MATERIALS AND METHODS
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PART A
DIALLEL CROSS

The field experiments were conducted at the Central Institute for Cotton Research, Regional Station, Coimbatore (latitude 11°N) during the year 1978-79. The growing season here is between August and March. The winter is mild as in tropics and allows the normal growth and development of all cotton varieties including short day varieties.

During the period of crop growth, total rainfall recorded was 576.4 mm. Maximum temperature ranged from 28.1° to 33.5°C and the minimum temperature ranged from 18° to 22.8°C. Relative humidity in the morning at 07.30 hrs ranged from 74 to 92 and in the afternoon at 14.30 hrs 38 to 62. Due to unusual rains at the time of boll opening, the basal bolls were damaged considerably.

I. Parental materials

Ten Gossypium hirsutum varieties were selected from the Central Institute for Cotton Research, Regional Station, Coimbatore.

The variety 'Gujarat 67' is derived from an interspecific hybridization programme involving G.arboreum and G.hirsutum. It is the female parent of the popular intraspecific commercial hybrid, Hybrid-4. 'Laxmi' is a widely adapted variety for rainfed
tracts and the female parent of the commercial interspecific hybrid, 'Varalaxmi'. The varieties 'MCU 1' and 'MCU 5' are of South Indian origin, photosensitive grown under irrigated conditions. 'C 1998' and '108 F' are photoinsensitive, short duration varieties of Russian origin. 'Reba B 50' and 'Albar 49' are African selections acclimatized to low temperature, short day conditions. 'Acala 4-42' and 'Paymaster' are American uplands which are day-neutral varieties. The ten parental varieties were crossed in all possible combinations during the winter season 1976-77 and 1977-78.

**Experimental Design and Field Plot Techniques**

A total of ninety hybrids (direct and reciprocals) along with their parents were raised in a randomised block design replicated three times during the winter season 1978-79. Each entry consisted of a single row of ten plants. A spacing of 45 cm between plants was given within the row. An inter-row spacing of 75 cm was adopted. Five plants excluding the border plants in each row were selected at random and tagged for recording observations. Standard agronomic practices and appropriate plant protection measures were followed.

**Observations Recorded**

Observations were recorded on the following nine economic characters:
1. **Number of bolls:** Total number of bolls retained in the plant till the final harvest.

2. **Number of locules:** Five bolls from each cross and from each replication were selected and the average number of locules were calculated.

3. **Seeds per boll:** Five bolls in each cross from each replication were selected and average number of seeds per boll were determined.

4. **Boll weight:** Five bolls in each cross from each replication were selected, the whole seed cotton was weighed and the average mean boll weight in g was calculated.

5. **Seed index:** Weight of 100 seeds in g per plant.

6. **Lint index**

\[
\text{Lint index} = \frac{\text{Weight of 100 seeds} \times \text{Ginning percentage}}{100 \text{ minus ginning percentage}}
\]

The quantity of lint obtained from one hundred seeds expressed in g furnishes a measure of lint produced per seed. It was computed as mentioned above.

7. **Yield:** Total as well as damaged seed cotton produced on the plant was picked and weighed and recorded for individual plant as the yield and expressed in grams.

8. **Mean halo length:** This gives an overall estimate of fibre length of the lint without the lint being taken out of the seed. For this fibres are combed in the
form of halo or butterfly and measurements are taken with the aid of a specially devised disc. Three measurements were taken on five combed halos and averaged over three replications.

9. Ginning per cent: is the ratio of weight of lint to that of seed cotton expressed as given below:

\[
\text{Ginning per cent} = \frac{\text{Weight of lint}}{\text{Weight of seed cotton}} \times 100
\]

The following code words were used for parents for diallel experimental studies.

<table>
<thead>
<tr>
<th>Parents</th>
<th>Code words</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gujarat 67</td>
<td>P_1</td>
</tr>
<tr>
<td>2. Laxmi</td>
<td>P_2</td>
</tr>
<tr>
<td>3. MCU 1</td>
<td>P_3</td>
</tr>
<tr>
<td>4. MCU 5</td>
<td>P_4</td>
</tr>
<tr>
<td>5. Reba B 50</td>
<td>P_5</td>
</tr>
<tr>
<td>6. Albar 49</td>
<td>P_6</td>
</tr>
<tr>
<td>7. Acala 4-42</td>
<td>P_7</td>
</tr>
<tr>
<td>8. Paymaster</td>
<td>P_8</td>
</tr>
<tr>
<td>9. 108 F</td>
<td>P_9</td>
</tr>
<tr>
<td>10. C 1998</td>
<td>P_{10}</td>
</tr>
</tbody>
</table>

a) Graphic analysis (GA)

b) Combining ability analysis (CA)

c) Genetic analysis (Ge)
### Source and distinguishing morphological features of the parents

<table>
<thead>
<tr>
<th>Parents</th>
<th>Source</th>
<th>Duration in days</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gujarat 67</td>
<td>Gujarat State (India)</td>
<td>175-190</td>
<td>Widely adapted to irrigated areas. Indo-American type with <em>G. arboreum</em> genes introgression. Female parent of intraspecific hybrid, Hybrid-4. Fibre length: 30.17 mm.</td>
</tr>
<tr>
<td>2. Laxmi</td>
<td>Karnataka State (India)</td>
<td>175-190</td>
<td>Widely adapted to rainfed areas and the female parent of interspecific hybrid, Varalaxmi. Fibre length: 25.60 mm.</td>
</tr>
<tr>
<td>3. MCU 1</td>
<td>Developed by the Cotton Breeding Station of Tamil Nadu Agricultural University, Coimbatore in the year 1943</td>
<td>165-180</td>
<td>Photosensitive, suited for irrigated winter areas of South India. Fibre length: 26.77 mm.</td>
</tr>
<tr>
<td>4. MCU 5</td>
<td>Developed by the Cotton Breeding Station of Tamil Nadu Agricultural University, Coimbatore in the year 1968</td>
<td>140-155</td>
<td>Photosensitive, suited for irrigated areas of South India. Fibre length: 35.0 mm.</td>
</tr>
</tbody>
</table>

Contd...
<table>
<thead>
<tr>
<th>Parents</th>
<th>Source</th>
<th>Duration in days</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Reba B 50</td>
<td><strong>African</strong></td>
<td>165-180</td>
<td>Acclimatized to low temperature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Short day condition. Rain grown.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre length: 28.7 mm.</td>
</tr>
<tr>
<td>6. Albar 49</td>
<td><strong>African</strong></td>
<td>165-180</td>
<td>Adapted to rainfed conditions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre length: 29.3 mm.</td>
</tr>
<tr>
<td>7. Acala 4-42</td>
<td><strong>American Upland</strong></td>
<td>155-170</td>
<td>Photoinsensitive.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre length: 29.7 mm.</td>
</tr>
<tr>
<td>8. Paymaster</td>
<td><strong>American Upland</strong></td>
<td>130-140</td>
<td>Photoinsensitive.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre length: 26.5 mm.</td>
</tr>
<tr>
<td>9. 108 F</td>
<td><strong>Russian origin</strong></td>
<td>165-180</td>
<td>Photoinsensitive.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre length: 25.1 mm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fibre length: 22.5 mm.</td>
</tr>
</tbody>
</table>
Graphic analysis

Data from $F_1$ and parents were subject to an analysis proposed by Jinks and Hayman (1953) as illustrated by Aksel and Johnson (1962). In this analysis the following statistical parameters were estimated from the data.

- $V_r$ : The variance of offspring of the $r^{th}$ parental array
- $W_r$ : The covariance of offspring of $r^{th}$ array with respect to non-recurring parent
- $W_r'$ : The covariance of offspring of $r^{th}$ array with respect to array mean
- $V_0L_0$ : The variance of all parental means
- $V_0L_1$ : The variance of array mean
- $W_0L_0$ : The mean covariance between parents and the arrays
- $V_1L_1$ : The mean variance of arrays
- $(ML_1 - ML_0)^2$ : The square of difference between the mean of the parents and the mean of their $n^2$ progeny.

By utilizing the regression values, the $W_r$, $V_r$ and $W_r'$, $W_r$ graphs were drawn for all the characters studied and the limiting parabola in the former case was constructed using the formula $W_r^2 = V_r \cdot V_p$. Values of $V_r$ and $W_r = \left( V_r \times V_0L_0 \right)^2$ points were used as the external limits of the parabola.

Testing of hypothesis: The uniformity of $W_r-V_r$ would indicate the validity of the hypothesis postulated by Jinks and Hayman (1953) and Hayman (1954a).
The failure of the hypothesis was detected by significant deviation of the regression coefficient 'b' from unity but not from zero for Wr, Vr and from 0.5 and zero for Wr', Wr regression value with n-2 degrees of freedom.

\[ t^2 \] test: The validity of the assumptions for graphic and genetic analyses as postulated by Hayman (1954) was tested by

\[
\frac{(n-2)}{2} \times \frac{(\text{Var } Vr - \text{Var } Wr)^2}{\text{Var } Vr \times \text{Var } Wr - \text{Cov}^2 (Vr, Wr)}
\]

which is an F with 4 and (n-2) degrees of freedom. Significant 't^2' indicated failure of at least one of the assumptions postulated.

Deviation of regression coefficient (b) from zero and unity:

The regression of covariance on variance and its SE were calculated as:

\[
b = \frac{\text{Cov} (Wr, Vr)}{\text{Var} (Vr)}
\]

Standard error (b) = \[ \left[ \frac{\text{Var } Wr - b \times \text{Cov} Wr, Vr}{\text{Var } Vr \times (n-2)} \right]^{1/2} \]

The significance of b from zero and unity was tested as follows:

\[
\frac{(b - 0)}{\text{SE} (b)} \quad \text{and} \quad \frac{(1 - b)}{\text{SE} (b)}
\]

These values were tested against value of 't' for n-2 degrees of freedom.
Heterosis was estimated as percentage of increase or decrease exhibited by the $F_1$ over mid-parental values (Briggle, 1963).

Heterosis: Deviation of hybrid from mid-parent (per cent) $= \frac{F_1 - MP}{MP} \times 100$

Combining ability analysis

General and specific combining abilities were estimated from the diallel cross by adopting Method-I and Model (1) of Griffing (1956) which includes parents and both direct and reciprocal hybrid combinations. For calculations of general combining ability and specific combining ability, the original mean values of arrays were used. The analysis of variance, expectations of mean sum of squares, calculation of gca, sca and reciprocal effects, variances in respect of effects and standard errors in combining ability analysis are furnished below.

The analysis of variance by Griffing (1956) Method-I and Model-I is as follows:

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>Sum of squares</th>
<th>Mean sum of squares</th>
<th>Expectation of mean sum of squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCA</td>
<td>P-1</td>
<td>Sg</td>
<td>Mg</td>
<td>$6^2 + \frac{2(P-1)}{P} 6^2 S + \frac{2 P 6^2 g}{P}$</td>
</tr>
<tr>
<td>SCA</td>
<td>$\frac{P(P-1)}{2}$</td>
<td>Ss</td>
<td>Ms</td>
<td>$6^2 + \frac{2(P^2-P+1)}{P^2} 6^2 S$</td>
</tr>
<tr>
<td>RCA</td>
<td>$\frac{P(P-1)}{2}$</td>
<td>Sr</td>
<td>Mr</td>
<td>$6^2 + 2 6^2 r$</td>
</tr>
<tr>
<td>Error*</td>
<td>M</td>
<td>Me</td>
<td>Me'</td>
<td>$6^2$</td>
</tr>
</tbody>
</table>
Where,

\[ S_g = \frac{1}{2} P \sum_i (x_{i.} + x_{.i})^2 - \frac{2}{p^2} x^2 \ldots \]

\[ S_s = \frac{1}{2} \sum_i \sum_j x_{ij} (x_{ij} + x_{ji}) - \frac{1}{2} P \sum_i (x_{i.} + x_{.i})^2 + \frac{1}{p^2} (x_{...})^2 \]

\[ S_r = \frac{1}{2} \sum_i \sum_j (x_{ij} - x_{ji})^2 \]

**Expectation of error mean sum of squares**

\[ Me' = \frac{Me}{b \times c} \]

Where,

\[ Me' = \text{Error M.S.S. from analysis of variance} \]

\[ b = \text{blocks} \]

\[ c = \text{number of plants in the block (c)} \]

**Calculation of effects**

**General combining ability effect (gca)**

\[ gca \text{ effect (} \hat{g}_1 \text{)} = \frac{1}{2P} (x_{i.} + x_{.i}) - \frac{x_{...}}{p^2} \]

Where,

\[ P = \text{Number of parents} \]

\[ x_{i.} = \text{Row total of parents in the array} \]

\[ x_{.i} = \text{Column total of parents in the array} \]

\[ x_{...} = \text{Grand total of diallel table} \]
**Specific combining ability effect** (sca)

\[ \Lambda_{ij} = \frac{1}{2} (x_{ij} + x_{ji}) - \frac{1}{2P} (x_{i.i} + x_{.i} + x_{.j} + x_{.j}) + \frac{1}{P^2} x_{...} \]

Where,

- \( P \) = Number of parents
- \( x_{i} \) = Array means of \( F_1 \)
- \( ji \) = Array means of reciprocal \( F_1 \)
- \( i. \) = Row total of first parent
- \( .i \) = Column total of first parent
- \( ji \) = Row total of second parent
- \( .j \) = Column total of second parent
- \( x_{...} \) = Grand total of diallel table

**Reciprocal effects**

\[ \Lambda_{rij} = \frac{1}{2} (x_{ij} - x_{ji}) \]

Where,

- \( ij \) = Array means of \( F_1 \)
- \( ji \) = Array means of reciprocal \( F_1 \)

The variances of these effects and differences between effects were estimated as follows:

\[
\text{Variance of } (\Lambda_{i}) = \frac{p - 1}{2P^2} \Lambda^2
\]

\[
\text{Variance of } (\Lambda_{ij}) = \frac{1}{2P^2} (P^2 - 2P + 2) \Lambda^2
\]
Variance of \((r_{ij}) = \frac{1}{2} \sigma^2\)

Where,

\(\sigma^2 = \text{M.S.S. due to error in analysis of variance/number of plants studied.}\)

**Calculation of standard error**

\[
\text{S.E. of } (\bar{d}_i) = \sqrt{\text{Variance } (\bar{d}_i)}
\]

\[
\text{S.E. of } (\bar{d}_{ij}) = \sqrt{\text{Variance } (\bar{d}_{ij})}
\]

\[
\text{S.E. of } (r_{ij}) = \sqrt{\text{Variance } (r_{ij})}
\]

Standard errors were used for the test of significance of \(\text{sca, gca}\) and reciprocal effects.

**Genetic analysis**

**Estimates of \(D, F, H_1, H_2, h^2\) and \(E\)**

The theory and methods of analysis of Hayman (1954) were extended to estimate the genetic parameters namely, \(D, F, H_1, H_2, h^2\) and \(E\). These were calculated by the following formulae.

- \(D'\) = Component of variation due to additive effects of the genes
- \(F'\) = The covariance of additive and dominance effects
- \(H_1'\) = Component of variation due to dominance effects of genes
- \(H_2'\) = \(H_1 (1 - (u - v)^2)\) where, \(u = \text{proportion of positive alleles while } v = \text{proportion of negative alleles, } U + V = 1.\)
'h^2' = Dominance effects (as the algebraic sum overall loci in heterozygous phase in all crosses)

'E' = The expected environmental variation obtained from error variance divided by number of replications

Where,

'D' = V_0L_0 - E

'F' = 2 V_0L_0 - 4 W_0L_01 - 2 (n-2) E/n

'H_1' = V_0L_0 - 4 W_0L_01 + 4 V_0L_01 - (3n - 2) E/n

'H_2' = 4 V_1L_1 - 4 V_0L_1 - 2 E

'h^2' = 4(ML_0 - ML_0)^2 - 4 (n-1) E/n^2

The genetic components were tested by 't' test for significance by using the standard error of respective genetic parameters. The standard errors were calculated by using (i) the equation

S^2 = \frac{1}{2} Var. (Wr - Vr) and (ii) the terms of main diagonal of covariance matrix given by Hayman (1954) as corresponding multipliers.

**Ratios of genetic components**

From the estimated components, the following genetic ratios were calculated.

\( \frac{H_1}{H_2} \) = Mean degree of dominance over all loci

\( \frac{H_2/4H_1}{4} \) = The proportion of genes with positive and negative effects in the parents

\( \frac{AD/AR}{4} \) = Provides the proportion of dominant and recessive genes in the parent
\[ \frac{1}{2} D + \frac{1}{2} A_1 - \frac{1}{2} A_2 - \frac{1}{2} F \]

Heritability estimates in narrow sense.

\[ \frac{1}{2} D + \frac{1}{2} A_1 - \frac{1}{2} A_2 - \frac{1}{2} F + \hat{E} \]

The correlation between parental order of dominance \((Wr + Vr)\) and parental measurements \((Yr)\) was computed. A significant positive correlation indicates that most of the dominant genes had negative effects for that character, while significant negative value indicates that most of the dominant genes had positive effects.

\[ \frac{1}{2} (D - H_1) \pm SE: \] Dominance effects of genes were generally not significantly different from additive effects as measured by \(\frac{1}{2} (D - H_1) \pm SE\). Sampling variation of estimates of \(Wr - Vr\) were used to provide an approximate SE for testing the significance of \(\frac{1}{2} (D - H_1)\).

**Estimation of most dominant and recessive parent**

According to Hayman (1954) \(VD = (V_0L_0)x_1\); \(VR = (V_0L_0)x_2\)

and \(WD = (V_0L_0)x_1\); \(WR = (V_0L_0)x_2\)

Where,

\[ V = Vr; \ W = Wr; \ D = \text{Dominant}; \ R = \text{Recessive} \text{ and } x_1 \text{ and } x_2 \text{ are the roots of an equation given below.} \]

\[ (V_0L_0)x^2 - (V_0L_0)x + (\bar{V}_0L_0 - V_1L_1) \]

The value for completely dominant parent is \(YD = \bar{Y}R + b[(WD + VD) - (\bar{W}_0L_0 + V_1L_1)]\) value of the completely recessive parent is \(Yr = \bar{Y}R + b[(WR + VR) - (\bar{W}_0L_0 + V_1L_1)]\)
In fact YD and YR are the predictions of the possible limits of selection for amongst the genes exhibiting dominance (Hayman, 1954).
PART B

LINE x TESTER ANALYSIS

The field experiments were conducted at the Central Institute for Cotton Research, Regional Station, Coimbatore during the winter season 1979-1980.

Total rainfall during the period of crop growth was 982.0 mm. Maximum temperature ranged from 27.9° to 34.0°C and minimum temperature ranged from 16.0° to 22.0°C. Relative humidity in the morning at 07.30 hrs ranged from 77 to 95 and in the afternoon at 14.30 hrs 30 to 74 per cent.

I. Parental materials

'Gujarat 67', 'Laxmi', 'MCU 1', 'MCU 5', 'Reba B 50', 'Albar 49', 'Acala 4-42', 'Paymaster', '108 F' and 'C 1998' were used in the diallel analysis. As the first three varieties were late maturing, medium duration varieties like SRT 1, ROIL 3 (Reba-Okra-Isogenic line), early maturing varieties like MCU 7 and Bikaneri Nerma were used as eleven lines (females).

The three non-cultivated races palmeri, morrilli and richmondii, known for their resistance to disease and pests (Kappleman et al., 1979) and other desirable characters were used as testers (males) to study the nature of gene action involved in the non-cultivated perennials with the commercial cultivars.
II. Development of Experimental Materials

The eleven commercial cultivars were used as lines (females) and crossed with the three non-cultivated races as testers (males) during the year 1978-1979.

III. Experimental Design and Field Plot Techniques

The resultant 11 x 3 viz., 33 combinations along with 14 parents and 4 commercial hybrids, namely, 'Hybrid-4', 'CPH 2', 'J.K.Hybrid-1' and 'Varalaxmi' were tested in a randomised block design with three replications during the year 1979-1980. Each entry consisted of a single row of six plants. A spacing of 75 cm between plants and row was given. Three plants were selected in each replication for recording observations.

All the characters in diallel analysis and ten characters namely, mean maturity date, seeds per boll, bolls per plant, boll weight, seed index, lint index, yield per plant, ginning per cent, 2.5% span length, uniformity ratio were analysed in the computer and the other five characters were analysed separately. Wherever controls have not been included in the analysis of variance controls vs. rest were analysed using 't' test.

Three plants were selected in each replication for recording the observations.

1. Plant height: Height measurements were recorded from the soil level to the tip of the main stem after the final harvest.
2. Number of monopodia: The average number of vegetative branches per plant.

3. Number of sympodia: The average number of fruiting branches per plant.

4. Mean maturity date: A measure of the relative maturity of the plant (Christidis and Harrison, 1955).

\[ MMD = \frac{(W_1 H_1) + (W_2 H_2) + \ldots + (W_n H_n)}{W_1 + W_2 + \ldots + W_n} \]

Where,

\[ W = \text{Weight of lint or weight of seed cotton.} \]
\[ H = \text{Number of days from planting to the harvest.} \]
\[ \text{and } 1, 2, \ldots, n = \text{consecutive periodic harvest numbers.} \]

5. Seeds per boll: As mentioned in diallel analysis.

6. Number of motes: Undeveloped and immature seeds expressed in percentage.

7. Number of ovules: Ovules attachment in one locule from each locule of 5 ovaries were counted and averaged.

8. Bolls per plant: As in diallel analysis.

9. Boll weight (g): As in diallel analysis.

10. Seed index: As in diallel analysis.

11. Lint index: As in diallel analysis.
12. **Yield per plant**: As in diallel analysis.

13. **Ginning per cent**: As in diallel analysis

14. **2.5% span length**: Staple length measured in mm through digital fibrograph.

15. **Uniformity ratio**: Obtained from tests in the digital fibrograph. Ratio of 50 per cent span length to 2.5 per cent span length expressed as percentage.

The manufacturers of the instrument have suggested the following classification.

<table>
<thead>
<tr>
<th>Category</th>
<th>Range of uniformity values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Below 42</td>
</tr>
<tr>
<td>Fair</td>
<td>42 to 43</td>
</tr>
<tr>
<td>Average</td>
<td>44 to 45</td>
</tr>
<tr>
<td>Good</td>
<td>46 to 47</td>
</tr>
<tr>
<td>Excellent</td>
<td>Above 47</td>
</tr>
</tbody>
</table>

A representative sample of each entry was analysed for the fibre fineness and fibre bundle strength.

16. **Fibre fineness**: Based on micronaire value, the cottons can be classified in the following groups.

<table>
<thead>
<tr>
<th>Category</th>
<th>Range of micronaire value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very fine</td>
<td>Below 3.0</td>
</tr>
<tr>
<td>Fine</td>
<td>3.0 to 3.9</td>
</tr>
<tr>
<td>Average</td>
<td>4.0 to 4.9</td>
</tr>
</tbody>
</table>
Coarse 5.0 to 5.9
Very coarse 6.0 and above

17. Fibre bundle strength:

<table>
<thead>
<tr>
<th>Category</th>
<th>Range of bundle strength values PSI (lb/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>Below 6.5</td>
</tr>
<tr>
<td>Low</td>
<td>6.5 to 6.9</td>
</tr>
<tr>
<td>Average</td>
<td>7.0 to 7.9</td>
</tr>
<tr>
<td>Good</td>
<td>8.0 to 8.9</td>
</tr>
<tr>
<td>Very Good</td>
<td>9.0 and above</td>
</tr>
</tbody>
</table>

The following code words were used for parents for line x tester experimental studies.

<table>
<thead>
<tr>
<th>Lines</th>
<th>Testers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Albar 49 (L₁)</td>
<td>1. Palmeri (T₁)</td>
</tr>
<tr>
<td>2. MCU 5 (L₂)</td>
<td>2. Morrilli (T₂)</td>
</tr>
<tr>
<td>3. MCU 7 (L₃)</td>
<td>3. Richmondii (T₃)</td>
</tr>
<tr>
<td>4. Acala 4-42 (L₄)</td>
<td></td>
</tr>
<tr>
<td>5. 108 F (L₅)</td>
<td></td>
</tr>
<tr>
<td>6. SRT 1 (L₆)</td>
<td></td>
</tr>
<tr>
<td>7. Bikaneri Nerma (L₇)</td>
<td></td>
</tr>
<tr>
<td>8. ROIL 3 (L₈)</td>
<td></td>
</tr>
<tr>
<td>9. Reba B 50 (L₉)</td>
<td></td>
</tr>
<tr>
<td>10. C 1998 (L₁₀)</td>
<td></td>
</tr>
<tr>
<td>11. Paymaster (L₁₁)</td>
<td></td>
</tr>
</tbody>
</table>
## Source and distinguishing features of the parents

<table>
<thead>
<tr>
<th>Parents</th>
<th>Source</th>
<th>Duration in days</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmeri</td>
<td>USDA (United States Department of Agriculture)</td>
<td>Perennial</td>
<td>Typical shrub, pyramidal in outline, lacinated character of the leaf, small light yellow flower with petal spot, small sized bolls, opening widely, boll weight 2.06 g, fibre length 22.8 mm, micronaire 3.90, and bundle strength 8.9 PSI/lb/mg.</td>
</tr>
<tr>
<td>Morrilli</td>
<td>USDA</td>
<td>Perennial</td>
<td>Rounded bushy, leaf small but normal, medium yellow flower without petal spot, bolls small, round and do not open widely, boll weight 2.20 g, fibre length 24.8 mm, micronaire 4.0, and bundle strength 8.4 PSI/lb/mg.</td>
</tr>
<tr>
<td>Richmondii</td>
<td>USDA</td>
<td>Perennial</td>
<td>Branched shrub with flexible stems that tend to crawl on the ground, flowers and bolls slightly bigger than Palmeri and Morrilli, no petal spot is present and the bolls do not open widely, boll weight 2.67 g, fibre length 25.4 mm, micronaire 3.0, and bundle strength 8.3 PSI/lb/mg.</td>
</tr>
</tbody>
</table>

Contd...
<table>
<thead>
<tr>
<th>Parents</th>
<th>Source</th>
<th>Duration in days</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROIL 3</td>
<td>Developed at the Central Institute for Cotton Research, Regional Station, Coimbatore.</td>
<td>175-185</td>
<td>Reba okra near isogenic line. Fibre length 27.0 mm.</td>
</tr>
<tr>
<td>SRT 1</td>
<td>Gujarat State (India)</td>
<td>175-185</td>
<td>Resistant to jassids having hairs on the leaf. Fibre length: 28.0 mm.</td>
</tr>
<tr>
<td>MCU 7</td>
<td>Developed at the Cotton Breeding Station of Tamil Nadu Agricultural University, Coimbatore</td>
<td>150-165</td>
<td>Radiation induced mutant suited for multiple cropping in delta areas. Fibre length: 24.6 mm.</td>
</tr>
<tr>
<td>Bikaneri Nerma</td>
<td>Rajasthan State (India)</td>
<td>165-175</td>
<td>Photoinsensitive, suited for both irrigated and rainfed conditions. Fibre length: 22.7 mm.</td>
</tr>
</tbody>
</table>
Line x Tester analysis

This method has been used on a limited scale for estimating \( gca \) of inbreds and \( sca \) of hybrids. A heterozygous tester including even a double cross could be used for testing \( gca \) and homozygous tester for testing \( sca \). Kempthorne (1957) defined \( gca \) and \( sca \) \( (\sigma_{gca}^2 \text{ and } \sigma_{sca}^2 \text{ respectively}) \) in terms of covariance of half sibs (H.S.) and full sibs (F.S.) in random mating population where \( \sigma_{gca}^2 \) in cov. H.S. and \( \sigma_{sca}^2 \) is cov. F.S. - 2 cov. H.S. He presented an experiment related to experiment II of Comstock and Robinson (1952) which was analogous to the line x tester analysis.

STATISTICAL PROCEDURES

The overall mean values of the three replications for each parent or hybrid for each character was taken for estimation of heterosis. Heterosis was calculated as the per cent deviation of mean of the \( F_1 \) hybrid from the mid value (MP) between two corresponding parents.

\[
\text{Heterosis} = \frac{\overline{F}_1 - \text{MP}}{\text{MP}} \times 100
\]

\[
\text{Deviation of hybrid from better parent} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100
\]

All the values for heterosis over the mid-parent and better parental values have been represented graphically (Figs. 17 to 33).
The means of each replication for the above mentioned characters of the hybrids, parents were subjected to line x tester analysis and the variance of gca of parents and sca of different combinations were worked out, based on the procedures developed by Kempthorne (1957) as indicated below.

<table>
<thead>
<tr>
<th>Source</th>
<th>D.F.</th>
<th>M.S.</th>
<th>ESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replications</td>
<td>(r-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments</td>
<td>(mf + P - 1) or mf + P + C-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>P-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crosses</td>
<td>(mf-1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parents vs. crosses 1
Control vs. rest 1

Males  (m-1)  \[ M_1 \]  \[ 6^{-2} + r \left[ \text{Cov. (FS)} - 2\text{Cov. (H.S)} \right] + \left[ m \text{ Cov. (H.S.)} \right] \]

Females  (f-1)  \[ M_2 \]  \[ 6^{-2} + r \left[ \text{Cov. (F.S)} - 2\text{Cov. (H.S)} \right] + \left[ f \text{ Cov. (H.S.)} \right] \]

Male x Female interaction  (m-1) (f-1)  \[ M_3 \]  \[ 6^{-2} + r \left[ \text{Cov. (F.S)} - 2\text{Cov. (H.S)} \right] \]

Error  (r-1) (mf-1)  \[ M_4 \]  \[ 6^{-2} \]

Where,

m = number of male parents
f = number of female parents
r = number of replications
Cov.(H.S) = Covariance of half sibs
\[
= \frac{(M_1 - M_3) + (M_2 - M_3)}{r (m+f)}
\]

Cov.(F.S) = Covariance of full sibs
\[
= \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4) + 6r \text{ Cov.}(H.S)}{- r (f + m) \text{ Cov.}(H.S)}
\]

Variance due to gca \( \sigma_{gca}^2 \) and variance due to sca \( \sigma_{sca}^2 \) were estimated as follows from the covariance of half sibs and full sibs.

\[ \sigma_{gca}^2 = \text{Covariance of (H.S)} \]
\[ \sigma_{sca}^2 = \text{Covariance of (F.S)} - 2 \text{ Covariance of (H.S)} \]

**Estimation of gca and sca effects**

The model used to estimate the gca and sca effects of the ijk observation was

\[ x_{ij} = \bar{\mu} + \bar{g}_i + \bar{g}_j + \bar{s}_{ij} + \bar{e}_{ijk} \]

Where,
\[
\bar{\mu} = \text{population mean} \\
\bar{g}_i = \text{gca effect of } i^{th} \text{ male parent} \\
\bar{g}_j = \text{gca effect of } j^{th} \text{ female parent} \\
\bar{s}_{ij} = \text{sca effect of } ij^{th} \text{ combination} \\
\bar{e}_{ijk} = \text{error associated with } ijk^{th} \text{ observation} \\
i = \text{number of male parents} \\
j = \text{number of female parents and} \\
k = \text{number of replications} \]
The individual effects were estimated as indicated below.

i) \[ \mu = \frac{x...}{m.f.r} \]

Where,

\[ x... = \text{Total of all the hybrid combinations} \]

ii) \[ \frac{\alpha i}{f.r} = \frac{x_i...}{m.f.r} - \frac{x...}{m.f.r} \]

Where,

\[ x_i... = \text{Total of } i^{th} \text{ male parent over all females and replications} \]

iii) \[ \frac{\alpha j}{m.r} = \frac{x.j.}{m.f.r} - \frac{x...}{m.f.r} \]

Where,

\[ x.j. = \text{Total of } j^{th} \text{ female parent over all male parents and replications.} \]

iv) \[ \frac{S_{ij}}{r} = \frac{x(ij)...}{f.r} - \frac{x_i...}{f.r} - \frac{x.j.}{m.r} + \frac{x...}{m.f.r} \]

Where,

\[ x(ij) = ij^{th} \text{ combination total of hybrid between } i^{th} \text{ male and } j^{th} \text{ female over all replications.} \]

The standard errors pertaining to gca effects of males and females and sca effects of different combinations were calculated as indicated below.
\[ \text{S.E} (\hat{g}_i) \text{ male} = \sqrt{\frac{\text{Error variance}}{r.f}} \]

\[ \text{S.E} (\hat{g}_j) \text{ females} = \sqrt{\frac{\text{Error variance}}{r.m}} \]

\[ \text{S.E} (\hat{g}_{ij}) \text{ male x female combination} = \sqrt{\frac{\text{Error variance}}{r}} \]