Cotton Growth and Development

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Introduction
Management of cotton requires an understanding of the growth habit and responses of the plant to the environment and to the management used. This publication provides basic information for understanding how a cotton plant develops and some of the factors that can alter the pattern of development.

Seasonal Development of the Cotton Plant
Cotton is a perennial plant in many parts of the tropics and subtropics where it may reach a height of 15–20 feet. In Florida and across the U.S. Cotton Belt, cotton is grown as an annual and attains a height of 2–5 feet or more if moisture and plant nutrients (primarily nitrogen) are not limiting. Air temperatures in the 90°–95°F range are considered near optimum for growth. Very little growth takes place below 60°F or above 100°F, especially if soil moisture is low. However, cotton is considered drought tolerant because of its extensive root system and its ability to set fruit over an eight week period. An average daily growth rate for the roots of ½ inch may occur until first flower (50-60 days) when root growth begins to level off and then declines starting about 90 days after planting.

High quality seed for planting is key to obtaining good stands of cotton plants. Seeds consist of two cotyledons and an embryo. Prior to ginning and delinting, the top layer of the seed coat has two types of fiber, long lint fiber and short linters. Each fiber is a single cell that elongates until cotton is ready for harvest. After ginning and acid delinting, seed are treated with fungicide prior to planting. Fungicides aid in stand establishment since acid delinting results in cracks in the seed coat, giving disease organisms an entry point into the germinating seed. Germination begins within a few hours after moisture is taken up. The cotyledons eventually form the first green leaves as well as contain stored food that supplies energy for germination and early development.

Approximately 4–10 days after planting, cotyledonary or seed leaves are fully expanded (Table 1). These leaves are on node number 0 and are borne on opposite sides of the main stem. The nodes above the seed leaves occur in a spiral arrangement around the stem and bear a single true leaf. At the base of each main stem leaf, in the angle between the leaf and the stem, there are two or sometimes three axillary buds. These buds give rise to vegetative branches on the lower nodes (nodes 2 through 5 or 6). At nodes 6 or 7, and above, generally on lateral branches, are fruiting branches, which bear the floral buds, or cotton squares that become bolls. If a cotton plant does not produce squares by node 9, a problem exists and its cause(s) should be determined and corrected if possible.

The time required for development from pinhead square to white bloom is approximately 23 days (Table 1). Pollination occurs on the first day the flower is open (white bloom...
Cotton Growth and Development

Table 1. Typical growth and development of a cotton plant

<table>
<thead>
<tr>
<th>Event</th>
<th>Time Required (Days)</th>
<th>Average Time Required (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting to emergence</td>
<td>4–14</td>
<td>7</td>
</tr>
<tr>
<td>Planting to 1st square</td>
<td>35–45</td>
<td>39</td>
</tr>
<tr>
<td>Planting to 1st bloom</td>
<td>55–70</td>
<td>62</td>
</tr>
<tr>
<td>Pinhead square to white flower</td>
<td>20–35</td>
<td>33</td>
</tr>
<tr>
<td>White flower to pink flower</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pink flower to open boll</td>
<td>50–60</td>
<td>55</td>
</tr>
</tbody>
</table>

Cotton growth and development generally occur in the following stages:

1. **Planting to emergence**: 4–14 days to 7 days
2. **Planting to 1st square**: 35–45 days to 39 days
3. **Planting to 1st bloom**: 55–70 days to 62 days
4. **Pinhead square to white flower**: 20–35 days to 33 days
5. **White flower to pink flower**: 1 day to 1 day
6. **Pink flower to open boll**: 50–60 days to 55 days

**Stage 1 (Planting to emergence)**: This stage is the initial period following planting. The plant begins to grow, and it can take 4–14 days for the seed to emerge from the ground. The emergence of the plant is a critical stage in its development.

**Stage 2 (Planting to 1st square)**: Following emergence, the plant develops into a square. This stage is marked by the growth of leaves and the development of the first node. It typically takes 35–45 days, with an average of 39 days.

**Stage 3 (Planting to 1st bloom)**: This stage is characterized by the development of the first bloom. It takes 55–70 days with an average of 62 days.

**Stage 4 (Pinhead square to white flower)**: The transition from the pinhead square to the white flower stage is important for cotton development. This stage lasts 20–35 days, on average 33 days.

**Stage 5 (White flower to pink flower)**: This stage lasts for 1 day, indicating the change from white to pink flower.

**Stage 6 (Pink flower to open boll)**: The final stage before boll formation takes 50–60 days, with an average of 55 days.

Cotton is indeterminant, meaning that flowering will continue until stopped by frost, drought, full boll load, insect attack or some other cause. Shedding of squares, flowers, or young bolls is common. Under good conditions, only 35–40% of the squares normally produce mature bolls. Once bolls are 12 days old or older, they usually will not shed unless the plant suffers severe stress (temperature, moisture, insect, nutritional or disease). The time required for development from the pink flower stage to the open boll stage is approximately 55 days. Cloudy weather and below-optimum temperatures increase the boll maturation period. Late in the growing season, 65–70 days are required for development from the pink flower to the open boll stage.

Cotton fibers (lint) are produced on the seed inside the boll. Normally, 100–120 bolls are required to produce a pound of seed cotton (160–170 for a pound of lint). However, varieties that produce relatively small bolls may require more bolls to produce a pound of seed cotton. Also, bolls developing later in the season are smaller and therefore more are required to produce a pound of cotton lint. Figure 2 (Landivar and Benedict 1996) shows a diagrammatic sketch of a cotton plant with mainstem nodes and fruiting nodes and general plant architecture.

**Fruit Shed**

Cotton has the potential for setting about 90% of the crop in the first three weeks of blooming (Table 2). However, fruit shed usually causes the setting period to be considerably longer (8 weeks typically). Fruit shed in cotton is a physiological process. Squares and small bolls shed because...
an abscission zone forms between the fruiting branch and the peduncle (boll stem). During the abscission process, enzymes loosen the connection between the cells allowing the weight of the square or boll to break the peduncle. The weakening of cells at the abscission zone is controlled by the balance of plant hormones, ethylene, and abscissic acid (ABA), which promote abscission and indole acetic acid (IAA) that inhibits abscission. Because of the process involved, several days are required between the stimulus causing shed and the actual loss of fruit. Insect feeding on small squares prior to bloom may also contribute to fruit shed. Large squares, blooms, and medium to large size bolls are most resistant to shed, possibly due to their high proportion of IAA (which inhibits abscission) to ethylene and ABA (which promote abscission). Conversely, small to medium-sized squares and small-sized bolls have a high proportion of ethylene and ABA to IAA and are therefore more likely to shed their bolls.

Factors That May Cause Shed

Cotton sheds fruit for a variety of reasons. Some of the more important causes for abscission that have been identified and studied are listed below.

Reduced Photosynthate Supply

Photosynthates are sugars produced through photosynthesis and used in plant growth (leaves, squares, bolls, etc.). The amount of sugars in a plant may be reduced if the supply is reduced or if the demand for the sugars increases. The supply is reduced with low light, older leaves, water and nutrient stress, foliage damage from insects and environmental events, and extreme temperatures. The demand increases with the presence of immature bolls, rank plant growth, and high day and night temperatures.

Light

Sunlight is required by cotton plants to produce photosynthate. Full sunlight is required for maximum photosynthesis. During cloudy or overcast weather, photosynthesis is greatly reduced. Furthermore, the higher temperatures of the summer increase the need for sugars, which increase the amount of shed. During cloudy weather, young bolls are the main fruit size to be shed.

Even with full sunlight, rank growth cotton may experience considerable self-induced fruit shed. This is because in this type of cotton, once fruit gets to the bloom or small boll stage, the leaves feeding sugar to these fruit (the leaf at the base of the fruit or one adjacent to it) are already shaded by new foliage growth at a higher level in the canopy. Loss of these fruit causes the cotton to put more sugars into leaves, stems, nodes, etc., thus perpetuating the problem.

Temperature Extremes

Cold temperatures reduce photosynthesis and sugar production resulting in shed. Generally, cotton is more tolerant of high temperatures. However, if cotton is unable to cool itself below 90°F through evaporation, shed will occur. Evaporative cooling becomes difficult if there is insufficient soil moisture and/or if the humidity is extremely high.

Another cause of boll shed is high nighttime temperatures when pollen sterility may occur. This type of shed occurs 17–19 days following night temperatures that remain at 85°F or above.

Soil Moisture

Both excess and insufficient soil moisture are known to cause fruit shed. In the case of excess soil moisture (to the point of saturation), oxygen levels in the soil are decreased causing stomates to close, which reduces photosynthesis and evaporative cooling, causing increased fruit shed.

An insufficient amount of soil moisture has several effects on a plant that can lead to shed. First is the inability of the plant to regulate its temperature through evaporative cooling. This occurs when a plant cannot obtain moisture from the soil. Second, prolonged low soil moisture levels prematurely age leaves causing a reduction in photosynthate supply and shed.

<table>
<thead>
<tr>
<th>Week of Blooming</th>
<th>% of Total Blooms</th>
<th>% Blooms Set</th>
<th>% of Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>94</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>78</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>43</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>
Moisture in Bloom
Another adverse effect of moisture on shed occurs when open blooms contain water (as might occur with an early-morning rainfall). Water causes pollen to rupture, thereby preventing pollination. Unpollinated flowers are shed.

Nitrogen
As with several other factors mentioned above, both insufficient and excess nitrogen can lead to fruit shed. The effect of nitrogen deficiency on fruit set is twofold. First, nitrogen-deficient plants stop developing new nodes and squares and enter premature cutout (the point at which the cotton plant stops producing additional fruiting forms). Second, nitrogen deficiency slightly increases shed of young bolls presumably due to slowing the formation of photosynthate.

Excess nitrogen is currently thought to increase fruit shed by favoring rank growth, which leads to shading (see section on “Light”), reduced photosynthesis, and shed.

Diseases
Some causes of vascular wilts, such as Fusarium and Verticillium, increase fruit shed by preventing the plant from moving water and sugars to the fruit. Additionally, some strains of Verticillium induce the production of the abscission formation hormones ethylene and ABA. Early squares have been shed from Fusarium infections in the bloom and as many as 30% more squares have shed without fungicide/insecticide applications during bloom as those that have had fungicide/insecticide.

Early Cotton
There are several reasons to set a crop of cotton as quickly as possible and avoid relying on a late or top crop. These reasons include the following:

- A cotton plant has a greater number of blooms during the initial weeks of flowering than later in the fruiting period (Table 2).
- A cotton plant sets a higher percent of blooms during the first weeks of flowering (Table 2). When taken together, these two factors result in a potential of 88% of the crop being made in the first three weeks of flowering.
- Bolls set during the first 3 weeks of fruiting usually are the largest and contain the highest quality fiber. Late-set bolls are frequently smaller and may contain finer and less mature fiber.

Growing Degree Days
One of the keys to cotton growth and development is temperature. Without a temperature that is sufficient for physiological processes to take place, adequate light, nutrients, and water would be of little use to a cotton plant. Researchers have shown that the cotton plant develops on an orderly schedule that is controlled largely by temperature and that the minimum temperature at which a cotton plant grows is approximately 60°F. From this knowledge came the concept of DD-60s or growing degree-day summations (Table 3). Degree-days for cotton are calculated as follows:

\[
\text{Degree-Days} = \frac{(Daily\ high\ temperature + Daily\ low\ temperature)}{2} - 60\degree F
\]

Although the growing degree-day concept is applicable to most situations, some factors such as cultivar or geographic location may cause poor approximations of actual plant growth. Likewise, problems may be encountered if plants are under water or nutrient stress or have been damaged by insects, weather, or chemicals. Table 3 gives the generally accepted DD-60s for cotton in the southeast.

<table>
<thead>
<tr>
<th>Event</th>
<th>DD-60s from Planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence (stand establishment)</td>
<td>45–130</td>
</tr>
<tr>
<td>Appearance of first square</td>
<td>440–530</td>
</tr>
<tr>
<td>Appearance of first flowers</td>
<td>780–900</td>
</tr>
<tr>
<td>Peak blooming</td>
<td>1350–1500</td>
</tr>
<tr>
<td>First open boll</td>
<td>1650–1850</td>
</tr>
<tr>
<td>Defoliation</td>
<td>1900–2600</td>
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</tbody>
</table>

Summary
A considerable body of knowledge on the development of the cotton plant has been generated through research. This publication was written to provide an introduction to the understanding of how a cotton plant develops. For more complex developmental problems and interactions not covered in this publication, consult a UF/IFAS Extension specialist.
Reference