Cotton Growth and Development[1]

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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 US Cotton Belt, cotton is grown as an annual and attains a height of 2–5 feet or more when growth regulators are used for height control for better in season and harvest management. Air temperatures in the 90°F–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 (July and August). 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 decline 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 and 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, 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 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 stage), generally early in the day. The flower turns pink (or red) after pollination. The interval between corresponding nodes on successive fruiting branches (vertical flowering

1. This document is SS-AGR-238, one of a series of the Agronomy Department, UF/IFAS Extension. Original publication date January 2005. Revised January 2015 and November 2018. Visit the EDIS website at http://edis.ifas.ufl.edu.

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interval) is 2–3 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 2–3 days later. The interval between successive flowers on the same fruiting branch (horizontal fruiting interval) is 5–6 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. A graphic depiction is shown in Figure 1 (NCC 1996).

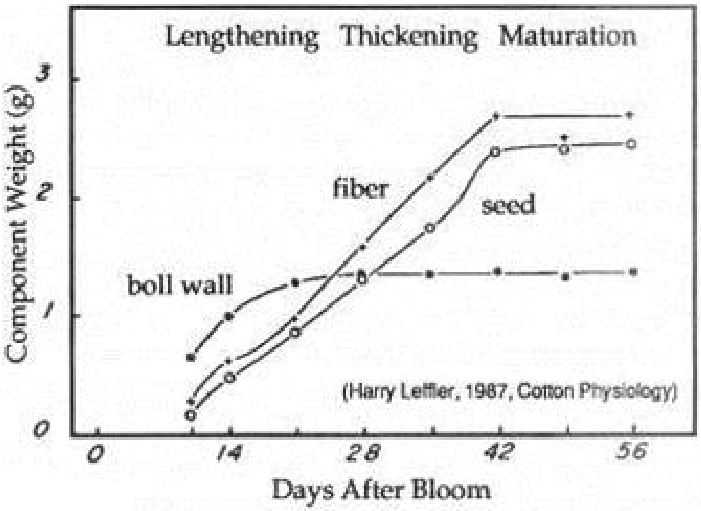

Figure 1. Bolls are full size 21 days after flowering; fiber and seed development requires and additional 28–35 days (NCC 1996).
Credits: Landivar and Benedict (1996)

Cotton has indeterminant growth, 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 will not shed unless the plant suffers severe stress (temperature, moisture, insect, nutrition 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.

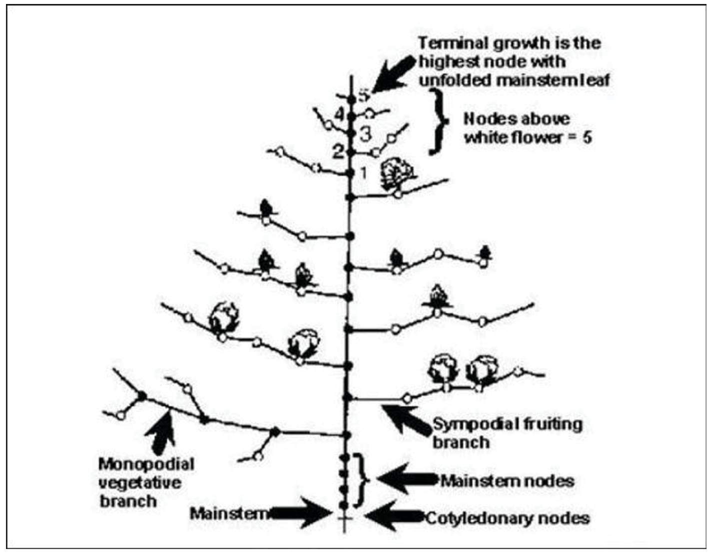

Figure 2. Diagrammatic sketch of cotton plant showing mainstem nodes (M), fruiting nodes (O), and general plant architecture for NAWF = 5
Credits: Landivar and Benedict (1996)

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), which inhibits abscission. Because of the process involved, several days are required between the stimulus causing shed and the actual loss of fruit. Insects feeding on small squares prior to bloom may also contribute to fruit shed. Large squares, blooms, and medium- to large-sized 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, smal- 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 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. Nighttime temperatures below 68°F can result in hardlocked cotton, as the cool temperatures delay pollination on white flowers opening the morning of cool temperatures, allowing more time for fungal spores to penetrate the pollen tube with the pollen grains (Mailhot, et al.).

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 ages 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. Nonpollinated 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 applications.

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.
- A delay in setting fruit encourages plants to grow taller. This may lead to lodging and makes pest control more difficult.
- 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.
- Later cotton requires more irrigation water and pesticides to protect against various insects.
- The longer the crop is in the field, the higher the chance of hurricane and other environmental damage.

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:

((*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-60s for cotton in the southeast.

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.

References

Landivar, J. A., and J. H. Benedict. 1996. *Monitoring system for the management of cotton growth and fruiting*. College Station, TX: Texas Agricultural Experiment Station Bulletin B02

Mailhot, D. J. G, Srivastava, P., Marois, J. J., Osekre, E. A., and Wright, D. L. 2012. "Effect of weather conditions on severity of hardlock in cotton." *Current Microbiology* 61:2: 181–189.

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

Event	Time Required (Days)	Average Time Required (Days)
Planting to emergence	4–14	7
Planting to 1st square	35–45	39
Planting to 1st bloom	55–70	62
Pinhead square to white flower	20–35	23
White flower to pink flower	1	1
Pink flower to open boll	50–60	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	4
4	27	21	9
5	10	13	2
6	2	11	1

Table 3. DD-60s required for cotton development

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