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2000 Florida Cotton Production Guidelines: Development of a Cotton Plant[1]

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The cotton plant is a perennial in many parts of the tropics and subtropics where it may reach a height of 15 to 20 feet. In Florida, cotton is grown as an annual and attains a plant height of 2 to 5 feet or more if moisture and plant nutrients (primarily nitrogen) are in excess. Air temperatures in the 90o to 95oF range are considered near optimum for growth. Very little growth takes place below 60oF and temperatures above 100oF for several days can be unfavorable, especially if soil moisture is low. However, cotton is usually considered drought tolerant because of its extensive root system. An average daily growth rate for the roots of 1/2 inch for the growing season is not uncommon.

Approximately 4 to 10 days after planting, cotyledonary or seed leaves are fully expanded (Table 1). These leaves are on node #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 and sometimes three buds. These buds (called axillary buds) give rise to vegetative branches on the lower nodes (nodes 2 through 5 or 6). At nodes 6 or 7, and above, they give rise to fruiting branches which bear the floral buds, or cotton squares, on nodes located on the lateral branches. 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 a pinhead square to a creamy-white, open bloom is approximately 23 days (Table 1). Pollination occurs on the first day the flowers are open (white bloom stage). The flowers turn pink (or red) the day following pollination. The interval between corresponding nodes on successive fruiting branches (vertical flowering interval) is 2 to 3 days. For example, under optimum conditions a cotton plant having a white flower on the first lateral node of a fruiting branch will produce another white flower on the first lateral node of the next higher branch 2 to 3 days later. The interval between successive flowers on the same fruiting branch (horizontal fruiting interval) is 5 to 6 days. Following fertilization, the hollow fibers begin to lengthen and will reach their final staple length in approximately 3 weeks. For the next several weeks, the walls of the fibers thicken through the deposition of successive layers of cellulose.

Varieties grown in Florida are indeterminant, that is, flowering will continue until stopped by frost,

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drought, insect attack or some other cause. Shedding of squares, flowers or young bolls is common. Under good conditions, only 35 to 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 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 open boll stage.

Normally, 90 to 120 bolls are required to produce a pound of seed cotton. 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.

Fruit Shed

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 abscisic acid (ABA) which promote abscission and indole acetic acid (IAA) which inhibits abscission. Because of the process involved, several days are required between the stimulus causing shed and the actual loss of fruit. 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.

Causes for Shed

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

* Reduced Photosynthate Supply - This is just a fancy term for reduced amount of sugars in the cotton plant. The sugars are 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 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 weather or under moderate overcast, photosynthesis is greatly reduced. Furthermore, the higher temperatures of the summer increase the need for sugars increasing 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. perpetuating the problem.

* Temperature Extremes - Cold temperatures reduce photosynthesis and sugar production resulting in shed. Generally, cotton is more tolerant to high temperatures. However, if cotton is unable to cool itself below 90oF 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 due to high night-time temperatures when pollen sterility may occur. This type of shed occurs 17-19 days following night temperatures that remain at 85oF or above.

* Soil Moisture - Excess or insufficient soil moisture are both known to cause fruit shed. In the case of excess soil moisture (to the point of saturation), oxygen levels in the soil are decreased which in turn causes stomates to close which reduces photosynthesis and evaporative cooling both of which increase 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. Secondly, prolonged low soil moisture levels prematurely age leaves causing a reduction in photosynthate supply and shed.

* 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 two-fold. First, nitrogen deficient plants stop developing new nodes and squares and enter premature cutout. Secondly, 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 previous discussion of "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 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:

1. A cotton plant has a greater number of blooms during the initial weeks of flowering than later in the fruiting period (Table 2).

2. A cotton plant also 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.

3. 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.

4. A delay in setting fruit encourages plants to grow taller. This may lead to lodging and makes pest control more difficult.

5. Pest populations tend to increase as the season progresses. Protecting squares and young bolls late in the growing season is more difficult (and expensive) than protecting an early crop.

Growing Degree Days

One of the key ingredients that enables a cotton plant to grow and develop 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. Efforts by a number of scientists 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 60oF. From this knowledge came the concept of DD-60's or growing degree-day summations (Table 3). Degree-days for cotton are calculated as follows:

((Daily high temperature+Daily low temperature) ÷ 2) - 60°F= Degree-Days

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-60's for cotton in the southeast.

Table 1. Typical growth and development of a cotton plant.

Event	Time Required (Days)
Planting to emergence	4-10
Planting to 1st square	40-50
Planting to 1st bloom	60-70
Pinhead square to white flower	23
White flower to pink flower	1
Pink flower to open boll	55

Table 2. Development of fruiting in cotton.

Week of Blooming	% of Total Blooms	% Blooms Set	% of Crop
1	8	94	21
2	24	78	43
3	29	43	24
4	27	21	9
5	10	13	2
6	2	11	1

Table 3. Growing degree-days (base 60° F) required for several phenological stages in cotton.

Event	DD-60's from Planting
Emergence (stand establishment)	45-130
Appearance of first square	480-530
Appearance of first flowers	740-1150
Peak blooming	850-1625
First open boll	1690-2050
Defoliation	2550-4600