

# Crop growth stages

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## Day degrees

The cotton plant is quite predictable and well understood in the way in which it grows

and responds to the environmental or management factors that are applied to it. A crop can therefore be monitored and influenced to achieve desirable outcomes.

Temperature has a major influence on the rate of development and growth of the cotton plant, especially early in the season. This relationship between temperature and growth rate is described as Day Degrees.

The relationship between plant growth and temperature for Australian conditions is described by the following equation.

$$\text{Day Degrees} = \frac{(\text{Maximum Temp} - 12) + (\text{Minimum Temp} - 12)}{2}$$

Example:

$$\text{Maximum temp} = 30^{\circ}\text{C}, \text{ Minimum Temp} = 20^{\circ}\text{C} \quad \frac{(30-12) + (20-12)}{2} = 13 \text{ Day Degrees}$$

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

$$\text{Day Degrees} = \frac{(\text{Maximum Temp} - 12)}{2}$$

## BE AWARE OF

- Temperature has a major influence on the rate of development and growth of the cotton plant.
- Seedling establishment is best if minimum soil temperatures in the seed zone are at least 16°C for 3 days at sunrise.
- The aim is to keep in balance the reproductive and vegetative growth to produce the highest amount of cotton at harvest.
- The 'Crop Development Tool' on the Cotton CRC website can assist growers and consultants in monitoring their crop development.
- Not regularly monitoring crops can make management difficult and less effective.

The average day degrees for vegetative and reproductive growth in Australia are shown in Table 1.

**TABLE 1.**

Average day degrees for vegetative and reproductive growth of cotton in Australia.

Phase	Day Degrees
Sowing to Emergence	80
Growth of One Node	40
Initiation of Square	220
Sowing to first Square	505
Square to Flower	270
Flower to max boll size	310
Max boll size to mature	365
Mature to fully open	75
Flower to open boll	750

In warmer climates, Day Degrees may over-estimate the development of the crop. As in the cooler climates where cool temperatures (<11°C) delay the development of the crop so too can excessively hot temperatures, (>35°C).

Growers and consultants can track their crop progress and compare with historical averages (generated from climate data) using the day degree calculator on the CRC website. <http://CottASSIST.cottoncrc.org.au/DDC/DDCTool.aspx>

In very high temperatures as well as crop development being slowed so is crop growth. Very high temperature increase the use of plant uses resources and energy to transpire and respire in an effort to keep cool. In addition reduced leaf biomass and fruit shedding can be a result of high day and night time temperatures.

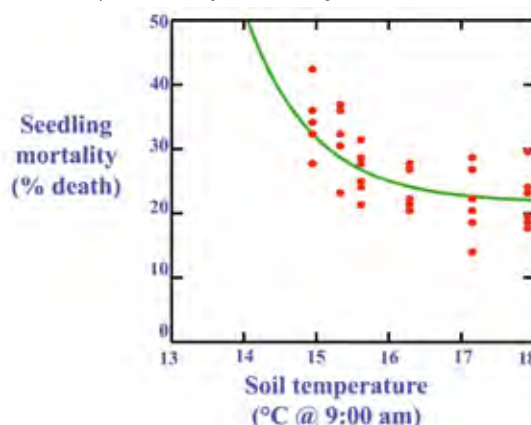
## Germination and emergence

As soon as a cotton seed touches moist soil, it will take in (or imbibe) moisture and begin to germinate.

Emergence is when the cotyledons break the soil surface and unfurl. The warmer the soil temperatures, the

**FIGURE 1.**

Impact of soil temperature on Seedling Mortality. Temperature is the average minimum soil temp. for the 7 days after sowing.



quicker this will happen. Seedling establishment is best if minimum soil temperatures in the seed zone are at least 16°C for 3 days at sunrise. At temperatures below this, seedlings are more susceptible to seedling diseases, black root rot and *Fusarium* species.

Studies conducted by Dr David Nehl (NSWDPI) have shown dramatic increases in seedling mortality once minimum soil temperatures fall below 15°C in the week post planting (see Figure 1).

## The growth of a cotton plant

The cotton plant has an indeterminate growth habit, which means it puts its fruit on over a period of time not all at once. The rate of development can be mapped through the life of the crop and it follows a specific pattern. This growth is driven mainly by temperature and therefore we use the day degrees calculation to monitor and predict crop development.

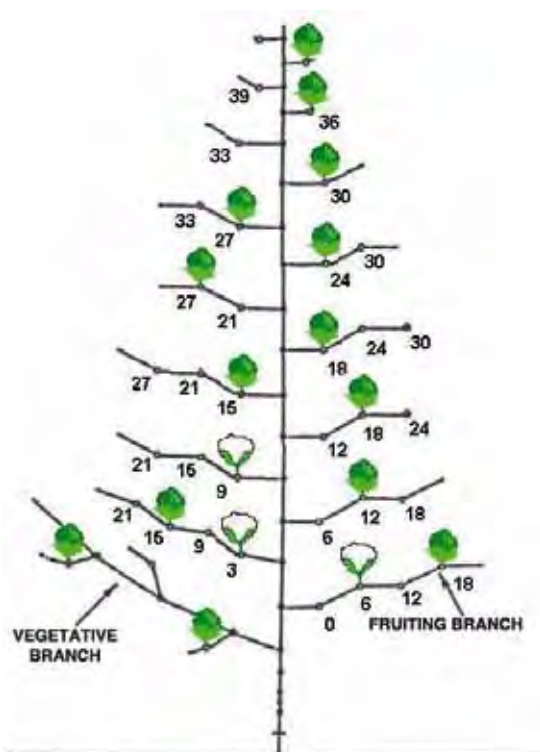
There are two aspects of the growth of a cotton plant, vegetative and reproductive growth. Due to the indeterminate nature of the cotton plant the vegetative and reproductive growth occur in parallel. The aim is to keep in balance the reproductive and vegetative growth to produce the highest amount of cotton at harvest.

The following diagram shows the average time of development of the fruiting sites for cotton; for example on this plant the fruit at the very top of the plant will start (and finish) developing about 27 days after the first fruit at the bottom of the plant.

In the development of a cotton boll, the fruiting structure goes through 3 distinct phases as shown below.

### FIGURE 2.

Rate of development of fruiting sites on a cotton plant, adapted from Oosterhuis 1990



In the development of a cotton boll, the fruiting structure goes through 3 distinct phases as shown below



#### Square.

The flower 'bud'.



#### Flower.

The blooming of the cotton flower; it is a white flower which turns pink after one day, post fertilisation and withers and falls off.



#### Boll.

After the flower petals fall off, what remains is the fertilised boll, or fruit of the cotton plant. This boll grows in size developing the seed and fibre in side. At maturity the boll walls crack and the lint dries out into the ball of cotton.

### Squaring

First Square is the beginning of the reproductive phase of growth of the cotton plant. Normally this occurs between the 6th and 10th node depending on seasonal conditions and variety. Initiation of this first square normally occurs at the time the true leaf on node 4–5 is unfurled. As the plant grows additional fruiting structures will emerge at about one every three days for first position fruit which are those which are closest to the main stem. The rate of appearance of squares will however, slow as the crop starts to develop a fruit load.

### Flowering

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.

### Boll filling

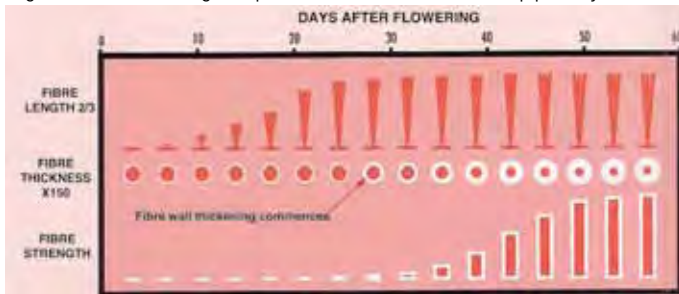
After fertilisation, the boll or fruit begins to develop. The boll is divided into segments of capsules called locks. These contain the seed and lint. Typically the boll has 3 to 5 locks which contain 6–9 seeds.

The boll increases in size rapidly after fertilisation of the flower and reaches its full size about 20–25 days later. Fibre length is determined during this period, and the maturity or micronaire of the fibre occurs in the second half of the bolls development which in total will take about 50 days (Figure 3).

Once mature, the boll will split and the cotton seed and fibre will expand out of the capsule to form a white fluffy bundle of seed and lint

**FIGURE 3.**

The fibre develops in length for about 18-24 days after flowering (temperature dependant). Shortly before this elongation stops, thickening of the fibre wall begins, and it continues for about 40 days or so until shortly before the boll opens. The degree of fibre thickening is dependant on factors that effect crop photosynthesis.



**Cut out**

As the cotton plant continues to develop bolls, the demand for carbohydrates that are produced in the leaves increases. Eventually the demand by the bolls exceeds supply, resulting in the production of new fruiting nodes ceasing and the shedding of excess bolls, less than 14 days old. This point is known as ‘cut-out’. An approximation of the timing of cutout is when a crop has reached on average 4 nodes above white flower (NAWF). About this time the earlier set boll will start to open and measurements nodes above cracked boll should be used to determine the timing of the last irrigation and defoliation

**Monitoring growth rate and development**

The cotton plant has a structured growth habit which is driven by temperature or day degrees, and therefore its development can be tracked throughout the season. The following outlines some measurements which may assist in the management of the crop for maximum potential.

**Measuring NAWF (Nodes Above White Flower)**

The NAWF measure is a used to assess health and the time to cut out of the crop (4 NAWF) and it is used to signal the last effective square. At first flower in a healthy crop the NAWF should be above 7. An aim for cotton growers in trying to maximise yield potential is to try to keep the NAWF above 4.5 for as long as possible. Once the NAWF falls below 4 cut-out is reached.

**Measuring NACB (Nodes Above Cracked Boll)**

The NACB measure is used to determine the time required before the crop reaches maturity. When the crop reaches the ‘4 NACB’ stage, the uppermost boll will have reached ‘effective’ maturity, when fibre development on all bolls is complete and defoliation can occur without risk of reducing yield and quality (refer to figure 4).

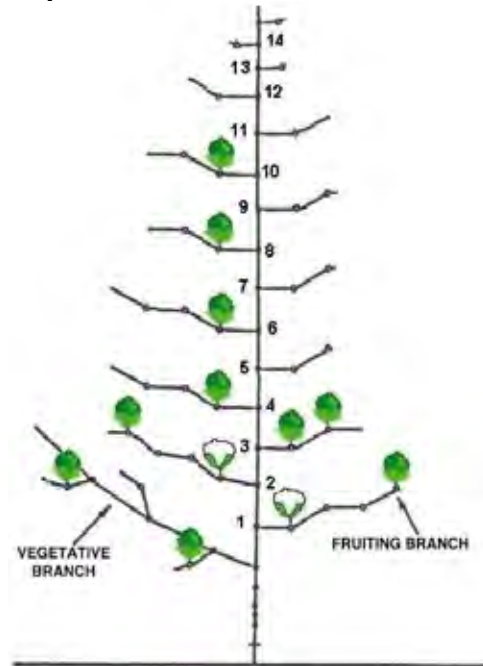
On average, bolls will sequentially open at a rate of a **node every three days**. This will depend on a number of factors, particularly climatic conditions.

**When NACB doesn’t work**

In situations such as heavily tipped conventional crops,

**FIGURE 4.**

Fruiting Branches (FB) are numbered 1-14 in this example Cracked Boll is FB2, Last Harvestable Boll is FB 10 and Nodes 9, 7 and 5 have no fruit. **NACB** on this plant is **8**. Assuming the bolls open at **3 days per node**, the crop will reach **4 NACB in 12 days**.



thin stands with plants with high numbers of vegetative branches and also in crops which have restarted after late season rainfall, fruit set will not be uniform in these crops; the NACB technique does not give an accurate indication of maturity. The only reliable method is to cut bolls (See figure 5).

Bolls have reached maturity when they are difficult to cut with a sharp knife, the seed embryo is developed and the seed coat has turned brown and black.

As with all determinations of crop maturity it is critical that only bolls which will be harvested are monitored.

**Measuring Vegetative Growth Rate (VGR)**

Measuring the VGR is a method of assessing the growth rate of the crop. It is a simple measurement which compares the change in the height to node ratio over time. This method developed in Australia for Australian conditions is the most accurate way in which to assess this ratio.

$$VGR = \frac{(\text{This weeks height} - \text{last weeks height})}{(\text{This weeks nodes} - \text{last weeks nodes})}$$

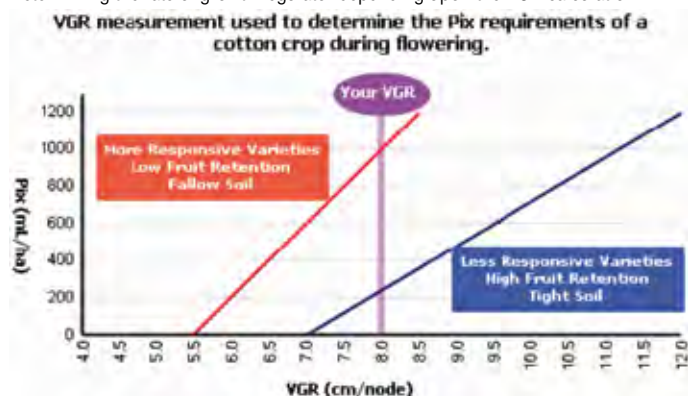
**FIGURE 5.**

Appearance of youngest bolls when cut, showing corresponding NACB.



**FIGURE 6.**

Determining the rate of growth regulator depending upon the VGR calculation.



### The decision to apply a growth regulator

It is important to keep the reproductive and vegetative growth in balance. As the crop early in its life cycle will be developing in warm and moist conditions, the tendency in these conditions is for the vegetative growth may over run the reproductive growth. Applications of Mepiquat chloride may be required to limit the vegetative growth, especially during the critical squaring and early flowering stages of development. Figure 6 shows the rate of growth regulator to use depending upon the VGR calculation.

### Factors which will influence the decision include

- **Fruit Status:** High fruit retention can limit vegetative growth as the plant needs to allocate resources to filling young bolls, and hence less is available to produce vegetative growth. The opposite applies for crops with low retention.
- **Moisture Status:** Growth regulator applications combined with moisture stress can result in yield reductions. Before applying a growth regulator, consider if there is any chance that the crop may get 'hot' or water logged within the days or week after application.
- **Field History:** Some fields (or parts of fields) are prone to rank growth or alternatively grow poorly. This will influence sampling for VGR and may lead to differential application rates. Often fallow fields may be more prone to excessive growth than back-to-back fields.
- **Variety:** A number of trials have been conducted to look at the response of different CSD varieties to Pix® applications. The trials have shown that varieties vary in yield responsiveness to applications of Pix®, often independent of height responsiveness.

The 'Crop Development Tool' on the Cotton CRC website can assist growers and consultants in monitoring their crop development, and help provide information on managing the balance of fruit and vegetative crop growth to optimise yield. <http://CottASSIST.cottoncrc.org.au/CDT/>

### Measuring fruit retention

To get an indication of the fruit demand of a crop a quick method is to look at first position fruit retention.

This measurement when carried out a number of times throughout the season will give an assessment of the yield potential the crop has.

There are two main ways to measure the fruit retention:

#### 1. 1st Position Fruit retention

Crop yield and maturity is not affected if the 1st position fruit retention is maintained at around 60% at the time of first flower. After flowering, 1st position fruit retention is of limited value.

1. Select a plant and count the number of fruiting branches. Count as high as the last fully expanded leaf.
2. Count the number of first position square and bolls. First position fruit are those closest to the main stem. If the fruit is missing, you can see a small oval shaped scar left on the branch.
3. Conduct this fruit retention measurement on at least 30 plants per field at a number of points.
4. To calculate the 1st position retention
 
$$= \frac{\text{1st position squares} \times 100}{\text{Fruiting Branches}}$$

When first position fruit retention falls below 50%, it should signal some caution, but certainly not panic. Many people have experienced very low fruit retention and are still able to achieve good yields.

#### 2. Top 5 retention

This is a more rapid way of calculating fruit retention and may be more indicative of recent fruit loss.

1. Select a plant and count the number of squares in the 5 nodes below (and including) the node where there is a fully unfurled leaf.
2. Conduct this fruit retention measurement on at least 30 plants per field at a number of different points in the field.
3. To calculate the top 5 retention
 
$$= \frac{\text{1st pos. squares on the top 5 fruiting branches} \times 100}{5}$$

#### Further information:

Crop Development Tool – [www.CottASSIST.cottoncrc.org.au](http://www.CottASSIST.cottoncrc.org.au)

CSD – [www.csd.net.au](http://www.csd.net.au)