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# Combining Ability Analysis in Upland Cotton (*Gossypium hirsutum* L.)

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## ABSTRACT

Combining ability analysis for seed cotton yield and other related traits were studied in a set of diallel crosses involving five cotton genotypes of upland cotton. Both additive and non-additive gene effects were important in the inheritance of most of the traits. The parent CIM- 473, NIAB- 999 and ACALA1517/C showed high GCA while cross CIM- 473 x NIAB- 999 exhibited high SCA. Aforementioned parents and cross could be utilized for further selection of high yield.

**Key Words:** *Gossypium hirsutum;* Combining ability; Gene action

## INTRODUCTION

Combining ability describes the breeding value of parental lines to produce hybrids. General combining ability (GCA) effects are the average performance of a parent in combination with all other parents, whereas specific combining ability (SCA) effects are the deviation of the performance of two parents in a particular hybrid combination from that of expected from GCA effects of each parent. GCA effects reflect performance of parental lines in combination with all other lines, so parents with the highest GCA effects should have greater impact on trait improvement. Specific combining ability effects identify the best hybrid combinations, but they also identify complementary alleles for trait performance (Kearsey & Pooni, 1996). Novel combinations of beneficial alleles at multiple loci could lead to new potential for inbred improvement.

In order to choose appropriate parents and crosses, and to determine combining abilities of parents in the early generation, the diallel analysis has been widely used by plant breeders. Braden *et al.* (2003) and Christopher *et al.* (2003) on the basis of combining ability effects identified superior combining parents, which were subsequently used in the breeding programme with good results. Thus, the main objective of this experiment was to identify the best combining ability parents and their crosses, on the basis of their general and specific high yielding cotton genotypes.

## MATERIALS AND METHODS

**Plant material.** Five cotton genotypes were crossed in a half diallel mating design. The parent genotypes were CIM-473, commercial cultivar developed at Central Cotton Research Institute; NIAB-999, commercial cultivar developed at Nuclear Institute of Agriculture and Biology; rest of three were germplasm lines including CRIS-420, FVH-57 and ACALA 1517/C. ACALA lines are most widely used genotypes in hybridization programmes all over the world.

**Greenhouse cultivation.** Seeds of parental cultivars were grown in 30 cm x 30 cm earthen pots containing a mixture of equivalent volume of sand, soil and farmyard manure from mid November 2002 to mid march 2003 in green house. Temperature was maintained at 30°C during the day and 25°C at night by using steam as well as heaters. The plants were exposed to natural sunlight and supplemented with artificial lights, a photoperiod of 16 h. Seedlings were thinned to one plant per pot after two weeks of planting. After every 14 days, 0.25 g urea (46%N) was added to each pot and plants were watered daily. The genotypes were crossed in a diallel fashion excluding reciprocal crosses to obtain 10 hybrids. Parental cultivars were maintained through self pollination.

**Field evaluation.** Seeds of the $F_1$ along with their selfed parents were field planted during the crop season 2003-04 with a 75 cm and 30 cm row-to-row and plant-to-plant distance respectively, under the Completely Randomized Block Design with three replications. At maturity, the data regarding middle 8 competitive plants per replication were collected for the yield of seed cotton (g), plant height (cm), number of sympodial and monopodial branches. 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 in the fibre laboratory. Total produce of the plant was ginned and lint obtained from each sample was weighed. Hence, ginning outturn was calculated by the following formula:

$$\text{Ginning Out turn} = \frac{\text{Weight of lint in a sample}}{\text{Weight of seed cotton in a sample}} \times 100$$

Spin Lab. HVI- 900 is a computerized high volume instrument, which provides a comprehensive profile of raw fibre in respect of staple length (mm), microniare (µg/ inch$^2$) and staple strength (g/tex) of each plant.

**Statistical analysis.** The data were analyzed by Steel and Torrie analysis of variance technique (1980), which indicated significant differences among the hybrids and their parents. Traits thus found significant were further analyzed by following Griffing's Method 2, Model I (1956).

## RESULTS AND DISCUSSION

Analysis of variance for general (GCA) and specific combining ability (SCA) (Table I) indicated significant effects for all characters under study except fibre length and strength, which were non-significant for SCA. Baker (1978) suggested that the importance of general and specific combining ability should be assessed by estimating components of variance and expressing them as $2\ \sigma^2g/\ (2\ \sigma^2g + \sigma^2s)$ ratio. Closer this ratio to unity, greater will be the magnitude to additive genetic effects. The ratio computed for all characters (Table I) showed that dominant gene effects were more important for plant height and number of bolls per plant while both additive and dominant gene effects were important for seed cotton yield per plant, sympodial branches, monopodial branches and ginning out turn. Additive gene effects were relatively more important for boll weight, fibre strength, length and microniare. High estimates of SCA variances ($\sigma^2s$) were observed for seed cotton yield, boll number, sympodial branches, monopodial branches, ginning out turn (%) and plant height. The presence of repulsion phase linkage and linkage disequilibrium might have resulted in an over estimation of non-additive component. Sokol and Baker (1977) concluded that negative association between genes results in relatively larger estimates of SCA variances. Under such situation population improvement by recurrent selection to accumulate desirable genes and breaking of un-desirable linkages would be more appropriate.

The general combining ability effects of parents (Table II) indicated that genotype CIM-473 was best general combiner for seed cotton yield, number of bolls per plant, sympodial branches, ginning out turn and microniare followed by NIAB-999, which was best combiner for monopodial branches, plant height, microniare, fibre length while ACALA 1517/C was found best combiner for boll weight. The monopodial branches and plant height usually contribute towards late maturity, therefore, parents with negative GCA values were considered better. Similarly, higher microniare values contribute towards coarseness of fibre therefore, parents with negative GCA values were considered better.

The SCA effects of the crosses for seed cotton yield and other related traits are presented in (Table III). Cross CIM-473 x NIAB-999 had high SCA effects for seed cotton yield, number of bolls per plant, sympodial branches and monopodial branches. Cross combination of CIM-473 x CRIS-420 was found best combiner for fibre length and microniare, while for fibre strength and boll weight, FVH-57 x ACALA 1517/C had high SCA effects. CRIS-420 x FVH-57 was best specific combiner for plant height. Whereas, cross CIM-473 x ACALA 1517/C had high SCA effects for ginning out turn. Most of the crosses with high SCA had at least one high GCA parent. However, some crosses with high SCA had one parent with average GCA. The superiority of average x high, average x low or high x low combination may be due to the presence of genetic diversity among the parents and there could be some complementation indicating importance of non-additive gene effects (Singh & Chatrath, 1997).

The study of association between per se performance of parents and crosses in $F_1$ with that of the GCA and SCA effects (Table IV) revealed very high correlations between GCA effects and per se performance for boll weight, plant height, sympodial braches, monopodial branches, ginning out turn, fibre strength and microniare, while moderately high correlation was found for seed cotton yield, number of bolls per plant and fibre length. High correlation among the per se performance and GCA was an indicative of the importance of additive genetic effects. Thus, ability to

**Table I. Analysis of variance (mean sum of square) for general combining ability (GCA) and specific combining ability (SCA) for yield components and fibre traits in cotton (*Gossypium hirsutum* L.)**

| | | Plant Traits | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sources of Variation | D.F. | Yield Per Plant | Boll # Per Plant | Boll weight | Sympodial branches | Monopodial branches | Plant height | Ginning Out turn | Fibre strength | Fibre length | Microniare |
| GCA | 4 | 103.99** | 19.41** | 0.74** | 22.49** | 3.84 ** | 868.54** | 12.30 ** | 17.56** | 1.93** | 0.13** |
| SCA | 10 | 355.78** | 21.93** | 0.039 ** | 5.82** | 0.87** | 341.77** | 1.57** | 1.58 ns | 0.44 ns | 0.029** |
| Error | 28 | 5.01 | 0.42 | 0.01 | 0.37 | 0.098 | 11.69 | 0.17 | 1.51 | 0.29 | 0.007 |
| $\sigma^2g$ | | -70.50 | -0.70 | 0.19 | 4.66 | 0.83 | 147.49 | 3.00 | 4.47 | 0.42 | 0.034 |
| $\sigma^2s$ | | 350.77 | 21.51 | 0.03 | 5.45 | 0.87 | 330.08 | 4.75 | 0.07 | 0.15 | 0.022 |
| $2\ \sigma^2g/\ (2\ \sigma^2g+\ \sigma^2s)$ | | -0.67 | -0.07 | 0.92 | 0.63 | 0.66 | 0.47 | 0.55 | 0.99 | 0.85 | 0.75 |

ns,*,** Significant at P= 0.05 and 0.01 levels, respectively.

**Table II. General combining ability effects (GCA) of parental genotype for yield components and fibre traits in cotton (*Gossypium hirsutum* L.)**

| | Plant Traits | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Varieties | Yield Per Plant | Boll # Per Plant | Boll weight | Sympodial Branches | Monopodial Branches | Plant Height | Ginning outturn | Fibre strength | Fibre length | Microniare |
| CIM-473 | 6.52 | 1.81 | -0.05 | 1.82 | -0.23 | -5.11 | 1.73 | -1.35 | 0.33 | -0.22 |
| NIAB-999 | -0.72 | 0.75 | -0.30 | 0.63 | -0.49 | -9.75 | 0.73 | 2.27 | 0.34 | 0.04 |
| CRIS-420 | -0.61 | -0.01 | -0.02 | 0.96 | -0.33 | 3.67 | -1.33 | 0.12 | -0.44 | 0.02 |
| FVH-57 | -1.47 | 0.14 | -0.18 | -0.61 | -0.26 | -6.63 | -1.31 | 0.02 | -0.46 | 0.01 |
| ACALA1517/C | -3.72 | -2.69 | 0.55 | -2.80 | 1.31 | 17.82 | 0.18 | -1.06 | -0.69 | 0.15 |
| S.E ($g_i$) | 0.75 | 0.22 | 0.03 | 0.20 | 0.11 | 1.15 | 0.14 | 0.41 | 0.17 | 0.03 |
| S.E. ($g_i$-$g_j$) | 1.19 | 0.35 | 0.05 | 0.33 | 0.17 | 1.83 | 0.22 | 0.65 | 0.29 | 0.04 |

**Table III. Crosses with significant specific combining ability (SCA) effects for yield components and fibre traits of up-land cotton *Gossypium hirsutum* L.**

| Character | Cross | SCA effect | GCA effects of parents | Character mean in $F_1$ |
|---|---|---|---|---|
| Seed cotton yield per plant (g) | CIM-473 x NIAB-999 | 33.99 | High x low | 98.59 |
| | CIM-473 x CRIS-420 | 10.45 | High x low | 75.16 |
| | S.E ($S_{ij}$) | 1.54 | | |
| No. of Boll per Plant | CIM-473 x NIAB-999 | 7.88 | High x medium | 25.80 |
| | CRIS-420 x FVH-57 | 5.55 | Low x medium | 21.05 |
| | NIAB-999 x CRIS-420 | 3.01 | Medium x low | 19.11 |
| | FVH-57 x ACALA1517/C | 2.82 | Low x medium | 15.63 |
| | CIM-473 x CRIS-420 | 2.06 | High x medium | 19.22 |
| | S.E ($S_{ij}$) | 0.45 | | |
| Boll weight (g) | FVH-57 x ACALA1517/C | 0.91 | Low x high | 4.44 |
| | CIM-473 x NIAB-999 | 0.30 | Low x low | 3.84 |
| | S.E ($S_{ij}$) | 0.07 | | |
| Plant height (cm) | CRIS-420 x FVH-57 | -32.07 | High x low | 116.33 |
| | CIM-473 x NIAB-999 | -17.76 | Low x low | 118.77 |
| | NIAB-999 x ACALA1517/C | 18.37 | Low x high | 177.83 |
| | S.E ($S_{ij}$) | 2.35 | | |
| No. of sympodial branches per plant | CIM-473 x NIAB-999 | 4.15 | High x medium | 22.41 |
| | CRIS-420 x FVH-57 | 2.34 | High x low | 18.5 |
| | NIAB-999 x CRIS-420 | 1.51 | Medium x high | 18.91 |
| | S.E ($S_{ij}$) | 0.42 | | |
| No. of monopodial branches per plant | CIM-473 x NIAB-999 | -1.42 | Low x low | 2.85 |
| | NIAB-999 x CRIS-420 | 0.78 | Low x low | 3.39 |
| | S.E ($S_{ij}$) | 0.21 | | |
| Ginning out turn (%) | CIM-473 x ACALA1517/C | 1.75 | High x low | 38.83 |
| | CIM-473 x NIAB-999 | 1.43 | High x medium | 39.06 |
| | CIM-473 x FVH-57 | 1.32 | High x low | 36.91 |
| | NIAB-999 x CRIS-420 | 0.97 | Medium x low | 35.54 |
| | S.E ($S_{ij}$) | 0.28 | | |
| Fibre strength (g/tex) | FVH-57 x ACALA1517/C | 1.45 | Low x low | 21.83 |
| | CIM-473 x CRIS-420 | 1.08 | Low x medium | 21.43 |
| | S.E ($S_{ij}$) | 0.58 | | |
| Fibre length (mm) | CIM-473 x CRIS-420 | 0.89 | High x low | 29.72 |
| | FVH-57 x ACALA1517/C | 0.88 | Low x low | 29.58 |
| | S.E ($S_{ij}$) | 0.38 | | |
| Microniare (μg/inch) | CIM-473 x CRIS-420 | -0.20 | Low x medium | 4.5 |
| | NIAB-999 x CRIS-420 | -0.19 | Medium x medium | 4.77 |
| | CIM-473 x ACALA1517/C | 0.12 | Low x High | 4.95 |
| | S.E ($S_{ij}$) | 0.06 | | |

transmit desirable traits to progeny can be predicted from phenotypic performance of a plant. The best parents both on the basis of GCA effects and per se performance are also listed in Table IV. For the traits with high correlation between SCA and per se performance the ranking of the parents in both cases were nearly same.

High correlation between the SCA effects and per se performance of the $F_1$ crosses was observed for seed cotton yield, number of bolls per plant, plant height, sympodial branches, ginning out turn. Correlations were moderate for boll weight, monopodial branches, fibre length and microniare, while very low correlation was observed in term of fibre strength. High correlation signifies the contribution of non-additive gene effects in the inheritance of the traits.

## CONCLUSION

The results signify the importance of exploitation of both additive and non-additive genetic effects for attaining maximum improvement in yield and other yield based attributes. High GCA parents i.e. CIM-473 for seed cotton yield and NIAB-999 for quality components should be given due consideration in developing superior varieties.

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**Table IV. Promising parents and crosses for yield components and other fibre traits in *Gossypium hirsutum* L.**

| Character | Best parents based on | | | Best parents based on | | |
|---|---|---|---|---|---|---|
| | GCA | Per se performance | r | SCA | Per se performance | r |
| Seed cotton | CIM-473 | CIM-473 | 0.71 | CIM-473 x NIAB-999 | CIM-473 x NIAB-999 | 0.91 |
| yield per plant (g) | CRIS-420 | ACALA1517/C | | CRIS-420 x FVH-57 | CIM-473 x CRIS-420 | |
| | NIAB-999 | FVH-57 | | FVH-57 x ACALA1517/C | CRIS-420 x FVH-57 | |
| No. of boll per | CIM-473 | CIM-473 | 0.74 | CIM-473 x NIAB-999 | CIM-473 x NIAB-999 | 0.86 |
| plant | NIAB-999 | FVH-57 | | CRIS-420 x FVH-57 | CRIS-420 x FVH-57 | |
| | FVH-57 | NIAB-999 | | NIAB-999 x CRIS-420 | CIM-473 x CRIS-420 | |
| Boll weight (g) | ACALA1517/C | ACALA1517/C | 0.98 | FVH-57 x ACALA1517/C | FVH-57 x ACALA1517/C | 0.53 |
| | CRIS-420 | CRIS-420 | | CIM-473 x NIAB-999 | CRIS-420 x ACALA1517/C | |
| | CIM-473 | CIM-473 | | NIAB-999 x FVH-57 | CIM-473 x ACALA1517/C | |
| Plant height (cm) | NIAB-999 | NIAB-999 | 0.87 | CRIS-420 x FVH-57 | CRIS-420 x FVH-57 | 0.82 |
| | FVH-57 | CIM-473 | | CIM-473 x NIAB-999 | CIM-473 x NIAB-999 | |
| | CIM-473 | FVH-57 | | CRIS-420 x ACALA1517/C | NIAB-999 x FVH-57 | |
| No. of sympodial | CIM-473 | CIM-473 | 0.92 | CIM-473 x NIAB-999 | CIM-473 x NIAB-999 | 0.81 |
| branches per plant | CRIS-420 | CRIS-420 | | CRIS-420 x FVH-57 | CIM-473 x CRIS-420 | |
| | NIAB-999 | FVH-57 | | NIAB-999 x CRIS-420 | NIAB-999 x CRIS-420 | |
| No. of monopodial | CIM-473 | NIAB-999 | 0.97 | CIM-473 x NIAB-999 | CIM-473 x NIAB-999 | 0.44 |
| branches per plant | FVH-57 | FVH-57 | | CRIS-420 x FVH-57 | CRIS-420 x FVH-57 | |
| | CRIS-420 | CIM-473 | | CIM-473 x CRIS-420 | NIAB-999 x CRIS-420 | |
| Ginning out turn (%) | CIM-473 | CIM-473 | 0.98 | CIM-473 x ACALA1517/C | CIM-473 x NIAB-999 | 0.83 |
| | NIAB-999 | NIAB-999 | | CIM-473 x NIAB-999 | CIM-473 x ACALA1517/C | |
| | ACALA1517/C | ACALA1517/C | | CIM-473 x FVH-57 | CIM-473 x FVH-57 | |
| Fibre strength (g/tex) | NIAB-999 | NIAB-999 | 0.96 | FVH-57 x ACALA1517/C | NIAB-999 x CRIS-420 | 0.06 |
| | CRIS-420 | FVH-57 | | CIM-473 x CRIS-420 | N-999 x ACALA1517/C | |
| | FVH-57 | CRIS-420 | | N-999 x ACALA1517/C | FVH-57 x ACALA1517/C | |
| Fibre length (mm) | NIAB-999 | FVH-57 | 0.68 | CIM-473 x CRIS-420 | CIM-473 x NIAB-999 | 0.46 |
| | CIM-473 | CIM-443 | | FVH-57 x ACALA1517/C | CIM-473 x ACALA1517/C | |
| | CRIS-420 | NIAB-999 | | CRIS-420 x ACALA1517/C | NIAB-999 x FVH-57 | |
| Microniare (μg/inch) | CIM-473 | CIM-473 | 0.88 | CIM-473 x CRIS-420 | CIM-473 x CRIS-420 | 0.64 |
| | FVH-57 | FVH-57 | | NIAB-999 x CRIS-420 | CIM-473 x NIAB-999 | |
| | CRIS-420 | CRIS-420 | | CIM-473 x NIAB-999 | NIAB-999 x CRIS-420 | |