW 404 |
|  | Raj 4037 | | GW 322 x GW 404 | | GW 404 | GW 322 x GW 404 |
|  | PBW 343 | | GW 366 x Raj 4037 | | GW 366 | PBW 343 x GW 496 |
| Biological | GW 404 | | GW 322 x GW 404 | | GW 404 | GW 322 x GW 404 |
| yield per | GW 366 | | GW 11 x GW 404 | | GW 496 | GW 366 x GW 11 |
| plant | GW 11 | | GW 366 x GW 11 | | GW 366 | GW 322 x GW 366 |
| Harvest | GW 404 | | MP 4010 x GW 404 | | GW 404 | GW 322 x GW 11 |
| index | GW 496 | | HI 1544 x GW 404 | | HI 1544 | GW 11 x MP 4010 |
|  | GW 11 | | Raj 4037 x GW 404 | | - | GW 496 x GW 11 |
| Grain yield per plant | GW 404 | | GW 322 x GW 404 | | GW 404 | GW 366 x GW 11 |
|  | GW 11 | | GW 11 x GW 404 | | GW 366 | GW322 x GW 404 |
|  | GW 366 | | GW 366 x GW 11 | | PBW 343 | HI 1544 x MP 4010 |

It is desirable to search out parental lines with high gca effects and low sensitivity to environmental variation in a crop improvement programme with respect to combining ability effects. From the present study following broad inferences could be drawn.

1. In general, the crosses showing desirable sca effect for seed yield per plant also had high sca effects for some of it’s yield contributing characters viz., No. of tillers, No. of spikelets. No. of grains/ spike and biological yield/ plant.
2. Best performing parents were mostly good general combiners for majority of the characters.
3. The crosses exhibiting desirable sca effects did not always involve parents with high gca effects, thereby suggesting the importance of intrallelic interaction.

It is clear from above discussion, that on the basis of SCA effects and *per se* performance the crosses – GW 366 x GW 11, Raj 4037 x GW 496 and GW 322 x GW 404 emerged as good specific cross combinations for grain yield per plant. An over all appraisal revealed that the cross Raj 4037 x GW 496 emerged as good specific cross combinations for grain yield per plant. These crosses were the results of good x good, poor x poor and good x poor general combiners. These crosses hold great promise in improving the grain yield in future breeding programme of bread wheat.

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