



Introduction To A Cotton Plant

By Sandra Williams & Michael Bange (CSIRO)

Cotton belongs to the Malvaceae family of plants that includes rosella, okra and ornamental flowering hibiscus. As a perennial shrub, cotton may reach 3.5m in height, but grown commercially, it rarely exceeds 1.6m and its tap root can reach depths of 1.8m. Cotton is managed as an annual crop, so is sown, harvested and removed each year.

Cotton fibre forms around the developing seeds inside a protective capsule called a boll. When seed is mature the boll ruptures and opens, allowing the fibre to dry and unfurl. A cotton plant's primary purpose is to produce seeds — in uncultivated cotton, the fibre is just a by-product which the plant produces to aid in seed dispersal.

When cotton is picked, both the seed and the attached fibre are harvested, compressed into modules and transported to a gin where the seeds and contaminants (leaf and twigs) are separated from the fibre. The fibre is then compressed into 227 kg bales, classed according to fibre quality, and exported around the world to textile mills. A by-product of the ginning process is cotton seed, which is also a valuable commodity.

Cotton plant physiology

The success of a cotton crop relies on climate and management. In developing a good management strategy it is important to understand how cotton develops and grows in order to ensure that the crops needs are met to maximise yields.

Perennial growth habits

In its native habitat as a perennial shrub, cotton can survive year after year. Therefore in situations where the cotton crop has inadequate resources (moisture, nutrients or carbohydrates) it will drop or shed some flowers or small bolls (also called fruit). This is a way to guarantee its survival by using the limited resources available to support its leaves, branches, roots and the remaining fruit.

However being a perennial, the cotton plant has an indeterminate growth habit. This means that the plant develops fruit over an extended period of time, so in many cases the plant can often compensate after a stress event (i.e. pest attack), by continuing to grow and produce new fruit.

Cotton development

As a cotton plant develops it follows a specific pattern. The rate at which it develops is largely determined by

temperature. Cool temperatures (<15°C) and excessively hot temperatures (>36°C) can delay crop development. Although for the majority of the season and in most cotton growing regions early crop development is reliably predicted from seasonal temperature records by calculating Day Degrees (DD). DD describes the accumulation of heat units related to the daily maximum and minimum temperature that a crop experiences each day.

DD is described by the following equation:

$$DD = (\text{Maximum Temp.} - 12 + \text{Minimum Temp.} - 12) / 2$$

When minimum temperatures are less than 12°C, DD are calculated as:

$$DD = (\text{Maximum Temp.} - 12) / 2$$

TABLE 1:

Cotton growth stages with target DD

Cotton development	Notes	Accumulated DD after planting
Germination	Germination will start as a seed takes in (imbibe) moisture and temperatures are warm enough.	
Emergence	The two cotyledons (seed leaves) break the soil surface and unfold.	80
Vegetative growth	A cotton plant adds a new node every 42 DD or 2 - 4 days. This rate will slow as the crop approaches cutout.	
First square	A square is a flower bud. The first square occurs on the first fruiting branch at the 5-7th nodal position above the cotyledons, about 4 -6 weeks after emergence. 'Initiation of the first 'pinhead' square normally occurs when the true leaf on node 4-5 is unfurled, and signals the beginning of the reproductive phase. The 'squaring' period is generally 15-20 days.	505
First flower	The first square will develop into the first flower within 15-20 days (8-10 weeks after emergence). The cotton flower is white, with five petal flowers and normally opens first thing in the morning. The cotton plant is usually self pollinating and this occurs very shortly after the flower opens. Once fertilised the flower turns reddish purple and then desiccates as the boll begins to develop.	777
Flowering to max boll size	After the flower petals fall off, a fertilised boll (fruit) is visible. In 20-25 days this boll will reach its maximum boll size. After fertilisation, the boll begins to develop. The boll is divided into 3-5 segments called locks, which contain lint and 6-9 seeds. The number of locks is determined by the time a square has reached a 'pinhead' in size.	1087*
Open boll	Under optimum conditions it takes about 50 days from flowering to having an open boll.	1527*

*Note that these are estimates for individual bolls and do not represent whole crop development.



This accumulation of DD has been calibrated with specific targets for a range of cotton development events (Table 1). The term 'cold shock' refers to when minimum temperature $\leq 11^{\circ}\text{C}$, and cotton development is delayed. The DD requirement for first square and first flower increases by 5.2 every time a cold shock occurs.

FIGURE 1:

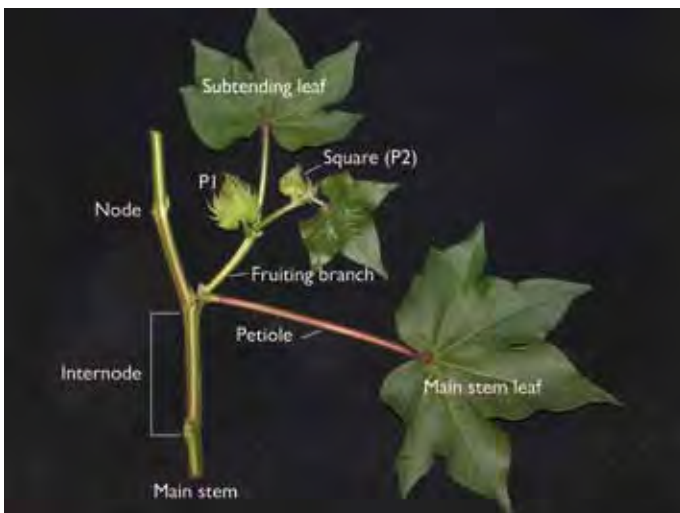
Progression from square to boll. (Photo: Paul Grundy, DAFF QLD)



During cotton plant growth and development, two types of branches, vegetative (monopodial) and fruiting (sympodial) will arise. Having only one meristem (growing point), vegetative branches grow straight and look much like the main stem. Vegetative branches can also produce fruiting branches. The first fruiting branch will generally arise from nodes 6 or 7. With the potential to grow multiple meristems, this branch will grow in a zig-zag pattern and produce multiple fruiting positions. Figure 2 shows a fruiting branch that has formed above a main stem leaf. This branch has produced two fruiting structures along with their subtending leaves. The pattern of development and growth of the plant as a whole is described in Figure 3, where the development of new fruit occurs at the top of the plant on new fruiting branches as well as along older fruiting branches.

FIGURE 2:

A developing fruiting branch and associated structures. (Photo: Paul Grundy, DAFF QLD)



Cotton growth

Maintaining vigorous vegetative growth before flowering is important as it is these leaves, branches and roots that will support/supply the future boll load. As a cotton plant develops, new leaves grow and expand, producing carbohydrates to allow new growth of leaves and the developing roots. Once reproductive structures begin to develop, vegetative and root growth will normally slow down as the plant begins to supply resources to the

developing fruit. When there are excess resources to the needs of the developing fruit, the rate of vegetative and reproductive growth continues. Good crop management aims to keep the reproductive and vegetative growth in balance for as long as the season allows, timing cutout to maximise the number of mature fruit (bolls) at harvest. The longer the period of fruit production before cutout generally translates into higher yields. At cutout the supply of carbohydrates, water and nutrients equals the amount needed by the developing bolls and other growth ceases.

During crop growth certain growth parameters (e.g. node production and fruit retention) should be measured and recorded to help with management decisions for maximum yield. The Cottassist Crop Development Tool can help with these measurements.

In some situations where there is plenty of water and nutrients, excessive vegetative growth can occur. Growth regulators such as Mepiquat Chloride can help manage this growth. Measuring Vegetative Growth Rate (VGR) is an effective technique used to assist with these decisions. See Chapter 6 Using Mepiquat Chloride for further information.

Approaching cutout bolls grow, and they become larger sinks for carbohydrates, water and nutrients, leaving less available for new growth. NAWF (Nodes above white flower) is the number of nodes from the uppermost first position white flower to the terminal. This number will

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FIGURE 3:
Rate of development of fruiting sites on a cotton plant, adapted from Oosterhuis 1990. Note: 3 days = 1 new fruiting site

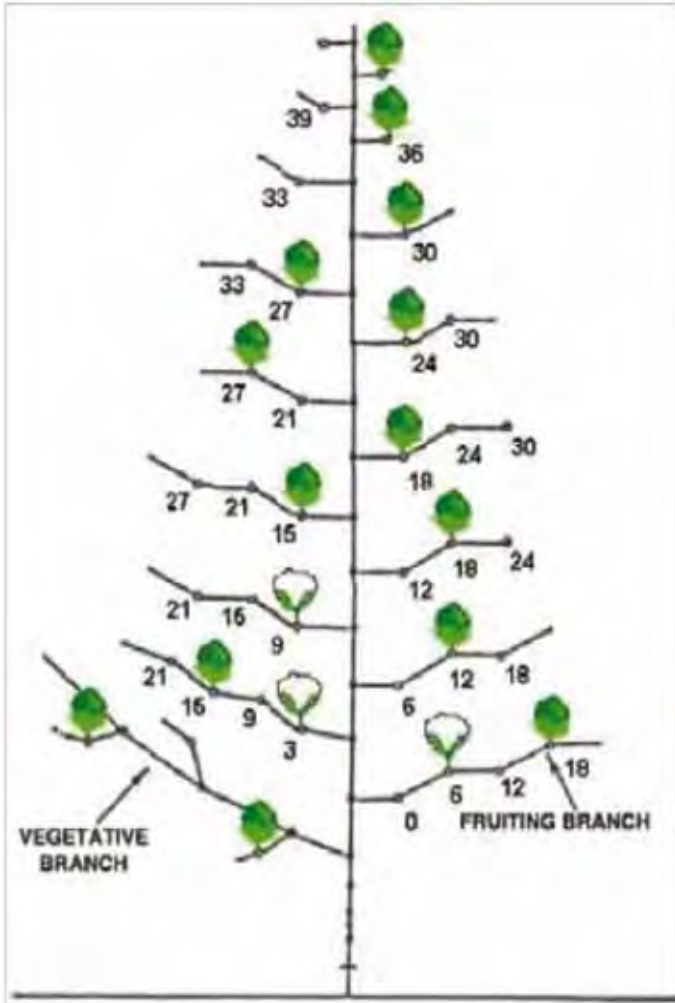


FIGURE 4:
A diagrammatic representation of the internal structure of an individual fibre. (Source FIBREpak Figure 3.3)

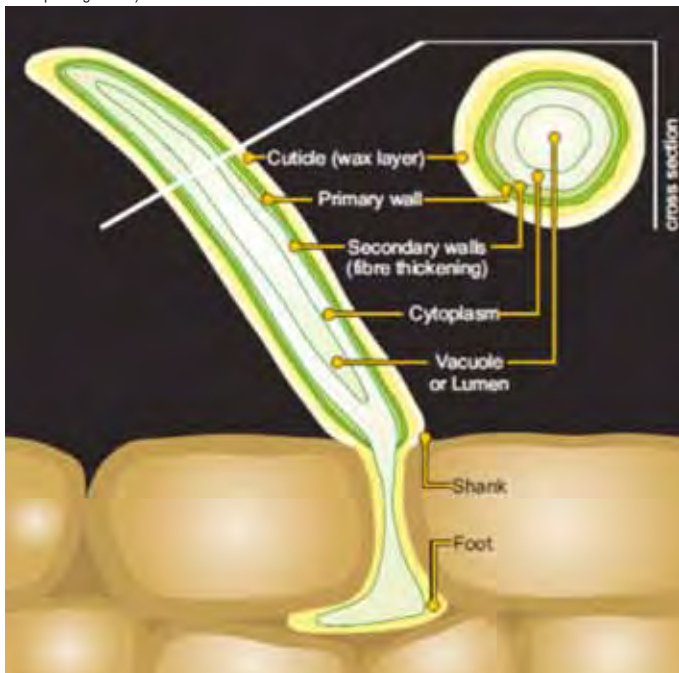


TABLE 2:
Cotton fibre development

Fibre development	Notes
Initiation	This occurs just before flowering and at flowering. It is the initiation of fibre cells on the seed coat which can take up to 3 days. After the initial burst of fibre initiation a second set of fibre cells are initiated. These develop into the fuzz left behind on the seed after ginning.
Elongation	This is the rapid expansion and growth of the fibre cell's primary wall (partially controlled by internal water/turgor pressure). During this time the plant is sensitive to stress (water, nutrition and cool temperatures). Final fibre length of is determined both by the length of this period and rate of fibre elongation.
Secondary wall thickening or fibre thickening	Is the formation of the secondary wall where cellulose (a product of photosynthesis) is laid down in layers inside the fibre cell's primary wall. The amount of cellulose deposited is affected by factors that affect photosynthesis. Due to fluctuations in photosynthesis on a daily basis, fibre growth rings are formed. They consist of 2 cellulose layers, a thicker layer that is formed during the day and a more porous layer that is laid down at night.
Maturation	This is where the fibre cells dry out and the fibre becomes a twisted ribbon-like structure. Mature fibre is easily detached from the fuzzy seed.

naturally decrease as the season progresses as growth slows from the terminal, and as flowering progressing in a pattern up the plant, the NAWF will decrease. Cutout occurs when NAWF approaches the top of the plant and flowering ceases (NAWF = 4 or 5). More information on measuring NAWF and cutout can be found in Chapter 21 Preparing for harvest.

Just as flowering progresses in a pattern up the plant, so does the maturation and opening of bolls. Therefore measuring the number of nodes from the uppermost first position cracked boll (NACB – nodes above cracked boll) to the terminal is an effective way to determine crop maturity. Crops are considered mature and ready for defoliation decisions if they have reached 4 or 5 NACB. More information on measuring NACB can be found in Chapter 21 Preparing for harvest.

Cotton fibre biology

Cotton fibres begin their development as single cells that start to form on the unfertilised seeds, called ovules, just before flowering. Cotton fibre is almost pure cellulose, is non-allergenic, and has unique breathable characteristics that make it widely sought after to use in clothing, from undergarments to high-end fashion.

Fibre development can be divided into four phases as outlined in Table 2 .

For more information the following resources and tools are available at https://www.mybmp.com.au/auth_user/grower_tools_and_resources.aspx

- FIBREpak
- CottASSIST Crop Development Tool
- NORpak



Common terms for cotton growth and monitoring

Cotyledons are the seed leaves that appear as a symmetrical pair of leaves at seedling emergence.

First true leaf is the first leaf developed by a seedling with the appearance and arrangement of a normal cotton leaf.

Main stem leaves are leaves that are connected directly with the main stem.

Subtending leaves are leaves that are connected directly to a fruiting branch.

A **petiole** is a stem like structure that connects a leaf with the stem.

A **node** is the junction between leaves or branches and the main stem.

The **internode** is the space on the main stem between successive leaves or branches. Nodes on the dominant or main stem are known as main stem nodes, and are usually numbered upwards starting from the first node produced after the cotyledons.

A **plant terminal** is the growing point on the main stem. Also present on the vegetative/lateral branches. If the terminal is damaged (known as 'tipping out'), new terminals can be initiated from dormant auxiliary buds below the damaged section.

Square. The flower 'bud'.

First square describes the stage when the first flower bud is produced on the first (lowest) fruiting branch and has its subtending leaf unfurled on 50% of the plants.

Flower. The cotton flower normally opens before midday. Self-pollination occurs very shortly after opening. The flower turns pink after one day, then withers and falls off.

First flower is the time at which there is an average of one open flower per metre of row.

A **Boll** is the fruit of the cotton plant that develops after the flower has opened and been fertilised. The boll is divided into segments of 3-5 capsules called locks, each containing lint and 6-9 seeds. Once mature, the boll walls crack and fold outwards (open) and the cotton seed and fibre expand out of the capsule to form a white fluffy bundle of seed and lint.

Vegetative branches (Laterals) are similar in form to the main stem. These branches most frequently emerge from the main stem nodes below the fruiting branches (in nodes 2-6). Vegetative branches may produce their own fruiting branches that give rise to pickable bolls.

Fruiting branches usually arise from 6 or more main stem nodes above the soil surface (and often above several

vegetative branches), these branches have several nodes, each with a square and subtending leaf. Fruiting branches have a zigzag growth habit.

Fruit position refers to the location of fruit (Square, flower or boll) upon the fruiting branch. The first position (P1) is the fruit closest to the main stem (if present, or there may only be an abscission scar where the fruit once was). Sequential fruit are numbered outwards (P2, P3 etc).

Retention is the proportion of fruiting sites on a plant that are present versus those that have been lost.

Tipping is the loss of the terminal growing point (terminal), causing the plant to develop multiple stems.

Shedding describes the abortion and loss of squares and bolls from the cotton plant. Shedding can be due to the plant balancing the supply and demand for the products of photosynthesis, and can be strongly influenced by factors that negatively affect photosynthesis (such as cloudy weather), or in response to pest damage to the fruit. Young fruiting forms (squares) are more likely to be shed than the more developed squares, flowers and bolls.

Vegetative Growth Rate or VGR is a measurement of plant height and the number of nodes used to help with decisions regarding early season growth regulators (refer to chapter 6).

Cut-out or last effective flower occurs when the plant's demand for assimilate (products of photosynthesis) finally exceeds supply so that further growth and production of new squares virtually ceases, normally when the plant reaches about 3-4 NAWF. At cut-out no more harvestable fruit is set and the earlier set bolls will start to open.

Nodes above white flower (NAWF) describes the number of nodes from the uppermost first position white (freshly opened) flower to the plant terminal. This measurement is used to determine a crop's growth rate or vigour and can be used to assess the rate at which a crop is 'cutting-out'.

Nodes above cracked boll (NACB) describes the number of nodes between the very top of the plant and the nearest underlying branch that has a boll in the first position (closest to the main stem) that has begun to split and open. This measurement is used to assess crop maturity and determine when to start defoliation.

Defoliation is when the crop is treated with defoliant chemicals to remove the leaves and open the last remaining bolls in preparation for harvest.

Lint is cotton fibre that forms around the developing seeds.