Materials and Methods

CHAPTER III
MATERIALS AND METHODS
Field experiments were conducted at Eastern block of Tamil Nadu Agricultural University, Coimbatore during summer season of 2015 and 2016 to investigate the influence of mechanization in cotton with varying crop geometry. The details of the materials used and the methods employed during the course of investigation are presented in this chapter.

3.1. MATERIALS

3.1.1. Experimental site and location

The field experiments were conducted in Field No.36E at Eastern Block, Department of Farm Management, Tamil Nadu Agricultural University, Coimbatore. The farm is geographically situated in western agro climatic zone of Tamil Nadu at 11° North latitude and 77° East longitude at an altitude of 426.7 m above mean sea level.

3.1.2. Climate and Weather

The experimental location is situated in Semi Arid Tropics (SAT). The normal climatic conditions of Coimbatore based on 50 years weather data are as follows. The mean annual rainfall of Coimbatore is 674.2 mm distributed over 47 rainy days. The annual mean maximum and minimum temperature are 31.5°C and 21°C. Mean relative humidity at 07.22 and 14.22 hrs ranged from 84.9 and 49.1 per cent. The mean bright sunshine hour is 7.3 hours/day. The mean solar radiation was 429.2 cal/cm²/min. Weekly weather conditions that prevailed during the cropping periods are furnished in Appendix I and II and depicted in Fig. 1 and 2.

Cotton crop raised during first year in summer (February to August, 2015) received 314.8 mm of rainfall distributed in 22 rainy days. Weekly mean pan evaporation rate ranged from 3.6 to 8.2 mm with a mean of 6.1 mm/day. Maximum mean weekly temperature ranged from 30.2 to 36.2°C with a mean of 33.1°C and minimum temperature ranged from 18.3 to 25.5°C with a mean of 23.2°C. Relative humidity ranged between 75.6 and 94.0 per cent with a mean of 83.8 per cent and 23.7 to 72.1 per cent with a mean of 48.5 per cent at 07.22 and 14.22 hrs, respectively. The bright sunshine hours ranged from 3.4 to 10.6 hr/day with a mean of 7.1 hr/day and wind velocity ranged from 3.6 to 14.1 km/hr with a mean of 6.9 km/hr.
Fig 1. Weather parameters prevailed during the cropping period (Summer, 2015)
Fig 2. Weather parameters prevailed during the cropping period (Summer, 2016)
Cotton crop raised during second year in summer (February to August, 2016) received 126.7 mm of rainfall distributed in 15 rainy days. Weekly mean pan evaporation rate ranged from 5.1 to 7.7 mm with a mean of 6.8 mm/day. Maximum mean weekly temperature ranged from 27.6 to 37.9°C with a mean of 34.0°C and minimum temperature ranged from 21.0 to 26.0°C with a mean of 24.0°C. Relative humidity ranged between 76.9 and 89.3 per cent with a mean of 81.6 per cent and 33.7 to 64.6 per cent with a mean of 47.7 per cent at 07.22 and 14.22 hrs, respectively. The bright sunshine hours ranged from 1.0 to 9.9 hr/day with a mean of 7.1 hr/day and wind velocity ranged from 4.2 to 21.1 km/hr with a mean of 8.1 km/hr.

3.1.3. Soil Characteristics

The composite soil samples collected initially from the experimental field (F.No:36E) of the study were analyzed for physical and chemical properties and are presented in Table 1.

Table 1. Soil characteristics of the experimental field

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>Summer, 2015</th>
<th>Summer, 2016</th>
<th>Methods used</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Mechanical properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Clay (%)</td>
<td>30.4</td>
<td>30.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Silt (%)</td>
<td>18.7</td>
<td>18.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Coarse sand (%)</td>
<td>26.4</td>
<td>26.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Fine sand (%)</td>
<td>24.5</td>
<td>24.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Texture</td>
<td>Sandy clay loam</td>
<td>Sandy clay loam</td>
<td>International pipette method</td>
<td>Piper (1966)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Chemical properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>EC (dSm⁻¹)</td>
<td>0.6</td>
<td>0.5</td>
<td>Conductometry (1:2 soil water suspension)</td>
<td>Jackson (1973)</td>
</tr>
<tr>
<td>2.</td>
<td>pH</td>
<td>7.6</td>
<td>7.8</td>
<td>1:2 soil: water suspension</td>
<td>Jackson (1973)</td>
</tr>
<tr>
<td>3.</td>
<td>Organic carbon (%)</td>
<td>0.32</td>
<td>0.41</td>
<td>Wet chromic acid digestion</td>
<td>Walkley and Black (1934)</td>
</tr>
<tr>
<td>4.</td>
<td>Available nitrogen (kg/ha)</td>
<td>210</td>
<td>212</td>
<td>Alkaline permanganate</td>
<td>Subbiah and Asija (1956)</td>
</tr>
<tr>
<td>5.</td>
<td>Available phosphorus (kg/ha)</td>
<td>12.6</td>
<td>13.0</td>
<td>Colorimetry</td>
<td>Olsen et al. (1954)</td>
</tr>
<tr>
<td>6.</td>
<td>Available potassium (kg/ha)</td>
<td>429</td>
<td>422</td>
<td>Neutral normal ammonium acetate</td>
<td>Stanford and English (1949)</td>
</tr>
</tbody>
</table>
The soil of the experimental fields was sandy clay loam in texture, belonging to *Typic Ustrolept* series. The nutrient status of soil at the beginning of experiment was low in available nitrogen (210 kg/ha), medium in available phosphorus (12.6 kg/ha) and high in available potassium (429 kg/ha).

### 3.1.4. Season

The experiments were conducted during summer season of 2015 and 2016. The date of sowing and harvest are given below.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Date of sowing</th>
<th>Date of harvest</th>
<th>Field duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment I</td>
<td>23.02.2015</td>
<td>12.08.2015</td>
<td>172</td>
</tr>
<tr>
<td>Experiment II</td>
<td>12.02.2016</td>
<td>03.08.2016</td>
<td>173</td>
</tr>
</tbody>
</table>

### 3.1.5. Crop and Variety

The cotton variety ‘Surabhi’ was used as the test variety. The details of the variety used in the present study are presented in Table 2.

**Table 2. Characteristics of cotton test variety Surabhi**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Parentage</td>
<td>MCU 5 VT (MCU 5 x <em>G. mexicanum</em>)</td>
</tr>
<tr>
<td>2.</td>
<td>Plant habitat</td>
<td>Extra long stable, <em>verticillium</em> wilt resistant</td>
</tr>
<tr>
<td>3.</td>
<td>Duration (days)</td>
<td>170</td>
</tr>
<tr>
<td>4.</td>
<td>Seed cotton yield</td>
<td>2200</td>
</tr>
<tr>
<td>5.</td>
<td>Ginning outturn (%)</td>
<td>35</td>
</tr>
<tr>
<td>6.</td>
<td>2.5 % span length</td>
<td>32.5 to 33.5</td>
</tr>
<tr>
<td>7.</td>
<td>Micronaire (10⁻⁶ g/inch)</td>
<td>3.2 - 4.3</td>
</tr>
<tr>
<td>8.</td>
<td>Fibre strength (g/tex)</td>
<td>24.0 - 27.2</td>
</tr>
</tbody>
</table>

### 3.1.6. Irrigation source

The experimental fields were irrigated with bore well water. For mechanized cultivation water was pumped from water source through 7.5 Hp submersible pump and conveyed to the field using PVC pipes (63 mm OD) after filtering through disk filter. Representative irrigation water sample was collected and analyzed (Jackson, 1973) for its characteristics and presented in Table 3.
Table 3. Quality of irrigation water

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>pH</td>
<td>7.62</td>
</tr>
<tr>
<td>2.</td>
<td>EC (dSm⁻¹)</td>
<td>1.60</td>
</tr>
<tr>
<td>3.</td>
<td>Cations (meq L⁻¹)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Calcium</td>
<td>4.83</td>
</tr>
<tr>
<td></td>
<td>b. Magnesium</td>
<td>6.84</td>
</tr>
<tr>
<td></td>
<td>c. Sodium</td>
<td>4.56</td>
</tr>
<tr>
<td></td>
<td>d. Potassium</td>
<td>0.36</td>
</tr>
<tr>
<td>4.</td>
<td>Anions (meq L⁻¹)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Carbonates</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>b. Bicarbonates</td>
<td>3.40</td>
</tr>
<tr>
<td></td>
<td>c. Sulphates</td>
<td>4.82</td>
</tr>
<tr>
<td></td>
<td>d. Chloride</td>
<td>6.30</td>
</tr>
<tr>
<td>5.</td>
<td>SAR</td>
<td>2.23</td>
</tr>
</tbody>
</table>

3.2. METHODS

3.2.1. Experimental details

The experimental field was prepared with necessary primary and secondary tillage operations to bring the soil to required level of tilth and leveled uniformly. After drawing soil samples (for analyzing the pre-experimental soil parameters) at random from different spots of the field, plots were formed according to layout plan.

3.2.2. Design and Layout

The experiments were laid out in split plot design with three replications. The layout plans are depicted in Fig. 3. The details of the experimental design are furnished below in Table 4.
Fig 3. Layout plan of the field experiment during summer, 2015 and 2016
Table 4. Details of experimental design

<table>
<thead>
<tr>
<th>Design</th>
<th>Split plot design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of replications</td>
<td>Three</td>
</tr>
<tr>
<td>Gross plot area</td>
<td>18.0 m x 9.0 m (162.0 m²)</td>
</tr>
<tr>
<td>Net plot area</td>
<td></td>
</tr>
<tr>
<td>45 cm x 15 cm</td>
<td></td>
</tr>
<tr>
<td>60 cm x 15 cm</td>
<td>9.0 m x 6.0 m</td>
</tr>
<tr>
<td>75 cm x 15 cm</td>
<td></td>
</tr>
<tr>
<td>75 cm x 30 cm</td>
<td></td>
</tr>
</tbody>
</table>

3.2.3. Treatment details

The treatments comprised of two cultivation methods assigned to main plot and four crop geometries allotted to sub plot.

Main plot: Cultivation method

M₁- Mechanized cultivation
M₂- Conventional cultivation

Sub Plot: Plant geometry

S₁ - 45 cm x 15 cm (148,148 plants/ha)
S₂ - 60 cm x 15 cm (111,111 plants/ha)
S₃ - 75 cm x 15 cm (88,888 plants/ha)
S₄ - 75 cm x 30 cm (44,444 plants/ha)

In mechanized method of cultivation, all the practices from sowing to harvest were done by different implements, whereas in conventional method of cultivation, all the practices from sowing to harvest were done as per the Crop Production Guide (CPG, 2012). The detailed cultivation practices both for conventional and mechanization methods are listed in Table 5.
Table 5. Methods and materials used for conventional and mechanized cultivation

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Particulars</th>
<th>Conventional cultivation</th>
<th>Mechanized cultivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Preparatory cultivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Field preparation</td>
<td>Disc plough, tractor plough twice and rotavator</td>
<td>Disc plough, tractor plough twice and rotavator</td>
</tr>
<tr>
<td>1.2</td>
<td>Ridges and furrow forming</td>
<td>Bullock drawn ridge former</td>
<td>Flat bed</td>
</tr>
<tr>
<td>1.3</td>
<td>Rectification</td>
<td>Manual</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Sowing</td>
<td>Manual dibbling of seeds along the ridges</td>
<td>Inclined plate planter (Paired row planting)</td>
</tr>
<tr>
<td>3.</td>
<td>Herbicide</td>
<td>Hand sprayer</td>
<td>Hand sprayer</td>
</tr>
<tr>
<td>5.</td>
<td>Weeding</td>
<td>Hand weeding</td>
<td>Power weeder weeding</td>
</tr>
<tr>
<td>6.</td>
<td>Irrigation</td>
<td>Surface irrigation</td>
<td>Drip irrigation</td>
</tr>
<tr>
<td>7.</td>
<td>Fertilizer</td>
<td>Broadcasting manually</td>
<td>Drip fertigation</td>
</tr>
<tr>
<td>8.</td>
<td>Pesticide spray</td>
<td>Power sprayer</td>
<td>Power sprayer</td>
</tr>
<tr>
<td>9.</td>
<td>Harvest aid application</td>
<td>-</td>
<td>Mepiquat chloride and Drop Ultra</td>
</tr>
<tr>
<td>10.</td>
<td>Harvest</td>
<td>Manual picking</td>
<td>Portable battery operated cotton picker</td>
</tr>
</tbody>
</table>

3.3. CROP MANAGEMENT

3.3.1. Field preparation

The experimental field was thoroughly ploughed with tractor drawn five tyned cultivator followed by two ploughings with cultivator and the clods were broken with rotavator. Well decomposed farmyard manure at the rate of 12.5 t/ha was applied uniformly before last ploughing. The field was uniformly levelled and prepared plots as per the layout plan. In conventional plots, ridges and furrows were formed at different
spacing as per the treatment schedule, whereas in mechanized cultivation plots, flat beds were formed.

3.3.2. Soil application of conventional fertilizer and fertigation

Recommended dose of fertilizer (80:40:40 kg/ha NPK) were applied as per the crop production guide. In conventional plots, the entire quantity of phosphorus and 50 per cent of N and K in the form of conventional fertilizer urea (46 per cent N), Single super phosphate (16 per cent \(P_2O_5\)) and muriate of potash (60 per cent \(K_2O\)) were applied as basal dose at sowing and the balance 50 per cent of N and K applied as top dressing at 45 DAS. In mechanized cultivation plots, conventional fertilizers viz., urea (46 per cent N), di-ammonium phosphate (18 per cent N and 46 per cent \(P_2O_5\)) and muriate of potash (60 per cent \(K_2O\)) were applied through drip fertigation. The fertilizer solution was prepared by dissolving the required quantity of fertilizer with water at 1:5 ratio and injected into the irrigation system through ventury assembly. The fertilizer and fertigation schedules are furnished in Appendix III.

3.3.3. Seeds and Sowing

Healthy and viable seeds of cotton variety Surabhi were used for the experiments. Seeds were sown in the ridges at 45 cm, 60 cm and 75 cm apart by dibbling two seeds/hill with plant spacing of 15 cm and 30 cm within the row, as per the treatments for conventional cultivation. In mechanized method of cultivation, seeds were sown in the flat bed by adopting paired row system under drip irrigation with spacing of 30/60 cm x 15 cm, 45/75 cm x 15 cm, 60/90 cm x 15 cm and 60/90 cm x 30 cm; inclined plate planter was used for sowing which facilitated row to row and also plant to plant spacing as per the treatment schedule. The planter had modular seed boxes where the seeds were filled temporarily and seeds dropped out through outlet opener into the opened furrow. The specification of inclined plate planter is furnished in Table 6.

3.3.3.1. Description and specification of inclined plate planter

A tractor mounted six row inclined plate planter was developed at CIAE, Bhopal. It consists of a main frame with tool bar, seed boxes, furrow openers and ground drive wheel system. The planter is provided with six seed boxes of modular design with
independent inclined plate type seed metering mechanism. The shoe type furrow openers are mounted on tool bar of main frame through clamps. The seed boxes are bolted to the furrow openers and seed box-furrow opener assemblies are adjustable for row-to-row spacing and work as a modular unit for sowing of each row. The drive to seed metering mechanism is transmitted from ground drive wheel through chain and sprockets. The ground drive wheel and power transmission system are fixed on the main frame. It is suitable for planting cotton, groundnut, gram, soybean, mustard etc. Row-to-row distance can be adjusted and planting of different seeds in different rows is also possible. The effective field capacity and field efficiency are 0.45- 0.65 ha/hr and 70 - 75 per cent, respectively (CIAE, 2010).

Table 6. Specification of inclined plate planter

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall dimensions (L x B x H), mm</td>
<td>2500 x 1215 x 1010</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>210</td>
</tr>
<tr>
<td>Source of power</td>
<td>35 hp or above, Tractor</td>
</tr>
<tr>
<td>Row spacing, mm</td>
<td>6 rows, 250 - 450 (Adjustable)</td>
</tr>
<tr>
<td>Plant spacing in rows, mm</td>
<td>150-300 (Adjustable)</td>
</tr>
<tr>
<td>Field capacity hr/ha</td>
<td>2 - 2.5</td>
</tr>
<tr>
<td>Type of seed used</td>
<td>Small and bold seeds</td>
</tr>
<tr>
<td>Nominal working width, mm</td>
<td>1350 -1800 (Adjustable)</td>
</tr>
<tr>
<td>Depth of planting, mm</td>
<td>30 -150 (Adjustable)</td>
</tr>
<tr>
<td>Type of seed metering mechanism</td>
<td>Inclined plate, Spiked ground wheel drives the seed plates through chain-sprocket and bevel gears</td>
</tr>
<tr>
<td>Furrow opener and closer</td>
<td>Shoe type furrow opener, plastic tubes convey the seeds to the boot</td>
</tr>
</tbody>
</table>

3.3.4. Cultural and plant protection practices

3.3.4.1. Herbicide application

As per the recommendation, pendimethalin at the rate of 1.0 kg a.i./ha was applied, as pre emergence herbicide on 3rd days after sowing for both mechanized and
conventional cultivation methods. The herbicide spray fluid was sprayed uniformly over
the soil surface using a hand operated knap-sack sprayer fitted with deflector nozzle.

3.3.4.2. Thinning and gap filling

Adequate care was taken to maintain optimum plant population. Gap filling was
done ten days after sowing (DAS) and thinning was done 20 DAS by retaining one
healthy seedling per hill in both mechanized and conventional method of cultivation.

3.3.4.3. Weeding

Hand weeding on 20 and 45 DAS was done in conventional cultivation plots,
whereas in mechanized cultivation plots, power weeder was used. The power weeder
spacing was kept altered to suit crop geometry as per the treatment schedule.

<table>
<thead>
<tr>
<th>Crop geometry</th>
<th>Power weeder used</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 cm x 15 cm</td>
<td>Micro power weeder</td>
</tr>
<tr>
<td>60 cm x 15 cm</td>
<td>BCS 720 power weeder</td>
</tr>
<tr>
<td>75 cm x 15 cm</td>
<td>Sharp garuda mini weeder</td>
</tr>
<tr>
<td>75 cm x 30 cm</td>
<td>Sharp garuda mini weeder</td>
</tr>
</tbody>
</table>

3.3.4.4. Irrigation

Surface irrigation was done for plots under conventional cultivation whereas in
mechanized cultivation, drip irrigation was adapted.

3.3.4.4.1. Surface irrigation

In surface irrigation, first irrigation was given immediately after sowing and life
irrigation on 3 DAS and subsequent irrigations were given based on pan evaporation
values from USWB open pan evaporimeter installed at Agromet observatory in
Tamil Nadu Agricultural University. Irrigation was scheduled at 5.0 cm depth with IW/CPE
ratio of 0.40 and 0.60 during vegetative and reproductive phase respectively.

3.3.4.4.2. Drip irrigation

In mechanized cultivation plots, drip lines were laid at varying crop geometry.
Immediately after sowing, the plots were irrigated until the soil reaches its saturation
point and subsequent irrigations were scheduled once in five days based on the following formula.

\[ W_{Re} = CPE \times Kp \times Kc \times Wp \times A-Re \]

Where,

- \( W_{Re} \) = Computed water requirement (litres/day)
- \( CPE \) = Cumulative pan evaporation for four days (mm)
- \( Kp \) = Pan factor (0.8)
- \( Kc \) = Crop factor
- \( Wp \) = Wetting area percentage (80 per cent)
- \( A \) = Area per plant
- \( Re \) = Effective rainfall (mm)

Time of operation of drip system to deliver the required volume of water per plot was computed using the formula,

\[ \text{Time of operation} = \frac{\text{Volume of water required}}{\text{Emitter discharge rate} \times \text{No. of emitter}} \]

3.3.4.5. Plant Protection

Imidachloprid at the rate of 2 ml/litre of water was sprayed at 25, 45 and 65 DAS to control the early incidence of sucking pests. Appropriate prophylactic protection measures were taken up to keep the crop free from pest and diseases.

3.3.5. Harvesting

Cotton picking was done manually in plots under conventional cultivation method. Battery operated cotton picker was engaged in plots under mechanized cultivation methods and the specification of cotton picker is given in Table 7. To facilitate the better cotton picking, harvest aid application of mepiquat chloride @ 50 g a.i./ha in two equal splits at peak squaring (55-65 DAS) and peak flowering (75 to 85 DAS) and drop ultra @ 500ml/ha at physiological maturity stage were applied to ensure synchronized maturity and defoliation for easy picking without contaminants.
Table 7. Specification of battery operated cotton picker

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight</td>
<td>620 g</td>
</tr>
<tr>
<td>Electric power</td>
<td>11 W</td>
</tr>
<tr>
<td>Voltage</td>
<td>DC12V</td>
</tr>
<tr>
<td>Speed</td>
<td>5400 RPM</td>
</tr>
<tr>
<td>Battery capacity</td>
<td>12V 8AMP</td>
</tr>
<tr>
<td>Charge time</td>
<td>6 hrs</td>
</tr>
<tr>
<td>Discharge time</td>
<td>6 hrs</td>
</tr>
<tr>
<td>Picking amount</td>
<td>180 -200 kg/day</td>
</tr>
<tr>
<td>Overall dimension</td>
<td>260 x 90 x 150 mm</td>
</tr>
</tbody>
</table>

3.4. BIOMETRIC OBSERVATIONS

Five plants from each net plot area were chosen at random and tagged. These plants were used for recording all biometric observations at different stages of crop growth as described below.

3.4.1. Growth parameters

3.4.1.1. Plant height

The height of the tagged plant was measured from the cotyledonary node to the tip of the last opened leaf and the mean was expressed in cm at 30, 60, 90 and 120 DAS.

3.4.1.2. Dry matter production

The crop dry matter was estimated at 30, 60, 90 and 120 DAS. Five plants at random were removed each time from the sampling row for the estimation of DMP. The samples were initially air dried and subsequently oven dried at 65°C for 72 hours until constant weight was obtained. The weight was recorded on moisture free basis and expressed as kg/ha. These samples were subsequently used for chemical analysis.
3.4.1.3. Number of monopodial branches/plant

The vegetative monopodial branches arising from axillary buds were counted from the tagged plants at 120 DAS and expressed in numbers per plant.

3.4.2. Physiological parameters

3.4.2.1. Leaf area index

From the selected plants in each treatment plots, leaf length and maximum width of the third leaf from the top was measured from five representative samples. Total number of leaves in each plant was counted. From these observations made on 30, 60, 90 and 120 DAS, the LAI was calculated using the following formula suggested by Ashley et al. (1963).

\[
\text{LAI} = \frac{L \times W \times N \times K}{\text{Land area (cm}^2\text{) occupied by one plant}}
\]

where,

- \( L \) = Length of the leaf in cm
- \( W \) = Width of the leaf in cm
- \( N \) = Number of the leaves per plant and
- \( K \) = Constant factor (0.775 for cotton)

3.4.2.2. Leaf area duration

The mean LAD was calculated by using the formula suggested by Power et al. (1967), which was further modified by Kvet et al. (1971).

\[
\text{LAI} = \frac{L_1 + L_2}{2} \times (t_2 - t_1)
\]

Where,

- \( L_1 \) and \( L_2 \) are the LAI at time \( t_1 \) and \( t_2 \).
3.4.2.3. Crop growth rate (CGR)

The crop growth rate was estimated by adopting the formula of Watson (1958) and expressed in g/m²/day.

\[
\text{CGR} = \frac{W_2 - W_1}{(t_2 - t_1)}
\]

Where,

\(W_1\) and \(W_2\) - dry weight of plants in g at times \(t_1\) and \(t_2\) respectively.

\(t_2 - t_1\) - time intervals in days between stages

3.4.2.4. Relative growth rate (RGR)

Relative growth rate (RGR) is defined as the rate of growth per unit plant weight, which provides more informative comparison of the plants relative performance in a given environment. The RGR was computed using the formula suggested by En Yi (1962) and expressed in mg/g/day.

\[
\text{RGR} = \frac{\log W_2 - \log W_1}{t_2 - t_1}
\]

Where,

\(W_1\) - whole plant dry weight (g) at stage \(t_1\)

\(W_2\) - whole plant dry weight (g) at stage \(t_2\)

\(t_2 - t_1\) - time intervals in days between stages

3.4.2.5. Net assimilation rate (NAR)

It is defined as the rate of increase in the plant dry matter per unit of assimilatory surface per unit time. The NAR is the rate of increase of leaf dry weight per unit area of leaf per unit time. This was calculated using the formula suggested by Williams (1946) and expressed in g/m²/day.

\[
\text{NAR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log L_2 - \log L_1)}{(L_2 - L_1)}
\]
Where,

\[ W_1 \text{ and } W_2 \text{ - dry weight of whole plant at time } t_1 \text{ and } t_2 \text{ respectively,} \]

\[ L_1 \text{ and } L_2 \text{ - leaf area at } t_1 \text{ and } t_2 \text{ respectively, and} \]

\[ t_{1-2} \text{ - time interval in days.} \]

3.4.2.6. Absolute growth rate (AGR)

The rate of increase in growth variable at time ‘t’ is absolute growth rate. It was measured by differential coefficient of ‘w’ with respect of time ‘t’. Absolute growth rate was calculated by using the following formula (Redford, 1967). It was expressed as g/day of dry matter production per plant.

\[
\text{AGR (dry matter)} = \frac{W_2 - W_1}{t_2 - t_1}
\]

Where,

\[ W_1 \text{ and } W_2 \text{ - dry matter weight (g) at the time } t_1 \text{ and } t_2, \text{ and} \]

\[ t_{1-2} \text{ - time interval in days.} \]

3.4.3. Biochemical parameters

3.4.3.1. Chlorophyll index

A chlorophyll meter (SPAD 502) designed by the Soil Plant Analysis Development (SPAD) section, Minolta Camera Co. Ltd., Japan was used to record SPAD readings. SPAD 502 readings were taken as described by Peg et al. (1993).

The SPAD 502 is self calibrated for variability in the output of LED and has built in error codes that help to prevent irregular measurement. Leaf chlorophyll absorbance is measured at a wavelength of 650 nm and non-chlorophyll absorbance is measured at a wavelength of 940 nm. A microprocessor calculates the SPAD value, which is proportional to the relative optical density based on the ratio between the two wavelengths (Monje and Bugbee, 1992).

Measurements were taken from upper most fully expanded leaf (4th leaf from the apex) (Wood et al., 1992). SPAD 502 readings were recorded on 30, 60, 90 and
120 DAS from five plants/plot. Five chlorophyll meter readings were taken around the midpoint of each blade of the leaf in a plant. Thus, fifty SPAD readings were taken from five plants to represent the mean SPAD 502 values of each plot (treatment).

3.4.3.2. Estimation of light interception

Light interception measurements were taken on 90 and 120 DAS using a Lux meter. Readings were recorded at the top, middle and ground level of the crop. Keeping the light intensity in the open as 100, light interception in per cent was calculated by using the following formula (Chellaiah, 1996).

\[
\text{Light interception (\%) = } \frac{\text{Light intensity in open (Lux)} - \text{Average intensity in crop (Lux)}}{\text{Light intensity in open (Lux)}}
\]

3.4.4. Earliness parameters

3.4.4.1. Number of days to appearance of first square (DFS)

Number of days from sowing to appearance of first square was noted from the ten selected plants and average number of days taken to appearance of first square was calculated and expressed.

3.4.4.2. Number of days to appearance of first flower (DFF)

Number of days from sowing to appearance of first flower was noted from the ten selected plants and average number of days taken to appearance of first flower was calculated and expressed.

3.4.4.3. Number of days to attain 50 per cent flowering

Number of days from sowing to appearance of 50 per cent flower was noted from the ten selected plants and average number of days taken to appearance of 50 per cent flower was calculated and expressed.

3.4.4.4. Number of days to first opening bolls (DFOB)

Number of days from sowing to first opening of bolls was noted from the ten selected plants and average number of days taken to opening of first bolls was calculated and expressed.
3.4.4.5. Boll maturation period (BMP)

Boll maturation period (days) was calculated by deducting number of days taken to flowering from number of days taken from planting to first boll opening and presented.

3.4.5. Yield attributes

3.4.5.1. Number of sympodial branches/plant

The reproductive sympodial branches arising from extra axillary buds were counted from the tagged plants at maturity stage and expressed in number per plant.

3.4.5.2. Number of fruiting points/plant

From five plants in each plot, total numbers of bolls retained by each plant were counted on 120 DAS and the mean values were expressed in numbers/plant.

3.4.5.3. Number of bolls/plant

From five plants in each plot, total numbers of bolls retained by each plant were counted on 120 DAS and the mean values were expressed in numbers/plant.

3.4.5.4. Boll weight

The weight of fully opened and matured bolls picked from five plants was recorded and expressed as mean boll weight in g/boll.

3.4.5.5. Boll setting percentage

The boll setting percentage was worked out from the number of fruiting points and number of bolls harvested from the tagged plants and expressed in percentage.

\[
\text{Boll setting percentage} = \frac{\text{Total number of bolls}}{\text{Total number of fruiting points}} \times 100
\]

3.4.6. Seed cotton yield

The seed cotton yield obtained from the net plot area was recorded and expressed in kg/ha.
3.4.7. Quality characteristics

3.4.7.1. Sample preparation

Seed cotton was randomly selected and picked from each treatment during the first harvest. The collected seed cotton was hand cleaned from contaminants like trash and dried leaves, insects damaged bolls and subjected for ginning. Cleaned and ginned lint samples of about 100 g was packed and labeled for quality testing.

3.4.7.2. High volume instrument system (HVI)

Various conventional instruments are integrated into a single compact operating system by using a state of art technology in optics, machines and electronics. The high volume instrument system provides measurement of fibre span length (mm), fibre fineness (μg/inch), fibre strength (g/tex), fibre maturity ratio and uniformity ratio. Cotton samples were tested for fibre quality parameters at the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore with HVI instrument (in ICC mode) by the method adopted from ASTM D-5867 given by Sundaram (1979).

3.4.7.3. Ginning out turn

The ratio of weight of lint to that of seed cotton was worked out and expressed in percentage by following the formula by Santhanam (1976).

\[
\text{Ginning out turn} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100
\]

3.4.7.4. Lint index

The quantity of lint obtained from 100 seeds after ginning was expressed as lint index (Santhanam, 1976).

3.4.7.5. Seed index

Hundred seeds selected at random after ginning was weighed and expressed as seed index (Santhanam, 1976).
3.4.7.6. 2.5 per cent Span length

It is the distances spanned by specific percent of the fibre in the test board. The 2.5 per cent span length is distance from the clamp of fibre board to a point up to which only 2.5 per cent of the fibre extends and expressed in mm (Sundaram, 1979).

3.4.7.7. Micronaire

It is the measure of fibre weight in microgram per inch length of fibre (µg/inch). The fibre fineness is another important quality character, which plays a prominent role in determining spinning performance of cotton. The fibre fineness denotes the size of the cross sectional dimension of fibre (Sundaram, 1979).

3.4.7.8. Fibre strength

It denotes the maximum tension at which the fibre is able to sustain before it breaks. It can be defined as the ratio of breaking strength of a bundle of fibres to its weight and expressed in gram/tex (Sundaram, 1979).

3.4.7.9. Elongation percentage

Elongation percentage was obtained with the help of high volume instrument as suggested by Sundaram (1979) and expressed as percentage.

3.4.8. Root studies

The root studies were made by measuring the tap root (rooting depth), root spread (cm) and root dry weight (g) at harvest of the crop. Root growth was measured using a modified trench method (Bohm et al., 1977). Trenches of a convenient depth and sufficient length on both sides of the sampling row were opened by digging with fork without snatching the rootlets and separated away from the sampling rows. The plants were carefully excavated until the tip of each plant root was just visible. The soil adhering to the plant was carefully removed by immersing in water tub and the soil was disintegrated and then observations were made. Rooting depth was measured from the collar region to tip of the deepest roots and expressed in cm. Root samples were air dried
initially followed by oven drying at 80°C till a constant weight is attained and root was weighed and expressed as g/plant.

3.4.9. Chemical analysis

3.4.9.1. Nutrient uptake by plants

The samples collected for the estimation of dry matter production were used for the estimation of nutrient uptake. The plant analysis was done at 30, 60, 90 and 120 DAS. The oven dried plant samples were ground using willey- mill and analyzed for total NPK (Table 8). Based on the contents, nitrogen, phosphorus and potassium uptake were calculated at the respective stages. The uptake values were computed to kg/ha by multiplying the nutrient content with corresponding total dry matter production.

Table 8. Details of the analytical methods employed in plant analysis

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Particulars</th>
<th>Methodology</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total nitrogen</td>
<td>Microkjeldahl digestion and distillation</td>
<td>Humphries (1956)</td>
</tr>
<tr>
<td>2</td>
<td>Total phosphorus</td>
<td>Alkaline KMnO4 method triacid digestion colorimeter</td>
<td>Jackson (1973)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Triacid digestion by flame photometer</td>
<td>Jackson (1973)</td>
</tr>
</tbody>
</table>

3.4.9.2. Available nutrient status in soil

Pre experiment composite soil samples were collected and analysed for mechanical and chemical properties. Post-harvest samples were collected from each treatment plot and analysed for the available nutrients of N, P₂O₅ and K₂O as per standard procedure (Table 1).

3.4.10. Observation on weeds

3.4.10.1. Weed density

A quadrat (0.25 m²) was placed at four randomly selected places in sampling area of each plot and the weed species were accounted and expressed as number/m². Weeds were grouped in to three categories like grasses, sedges and broad leaved weeds.
3.4.10.2. Weed dry weight

Two quadrates of 0.25 m² each were placed at random outside the net plot and the weed falling within the quadrat were removed, shade dried and oven dried at 70°C for 72 hours and the dry weight of weeds were expressed as kg/ha.

3.4.11. Observation on pest incidence

Population of insect pest was recorded as per established procedure and presented here under.

3.4.11.1. Sucking pest

Assessment of aphids, thrips, white fly and leafhoppers were made on three leaves each from top, middle and bottom portion in each of the five randomly selected tagged plants per plot and expressed as numbers per three leaves. The data were subjected to square root √x +0.5 transformations and then statistically analyzed.

3.4.12. Economic Analysis

Cost of cultivation and gross return for all the treatments were worked out on the basis of prevailing input cost and market price of the grain at the time of experimentation as suggested by Bhandari (1993). The net income was calculated by deducting the cost of cultivation from the gross return. The benefit cost ratio (BCR) was worked out as follows.

\[
\text{Gross return (₹/ha)}
\]

\[
\text{Benefit cost ratio} = \frac{\text{Gross return (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}
\]

3.4.13. Energy analysis

The required data from the experiment were collected and computed using the method suggested by Devasenapathy et al. (2009). The unit energy of input and output is furnished in Appendix IV.
3.4.13.1. Energy Efficiency (EE)

Cultural energy utilized through inputs and energy produced as products was calculated and expressed in Mega Joules (MJ). Energy efficiency was worked out taking into account the input and output energy for each treatment (Dazhong and Pimental, 1984).

\[
\text{Energy output (MJ/ha)}
\]

\[
\text{EE} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}
\]

3.4.13.2. Specific Energy (SE)

Specific energy of the treatment was calculated in terms of energy required to produce one kg of main produce and expressed in MJ/kg (Mohammadi and Omid, 2010).

\[
\text{Energy input (MJ/ha)}
\]

\[
\text{EE} = \frac{\text{Energy input (MJ/ha)}}{\text{Grain yield (kg/ha)}}
\]

3.4.13.3. Net Energy (NE)

The net energy of each crop was calculated by deducting the energy input from the energy output of particular treatment or practice (Mohammadi and Omid, 2010).

\[
\text{NE} = \text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)}
\]

3.4.13.4. Energy Productivity (EP)

Energy productivity is the quantity of physical output obtained for every unit of input and expressed as kg/MJ (Mohammadi and Omid, 2010).

\[
\text{Output (grain + byproduct) (kg/ha)}
\]

\[
\text{EP} = \frac{\text{Output (grain + byproduct) (kg/ha)}}{\text{Energy input (MJ/ha)}}
\]

3.4.13.5. Energy Intensity (EI)

Energy intensity is the ratio between energy output and cultivation expenses and expressed as MJ/₹ (Mohammadi and Omid, 2010).

\[
\text{Energy output (MJ/ha)}
\]

\[
\text{EI} = \frac{\text{Energy output (MJ/ha)}}{\text{Cost of cultivation (₹/ha)}}
\]
3.4.14. Statistical analysis

The data recorded on various parameters during the course of investigation and the summed up data were statistically analyzed following the analysis of variance for split plot design as suggested by Gomez and Gomez (1984). Wherever the treatmental differences were found significant (‘F’ test), critical difference was worked out at 0.05 probability level. Treatmental differences that were non significant were denoted by “NS”. The correlation analysis was made between yield components and yield.