FastStart™ Cotton Establishment Guide

DRIVE OPTIMAL YIELD POTENTIAL AND SUPPORT INDUSTRY GROWTH

10 YEARS OF R&D COLLABORATION — CSD & SYNGENTA

FastStart™

CSD COTTON SEED DISTRIBUTORS

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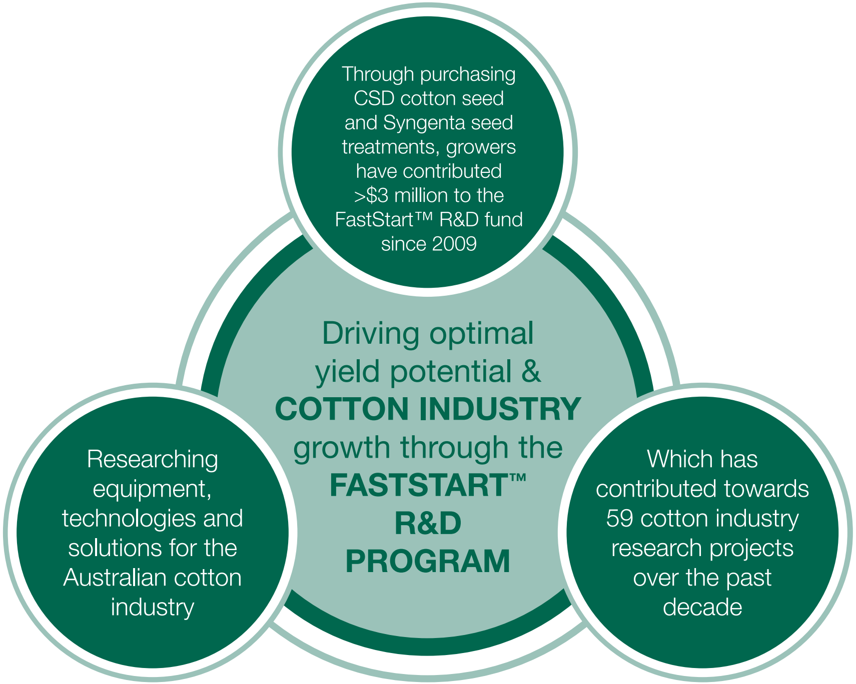
THE FASTSTART™ COTTON PROGRAM - CELEBRATING 10 YEARS OF ADVANCING COTTON CROP ESTABLISHMENT WITH AUSTRALIAN GROWERS

The FastStart Cotton Program was established as a partnership between Cotton Seed Distributors (CSD) and Syngenta to enhance the establishment and subsequent yield potential of Australian cotton crops through targeted research.

The Program is funded through a contribution from the sale of CSD seed treated with Syngenta Seedcare™ solutions. Through the purchase of cotton seed, growers have contributed more than $3 million to the FastStart Research and Development Fund since 2009. This has supported more than 50 research projects focussed on crop establishment challenges; Developing technologies, chemistry and management solutions for the Australian cotton industry.

For further information, visit: **www.faststartcotton.com.au**.



THE FASTSTART COTTON ESTABLISHMENT GUIDE

This FastStart Cotton Establishment Guide focuses primarily on irrigated cotton production systems and provides practical information on the key management steps required to ensure growers achieve the optimum plant stand. The Guide also makes references to dryland or semi-irrigated production types throughout, but for further information, please visit **www.csd.net.au** and **www.acresofopportunity.com.au**.

The FastStart Cotton Establishment Guide was produced by Cotton Seed Distributors with support from Syngenta and other parties as referenced throughout. Any information or data not referenced is sourced from CSD trials.

DISCLAIMER

This is a general guide only, and is not comprehensive or specific technical advice. Circumstances vary from farm to farm. To the fullest extent permitted by law, CSD and Syngenta expressly disclaim all liability for any loss or damage arising from reliance upon any information, statement or opinion in this guide or from any errors or omissions in this document.

THE FASTSTART PARTNERS

COTTON SEED DISTRIBUTORS LTD.

Cotton Seed Distributors (CSD Ltd) has been supplying quality cotton planting seed to the cotton industry since 1967.

Formed through the vision of Australia's foundation cotton growers, CSD remains committed to the success of today's cotton industry.

CSD is a major investor in cotton breeding, research and development, having developed a long and successful partnership with the CSIRO Cotton Breeding Program. CSD's objective is to deliver yield and quality outcomes to keep the Australian cotton industry at the premium end of the global fibre market by delivering elite varieties that are specifically bred and adapted to suit local growing conditions.

Please visit **www.csd.net.au** to find out more.

SYNGENTA

Syngenta is one of the world's leading agricultural technology companies with more than 28,000 employees in over 90 countries dedicated to the purpose: **Bringing plant potential to life**.

Through world-class science, global reach and commitment to customers, Syngenta delivers integrated solutions that bring together leading seed varieties, Seedcare and crop protection products with expert agronomic advice and technology that enables Australian growers to realise a greater share of their yield potential and to better manage risk.

Please visit **www.syngenta.com.au** to find out more.

SOME KEY RESEARCH PROJECTS AND OUTPUTS OF THE FASTSTART COTTON PROGRAM

- The development of best practice planting guidelines for good crop establishment, published as the FastStart Cotton Establishment Guide.
- A dedicated website (**www.faststartcotton.com.au**) with research, information and tools to assist growers, including:
  - An online **cotton planting rate calculator**.
  - A regionally specific **red-amber-green traffic light system** to provide guidance on when to plant.
  - A **replant calculator** to compare the potential establishment if you are considering replanting your crop.
  - The **FastStart Soil Temperature Network**, which uses soil temperature data from a network of weather stations across the cotton industry to guide planting decisions.
  - A **variety performance guide** to analyse the performance of a selected variety under different growing regimes for yield and fibre quality.
  - A **variety performance comparison** to compare cotton varieties by year and region.
- Vibrance Complete™, Cruiser Extreme® and Syngenta Seedcare products that provide protection against a range of cotton disease and insect pests.
- The **FastStart Cotton Establishment Awards** - a competition to showcase and reward best practice seedling establishment through grower case studies.
- The **FastStart Cotton Accreditation Course** - a free training module to equip cotton agronomists, consultants, rural retailers and on-farm staff with the principles and tools to advise growers on best practice cotton crop establishment.
- Highlights of research projects funded under the FastStart program include:
  - Pathology microscopes for the Australian Cotton Research Institute.
  - Investigation of field conditions and the impacts on planting.
  - Supporting the early season insect damage experiments.
  - Examination of abiotic stress.
  - Numerous projects into the control of Fusarium wilt.
  - Supporting Verticillium wilt trials.

CONTENTS

INTRODUCTION

Achieving even establishment of a cotton crop is critical in getting the crop off to a good start, as it can influence how the crop is to be managed. The aim for every cotton grower should be to plant the crop once, achieve the desired plant stand and evenness and get the crop off to a great start.

If the crop has a strong start, obtaining yield potential is much easier. At first flower, the aim is to have a uniform plant stand of 8 to 12 plants per metre, with a healthy root system, and free of biotic stresses such as seedling diseases, insects and weeds. The plant should have access to optimal nutrition and adequate water, and be developing good plant architecture and canopy cover.

CHAPTER 1: PHYSIOLOGY OF EARLY SEASON COTTON GROWTH

A cotton plant follows a very specific pattern of growth and development. Early in the growth cycle, development is primarily driven by temperature. This affects all plant physiological processes from the speed of water uptake by the seed and the rate of germination and emergence of the seedling, to the speed at which the crop reaches squaring and then flowering.

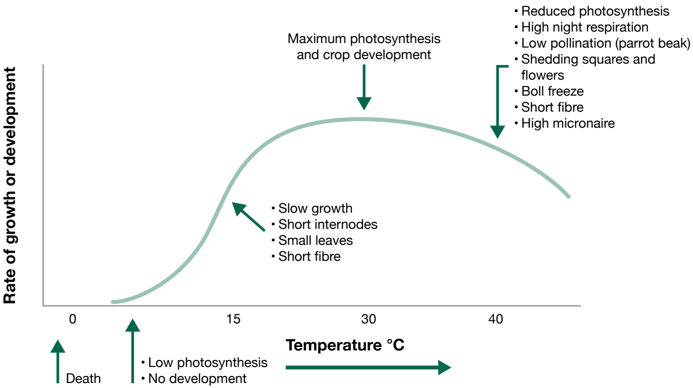


Figure 1.1: The effect of heat stress on the physiological processes of the cotton plant. (Bange and Brodrick, CSIRO, 2004).

The predictability of cotton allows for management and monitoring to influence crop growth and development. Using the relationship between the rate of development and temperature, a measure of crop progress is described as "day degrees".

When the temperature is below 12°C, cotton plant processes cease and the plant experiences what is termed as cold shock. During cold shock, the plant's development is retarded, thus slowing the overall growth and development. To ensure good early season growth, it is important to avoid seedling exposure to cold shock events.

In warmer climates, the Base 12 day degree calculation may overestimate the development of the crop. Excessively hot temperatures (> 35°C) can delay crop development, as the plant uses resources and energy to transpire in an effort to keep cool. Reduced leaf biomass and fruit shedding can also result from high day and night time temperatures.

The **1532 Day Degree calculation** accounts for both cold shocks and hot shocks (where cotton growth will be affected by heat).

For fast access to day degree calculations in your local area, visit **www.csd.net.au/ddc**.

Table 1.1: Accumulated day degree 'targets' after seed imbibed.

Cotton development	DD Base 12 (Industry standard)	DD 1532 (Experimental)
Emergence	80	TBA
First square	505	343
First flower	777	584
First open boll	1527	1077

GERMINATION AND EMERGENCE

As soon as a cotton seed touches moist soil, it will imbibe moisture and begin to germinate. In the initial stages, the seed is most sensitive to cool conditions; however this sensitivity decreases as the radical elongates, as shown in Figure 1.2.

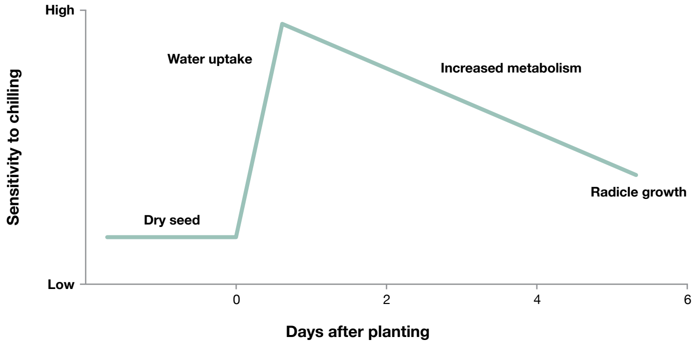


Figure 1.2: Cotton seed sensitivity to chilling injury through germination and emergence. (National Cotton Council, 1996).

Emergence is when the cotyledons break the soil surface and unfurls. The warmer the soil temperature, the quicker this will happen. Industry best practice recommends minimum soil temperatures in the seed zone of at least 14°C or above. At temperatures below this, seedlings grow slower and are more susceptible to seedling diseases and insect attack.

EARLY SEASON GROWTH

During early growth, the development of the cotton plant is primarily driven by temperature. However, as the plant develops, the rate of development can be influenced by competition for assimilates from photosynthesis, sunlight and water availability.

After emergence, the developing cotton plant is capable of producing a new node every 2 to 4 days (40 day degrees) but this rate of development is very much determined by temperature.

The initiation of squaring is determined mainly by temperature, but photoperiod and genotype also has an influence. Squaring can commence between nodes 4 and 10, but on average in Australia it occurs at node 7 (or at 505 day degrees - base 12 or 33 DD1532).

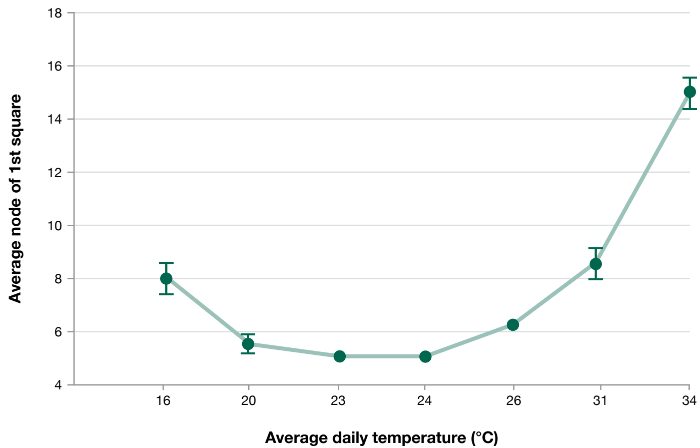


Figure 1.3: A cotton seedling's time to first square under differing average temperature regimes. (Bange, CSIRO, 2014).

DEVELOPMENT OF THE PLANT

The cotton plant has an indeterminate growth habit, which means it produces fruit 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 degree calculation to monitor and predict crop development.

The two phases of cotton plant growth are the vegetative and reproductive growth stages. While these stages overlap, the aim is to keep them in balance to produce the highest amount of cotton at harvest.

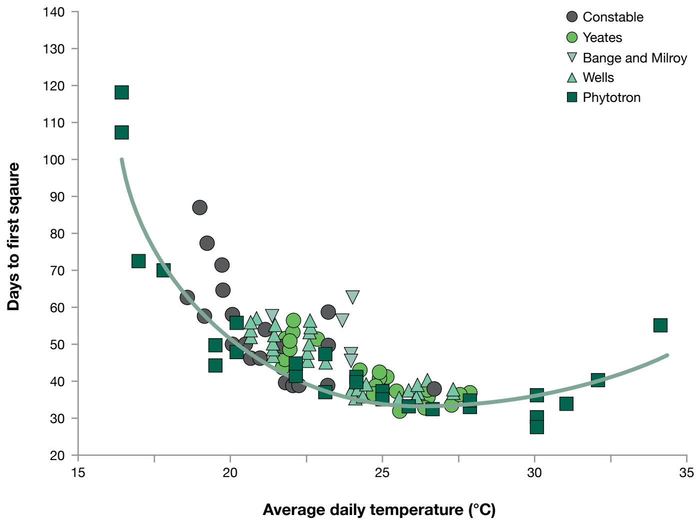


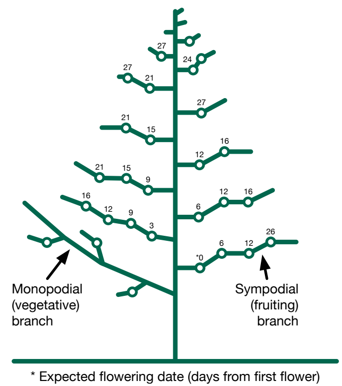
Figure 1.4: The influence of daily average temperature on the time taken to reach first square. (Bange, CSIRO, 2014).

Vegetative branches normally develop on the lower nodes of the main stem (nodes 6 to 10). A branch develops from a bud formed between the leaf and main stem node it is attached to. While vegetative branches do produce some squares, the process is slower and less efficient than the main stem fruiting branches. The number of fruit retained on vegetative branches is related to plant population and resources.

Fruiting branches normally commence between the 6th and 10th node depending on genetic varietal differences, plant population, temperature, water availability and nutrition. These branches are characterised by a zigzag growth from node to node and fruiting structures (squares) and associated leaf are at each axial of each node.

Figure 1.5 shows the average time of development of the fruiting sites for cotton. For example, the fruit at the very top of this plant will start (and finish) developing about 27 days after the first fruit at the bottom of the plant.

Figure 1.5: The rate of fruiting site development of a cotton plant. (Adapted from Oosterhuis, 1990).



Fruiting branch

A fruiting branch will have a boll with a subtending leaf on the opposite side of the fruiting branch or a scar where the leaf has fallen. A vegetative branch will have a boll but no leaf opposite and will be smooth stem with no evidence of a leaf.

Square - the flower 'bud'

'First square' is the beginning of the reproductive growth phase of the cotton plant, seen on the first (lowest) fruiting branch. Initiation of this first square normally occurs at the time the true leaf on node four or five is unfurled. As the plant grows, additional fruiting structures will emerge at the rate of about one every three days (or 40 day degrees) for first position fruit which are those closest to the main stem.

Flower

The cotton flower is white, with five petals which normally open 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

After the 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 inside. At maturity the boll walls crack and the lint dries out into the ball of cotton.

Figure 1.6: In the development of a cotton boll, the fruiting structure goes through three distinct phases.

TEN TIPS TO GET YOUR COTTON OFF TO A FAST START

1. Prepare fields early

Create a firm well-structured seed bed, free of weeds and impediments in the planting line.

2. Don't let nutrition be a limiting factor

Know the yield target you want to achieve, test your soils and know your nutrient levels. Have a strategy for fertiliser application to achieve your goal.

3. Select the right variety and seed treatment for your conditions

Know the seed quality before planting and adjust sowing rates accordingly. Syngenta seed treatments control insect pests and soil-borne diseases.

4. Be ready to go, don't let your planter let you down

Ensure the planter is level and all components are well maintained and operational.

5. Plant when conditions are right

Make sure you have the green light for cotton planting.

6. Planting is an important operation - do it once and do it right

Continuously monitor within fields, across fields and the property. Ensure planting speed, depth and pressure are correct for your situation and use lubricant to assist seed flow.

"Do everything precisely, on time and never later"

7. Select the desired plant population to maximise yield per hectare

Understand the impacts and adjust sowing rates accordingly for:

- Low soil temperatures
- Variety/seed type
- Establishment method
- Seedling mortality

Planting a few more seeds is good insurance.

Visit **www.faststartcotton.com.au/tools-and-calculators** to access the Cotton Planting Rate Calculator.

8. Reduce competition and promote good early season growth

Control weeds early and when they're small. Monitor the economic threshold for insect pests depending on the type of species, number and region.

9. Adequate soil moisture status is critical in ensuring desired growth rates at first flower (first irrigation)

Closely monitor soil moisture status, crop growth and development rates, temperature and rainfall forecasts.

Visit **www.csd.net.au/steff** to access the Simulated Time to Estimated First Flower tool (STEFF).

10. Have the crop growing healthily at first flower

Create strong plant architecture and aim to have 8 to 9 nodes above white flower (NAWF) at first flower.

CHAPTER 2: PRE-PLANTING

PRE-PLANTING WEED MANAGEMENT

Keeping fields weed free during the fallow period is essential. Weeds in fallows can increase the weed seed bank, provide a green bridge for pests/diseases, and reduce the soil moisture profile, leaving the moisture status of the planting zone uneven.

ROTATION CROPS AND FALLOWS

A fallow or rotation crop offers an excellent opportunity to control weeds and drive down the weed seed bank. It also allows you to rotate chemistry and use alternative weed control methods to reduce herbicide resistance build-up.

It is best practice to:

- Target weeds when they are small and most susceptible to herbicides.
- Ensure areas surrounding fields including fence lines, roads, irrigation channels and tree lines are kept weed free.
- Ensure any herbicide survivors are controlled using alternate methods to prevent them setting seed.
- Use rotation crops as a valuable tool for integrated weed management.

Winter and summer crops have the advantage of drying out the soil profile and allowing strategic cultivation to manage soil and weed problems. There is a wider range of herbicides available for use in rotation crops compared to cotton. Some weeds are more easily managed with alternate herbicides in the rotation crop cycle, than in cotton systems.

In cereal crops, where broadleaf weeds are easy and cheap to control, retaining cereal stubble cover for as long as possible also reduces weed establishment, encourages more rapid breakdown of weed seed on the soil surface, boosts water infiltration and reduces evaporation. It's important to consider the plant-back period for crop rotation herbicides as they can limit the rotation options and also harm cotton germination, emergence and early season growth.

PRE-PLANTING RESIDUAL HERBICIDES

There are a range of pre and post-planting herbicides that can be used in the cotton system. The use of these products has diminished in recent years as the industry has adopted Roundup Ready Flex®.

Pre-planting residual herbicides have the **advantage** in that they:

- Can be applied from several weeks prior to planting, right up until the planting operation.
- Can be effective for weeks and months post application.
- Can be applied prior to known weed problems to control those weeds before they emerge.
- Play an important role in the management of herbicide resistance, especially for glyphosate.
- Can be less expensive than non-residual alternatives.
- Can open up the window for further chemical applications and at lower rates if control is effective.

Some **disadvantages** are that they:

- Can damage cotton seedlings, reducing crop populations and retard early season growth (under certain circumstances).
- May need to be incorporated into the topsoil for optimum activity. Adequate incorporation of some residual herbicides is achieved through rainfall or irrigation, but others require thorough cultivation, which may conflict with other farming practices.
- Can prevent other crop choices if cotton is not planted or removed (low water supply, hail).
- Can incur additional costs.

FIELD CONDITIONS

In order to get the crop off to the best possible start, it is critical that the seedbed is in optimal shape and condition. To achieve a successful, uniform establishment:

- The field needs to be uniform.
- The stubble needs to be broken down or incorporated and removed from the planting line.
- The seedbed needs to be free of weeds.
- The soil tilth needs to be fine to enable good seed to soil contact.
- In lighter soil types, growers should consider using machinery to spread, level and break up stubble well before the planting process.
- The seedbed needs to be firm but not compact.
- You should know the tolerance of your planter to the soil conditions you have.

Waterlogging in both irrigated and dryland farming scenarios is a major impediment to high yields. It is critical that the field is of uniform grade and free of low spots that will cause water to pond. Adequate drainage in terms of slope and infrastructure is essential to get water on and off fields quickly.

KNOW YOUR SOIL TYPE

It is important to know your soil type because different soil types behave in different ways. For example, a clay soil will hold water better than a sandy soil, but will tend to be sticky and smear. Knowing what soil type you have will influence your management practices and ultimately how your crop will perform.

STUBBLE MANAGEMENT

The benefits that come from having standing stubble in the zone of the emerging crop include moisture retention, less erosion and protection from wind-blasting. However, this can all be outweighed if at planting, incorporated stubble impacts on plant germination and the final plant stand. Too much stubble can affect water infiltration, subbing up and impact seed placement, as well as providing a perfect environment for disease.

There are generally two types of stubble, either cereal stubble after a fallow or cotton stubble in back-to-back fields. The amount of stubble is dependent on numerous scenarios. Large crops produce more stubble, low winter rainfall means less stubble breakdown and cultural practices such as stalk pulling or burning will influence how much stubble remains to overwinter. Regardless of how much stubble is left behind, it is important at planting that it is removed from the planting line. If not, stubble in the slot or planter unit bounce can impact seed placement uniformity and seed/soil contact.

Trash whippers are commonly used to remove stubble from the tops of beds and will allow discs to plant into friable soil, not over or into solid stubble.

FIELD SCORES (IRRIGATED COTTON)

CSD has developed a field score ranking system which ranges from 1 to 5, with 1 being ideal for obtaining uniform plant establishment and 5 likely to result in patchy or poor establishment. A score of 5 would have the potential to delay emergence or the possibility of requiring a replant.

Field Score 1

Stubble fully broken down, usually cereal not cotton stubble. Firm seedbed which will support the planter unit. Beds have been rolled or shaped. Weed free. Seed zone free of soil particle size > 2 cm.

Field Score 2

Similar to field score 1 but presence of larger soil particles (up to 2 to 3 cm).

Field Score 3

Presence of soil particles up to 3 to 5 cm. Some stubble mixed into seed zone. The odd weed and the bed not as firm as 1 and 2, slightly sinking when pressure is applied to the bed.

Field Score 4

Presence of medium to large soil particles, up to 5 to 8 cm. Increasing amount of trash. No firmness to bed. Your feet start to sink when walking on bed. Starting to see cotton volunteers/fuzzy seed in back-to-back cotton situations.

Field Score 5

Presence of large particles up to 10 to 15 cm. Large remnants of past crop residues. Weeds present. No soil structure within the bed. A lot of air gaps. Beds sink away when walking on them. Remnants of cotton butts still in planter row, volunteers and high fuzzy seed levels in back-to-back cotton situations.

"Don't let nutrition be a limiting factor"

The first part of a fertility program is to regularly have soil tested to ascertain the current nutrient status of both macro and micro-nutrients. Additionally, analysis of soil pH and organic matter is used to assist in measuring trends. Once analysed, the soil test results can be used to plan the fertiliser program for the cotton crop based on:

- **Yield expectations** - e.g. a 16 bale/ha crop will remove 216 kg N/ha (see Table 2.1).
- **Soil nutrient status** - soil test results should be known well in advance of planting.
- **Soil type** - e.g. sandy soils will leach nutrients more than clays.
- **Soil condition** - e.g. compacted soils may have reduced rooting depth and fertiliser timing will be critical.

In modern cotton production systems, major crop nutrients such as nitrogen are applied as a split application. It is common practice that 60 per cent of fertiliser goes on prior to planting, with the balance applied by various methods once the crop has established. This allows cotton growers improved flexibility to manage for yield potential and to boost efficiency in recovery of applied nutrients.

In general, the first 60 days of a crop's life will use up to 130 kg N/ha (see Figure 2.1). It is therefore important to ensure that the crop has adequate nutrition from the start of the season.

Low rates of pre-applied nitrogen (particularly on back-to-back cotton) can lead to slow early season growth and can create a poor plant canopy and architecture leading into flowering. Very high rates of pre-applied nitrogen has the potential to produce excessive vegetative growth which will require growth management earlier than expected.

Table 2.1: Cotton yield nutrient removal (Rochester and Constable, CSIRO, 2006).

Yield b/ha	N	P	K	S	Ca	Mg	B	Cu	Zn	Fe	Mn
kg/ha							kg/ha				
10	125	24	37	10	6	14	56	24	110	164	15
12	155	28	44	12	7	17	70	28	129	191	18
16	216	37	59	17	9	23	99	36	166	244	24
18	245	42	67	19	10	26	113	40	185	270	27

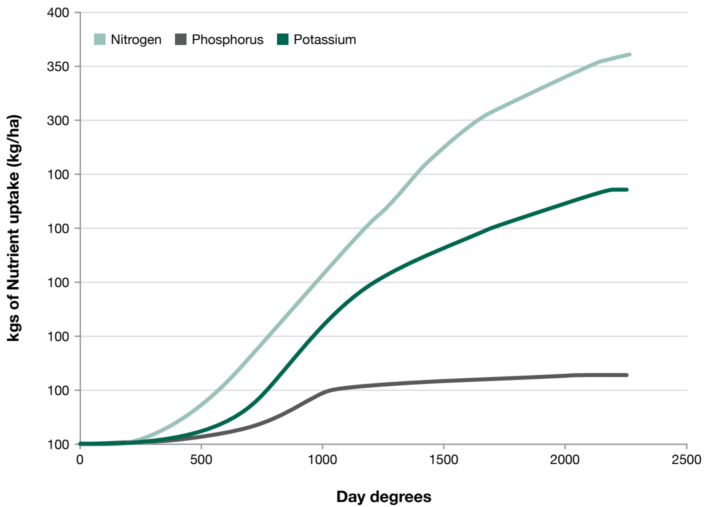


Figure 2.1: Nutrient uptake of a 12.5 bale/ha crop. (Rochester and Constable, CSIRO, 2006).

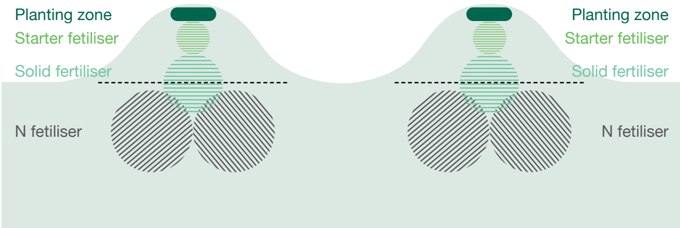


Figure 2.2: Schematic of placement of fertiliser.

Fertiliser placement is very important, as root burn can occur when some fertilisers are placed too close to the root system.

Nitrogen fertilisers should be placed a short distance from where seedling roots will grow, especially when N is applied close to sowing. Generally, the best responses and recoveries are achieved from urea or anhydrous ammonia placed either:

- More than 30 cm beneath the seed row if more than one month before sowing, or
- Shallower and to the side or both sides of the crop row, if closer to sowing

Nitrogen fertiliser needs to be placed near the developing cotton roots, but not so close that ammonia toxicity will damage the root system. Ideally, the fertiliser band should be below and to the side of the developing roots, allowing the root system to grow into the band (**NUTRIpak: A practical guide to cotton nutrition, Cotton Research and Development Corporation 2018**).

In general, assess the time of year that fertiliser is being applied and what product will be used as this will impact on where and how the fertiliser is placed.

The use of liquid fertilisers is another option early in the season to improve vegetative growth and can be used prior to a stress event such as waterlogging to offset any potential damaged caused through this period.

VARIETY SELECTION

Variety selection is one of the most important management decisions in the cotton production cycle. A number of criteria need to be considered and the final selection(s) often involves some compromise. Seldom does a variety come out on top in every category.

Plant breeding and crop management improvements are continuing to achieve yield gains for Australian growers. As illustrated in Figure 2.3, most of the improvements in yield have come from improved germplasm (48%). The interaction between improved germplasm and improved crop/field management practices accounted for 24% with the balance of 28% coming from improved crop/field management practices. The risk with selecting the wrong variety is that it can impact on yield, and therefore overall gross return as seen in Figure 2.4.

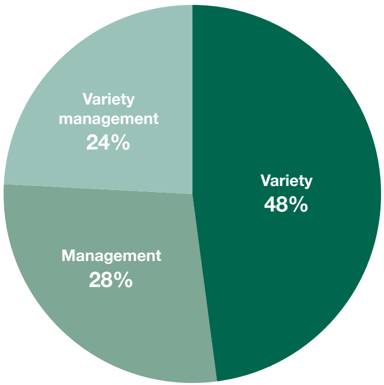


Figure 2.3: Yield improvement sources over the past 30 years. (Liu, Reid, Stiller and Constable, CSIRO, 2013).

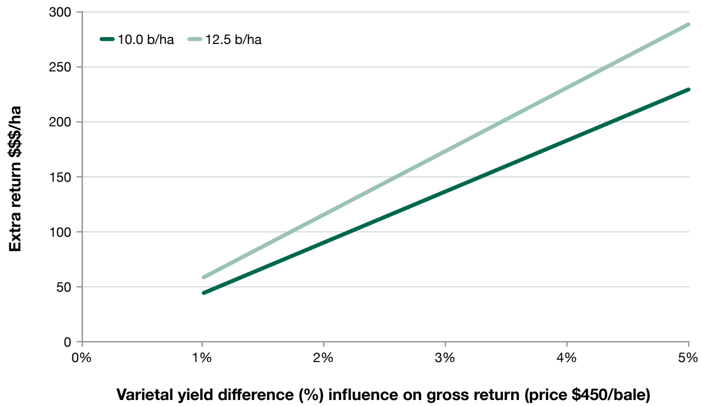


Figure 2.4: Varietal yield difference and its impact on gross return.

YIELD

Profitability of cotton farming is very much dependent on yield, as it outstrips the variable costs of production. Selected varieties must have high yield potential and also the ability to respond to improved management practices in the realms of irrigation and nutrition in particular.

The variety which will have the highest yield will vary depending on regional conditions and type of production system. Growers can compare the performance of different varieties for both yield and lint quality by visiting CSD's Variety Performance Comparison tool at www.csd.net.au/vpc. This provides regionally specific data from irrigated, semi-irrigated and dryland production systems.

DISEASES

The presence of soil-borne diseases on farms can influence variety selection. Plant breeders have successfully produced varieties with improved levels of resistance to the major soil-borne diseases Fusarium wilt and Verticillium wilt. The level of varietal resistance to these diseases are expressed as a disease ranking and can be found on the CSD website at **www.csd.net.au/disease-ranks**.

In fields where these diseases are present, growers should select a variety with a higher disease rank for the pathogen present. Higher levels of resistance will lead to lower rates of crop infection and reduced inoculum build up compared to more susceptible varieties. The CSIRO breeding team has also successfully developed germplasm with resistance to cotton bunchy top (CBT). Sicot 620 is the first commercial variety with CBT resistance with a wider suite of resistant varieties expected to be available in the future. Other key diseases which may affect the Australian cotton industry, such as black root rot, Alternaria leaf spot and boll rot, exhibit no differentiation in resistance in current varieties.

The Queensland Department of Agriculture and Fisheries (QDAF) and the NSW Department of Primary Industries (DPI) conduct annual surveys for the presence and severity of the main cotton diseases. For further information, growers can contact the relevant authority in your state.

Visit QDAF at **www.daf.qld.gov.au**.
Visit NSW DPI at **www.dpi.nsw.gov.au**.

FIBRE QUALITY

Fibre quality characteristics of the key varieties reflect the ultimate use for most of Australia's cotton, namely in high quality yarns produced in high speed ring spinning mills in Asia. This cotton is often purchased for a premium as it consistently meets high quality characteristics. Management practices and regional weather patterns can often have more influence than variety on the fibre quality produced. However, there are some fibre quality characteristics where the interaction of variety and management practices can help ensure the best product is produced.

Fibre length: In fully irrigated situations, fibre length from all major varieties generally meets market specifications. In dryland and semi-irrigated situations however, some varieties have the potential on occasions to produce fibre with length below base grade specifications, thereby incurring a penalty.

Fibre thickness: Thickness and maturity of the cotton fibre wall can be an issue. High micronaire can become a problem in a season of hot, dry conditions particularly in the central production regions. On the other hand, in cooler regions, low micronaire can impact high yielding varieties in seasons with below average day degrees or late planting.

Other key fibre quality parameters: such as strength, uniformity, colour and leaf grade are reasonably consistent across all current varieties, with the latter particularly influenced by weather conditions during defoliation and picking.

TECHNOLOGY CHOICE

Biotechnology has reduced the environmental impact of cotton production with significantly reduced pesticide application and residual herbicides use now common practice. Cotton growers have a choice of varieties containing either a combination of insect and herbicide tolerant genes, straight herbicide tolerant genes and conventional or non-GM options. Bollgard® 3 and Roundup Ready Flex® technologies provide Australian growers with simple tools to effectively protect cotton yields.

The Bollgard® 3 trait package is an important tool in the sustainable management of Helicoverpa spp., one of the cotton industry's most significant insect pests. Roundup Ready Flex® cotton is able to tolerate applications of Roundup Ready Herbicide® with PLANTSHIELD® in its vegetative and reproductive stages. Growers can apply Roundup Ready Herbicide® with PLANTSHIELD® in-crop to weeds when and where they appear, with full season tolerance.

SEED TYPE

The seed type of current commercial varieties fall into two categories - normal and low density. As the names suggest, this differentiation has to do with the density of the seed. Low density seed is characterised by an embryo which, unlike the normal density seed, does not completely fill the seedcoat. This characteristic leads to higher lint yield due to greater turnout percentage. However, these low density varieties also have lower seed weight and oil content, that translates to lower stored energy and has important implications for the seedling vigour of the variety.

CSD defines seedling vigour as the ability of normally germinated seedlings to progress to establishment in the field under a range of conditions. This is a quality parameter that represents the stage of development after germination and doesn't currently have a recognised test method in the way that germination is measured by the warm and cool germination tests. However, seed type information is provided in Table 2.2 and this can be used as a proxy for seedling vigour with the low density varieties having lower seedling vigour compared to the normal density varieties.

Table 2.2: Seed varieties by type and disease rank.

	Variety	Seed type	V.rank	F.rank
Bollgard® 3 Roundup Ready Flex®	Sicot 714B3F	Normal density	112(17)	128(8)
	Sicot 746B3F	Low density	102(36)	135(6)
	Sicot 748B3F	Low density	103(34)	132(6)
	Sicot 754B3F	Low density	99(27)	152(6)
	Sicot 707B3F	Normal density	106(18)	116(2)
	Sicot 606B3F	Low density	117(14)	n/a
Roundup Ready Flex®	Sicot 711RRF	Normal density	98(7)	99(4)
	Sicot 812RRF	Normal density	94(6)	113(4)
Conventional	Sicot 620	Low density	101(5)	n/a
	Siokra 250	Low density	98(5)	n/a

LOW DENSITY SEED CONSIDERATIONS

In favourable field conditions, all varieties are capable of high levels of establishment. Under such conditions, the germination percentage of the seed will have a greater influence on establishment percentage than seedling vigour. In less than ideal conditions, however, the seedling vigour of the variety can have a major influence on establishment.

Results from CSD's recent seedling vigour field trials demonstrate both the effect of field conditions on establishment as well as the influence of seedling vigour on establishment (Figure 2.5). The green columns represent the establishment percentage for five varieties each represented by one seedlot from the same seed source, so the germination percentage is very similar across the varieties. This particular trial was conducted in late October aiming for optimal conditions (see green light for planting in Chapter 3). In these conditions there was very high establishment overall and no significant difference between the varieties. The black columns represent the establishment of the same seedlots planted earlier the same year into stressful conditions (see red light guidelines in Chapter 3).

This data clearly shows that these poorer conditions have lead to a large decrease in establishment for all varieties compared to the optimal conditions. However, the magnitude of the drop in establishment is not the same for each of the varieties and there is now a significant difference in establishment. Varieties with greater seedling vigour (such as normal density varieties Sicot 714B3F and Sicot 707B3F) are better equipped to handle adverse conditions. Whereas low density varieties such as Sicot 748B3F, Sicot 746B3F and Sicot 754B3F have lower seedling vigour and are even more heavily impacted by poor conditions, leading to an even greater drop in establishment.

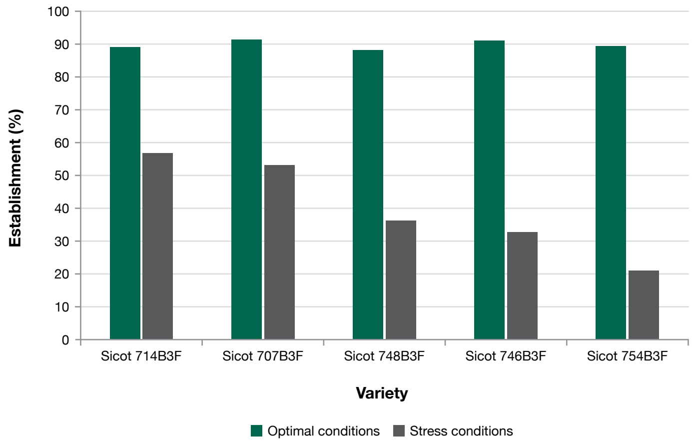


Figure 2.5: Effect of variety and field conditions on establishment percentage.

As a result, seed type should be taken into consideration when making planting decisions such as planting rate.

Other influences on variety selection include:

- **Regional adaptation:** seasonal conditions, short or long season
- Is there enough available water to provide a full allocation to the crop (semi-irrigated, dryland or full irrigation choices)?

These influences will assist with the varietal requirements for your circumstances. Your local CSD Extension and Development Agronomist can assist you in selecting the variety of choice for your region, based on trial results.

Contact details for your local representative can be found at: **www.csd.net.au/contact**.

PLANTING SEED INFORMATION

REQUIREMENTS AND QUALITY

Have your planting seed on-farm and ready to go. Discuss your requirements with your preferred CSD Agent prior to planting in relation to quantities and timing to ensure you are not waiting for seed to be delivered.

Check delivered seed quantities match what was ordered and update germination and seed size information to fine tune planting rate. Cotton Seed Distributors takes great pride in providing the highest quality cotton planting seed. CSD also provides cotton growers and consultants with current information on seed quality to enable further refinement to the planting operation.

IMPORTANT INFORMATION IS ON THE BAG

Variety, technology, seed treatment - although this may seem simplistic, it is important to check to ensure that the correct seed goes into the correct field (Figure 2.6 - green circle). Ensure all farm staff are aware of the chosen variety and technology for each field. Confusion may occur due to similarly named varieties across different technology groups. (e.g. Sicot 714B3F and Sicot 711RRF). CSD has tried to alleviate this issue by having the bag and seed colour identical, based on the technology type.

The AUSlot number (Figure 2.6 - red circle) is a critical number on the label and can be used along with the variety, to access the statement of seed analysis from the CSD website.

This information is available at **www.csd.net.au/auslots**.

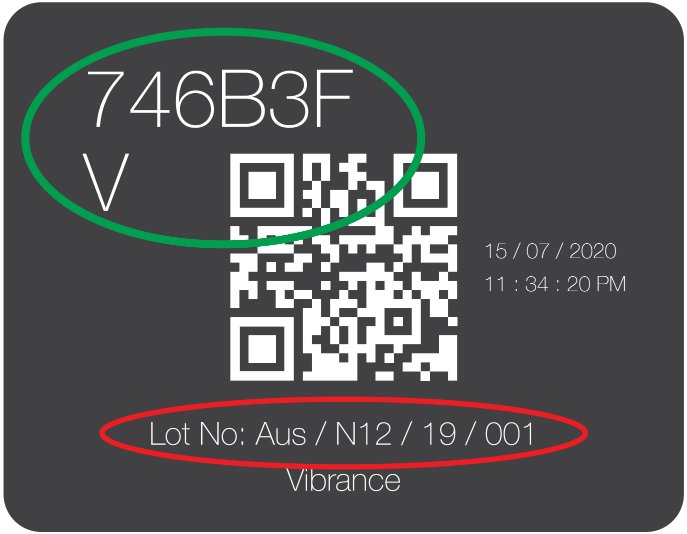
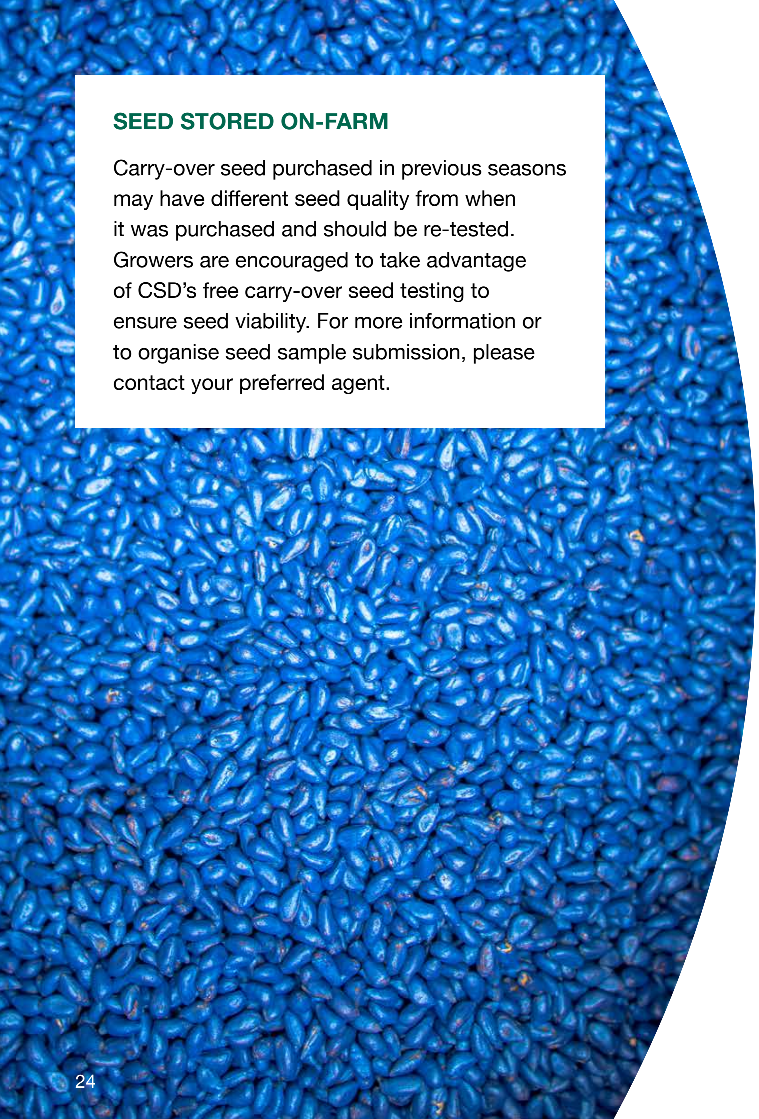


Figure 2.6: Seed variety, technology and quality information are printed on the bag sticker. The above image is a mock up version of what to expect.



SEED STORED ON-FARM

Carry-over seed purchased in previous seasons may have different seed quality from when it was purchased and should be re-tested. Growers are encouraged to take advantage of CSD's free carry-over seed testing to ensure seed viability. For more information or to organise seed sample submission, please contact your preferred agent.

WHAT INFORMATION IS CONTAINED IN A 'STATEMENT OF SEED ANALYSIS'?

The key information contained in the statement of seed analysis is specific quality data for an AUSlot, including results for germination, seeds per kilogram, mechanical damage and physical purity.

The germination results represent the physiological quality of the seedlot. The standard 'warm' germination test measures the germination potential or seed viability and represents the maximum germination under ideal conditions. This is a seven day test which is conducted under a cyclic 20/30°C temperature regime. To be considered germinated, a seedling must have a length from hypocotyl hook to radicle tip of no less than 40 mm and be free from abnormalities. The minimum seven day warm germination percentage for cotton planting seed is 80%.

The cool germination test measures seed vigour which represents the seeds potential for rapid and uniform germination and development of normal seedlings under a range of conditions. This test follows the same protocol but is conducted at a constant 18°C for 7 days. The minimum value for 7 day cool germination of cotton planting seed is 60%, but typically is above 70%.

CSD provides both warm and cool germination data on all AUSlots with the intent of providing growers and agronomists with useful and relevant data to make informed decisions at planting time.

Data is also provided on physical purity, as well as mechanical damage, which is assessed as a percentage of seeds with physical defects such as cracked or holed seed coat, or broken seed.

All germination values reported are for the whole sample including mechanically damaged seed.

PLANTER SETUP AND MAINTENANCE

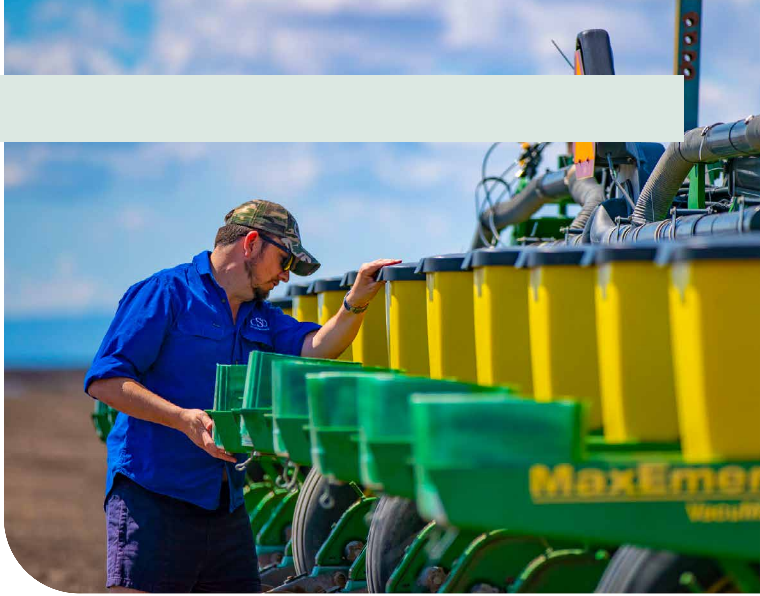
Precision planters are now the predominant type of planter units in use and it is critical to have them correctly setup and maintained.

Growers should ensure their planter is well serviced and operational well before planting time. Breakdowns can cost time and optimal planting conditions may be a missed opportunity. Keep a kit of spare parts (seed tubes, press wheels, scrapers, monitor cables, chains, nozzles, etc.) close by to allow for quick repairs. Planters should be calibrated for seeding rates as well as any other products being applied at planting.

Planting slot compaction may occur when planting into excess moisture, producing a compacted face on both sides of the seed slot. This affects moisture uptake by the seed and can reduce establishment. If press wheel pressure is too high, this can also cause compaction in moist soil and the resulting crust can impact on the seedling trying to push through. Stop and regularly check the planter in every field, particularly when planting into moisture.

Alternatively, if press wheel pressure is not ideal and baking conditions follow planting, the seeding slot may open up, a term known as ‘Kinze crack’. The planting row should be covered with a thin layer of dry soil to insulate and keep the moisture around the seed, also slowing the rate of drying of exposed wet soil faces.

Issues can arise when too much dry soil is swept into the seed slot, due to incorrect closing pressure causing poor moisture uptake by the seed. Conversely, heavy rain post-planting can cause soil crusting with a thick impenetrable layer above the seed.

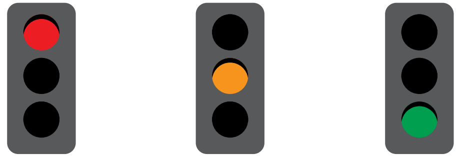


Operator training is important. Educate the operator so they have clear understanding of what the planting operation is trying to achieve and can detect problems quickly. Additionally, they need an understanding of when to stop. During planting, regularly check seed depth and the condition of the soil around the seed. This is especially important when planting on rain moisture where you may get some in-field variability. Operators and farm staff are encouraged to complete the free FastStart Accreditation Course, updated each season.

FastStart Accreditation Course is available by visiting **www.faststartcotton.com.au/accreditation**.

THE GREEN LIGHT FOR COTTON PLANTING

Planting the cotton crop is one of the most important operations on the farm. It sets the standard for the entire season. There are some key considerations that will help ensure that it is a once only task.



Ask yourself:

	RED LIGHT	AMBER LIGHT	GREEN LIGHT
☐ Is the soil temperature at 10 cm depth above 14°C at 8am AEST?	✗	✓ ✗ OR	✓
☐ Are forecast average temperatures for the week following planting on a rising plane?	✗	✗ ✓	✓
	STOP!	**STEADY!**	**GO!**

- If you cannot give a green tick next to at least one of these statements, then planting conditions are definitely unsuitable - **STOP!**
- If you can give a green tick to only one of these statements - be **CAUTIOUS**. Adjustments may need to be made.
- If you can give both statements a green tick - it's **GO!**

Other questions that need to be answered before planting starts

- Is the planter prepared for the coming season?
- Is the planter calibrated to the correct seeding rate?
- Is the planter adjusted for the correct planting depth?
- Does soil tilth/condition mean other operations needed? (E.g. rolling, meshing).
- Have planting speed limits been set?
- Have all staff operating the planter been trained?
- Planting in cool or poor soil conditions costs time, yield and quality. Don't get caught running the red light - **it will cost you!**

Having accurate seed quality information is essential in refining the planting operation

- View estimates on seed size at: www.csd.net.au/seeds-per-kilogram.
- AUSLot information:
  - Each seed lot has a batch number on the butt sticker of each bag. This number can be used to access actual seed quality at www.csd.net.au/auslots.
  - Select your variety, enter your AUSlot number and select search.
  - Data includes warm and cool germination percentage, physical purity and seeds per kilogram.

SOIL TEMPERATURE EFFECTS ON GERMINATION

Cotton is a temperature sensitive crop and the way the crop deals with temperature extremes is by shutting down or slowing physiological processes in the plant. Temperature experienced post-planting will also have an impact on the time taken for the plant to emerge. The slower the plant grows, the greater the chance of seedling death occurring through disease and insect damage. Figure 3.1 shows the critical times of an early seedling's life in terms of sensitivity to temperature.

This is why it is so important to monitor soil and air temperatures to find the appropriate window to plant the crop. It has been an Australian cotton industry guideline for many years that cotton planting should not begin before soil temperatures reach 14°C or above at 10 cm depth, at 8am AEST. Planting at temperatures below this will diminish root and shoot growth, reduce water and nutrient uptake and make plants much more susceptible to attack from seedling diseases and insects.

In some of the southern growing regions, it can be difficult to reach these temperatures in early October and therefore a forecast for rising air temperature and hence soil temperature will allow growers to start planting. Also, the average temperature forecast should be on a rising plane for the week following planting. This will ensure that the developing seedling takes the least time to emerge and has good vigour in early development.

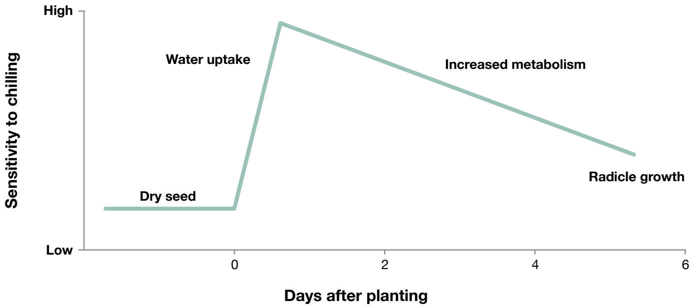


Figure 3.1: Cotton seed sensitivity to chilling injury through germination and establishment. (National Cotton Council, 1996).

FASTSTART COTTON TOOLS

The FastStart Soil Temperature Network consists of a network of approximately 50 automatic weather stations located across cotton production areas in New South Wales, Queensland, the Northern Territory and Western Australia - **www.csd.net.au/soil-temperature**.

These sensors are a real-time measure of the soil temperature at 10cm and can be used as a guide to whether conditions are suitable for planting cotton.

This FastStart Soil Temperature Network decision tool uses the accumulated day degrees over a 7-day forecast, whilst also taking into account the influence of cold shock, to give you a figure out of 100. This is then divided into four categories:

Table 3.1: FastStart Soil Temperature Network scoring.

< 30 DD	Very Poor	
< 60 DD	Poor / Caution	Warrants caution as a delay in emergence is likely and may impact upon germination percentages and/ or exacerbate seedling disease or soil insect attack. Management intervention is encouraged.
61-80 DD	Adequate	Considered adequate however ensure other planting parameters and conditions are ideal. Cotton will likely take greater than 7 days to emerge.
> 81 DD	Good	In excess of 81 DD is considered as the requirement for ideal germination and emergence.

Other useful tools on the FastStart website include:

- An online planting rate calculator.
- A replant calculator to compare the potential establishment if you are considering replanting your crop.
- A variety performance guide to analyse the performance of a selected variety under different growing regimes for yield and fibre quality.
- A variety performance comparison to compare cotton varieties by year and region.

Visit **www.faststartcotton.com.au/tools-and-calculators**.

TEMPERATURE EFFECTS ON SPEED OF GERMINATION

Temperature plays a vital role in germination rate and cotton seedling development. Below 12°C growth is severely retarded. Enzymatic activity within the cotton plant does not function properly until temperature is above 15°C. There is a strong relationship between time of establishment and soil temperature; as temperature increases so will the rate of germination and development. This is demonstrated in Figure 3.3 which depicts the relative growth of seed from the same seedlot germinated under laboratory conditions for seven days in a range of temperatures. Under field conditions, this delay in germination due to low temperatures can increase susceptibility to disease and insect damage, ultimately leading to reduced establishment. Although it is a less common issue in traditional cotton growing areas, there is also an upper limit to temperatures suitable to cotton germination. Above temperatures of 35-40°C germination may be negatively affected depending on the situation.

In the past there has been an emphasis on planting early to give the crop time to compensate for early insect damage, reduced insect control problems and reduced cost blow outs associated with late crops. With Bollgard® 3 crops, these factors are less important and these benefits will continue with new technology based varieties.

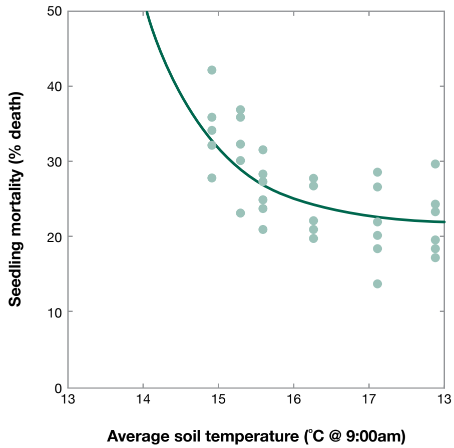


Figure 3.2: Impact of soil temperature on seedling mortality. Temperature is the average minimum soil temperature for the seven days after sowing (Nehl, NSW Department of Primary Industries).

Figure 3.3: Effect of temperature on 7 day germination on the same AUSlot.

IMPACTS OF TEMPERATURE ON DEVELOPMENTAL STAGE BY PLANTING DATE

Temperature at planting can have a major impact on when a plant reaches each stage of development; and can have consequences throughout the entire season. Table 3.2 shows the theoretical impact of four different planting dates on the developmental stages of the plant based on accumulated heat units and day degrees. In this example, planting on the 20th of September has no significant advantage on crop development compared to planting on the 15th of October. There are an extra 22 cold shock days by planting on the 20th of September compared to planting on the 15th of October. By the time a crop reaches open boll the later planting date is one day earlier than the early planting date based on temperature and day degrees, and yet there was 25 days difference between the planting dates.

Table 3.2: Development stage by planting date, using climate data at Hillston, NSW, during the 2016-17 season.

		PD1	Days	PD2	Days	PD3	Days	PD4	Days
Plant date		20 Sep		1 Oct		10 Oct		15 Oct	
Emergence	**80 DD**	9 Oct	19	16 Oct	15	26 Oct	16	27 Oct	12
1st Square	**505 DD**	24 Dec	95	23 Dec	83	24 Dec	75	24 Dec	70
1st Flower	**777 DD**	10 Jan	112	9 Jan	100	9 Jan	91	9 Jan	86
Open boll	**1527 CC**	28 Feb	161	26 Feb	148	28 Feb	141	27 Feb	135
Cold shock days	**12°C or less**	44		44		26		22	

Rhizoctonia solani, Pythium ultimum and *Fusarium spp.* (not the Fusarium wilt pathogen) can kill young plants during and after emergence.

Research from Cotton Seed Distributors has found that across the Australian cotton industry, the average establishment percentage is 72%.

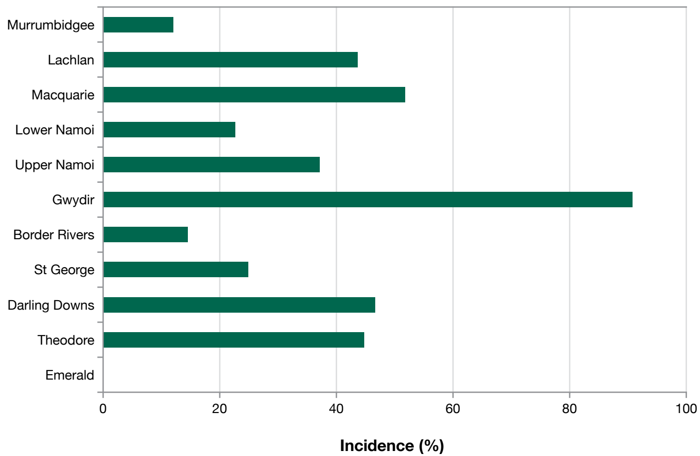


Figure 4.1: The incidence of black root rot of cotton in the 2018-19 season as recorded in early season cotton surveys (Smith, Queensland Department of Agriculture and Fisheries, 2020).

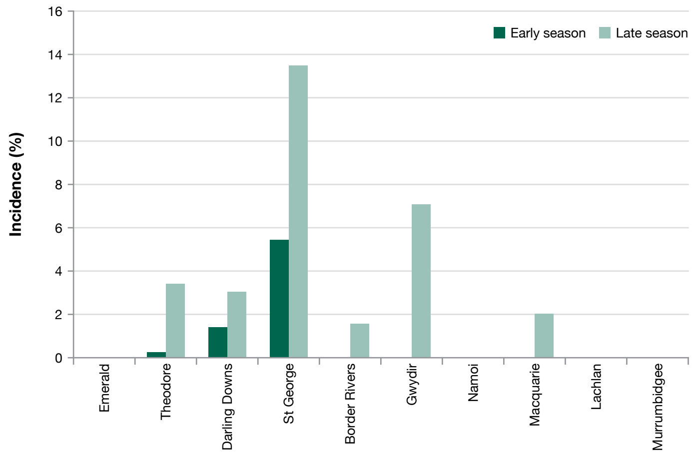


Figure 4.2: Early and late season Fusarium wilt. (Smith, Queensland Department of Agriculture and Fisheries, 2020).

Vibrance® Complete

The best seed deserves the best protection. That's why all CSD varieties are available with VIBRANCE® COMPLETE, the only seed treatment that provides all-in-one protection against Pythium, Rhizoctonia, Fusarium wilt and black root rot.

Plus, there's your choice of CRUISER EXTREME® or CRUISER® for robust early season protection against aphids, thrips and wireworms in the convenience and flexibility of a seed treatment.

Combined, these quality treatments from Syngenta protect your seedlings from disease and insect pests from germination right through to stand establishment, allowing plants to express their full yield potential.

VIBRANCE® COMPLETE from Syngenta is a fungicide seed treatment jointly developed by Cotton Seed Distributors and Syngenta under the FastStart program. VIBRANCE COMPLETE offers growers a superior crop establishment solution which is supported by research, disease surveys and grower feedback.

VIBRANCE® COMPLETE combines the activity of five active ingredients to provide broad spectrum disease control that ensures that the crop receives the best start, enhancing crop establishment and yield potential. Azoxystrobin, Fludioxonil, Metalaxyl-M, Sedaxane and Acibenzolar-S-methyl are the key active ingredients that make VIBRANCE COMPLETE so potent on disease.

Apart from controlling seedling diseases such as seedling damping off caused by Pythium spp. and Rhizoctonia solani, VIBRANCE® COMPLETE induces the natural plant defence mechanism of cotton plants that increases the plant resistance to certain diseases such as Fusarium wilt and black root rot. VIBRANCE® COMPLETE activates all treated plants in the field uniformly and becomes an important part of an integrated disease management program.

The significant benefits of VIBRANCE® COMPLETE include:

- A comprehensive disease management solution to enhance establishment.
- Improved plant stands - comprehensive trials show a 27% increase over untreated seed and 4% increase over DYNASTY COMPLETE treated seed.
- Reduced risk of replant from uneven or inadequate plant stands.
- Faster crop emergence.
- Improved early crop development.
- Enhanced early plant vigour.
- Reduced disease incidence.
- Improved yield potential.

CruiserExtreme® 1250

THE BENCHMARK IN EARLY SEASON CONTROL

CRUISER EXTREME® seed treatment makes in-furrow granular insecticides obsolete. It delivers comparable control of sucking and soil-dwelling pests in the convenience and flexibility of a seed treatment. There's no need for special equipment, calibration or refilling - and no worries about operator safety.

Key benefits:

- Robust protection against aphids, thrips and wireworms.
- Comparable performance as in-furrow granular insecticides.
- Convenient seed treatment:
  - No extra equipment, calibration or refilling needed.
  - Reduced worker exposure.
- Reduced risk of replant from poor stands.
- Available on all CSD varieties.

Cruiser

GETS YOUR CROPS OUT OF THE GROUND, FASTER

CRUISER® provides long-lasting residual control of aphids, thrips and wireworms. Affected pests cease feeding almost immediately and starve to death within 24 hours. The active ingredient in CRUISER® has optimum water solubility making it ideal for rapid uptake even under dry conditions, thus making it an ideal choice for dryland cotton.

Key benefits:

- Long-lasting control of sucking and soil-dwelling pests.
- Rapid uptake and systemic activity.
- Forms protective 'halo' around the seed.
- High solubility ideal for both irrigated and dryland cotton.
- Available on all CSD varieties.

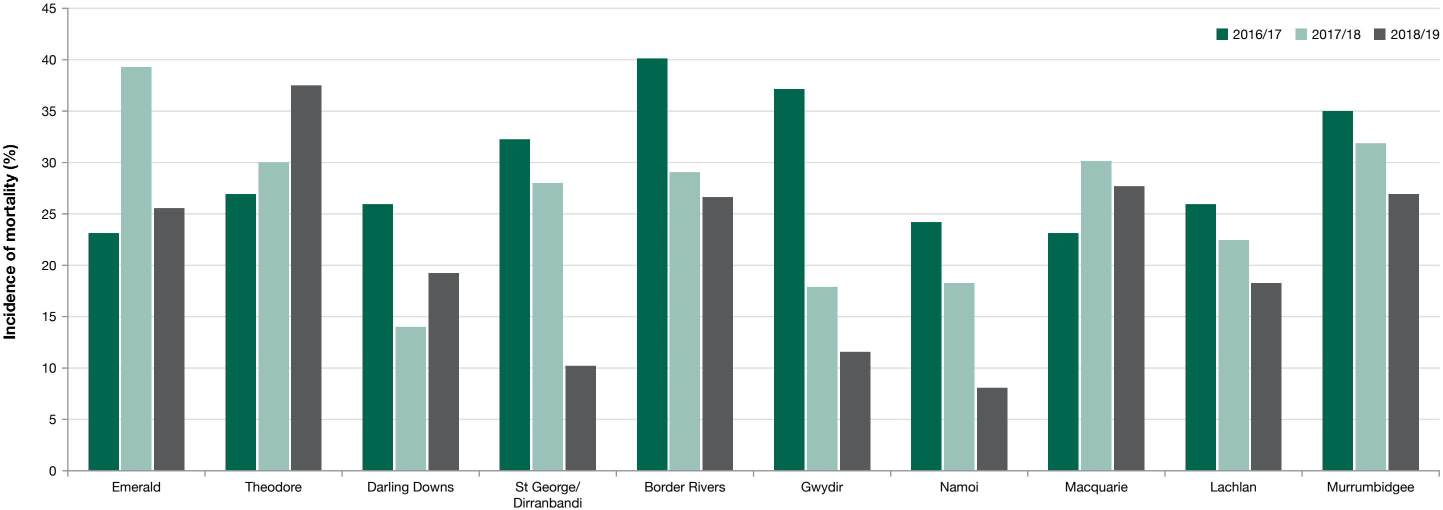


Figure 4.3: Seedling mortality of cotton over three seasons as recorded in early season cotton surveys (Smith, Queensland Department of Agriculture and Fisheries, 2020).

SEEDLING MORTALITY

The term seedling mortality is used to describe the difference between the number of seeds planted per metre of row and the final stand per metre. It includes losses due to non-germination of the seed, the impact of sub-optimum environmental and seedbed factors occurring during the establishment period, physical problems such as fertiliser or herbicide burn and seedling death both pre and post-emergence due to biotic factors (disease and soil insects predominantly). In many situations, it is difficult to apportion the relative contribution of each of these components to the final result.

The level of seedling mortality varies from year to year and also on a regional basis. It is important to factor seedling mortality into your planting rate decisions. Figure 4.3 gives a broad indication for regions, but seedling mortality will vary from field to field across a farm depending on varying conditions including field history, seedbed preparation, disease pressure, temperature, stubble level and establishment method. Seedling losses as a result of diseases and soil insects can be significantly reduced when the seed has been treated with VIBRANCE® COMPLETE and CRUISER®.

IMPORTANT CONTRIBUTORS TO SEEDLING MORTALITY

Environmental factors

Cool soil temperatures influence the rate of root and shoot growth. Slow growth uses up seed energy reserves (the seedling relies on seed reserves until the first true leaf is functioning) and also makes the seedling more vulnerable to attack from pathogens and soil insects.

It is evident that very high soil temperatures also impact on early seedling growth and survival. Growers need to familiarise themselves with predicted soil and air temperature trends for the week(s) ahead and plant according to the 'green light' recommendations (refer to Chapter 3: Temperature effects on planting).

Seed bed factors

Poor soil tilth, evidenced in cloddy unconsolidated beds containing incorporated undecomposed trash, mainly impacts on moisture movement to the seed. Soil water in the planting zone can disappear quickly when pre-watered or watered up and soil contact with individual seeds for water transfer will be poor. The solution lies in early bed preparation and extra passes at the ideal moisture content. Poorly consolidated beds can result in the seed being more prone to sinking when watered up, impacting on plant establishment due to issues related to excessive seed depth.

Stubble, especially large undecomposed pieces mixed in the bed or ending up in the planting trench, affects seed soil contact and hence moisture uptake and makes the seedling more vulnerable to disease. The problem is lessened by smashing up stubble effectively and incorporating it early.

Lack of oxygen, most commonly occurring when rain happens within a couple of days of watering up, or a continuous spell of rain on soil close to field capacity, can cause a high level of mortality on germinating seed. Close monitoring of rain forecasts and even adjusting depth of sowing can lessen the likelihood of this damage.

Certain soils, due to their inherent sand/silt ratio are very prone to crusting, after even minor rainfall events. The inability of the seedling to push through the crust exhausts its energy reserves and makes it vulnerable to soil pathogen and insect attack.

Remnant levels of residual herbicides from previous cropping or fallow weed control applications can be taken up by young roots, slowing

seedling growth, with all the consequent problems, or even killing seedlings. The same scenario can be caused by nitrogen fertiliser which due to its placement or timing has produced high levels of ammonia in the seedling root zone, burning the root tissue.

Biotic agents

A range of soil fungi exist in the soil, ready to attack young cotton seedlings.

The main soil-borne pathogens found across cotton growing regions are:

- ***Pythium spp.*****:** usually cause soft rot and stem collapse, leading to seedling death.
- ***Thielaviopsis basicola*****:** pathogen causing black root rot. This disease generally causes destruction of the outer layer of the root, leading to blackening of the root structure. It results in poor, stunted growth and also weakens the seedling exposing it to attack from other pathogens such as *Pythium* and *Rhizoctonia*.
- ***Rhizoctonia sp*****:** Cause sunken red/brown lesions on the lower stem and roots leading to poor/stunted seedling development.

The survival and development of most of these pathogens is favoured by cool, wet soil conditions. Avoiding planting into conditions that favour these seedling diseases will give you a greater chance of getting a better, stronger establishment.

For more information on these and many more diseases visit **www.cottoninfo.com.au/disease-management**.

CHAPTER 5: PLANTING CONSIDERATIONS

PLANTING POPULATION AND SEEDING RATE

When determining the optimal plant population, it is important to consider:

- Soil type and condition.
- Irrigated or dryland production system.
- Soil water holding capacity - planting into moisture, watering up or pre-irrigating.
- Long term average yields - based on area with plant population rates.
- Germination rates.
- Seedling mortality - disease and insects.
- Rainfall and temperature (soil temperature and forecast air temperature).
- Row spacing.

CSD recommends a plant stand of 10-12 plants per metre established for irrigated conditions in Central and Northern regions; and 12 plants per metre established in Southern regions. The recommended plant stand for dryland cotton is 6 to 8 plants per metre established.

BT COTTON TRAITS

The introduction of varieties containing Bt insecticide traits (Ingard®, Bollgard® II, Bollgard® 3) has led to a noticeable change in some plant growth characteristics, due to significantly less tipping out and also much higher levels of early fruit retention.

Over the past 20 years, CSD has carried out numerous plant stand trials, both in irrigated and dryland fields to assess yield, fibre quality and plant growth differences across a wide range of plant stands.

Most of these have been small plot replicated trials, harvested with single row plot pickers and treatment samples ginned through research gins for turnout per cent and fibre quality analysis. The assistance of the CSIRO cotton plant breeding team in harvesting many of these trials and Dr Warwick Stiller's analysis of the data is gratefully acknowledged.

PLANT STAND RECOMMENDATIONS FOR CONVENTIONAL VARIETIES

CSD have conducted numerus plant population trials in recent years to look at the optimum plant stand for maximum yield. Overall findings were that growers should aim to have 10 to 12 established plants per metre.

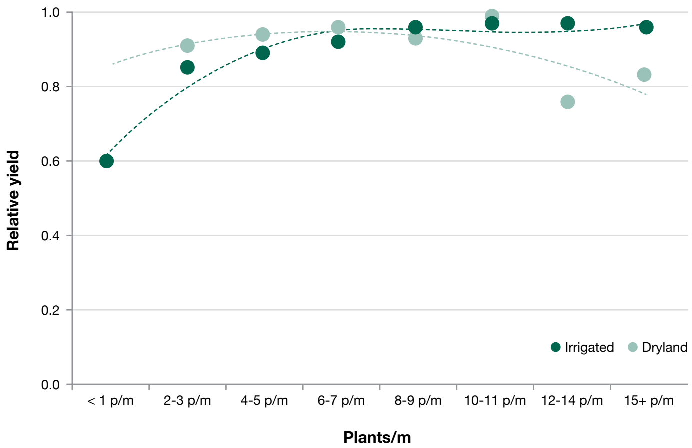


Figure 5.1: Summary of CSD plant population trials (21 irrigated and 9 dryland trials).

The yield trend has been reasonably similar across most of these trials, despite them being grown across a wide spread of locations, experiencing varying seasonal conditions and using a range of cotton varieties.

In irrigated fields, plant stands of 4 to 5 plants/m and less have consistently produced lower yields. In almost all of the 23 irrigated trials, the highest yield has come from a stand somewhere in the 10 to 15 plants/m range. The yield response illustrated in Figure 5.1. shows the relative yield across the population range after combining the data from all these trials.

To improve the relationship, the data has been grouped into ranges of stands rather than individual stands, which results in more trials contributing to each point on the graph. An important finding from these irrigated trials is that there has been no indication of a yield penalty associated with higher stands up to 15 plants/m.

This difference from plant stand response with conventional varieties could relate to higher earlier fruit retention having an effect on root development. Alternatively, the different plant structure with most mature bolls concentrated on the plant main stem and much less on vegetative branches initiating from tipping out may be a factor.

While fewer trials have been conducted in dryland situations the same general yield response is evident, although the data does fluctuate more due to the greater extremes dryland crops experience. In most trials, the best dryland yields have come from plant stands of 6 to 10 plants/m, regardless of row configuration. Lower stands of 3 to 5 plants/m and higher plant stands greater than 12 plants/m are penalised for yield in most situations due to poor plant stand uniformity or competition.

A cotton plant will compensate for any gaps in the plant stand by using its ability to produce more fruiting sites along the fruiting branch. This ability will help to increase yield under a ‘gappy’ plant stand. However, it will delay maturity which will influence micronaire and can also delay harvest.

CSD has conducted numerous trials over a number of years to look at the plants’ ability to compensate for row gaps and see what the ideal plant populations are, relative to circumstances.

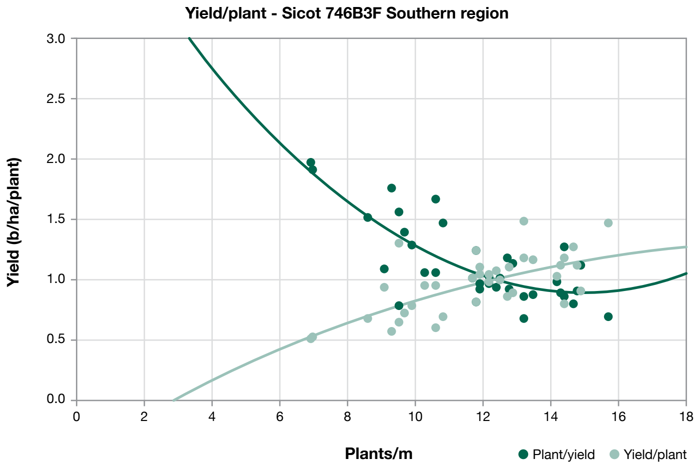


Figure 5.2: Southern region yield per hectare and yield per plant is optimised at around 12 plants per square metre.

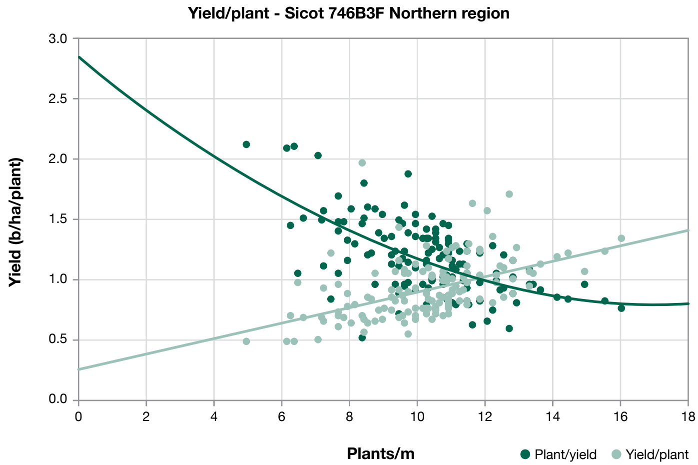


Figure 5.3: Nothern region yield per hectare and yield per plant is optimised at around 10 plants per square metre.

Current recommendations are:

- Approximately 10-12 plants per metre established is ideal for warm growing areas (north of Dubbo, NSW).
- Approximately 12 plants per metre established is ideal for cooler growing areas (south of Dubbo, NSW). This is due to the fruiting positions being set closer to the main stem with very few 3rd and 4th positions, which can take longer to mature and can cause significant issues associated with lower micronaire.

Low plant population can result in issues when something goes wrong. Populations that have skips or gaps, with greater than two 50 cm gaps in five metres can have reduced yield potential, as plants struggle to compensate for these gaps. The same can be said for double-ups with two seeds being planted on top of each other. Both seedlings compete against each other for resources and usually neither plant succeeds in reaching full potential. It is important that plant stand is uniform. Adjust seeding rates to compensate for equipment, time of planting (temperature) and soil conditions. Crop establishment is the most critical phase for achieving the highest yield. Poor preparation will lead to setbacks, which is difficult and expensive to recover from.

ROW SPACING

Generally, we see cotton grown on variants of one metre (40 inch) row spacings. In southern growing areas, row spacing is often narrowed down to 90cm (36 inch) and even to 75 cm (30 inch). These row spacings have been inherited from corn and vegetable programs. Wider row spacings such as 1.5 m (60 inch), 2 m (80 inch) and double skip (two rows in, two rows out) are often used in dryland situations or where water is limited. The aim of the wider row spacing is to maximise the water use efficiency of the crop.

Plant establishment survival (mortality percentage) will vary from region to region and can vary from field to field, based on differences in soil types/conditions.

Table 5.1: Plants per metre of row, plants per hectare.

	Row Spacing		
Plants/m	**30 inch (75 cm)**	**40 inch (1 m)**	**60 inch (1.5 m)**
10	133,333	100,000	66,660
12	160,000	120,000	79,992
14	186,667	140,000	93,324
16	213,333	160,000	106,666
18	239,999	180,000	119,988
	Plants/ha		

Table 5.2: Examples of planting rate calculations.

Example	**Poor soil conditions represent cool air temperatures for the week after planting, usually back to back with a field score of 3 to 5 and a low soil temperature (<14°C)**	**Good soil conditions represent rising warm air temperature post sowing, usually a fallow field with a field score of 2 or above and a warm soil temperature (<16°C)**
Desired plant stand	• 10 plants/m • 100,000 plants/ha	• 10 plants/m • 100,000 plants/ha
Divide by estimate plant survival	• 60% (40% establishment mortaliy) • 100,000 / 0.60 = 166,666	• 80% (20% establishment mortaliy) • 100,000 / 0.80 = 125,000
Divide by the germination percentage of your seed	• 89% • 166,666 / 0.89 = 187,265	• 89% • 125,000 / 0.89 = 140,449
Your seedling rate	• 187,265 seeds/ha • 18.7 seeds/m	• 140,449 seeds/ha • 14.0 seeds/m
Divide by seeds/kg for your variety	11,500 seeds/kg	11,500 seeds/kg
kg/ha required	187,265 / 11,500 = 16.3 kg/ha	140,449 / 11,500 = 12.2 kg/ha

REPLANTING

The decision to replant comes down to whether it is more likely to achieve better results with the current planting or by replanting.

It is desirable to have 8 to 10 plants (10 to 12 plants in cooler areas) per metre of row, distributed along the row as uniformly as possible. Potential yield declines as planting is delayed (refer to Figure 5.5).

An inadequate plant stand generally results in a decline in yield and also a decline in maturity of the crop. Cotton plants will compensate for gaps in the crops, but the delay in maturity will start to become an issue as these plants around the gaps take longer to mature, compared to those with a uniform plant stand. This is particularly important in southern growing regions.

Factors to consider with replanting

Before you consider replanting, it's important to understand the issues that caused low plant stand. You will need to be confident you can overcome these issues before you replant, or they will likely happen again.

Before you replant, consider:

- **Replanting date** - be aware of when yield potential will start to decline. Consider the micronaire period, especially in the cooler areas. Not only will yield decline but you may not be able to mature the fibre. Visit **www.faststartcotton.com.au/tools-and-calculators** to access the Replant Calculator.
- **Insects** - will damage by wireworms, thrips, or other pests reduce the stand further?
- **Weeds** - will a low population or 'gappy' plant stand encourage a weed problem?
- **Disease** - will Rhizoctonia, Pythium or black root rot reduce the stand further and are the current seedlings still being affected by disease?
- **Hail damage** - will the seedling regrow?
- **Herbicide damage** - has rain washed residual herbicides into the root zone?
- **Water** - will a flush help to wet the bed to germinate dry seeds or waterlog the seedlings?
- **Temperature** - what is the outlook? Is the soil temperature above 14°C, and do you have a rising temperature plane for the following week? (Refer to traffic light for planting temperature).

Figure 5.4 demonstrates the relative yield potential of plant stands that are variable or non-uniform compared with a uniform stand. A plant stand with high variability is described as one having two or more gaps greater than 50 cm in length every five metres of row. The data also shows that five to ten plants per metre of row has the best yield potential. A variable stand will reduce yield for all plant populations.

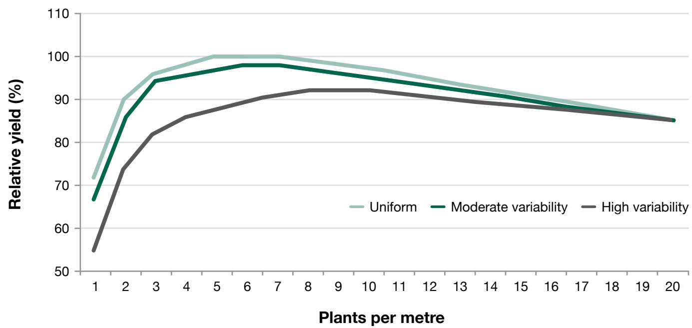


Figure 5.4: Relative yield potential at a range of plant stand uniformities (Constable, CSIRO, 1997).

Planting date will have different yield potential for a range of growing regions. Figure 5.5 and figure 5.6 shows that sowing to mid-October has the best yield potential for most locations. For cooler locations, yield potential will decline more rapidly for later sowings than in warmer locations (narrow planting window). In some situations, it might be better to run with the stand you have because replanting may not achieve the desired yield due to season length and could cause issues related to maturing cotton fibres and low micronaire.

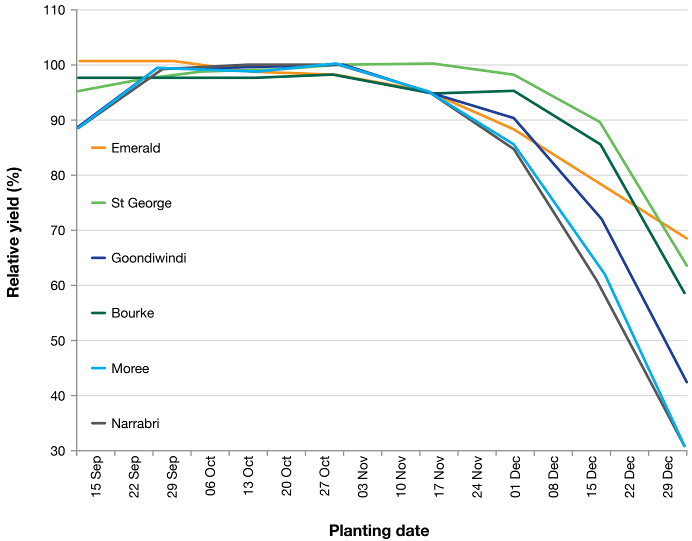


Figure 5.5: Relative yield potential for differing planting date and regions (hot and warm regions).

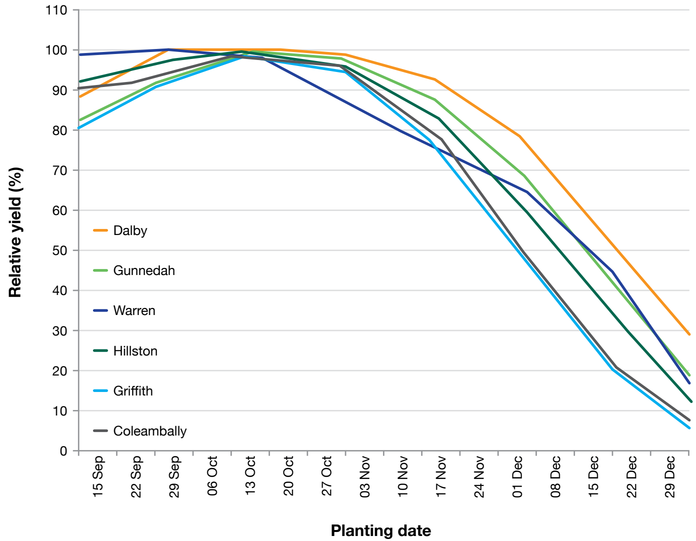


Figure 5.6: Relative yield potential for differing planting date and regions (cool and southern regions).

COTTON PLANTING RATE CALCULATOR

The cotton planting rate calculator (**www.csd.net.au/planting-rate-calculator**) can assist in determining the planting rate required in order to achieve a desired plant stand. There are a number of factors that need to be considered in order to determine this, namely:

- Variety
- Field conditions
- Disease levels of planting region and individual fields
- Establishment method
- Seed germination percentage
- Soil temperature at planting
- The 7-day forecast

It is important to note that all of these factors will influence the calculated seeding rate required to achieve an adequate plant stand. Therefore, it is important that each field is treated as a separate operation and the calculator is used as a tool in the decision making process.

Table 5.3: Comparing the extremes of low and high plant population on cotton plant growth and management.

Low plant population	High plant population
• Plants will have a much wider spread as they grow into the gaps. • Plants may fruit earlier, but be later in maturing. • More fruit concentrated on vegetative branches and closer to ground level. • Plant cut out will be delayed. • Decrease in picking efficiency. • More difficult to control plants in post-harvest operations e.g. root cutting.	• Plants will be taller, although more compact and with a more even fruit distribution. • Plants will put on more vegetative nodes, delaying fruiting. • More fruit concentrated on the main stem of fruiting branches. • Plants will cut out earlier. • Increase in picking efficiency. • Easier to control plants for post-harvest removal.

PLANTING

Although cotton does have an ability to compensate for gaps or unevenness of plant stand, it is critical to achieve plant stand uniformity to assist crop management through the season. Precision planters allow for even seed spacing and a uniform seed depth. Press wheels enable good seed soil contact to be achieved and there is also the opportunity to additionally apply starter fertiliser, insecticides or fungicides through various attachments.

PLANTER SPEED

One of the keys to plant stand uniformity is planter speed. The aim should be to plant with precision, not speed.

CSD has conducted planter speed trials to assess the effect on establishment of commercial planters at varying speeds. Sites varied in soil type, moisture, rotations, disease and insect pressure and weather conditions, with locations from Southern NSW to Central Queensland. The only variable in each trial was speed.

Each area had its own different seed drop (seed planting rate) - Figure 5.8 illustrates the percentage loss from the initial seed drop. For example, if the treatment was planted at 10 seeds/m and only 5 plants established for 10 km/h, this would represent 50 per cent establishment for 10 km/hour.

Results from the trials showed an ideal plant speed of around 8 to 10 km/hour. The average population decreased when the planter sped up past 10 km/h, while the percentage increased from 4 km/hour to 8 km/hour.

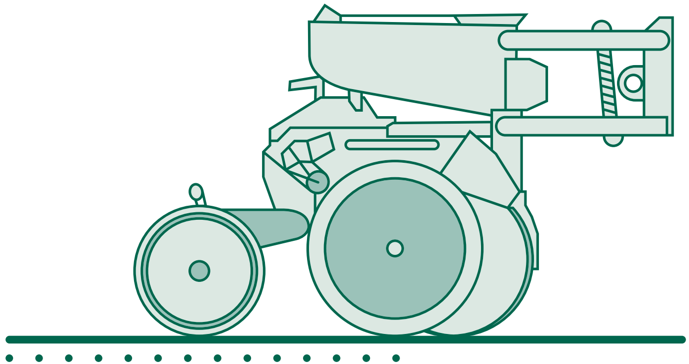


Figure 5.7: Ideal seed placement, uniformly spaced and at a uniform depth.

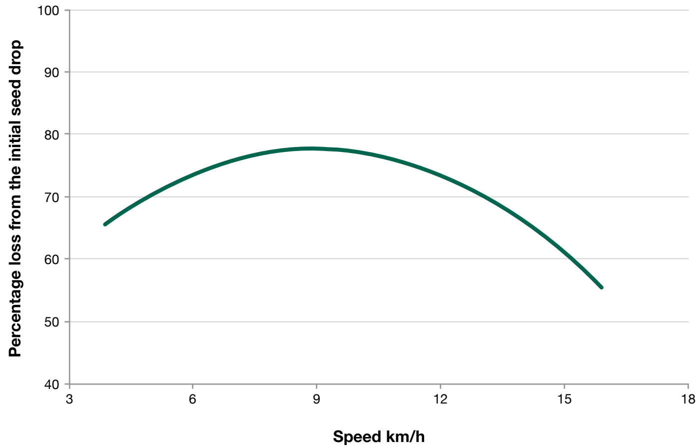


Figure 5.8: Effect of planting speed on establishment percentage.

PLANTING DEPTH

The depth you want your seed depends on the method of establishment and soil conditions. Many people use the 'knuckle method' as a quick and easy measurement tool in the field (Figure 5.9).

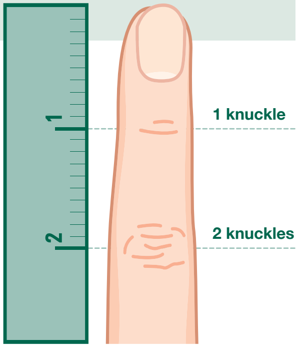


Figure 5.9: The 'knuckle method' of quickly measuring depth in the field.

When planting into moisture, some dry soil above the seed slot is useful to prevent moisture loss from around the seed. If there is too much however, a rainfall event after planting will turn this dry soil into wet soil and increase the difficulty for young seedlings pushing through. Check the consistency of the soil above the seed. If the pressure from the press wheels on the planter is set too high, you can get a compacted zone above the seed and the young seedling will have a tough time emerging. It is important not to plant too deep, as research has show that planting at depths of more than 5cm can compromise establishment, even under ideal conditions.

Table 5.4: Generic recommendation for planting depth based on establishment method.

Establishment method	Ideal depth
Planting into moisture (rain or pre-irrigated)	2.5 and 4.5 cm (1 to 1.5 knuckles)
Planting dry and watering up	2.5 cm (1 knuckle)

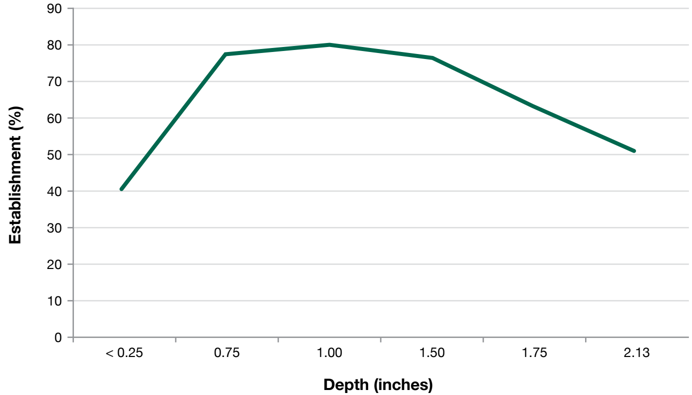


Figure 5.10: Effect of varying planting depths on final establishment (CSD trial, Wee Waa 2014).

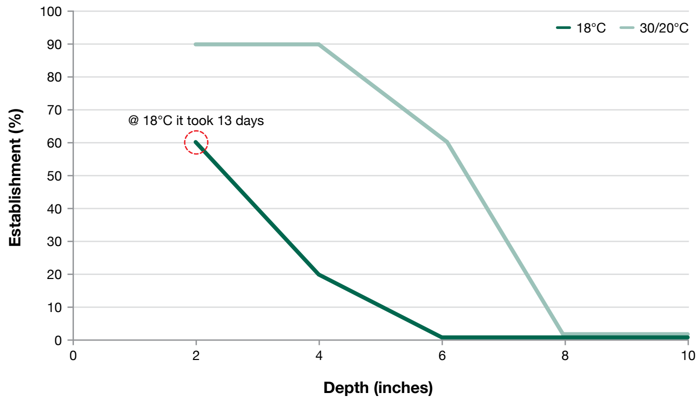


Figure 5.11: Interaction between planting depth and temperature on cotton establishment.

SEED LUBRICANT

Planter manufacturers all recommend the use of talcum powder or graphite for good reason. The use of lubricant improves seed flow and uniformity and also reduces wear rates on plates and boxes. This is the case in both brush type and vacuum planters.

In both laboratory and field tests carried out by CSD, there has been an improvement in seed drop and uniformity. In a bench test with a John Deere MaxEmerge™, the addition of lubricant improved seed uniformity by 7 per cent (see Table 5.5). A trial was conducted under field conditions examining standard John Deere plate, e-sets and hill drop seed plates. Across all planter plate types within the trial, there was an improvement in plant establishment with the use of lubricant.

Table 5.5: Bench top analysis of the benefits of seed drop uniformity through the use of seed lubricant.

	No lubricant	Lubricant
Uniformity	85%	92%

Table 5.6: Effect of the addition of lubricant in the establishment rate and uniformity of planting across three planter plate types.

		Plants/m	Average Gap	St. Dev Average Gap
Standard	No lubricant	11.84	8.48	6.31
	Lubricant	13.00	7.71	4.29
E-Sets	No lubricant	8.78	11.43	6.31
	Lubricant	11.34	8.95	5.51
Hill drop	No lubricant	6.72	15.08	13.31
	Lubricant	6.90	14.53	13.50

CHAPTER 6: ESTABLISHMENT METHOD

There are many different methods to establish a cotton crop, and a grower should assess their options by asking the following questions:

- Has rain fallen in the previous two weeks and is this enough moisture to plant on?
- How much water is available for the season and is there enough to pre-irrigate or water up?
- What sort of soil conditions exist? For example, a rough seedbed with large aggregates may need pre-irrigation to break the soil structure down.
- Is flushing up going to cool the soil and impact on plant establishment?

Each establishment method has advantages, disadvantages and limitations to consider (see table 6.1) - for example, ordering water which takes three weeks to arrive will impact planting timing.

Both pre-irrigated and watered-up establishment methods, the main consideration is uniformity of moisture. If in doubt, increasing the planting rate will compensate to create a more uniform plant stand.

PLANTING DRY AND WATERING UP

This method has advantages in hot climates, as it cools the soil and crop establishment is rapid. When planting dry, it's very important to be aware of the consistency of the seed bed. A poorly consolidated (or cloddy) hill can collapse and crack when the water hits it and can drop the seed down to greater depths, resulting in poor or variable establishment. This is especially important for crops coming out of corn or sorghum.

Planting can be followed by an over-the-top application of Roundup Ready® Herbicide, targeting newly emerged weeds.

PRE-IRRIGATION

Consider pre-irrigating when there is a large seed bank of difficult to control weeds and the soil is very dry and temperatures are high. Planting any shallower than 2.5cm doesn't allow the plant the chance to scrape off the seed coat at germination and the growth of that plant will be quite slow until the coat is thrown off.

If the beds are too wet at planting, you end up with a shiny, smeared planter slot which is very difficult for the young roots to penetrate. The result is often young seedlings dying from moisture stress, even if there is plenty of moisture down below.

PLANTING ON RAIN MOISTURE

Although the common method for dryland crops, many irrigators also aim to establish their crop on rain moisture to save water on pre- irrigation or watering up. There are a number of factors that will improve the likelihood of success with planting into rain moisture and some cautionary points for those attempting it on irrigated country.

STUBBLE

The presence of standing stubble will increase the chance of seedling survival in moisture planting situations dramatically, because it increases the amount of infiltration and hence moisture available to the seedling. It also reduces surface evaporation and protects the young seedling from the elements. Be aware that too much stubble that can have a negative impact at planting time with stubble causing hair-pinning and blocking of planter discs.

BARE FALLOWS IN IRRIGATION COUNTRY

A bare fallow can be a risky practice and often results in replanting if conditions are not ideal. Fields hilled for irrigation are designed to shed water, as illustrated in Figure 6.1, so you need to check whether moisture has infiltrated to any depth into the seed zone. In cloddy seedbeds the fine materials may be wet but the larger clods may be dry and may draw moisture away, drying the seed bed.

Check across a field to see whether the rainfall has been uniform. When planting, check soil moisture levels in the seed zone regularly. Planting depth may need to be adjusted throughout the planting operation due to movements in seed zone moisture.

In furrowed fields, rainfall will usually not fill the soil profile as well as irrigation, so after emergence soil moisture levels and the vigour of the young seedlings need to be monitored closely. In worst case scenarios an early first irrigation may be required.

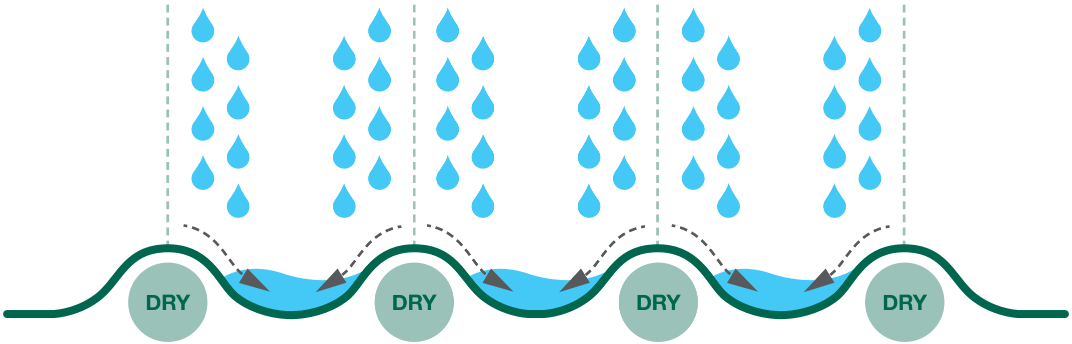
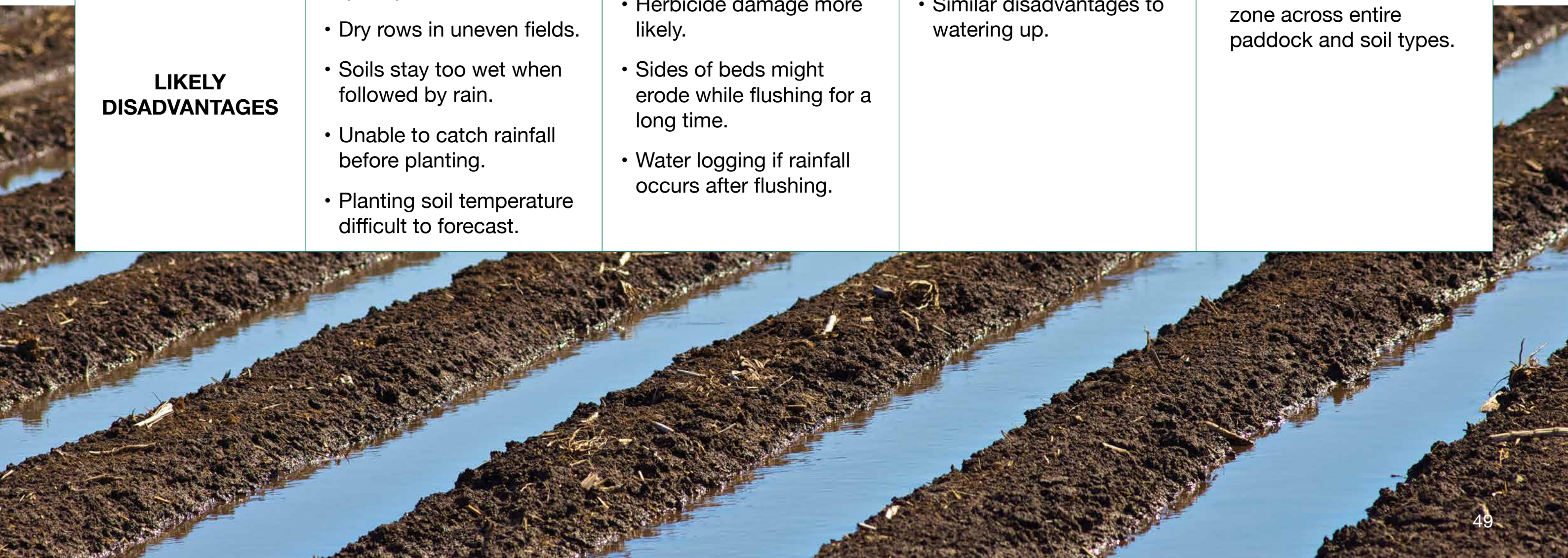


Figure 6.1: In conventional one metre hills the fallow rainfall sheds from the top of the hill to the furrow and out of the field.

Table 6.1: Advantages and disadvantages of different options for the first irrigation. Adapted from WATERpak, 2012.

	Pre-irrigation (prior to planting)	Watering up (after planting)	Pre-irrigation and late watering up	Establishing on rainfall moisture
LIKELY ADVANTAGES	• No time pressure to apply water. • In heavy clay soils, water losses can be less than keeping it in farm.	• Potential to take advantage from pre-planting rain event. • Easier to plant, especially whe beds are not 100% even.	• Helps in fixing plant stand problems. • Can give the crop the necessary 'boost' to get going after a slow start. • In cooler areas, allows the soil temperature to increase to eliminate cooler conditions from the watering up irrigation.	• Significant saving in use of irrigation water reserves.
LIKELY DISADVANTAGES	• Soil drying out too quickly. • Dry rows in uneven fields. • Soils stay too wet when followed by rain. • Unable to catch rainfall before planting. • Planting soil temperature difficult to forecast.	• Higher disease pressure. • Herbicide damage more likely. • Sides of beds might erode while flushing for a long time. • Water logging if rainfall occurs after flushing.	• Likely to use more water. • Similar disadvantages to watering up.	• Non uniform moisture distribution in the seed zone across entire paddock and soil types.



SOIL TEMPERATURE

Soil temperature at planting and the following air temperature regime played an important role in cotton establishment. Trials planted later in the planting window when soil temperatures were higher showed an improvement in the ratio of establishment of Sicot 746B3F to Sicot 714B3F (Figure 6.2).

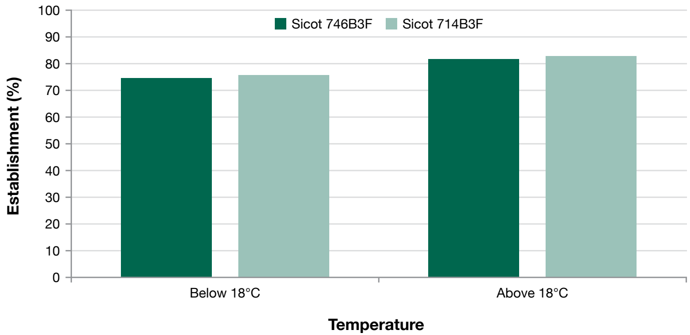


Figure 6.2: Effect of planting time and associated soil temperature conditions on establishment percentage. Namoi Valley 2016-19.

Analysis was conducted examining the influence of back-to-back and fallow conditions and establishment method impacting varietal stand in the CSD variety trials. There was no difference in the ratio of establishment between Sicot 746B3F and Sicot 714B3F due to field preparation. For both varieties it was lower in back-to-back situations than in fallow (Figure 6.3).

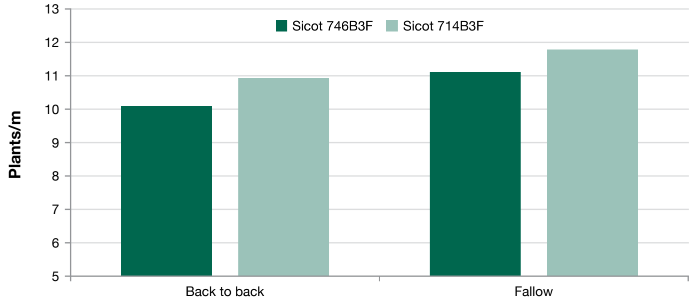


Figure 6.3: Effect of field preparation on variety establishment.

Watering up resulted in a marginally closer relationship between the two varieties than either pre-irrigation or planting on rain moisture (Figure 6.4).

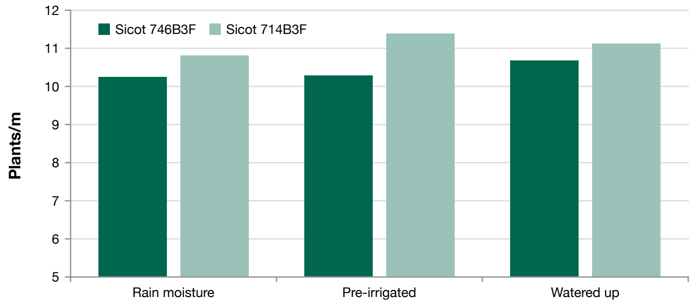


Figure 6.4: Effect of establishment method on variety establishment.

CHAPTER 7: ESTABLISHMENT TO FLOWERING

THE IMPORTANCE OF WEED CONTROL

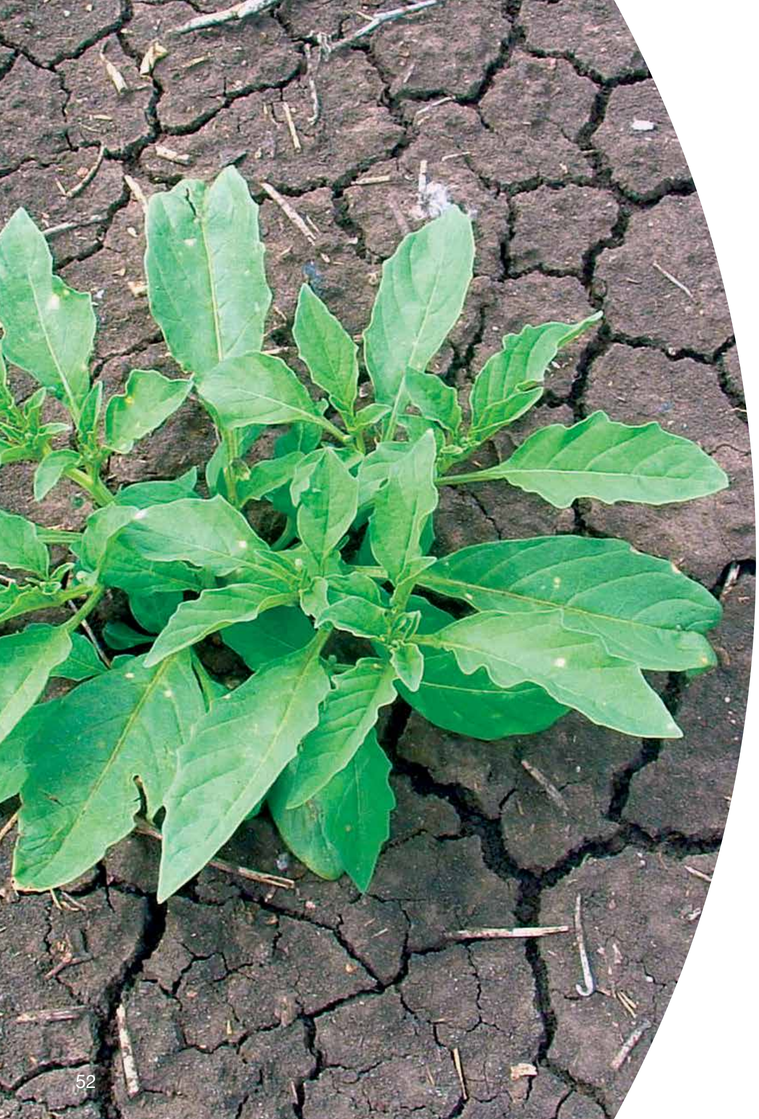
Integrated weed management (IWM) is the industry's strategy for timely control of weeds during and between cotton crops. Timing is one of the keys to successful intervention of weed control and can influence the effectiveness of the type of weed control method.

Weeds and volunteer cotton compete for water, sunlight and nutrients in a cotton crop. If weeds are not controlled, yield can be compromised due to competition. Weeds can also contaminate cotton lint during picking, and this may result in a downgrade of fibre quality.

Volunteer cotton growing between pickable rows can cause significant issues at picking with blockages, as well as reducing yield. Volunteer cotton plants provide a green bridge for insects and diseases. Insects and diseases that inhabit weeds and volunteer cotton gives both a competitive advantage over the emerging primary cotton crop during early growth stages.

There are number of ways of controlling both weeds and volunteer cotton:

- Pre-irrigation is an effective method of germinating volunteers and weeds prior to planting. Weed control following pre-irrigation can be with cultivation or herbicide application. This will help to reduce the volunteer and weed population. Where possible use two non-glyphosate weed control tactics in fallow and two non-glyphosate tactics in crop to target no survivors. These may be other modes of action or timely cultivation. Remember, 2 + 2 and 0 survivors.
- Pre-emergent residual and lay-by herbicides are an essential and necessary component of the herbicide program. Pre-emergent and lay-by herbicides are a good tool to support glyphosate sustainability and longevity.
- The keys to successfully keeping weeds and volunteer cotton under control are to use all the tools available. **Do not rely on just one tactic alone!**



THE CRITICAL PERIOD FOR WEED CONTROL

Early in the cotton growing season there is a critical time where weeds, if controlled when they are small, will not impact on crop yield potential.

The critical period is defined by the type and density of weeds, potential crop yields, the cost of weed control and the economic threshold the grower chooses. The critical period is defined in Table 7.1 for large and medium sized broadleaf and grass weeds in high yielding irrigated cotton, and lower yielding or dryland crops.

This method focusses on the management of Roundup Ready Flex® cotton crops because it is the most common grown in Australia, but is readily adapted to conventional crops as well.

WHAT CONSTITUTES A LARGE, MEDIUM BROADLEAF OR GRASS WEED?

- **Large broadleaf weeds:** Weeds which are larger than the cotton plant at maturity;
  - Noogoora burr group
  - Thornapples
  - Sesbania and budda pea
- **Medium broadleaf weeds:** All other weeds can be included in this group, including volunteer cotton
- **Grasses:** Includes the grasses and other grass like species, such as nutgrass

Roundup Ready Flex® technology offers flexibility in control of weed infestations quickly without injuring the young cotton crop.

THE CRITICAL PERIOD FOR WEED CONTROL

Adapted from "Using the critical period for weed control in Roundup Ready Flex Cotton", Charles, Taylor, Farrell, NSW DPI.

Table 7.1: The critical period for weed control. Adapted from 'Using the critical period for weed control in Roundup Ready Flex® Cotton' (Charles, Taylor, Farrell, NSW Department of Primary Industries, 2008).

	Weed density (weed/m row)	Critical period (day degrees)			
		1% threshold (high yield potential - irrigated)		3% threshold (lower yield potential - dryland)	
		Start	End	Start	End
Large broadleaf weeds	0.1	111	210	-	-
	0.2	111	310	178	222
	0.5	110	507	177	368
	1	110	678	175	508
	2	109	827	170	653
	5	105	959	158	798
Medium broadleaf weeds	0.1	111	172	-	-
	0.2	111	249	-	-
	0.5	110	416	-	-
	1	110	583	175	227
	2	109	748	170	331
	5	105	913	158	517
	10	101	987	142	661
Grass weeds	2	-	-	-	-
	3	123	141	-	-
	5	122	178	137	148
	10	121	259	136	206
	20	120	382	132	299
	50	115	600	124	477

EARLY SEASON INSECT PESTS

A number of insects are active feeders on young cotton plants attacking leaves, growing tips and squares. Because of the complexity of relationships between various insect groups (pest and predator), a certain level of damage can be tolerated without concern about yield loss or crop delay. Longer growing season areas, where there are more day degrees available for the crop to grow and compensate, can tolerate higher levels of damage than short season areas. Monitoring of damage and an understanding of the individual pest dynamics (i.e. ratio of adults to nymphs/larvae) is important in formulating control decisions and also what products to use. Insects from four key groups are frequently present in the early growth stages of the crop.

The main early season pests in cotton include:

- Thrips
- Mirids
- Tipworm
- Aphids

For more information on these insect pests, including the symptoms of their damage and guidance around herbicide application thresholds, consult the **Cotton Pest Management Guide (CRDC and CottonInfo)**.

MOISTURE STATUS AT FIRST FLOWER (FIRST IRRIGATION)

Soil moisture availability in the lead up to first flower plays an integral role in ensuring the crop enters the flowering period growing well. The timing of the first irrigation is dependent on many variables, such as soil water holding capacity, temperature, rainfall and crop developmental stage.

Water usage of the crop increases in the lead up to flowering and rapidly increases up until peak flowering. Therefore, in many situations the first irrigation plays an important role in setting up the plant for future growth and fruit retention, fibre quality and boll weight. The first irrigation timing is perhaps the most difficult irrigation decision. It is a balancing act between ensuring stored water in the soil profile is fully explored by the developing root system, while not stressing the plant and hindering both vegetative and reproductive development.

Irrigating late will reduce yield potential due to the impact of water stress on plant development. It is difficult to recover the growth needed for supporting fruit growth if water stress has slowed growth. Irrigating too early can predispose the crop to excess vegetative growth and limit root exploration into the soil profile, which can affect the subsequent irrigations. It is important to monitor your crop growth, development, vigour, soil moisture status and root expansion and extraction patterns as well as crop daily water use.

- **As a rule of thumb:**
  - Irrigate at 50-60 per cent available soil water within the root zone.
  - Traditionally in Australian conditions first irrigation occurs between 45-60 days after planting.
- **It is important to:**
  - Check weather forecasts as this will allow for fine tuning of the irrigation decision.
  - Monitor crop node development post squaring for signs of slowing growth.
- **Use of water tools:**
  - C-probes, capacitance probes and IR sensors can be useful in understanding water dynamics in the soil.
  - For more information, consult WATERpak, available via www.cottoninfo.com.au.

FIRST FLOWER RECOMMENDATIONS

At first flower, the water use and nutrient uptake of the crop increases and the management becomes a juggling act to prolong the duration of flowering by minimising crop stress for as long as possible. In the lead up to first flower, assessments can be made on crop progress and adjustments can be made to management to achieve goals.

At first flower, crops should carry between 60 and 80 fruit per metre depending on the plant stand. Higher fruit loads at this time will have a tendency to burden the plant and management will need to recognise this and respond with water and nutrients prior to the boll load slowing crop growth.

TOTAL NODES AND PLANT HEIGHT

The aim is to have the plant growing healthily up to and through first flower. At first flower the aim would be to have in excess of 15 to 16 nodes (six to seven vegetative nodes, eight to ten fruiting branches).

However, caution is warranted not to have the plant growing too vegetatively or excessively. At first flower, plant height is expected to be about 50 to 60 cm, aiming to have a frame that will support a high fruit load during the flowering period. New node vegetative growth rate should not exceed six to seven centimetres per node at this time.

NODES ABOVE WHITE FLOWER (NAWF)

The NAWF measurement is a function of the rate of growth from first square to first flower. At first flower the aim should be to have the NAWF value in excess of eight. High NAWF values can be used as a shock absorber, enabling the crop to better cope with minor setbacks and stress such as a couple of days of hot temperatures.

When it has NAWF less than eight, the crop will need careful management through the flowering period to prolong the reproductive life of the crop. Higher NAWF figures can mean excessive growth, but they should be interpreted in conjunction with fruit load and also season length (location) to see if further management is required to slightly check the plant.

Begin monitoring for NAWF when approximately half the plants have a pink or white flower on a fruiting branch. Count the number of nodes above the highest first position white flower, including the node nearest the terminal with an associated unfurled leaf approximately the size of a five to ten cent piece.

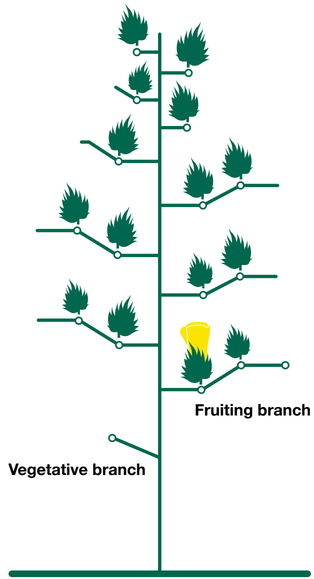


Figure 7.1: Schematic of a cotton plant with nine NAWF at first flower.

NAWF should be monitored throughout the flowering period to help assess the performance of the crop. The longer a crop flowers, the higher the yield potential (subject to season length).

One thing you cannot plan for is the climatic conditions. All you can do is have the plant in the best possible shape to perform to its potential, no matter what the season throws at you. Having a plant conforming to these ideals will ensure that, regardless of seasonal conditions, the crop will be able to absorb and rebound from stress.

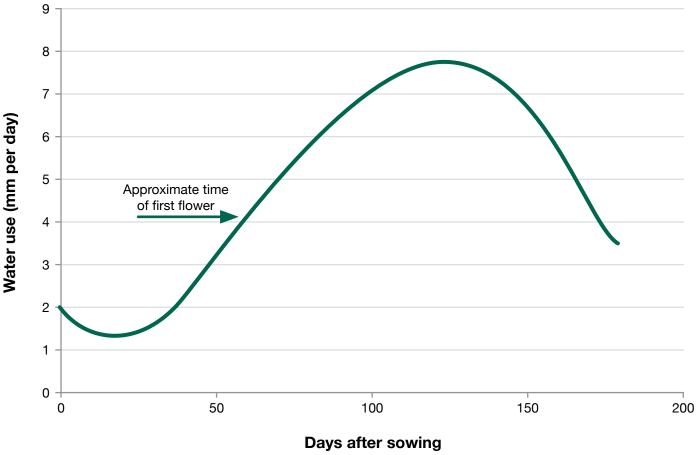


Figure 7.2: Average daily water use of Australian cotton crops (29 crops 7 years).

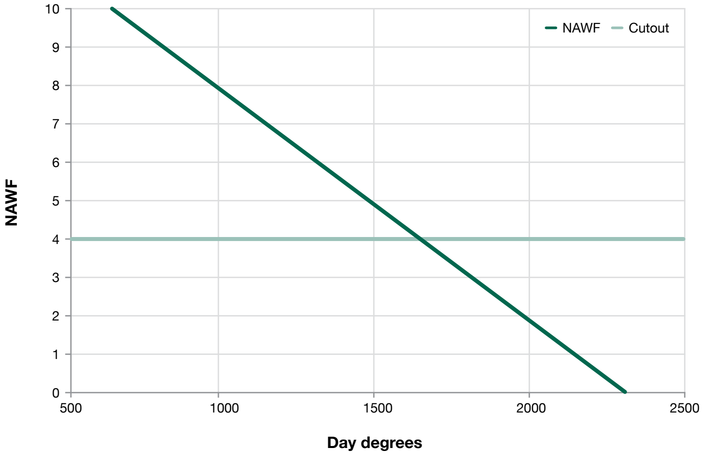


Figure 7.3: Average decline of NAWF for CSD Ambassador Network fields.

COTTON PLANT MONITORING

In order to manage irrigation timing, crop growth rates and targets, it is important to monitor the plant regularly with information on crop progress compared to targets. This will enable specific crop management, and allow for remedial action if required.

PLANT POPULATION

Aim for a plant population of eight to twelve evenly spaced cotton plants per metre row. Uniformity is as important as the plant population because it can impact not only the yield potential, but the growth and development of the young cotton plant.

PLANT HEIGHT AND TOTAL MAIN STEM NODES

Monitoring these is important in determining the growth rate of the cotton seedling and can be used as an early indicator of crop health. Additionally, they are critical in correct growth regulator decisions and rate determinations (see Table 7.2).

EARLY SEASON FRUIT RETENTION

In full season areas the cotton plant is able to compensate for lower first flower retention figures; however in cooler season areas retention levels will need to be adjusted to account for the shorter season length. An understanding of the square retention is important because excessive losses in the lead up to first flower - either due to insects or environmental factors - will impact on insect control decisions.

Data from CSD Ambassador and variety trials indicate that high yielding crops tend to have high retention, i.e. greater than 80% at first flower.

Table 7.2: Key growth parameters at first flower.

Characteristic	How measured	Comments
Plant height (cm)	From cotyledon scars to growth terminal	Target 50-60 cm
No. Vegetative branches (VB)	Cotyledons excluded from count. Straight structures, no scars or squares	Range 4-7 generally
No. Fruiting branches (FB) or squaring nodes (SN)	FB have slight angular change where square attached or scar (square absent)	8-10 at first flower is the target
Total nodes	Uppermost SN is the terminal leaf	Range of 14-18 at first flower
Nodes above white flower (NAWF)	Number of nodes to the terminal node where the WF = 0	8-10 at first flower is target
First position retention (%)	Sum squares present at first position on FB, divided by total potential first positions on all FB	Range from 65-95% at first flower is target

MEASURING VEGETATIVE GROWTH RATE (VGR)

Cotton is a perennial plant and has an inbuilt tendency for vegetative growth to dominate over the reproductive growth phase. The use of mepiquat chloride can assist with improving the ratio of reproductive to vegetative growth at and/or during early flowering, especially in very favourable growing conditions. However, unnecessary or excessive use of the product can be detrimental to final yield.

The use of Vegetative Growth Rate (VGR) measurements can assist with decision making. Measurements should commence as the crop approaches first flower i.e. approximately 12 main stem nodes. The monitoring should continue for the first half of flowering, as rapid increases in growth can occur anytime in this period.

HOW TO DETERMINE VEGETATIVE GROWTH RATE

On at least 20 randomly chosen plants;

1. Measure plant height (as described in Table 7.2)

2. Determine total nodes (as described in Table 7.2)

Carry out the same procedure a week later, and then use the following formula to calculate the VGR, the rate of internode increase (cm/node):

$$\text{VGR} = \frac{\text{This week's height - last week's height}}{\text{This week's total nodes - last week's total nodes}}$$

VGR values greater than 7.5 may indicate a need for the product.

Table 7.3 indicates some of the other growth parameters that will also influence this decision making.

Table 7.3: Growth parameters at first flower that indicate likely mepiquat chloride response. Adapted from 'Management Considerations in Cotton Production' (Kirby, 1996).

Parameter	Mepiquat chloride indicated
Height	> 70 cm
Growth rate	> 2.5 cm per day
Node growth rate	< 3 days per node
Maximum internode distance	> 7.5 cm
Vegetative nodes	> 7
Bottom five retention	< 60%
Top five retention	< 80%
NAWF @ first flower	> 8.5
Weather	Cloudy/rain
Water relations	Excessive

These indicators can be used at first flower to assess where a crop is up to in terms of vegetative growth and whether growth regulation is required. Having only one of these indicators does not necessarily mean growth regulation is required, but having several indicates a likely response to growth regulation.

During flowering it is important to monitor the crop internode growth. Another way of looking at ascertaining where the crop is up to is by looking at the fourth to fifth internode interval from the top of the plant, which gives a good understanding of what the crop is doing. This node represents 90% of its current length. If this node is longer than 7.5cm, look at the previous nodes sixth to seventh from the top and the younger nodes, third to fourth from the top. This will allow a comparison of 9-12 days growth and will help in understanding how the crop is tracking.

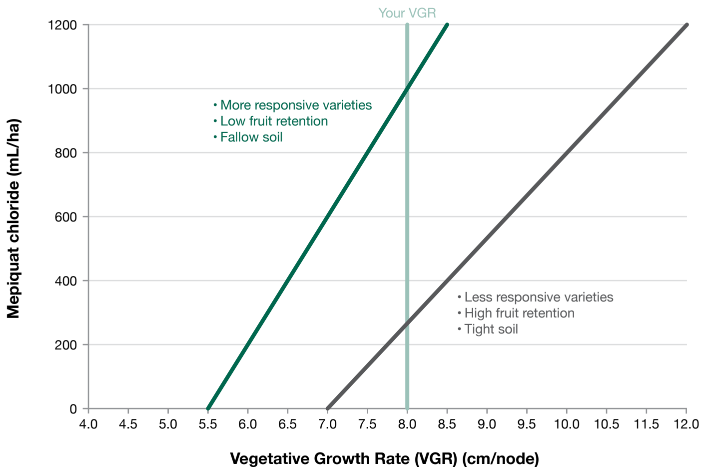


Figure 7.4: The VGR tool incorporating VGR measurements and other crop factors.

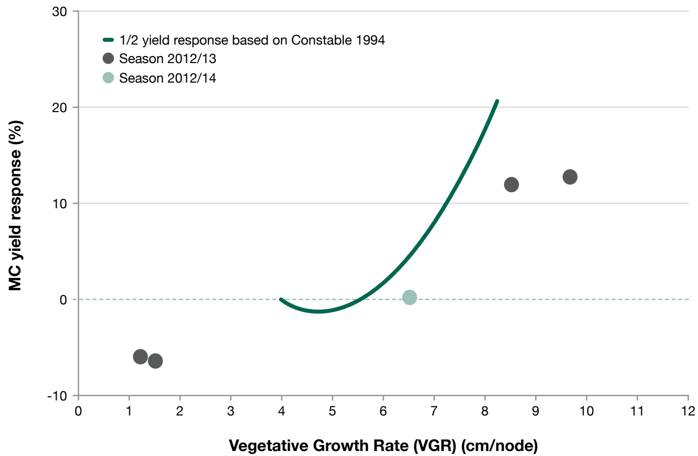


Figure 7.5: Yield response to Mepiquat chloride from non Bt cotton with recent measures in Bt cotton crops (Williams, CSIRO, 2014).

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REFERENCES

CHAPTER 1: PHYSIOLOGY OF EARLY SEASON COTTON GROWTH

- **Figure 1.1:** The effect of heat stress on the physiological processes of the cotton plant. (Bange and Brodrick, CSIRO, 2004).
- **Figure 1.2:** Cotton seed sensitivity to chilling injury through germination and emergence. (National Cotton Council, 1996).
- **Figure 1.3:** A cotton seedling's time to first square under differing average temperature regimes. (Bange, CSIRO, 2014).
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- **Figure 1.5:** The rate of fruiting site development of a cotton plant. (Adapted from Oosterhuis, 1990).
- **Figure 1.6:** In the development of a cotton boll, the fruiting structure goes through three distinct phases.
- **Table 1.1:** Accumulated day degree 'targets' after seed imbibed.

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CHAPTER 3: PLANTING OPERATION

- **Figure 3.1:** Cotton seed sensitivity to chilling injury through germination and establishment. (National Cotton Council, 1996).
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- **In-text reference:** CSD Facts on Friday, Cotton Planting and Establishment: Part 1.
- **Figure 4.1:** The incidence of black root rot of cotton in the 2018-19 season as recorded in early season cotton surveys (Smith, Queensland Department of Agriculture and Fisheries, 2020).
- **Figure 4.2:** Early and late season Fusarium wilt. (Smith, Queensland Department of Agriculture and Fisheries, 2020).
- **Figure 4.3:** Seedling mortality of cotton over three seasons as recorded in early season cotton surveys (Smith, Queensland Department of Agriculture and Fisheries, 2020).

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RESOURCES

CHAPTER 1: PHYSIOLOGY OF EARLY SEASON COTTON GROWTH

- 1532 Day Degree Calculator.

CHAPTER 2: PRE-PLANTING

- Variety Performance Comparison tool: www.csd.net.au/vpc.
- Varietal resistance to disease ranks: www.csd.net.au/disease-ranks.
- Queensland Department of Agriculture and Fisheries: www.daf.qld.gov.au.
- NSW Department of Primary Industries: www.dpi.nsw.gov.au.
- CSD Extension and Development Agronomist contacts: www.csd.net.au/contact.
- AUSlot information: www.csd.net.au/auslots.

CHAPTER 3: PLANTING OPERATION

- Seeds per kilogram by variety: www.csd.net.au/seeds-per-kilogram.
- AUSlot information: www.csd.net.au/auslots.
- FastStart Soil Temperature Network: www.csd.net.au/soil-temperature.
- FastStart tools and calculators: www.faststartcotton.com.au/tools-and-calculators.

CHAPTER 4: SEED TREATMENTS FOR A GREAT START

- Further information on seedling diseases: www.cottoninfo.com.au/disease-management.

CHAPTER 5: PLANTING

- The cotton planting rate calculator: www.csd.net.au/planting-rate-calculator.

CHAPTER 6: ESTABLISHMENT METHOD

- WATERpak: www.cottoninfo.com.au/publications/waterpak.

CHAPTER 7: ESTABLISHMENT TO FLOWERING

- Cotton Pest Management Guide: www.cottoninfo.com.au/publications/cotton-pest-management-guide.
- WATERpak: www.cottoninfo.com.au/publications/waterpak.

Visit **www.faststartcotton.com.au** for more information