

Combining Ability Studies in Some Quantitative and Qualitative Traits of *Gossypium hirsutum* L.

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ABSTRACT

Combining ability studies were conducted in some quantitative and qualitative traits of upland cotton genotypes involving four parents crossed in a diallel fashion in glass house conditions. Only non-additive gene effects were found vital in the inheritance of all the traits under study. The parents CIM-435, Express and Huma-15 showed high GCA, while crosses; CIM-435 × Huma-15, CIM-435 × Express, LRA-5166 × Express and HUMA-15 × Express exhibited higher SCA and reciprocal effects and thus could be exploited for further selection of key traits.

Key Words: Combining ability; Qualitative and quantitative traits; *Gossypium hirsutum* L.

Abbreviations: GCA = general combining ability; SCA = specific combining Ability.

INTRODUCTION

The triumph of any plant improvement plan depends largely upon the availability of genetic variation in the heredity material for the preferred plant traits. In any hybridization program, identification and selection of superior parental lines are required to construct genetically diverse and potentially rewarding germplasm by gathering fixable gene effects more or less in a homozygous line. Estimates of genetic variation and combining ability are useful in determining the breeding value of some populations and the appropriate procedures to use in a breeding program. The general combining ability effects are important indicators of the value of genotypes in hybrid combinations. Differences in general combining ability effects have been attributed to additive, additive × additive and higher-order additive interactions, whereas differences in specific combining ability have been attributed to non-additive genetic variance (Falconer, 1996). Information concerning to the different types of gene action, relative magnitude of genetic variance and combining ability estimates are significant strictures to shape the genetic makeup of a crop like cotton. This important information could prove an essential strategy to the cotton breeders in the screening of better parental combinations for further enhancement.

Diallel analysis has been widely used by plant breeders in the selection of parents and crosses in the early generations. Christopher *et al.* (2003) used combining ability analysis for the identification of superior combining parents, which were subsequently used in the breeding programme with good results. Braden *et al.* (2003) and Zhang *et al.* (2003) argued that combining ability analysis provides sufficient chance to cotton breeders to understand

the basis on which certain parental lines could be exploited in the breeding program.

The present research work was conducted to evaluate some cotton genotypes and their crosses for their relative performance regarding combining ability effects for quantitative and qualitative traits.

MATERIALS AND METHODS

The present research was conducted in the experimental area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2001 - 03. The plant material used in the present study was developed by crossing 4 different varieties, viz. CIM-435, LRA-5166, Huma-15 and Express. The plant material was collected from cotton germplasm of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The four parents were grown under controlled conditions in glass house during the month of November 2001. Day and night temperatures in glasshouse were maintained using steam and electric heaters. The day light during winter was supplemented by lighting mercury vapour lamps. When the parental lines started to flower, these were crossed in all possible combinations. Maximum number of attempts was made to develop sufficient F₀ seed.

The F₀ seed of 12 hybrids and 4 parents were planted in the field during June 2002. Each entry was sown in three replications by using randomized complete block design (RCBD). The seeds were dibbled to ensure uniform plant population in single row plot having nine plants spaced 30 cm within and 75 cm between the rows. Recommended agronomic and cultural practices (thinning, hoeing, fertilization, irrigation etc.) were applied to cotton crop as and when required. At maturity, the data were taken on the

middle five plants, leaving two plants on either end of the row to avoid the border effects. The data on plant height (cm), number of bolls per plant, boll weight (g) and seed cotton yield per plant (g) and lint percentage were recorded. The matured bolls were picked after every two weeks as soon as bolls started to open and seed cotton was collected in the Kraft paper bags. Clean and dry samples of the seed cotton were weighed and then ginned separately with Single Roller Electric Ginner. Total produce of the plant was ginned and lint obtained from each sample was weighed. Hence, lint percentage was calculated by the following formula:

$$\text{Lint percentage} = \frac{\text{Weight of lint in a sample}}{\text{Weight of seed cotton in a sample}} \times 100$$

The data on fiber length (mm), fiber strength (g tex⁻¹) and fiber fineness (g inch⁻¹) was recorded using Spinlab high volume instrument (HVI-900) in the Department of Fiber Technology, University of Agriculture, Faisalabad.

Statistical analysis. The averaged data were subjected to the standard technique of analysis of variance (Steel & Torrie, 1980), which indicated significant differences among the parents and their hybrids. Traits thus found significant were further analyzed for general and specific combining ability as defined by Sprague and Tatum (1942) and reciprocal effects as defined by Griffing (1956) Method I, Model II.

RESULTS AND DISCUSSION

Combining ability effects. The mean squares obtained from combining ability analysis (Table I) revealed that variances resulting from GCA effects were significant ($P < 0.01$) for all the characters like plant height, number of bolls/plant, boll weight, seed cotton yield/plant, lint percentage, fiber length, fiber strength and fiber fineness. Similar results were also found for SCA and reciprocal effects. The estimates of component of variance (Table II) clarified that the variance due to SCA was much higher in magnitude and more vital than GCA and reciprocals in case of plant height (52.02), number of bolls/plant (58.2), boll weight (28.9), seed cotton yield/plant (61.7), fiber length (31.0) and fiber strength (56.2) showing thereby the predominance of non-additive type of gene action in the inheritance of these traits. This reflected that the major portion of genetic variance (in percentage) for these characters is due to non-additive type of gene action with dominance or epistatic effects. Ghaffoor and Khan *et al.* (1987), Sayal *et al.* (1997) and Hassan *et al.* (1999) also reported the importance of SCA effects regarding such characters. Skool and Baker (1977) concluded that negative association between genes results in relatively larger estimates of SCA variances.

Likewise, the estimates of components of variance clarified that the variance due to reciprocals was much higher in magnitude than SCA and GCA for the characters

like lint percentage (43.7) and fiber fineness (45.4) showing the prevalence of non-additive type of gene action in the inheritance of these traits. The presence of repulsion phase linkage and linkage disequilibrium might have resulted in an over estimation of non-additive component. Under such situation, population improvement by recurrent selection to accumulate desirable genes and breaking of un-desirable linkages would be more appropriate.

General combining ability effects. The GCA values of all the parents were compared, which revealed that for plant height, fiber length and fiber strength, CIM-435 has the highest positive value of 1.771, 0.473 and 0.174, respectively. CIM-435 appeared to be a good general combiner for all these characters. The variety Express obtained highest GCA value for number of bolls/plant (0.849), boll weight (0.120), seed cotton yield/plant (5.073) and fiber fineness (0.0535) and proved to be the best general combiner. Similarly for lint percentage (0.326) and fiber fineness (-0.049), it is Huma-15 that out performed other genotypes. Higher fiber fineness values contribute towards coarseness of fiber, therefore parents with negative GCA values were considered better (Rauf *et al.*, 2006). However for other plant characters under study, Huma-15 proved to be a bad general combiner followed by LRA-5166 (Table III). So it is suggested that Express and CIM-435 could be exploited for varietal improvement for different cross combinations. Sufficient literature is available in support of such inferences (Kalwar *et al.*, 1999; Hassan *et al.*, 2000), where it was also concluded that best yielding parents having high GCA produced the best hybrid combinations.

Specific combining ability. The comparison of the crosses for their SCA values is shown in Table IV. The cross combination of LRA-5166 × Express showed highest values for plant height (3.479), number of bolls/plant (2.888) and fiber strength (1.628). This combination involves genotype Express, which is good general combiner for number of bolls/plant and LRA-5166, which proved to be a bad combiner for number of bolls/plant. This showed that though LRA-5166 is bad combiner for this character yet showed its promise in this combination as well as for fiber length in combination with Huma-15. This indicated that parents having low general combining ability might show good potential in varietal combinations. Similar behavior of the some of the parents had been noted in earlier studies (Azhar & Rana, 1993). Hybrid combination of CIM-435 × Express appeared to be of great potential with their numerical values of 0.156 for boll weight and 11.001 for seed cotton yield. Similarly the cross combination CIM-435 × Huma-15 out performed other combinations for lint percentage (1.11). For fiber fineness, cross combination Huma-15 × Express (0.181) revealed to be the best. These results showed that the better performance of these hybrids might have been the results of high GCA value of CIM-435 and Express as shown in Table IV for these characters. Siddique and Patil (1992) and Mukhtar *et al.* (2005) also observed similar observation in their studies on cotton.

Table I. Mean square due to GCA, SCA and Reciprocal effects for various characters of (*Gossypium hirsutum* L.) in a 4 × 4 diallel cross experiment

| Source of variation | d.f. | Plant height | Number of bolls per plant | Boll weight | Seed cotton yield per plant | Lint %age | Fiber length | Fiber strength | Fiber fineness |
|----------------------------|------|--------------|---------------------------|-------------|-----------------------------|-----------|--------------|----------------|----------------|
| General combining ability | 3 | 19.782* | 8.643* | 0.269** | 130.021 * | 2.775 * | 1.862** | 1.534 * | 0.096** |
| Specific combining ability | 6 | 17.728* | 16.293** | 0.232** | 185.668** | 3.743** | 1.546** | 3.285** | 0.128** |
| Reciprocals | 6 | 12.889** | 6.137 * | 0.230** | 94.550 * | 5.063** | 1.535** | 1.574 * | 0.178** |
| Error | 30 | 5.323 | 2.418 | 0.0139 | 38.925 | 0.765 | 0.235 | 0.496 | 0.021 |

*, ** shows significant and highly significant differences, respectively

Table II. Estimates of components of variance due to GCA, SCA and reciprocal effects for various characters of (*Gossypium hirsutum* L.) in a 4 × 4 diallel cross experiment

| Source of variation | d.f. | Plant height | Number of bolls per plant | Boll weight | Seed cotton yield per plant | Lint %age | Fiber length | Fiber strength | Fiber fineness |
|----------------------------|------|--------------|---------------------------|-------------|-----------------------------|-----------|--------------|----------------|----------------|
| General combining ability | 3 | 0.357 | -0.871 | 0.005 | -5.593 | -0.112 | 0.042 | -0.204 | -0.004 |
| Specific combining ability | 6 | 2.902 | 9.275 | 13.158 | 3.955 | 4.263 | 6.785 | 11.731 | 5.195 |
| Reciprocals | 6 | 6.403 | 5.462 | 0.011 | 87.226 | 0.601 | 0.192 | 0.978 | 0.017 |
| | | 52.057 | 58.162 | 28.947 | 61.674 | 22.878 | 31.018 | 56.239 | 22.078 |
| Error | 30 | 43.276 | 25.748 | 36.842 | 27.522 | 29.121 | 37.964 | 28.522 | 27.273 |

* Upper values denote variance estimates, ** Lower values denote variance components in percentage

Table III. Estimates of general combining ability effects for various characters of (*Gossypium hirsutum* L.) in a 4 × 4 diallel cross experiment

| Varieties | Plant height | Number of bolls per plant | Boll weight | Seed cotton yield per plant | Lint %age | Fiber length | Fiber strength | Fiber fineness |
|--------------|--------------|---------------------------|-------------|-----------------------------|-----------|--------------|----------------|----------------|
| CIM-435 | 1.771 | 0.161 | 0.024 | 1.153 | -0.055 | 0.473 | 0.174 | 0.018 |
| LRA-5166 | 0.646 | -0.738 | -0.062 | -3.581 | -0.404 | -0.167 | 0.135 | -0.0231 |
| HUMA-15 | -1.521 | -0.272 | -0.083 | -2.645 | 0.326 | -0.264 | -0.275 | -0.049 |
| EXPRESS | -0.896 | 0.849 | 0.120 | 5.073 | 0.133 | -0.042 | -0.034 | 0.0535 |
| CD (gi – gj) | 1.331 | 0.604 | 0.003 | 9.731 | 0.191 | 0.059 | 0.124 | 0.005 |

Table IV. Estimates of specific combining ability effects for various characters of (*Gossypium hirsutum* L.) in a 4 × 4 diallel cross experiment

| Cross combinations | Plant height | Number of bolls per plant ¹ | Boll weight | Seed cotton yield per plant ¹ | Lint %age | Fiber length | Fiber strength | Fiber fineness |
|--------------------|--------------|--|-------------|--|-----------|--------------|----------------|----------------|
| CIM-435 × LRA-5166 | 0.979 | -0.274 | 0.057 | -0.125 | 0.507 | -0.274 | -0.880 | 0.049 |
| CIM-435 × Huma-15 | 2.146 | 0.476 | -0.067 | 0.073 | 1.110 | 0.444 | 0.378 | 0.033 |
| CIM-435 × Express | 1.188 | 2.172 | 0.156 | 11.061 | -0.771 | 0.143 | 0.471 | 0.112 |
| LRA-5166 × Huma-15 | -0.396 | -0.874 | 0.092 | -0.669 | -0.739 | 0.640 | 0.314 | -0.002 |
| LRA-5166 × Express | 3.479 | 2.888 | -0.038 | 8.412 | 0.601 | 0.383 | 1.628 | 0.027 |
| HUMA-15 × Express | -0.354 | 0.455 | 0.089 | 2.815 | 0.881 | -0.232 | -1.108 | 0.181 |
| CD (Sij – Sik) | 3.992 | 1.813 | 0.010 | 29.193 | 0.574 | 0.176 | 0.372 | 0.016 |

Table V. Estimates of reciprocal effects for various characters of (*Gossypium hirsutum* L.) in a 4 × 4 diallel cross experiment

| Cross combinations | Plant height | Number of bolls per plant | Boll weight | Seed cotton yield per plant | Lint %age | Fiber length | Fiber strength | Fiber fineness |
|--------------------|--------------|---------------------------|-------------|-----------------------------|-----------|--------------|----------------|----------------|
| CIM-435 × LRA-5166 | -1.833 | -0.733 | -0.018 | -2.960 | 0.507 | 0.52 | -0.263 | -0.072 |
| CIM-435 × Huma-15 | -0.833 | 0.450 | -0.022 | 0.658 | -1.013 | -0.217 | 0.415 | -0.187 |
| CIM-435 × Express | -1.833 | -0.933 | 0.278 | 2.477 | -0.811 | 0.723 | -0.425 | -0.242 |
| LRA-5166 × Huma-15 | -1.5000 | -1.133 | -0.101 | -6.163 | 0.088 | 0.472 | -0.322 | -0.197 |
| LRA-5166 × Express | -1.000 | -0.0167 | -0.041 | -1.051 | -0.698 | 0.487 | 0.610 | -0.215 |
| HUMA-15 × Express | -2.000 | -0.717 | 0.007 | -2.058 | 2.598 | -0.548 | -0.473 | -0.303 |
| CD (rij – rki) | 5.323 | 2.418 | 0.014 | 38.925 | 0.765 | 0.235 | 0.496 | 0.021 |

Reciprocal effects. Table V indicated that the combinations CIM-435 × Express showed its superiority for boll weight (0.278), seed cotton yield/plant (2.477) and fiber length

(0.723) followed by CIM-435 × Huma-15 for number of bolls/plant (0.450) and LRA-5166 × Express for fiber strength with a numerical value 0.610. For fiber fineness, it

is Huma-15 × Express that showed their promise for the improvement of this character. These results revealed the contribution of a high degree of maternal effects. It is therefore recommended that these crosses should not be mixed with direct crosses as had been recommended by some of the authors (Khan *et al.*, 1991; Pavasia *et al.*, 1999).

The above results indicate the significance of exploitation of non-additive gene action for attaining utmost improvement in quantitative and qualitative traits in the present study as none of the character exhibited additive type of gene action. The parents CIM-435, Express and Huma-15 showed high GCA while crosses; CIM-435 × Huma-15, CIM-435 × Express, LRA-5166 × Express and HUMA-15 × Express exhibited higher SCA and reciprocal effects. It is suggested that population improvement by reciprocal recurrent selection to accumulate desirable genes and breaking un-desirable linkages would be more appropriate (Rauf *et al.*, 2005).

CONCLUSION

The results signify the importance of non-additive genetic effects for attaining maximum improvement in quantitative and qualitative traits. Parents having high GCA values i.e., CIM-435 for plant height, fiber length and fiber strength; Express for number of bolls per plant, boll weight, seed cotton yield/plant and fiber fineness and Huma-15 for lint percentage and fiber fineness should be given due consideration in developing superior genotypes.

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