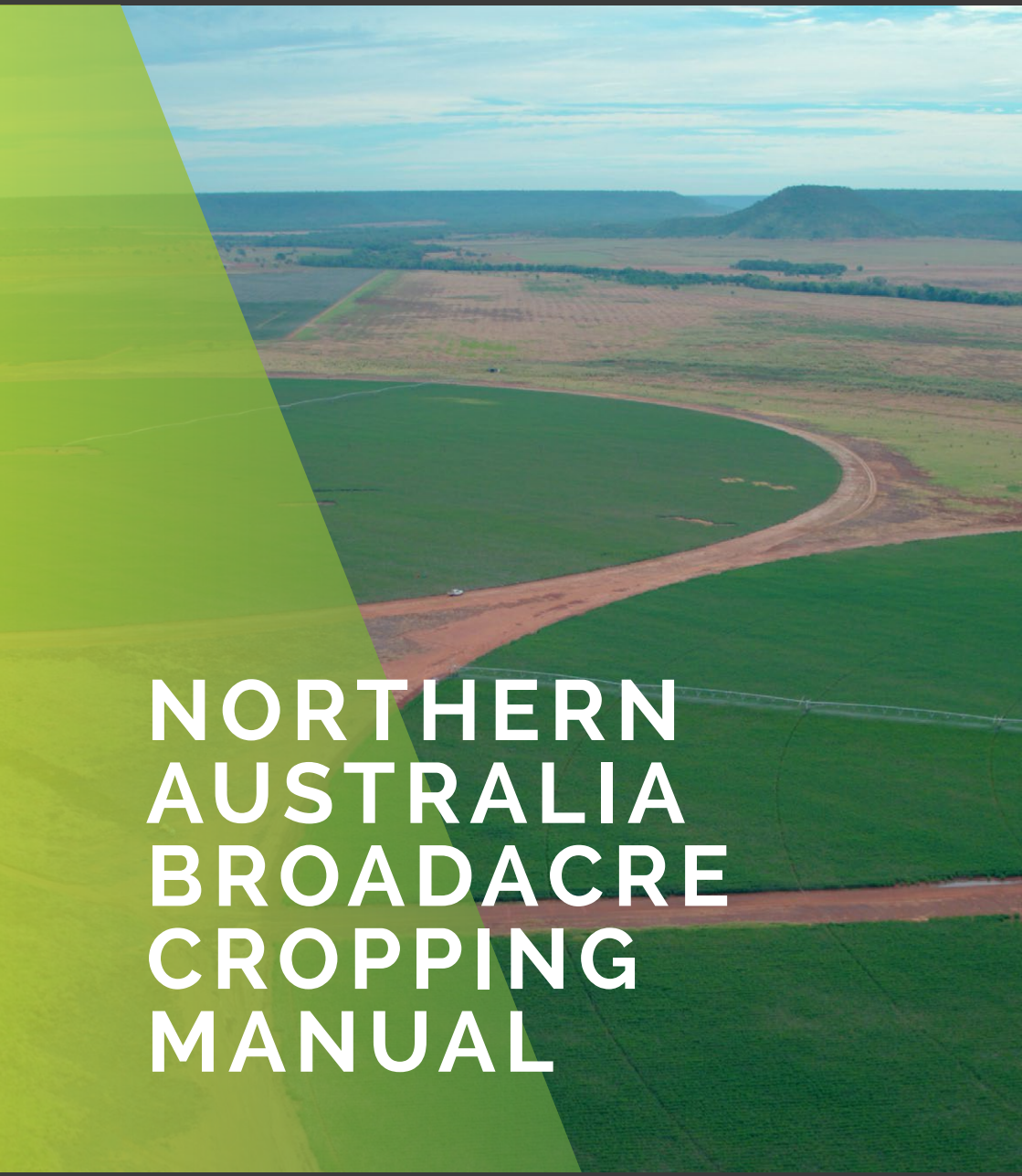


NORTHERN AUSTRALIA BROADACRE CROPPING MANUAL

2022 Edition

NT FARMERS



Northern Australia Broadacre Cropping Manual
2022 Edition

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Northern Territory Farmers Association Inc
T: (08) 89833233
E: admin@ntfarmers.org.au
www.ntfarmers.org.au



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FOREWORD
NT FARMERS ASSOCIATION

The Northern Territory Farmers Association (NT Farmers) represents and advocates for the plant-based industries of the NT. As a peak industry body, NT Farmers promotes agricultural development in the Northern Territory and directly assists growers with a comprehensive range of support services. NT Farmer's mission is to assist the NT plant based agricultural industry reach $1 billion in farm gate output by 2030. Northern Australia, in particular the NT, presents significant opportunities to diversify the agricultural sector from being predominantly for livestock production which represents over 50% of farms in the region. Plant-based agriculture is playing an increasingly important role in the NT's economy, particularly in regional areas.

The development of this grower manual demonstrates the capacity at which the broadacre cropping sector has grown particularly in the NT over the last few years. The production of plant-based agricultural crops is pivotal to the success and long-term viability of the industry in Northern Australia. This manual aims to be a valuable resource tool that supports existing and potential growers to adopt and use 'myBMP' for their emerging farming systems across the north. A focus and emphasis in this manual will be on dryland farming systems seeing the utilisation of the wet season rainfall events with the lead taken from existing resources such as NORpak, CPMG, ORIA and other GRDC manuals.

The NT climate is largely conducive for plant-based agricultural development. The top end of the region is located in a tropical zone, experiencing relatively consistent and sufficient rainfall each year. The NT is in a strong position to increase the cropping of cotton, grains and fodder, while integrating cattle operations. Of these crops, cotton is envisaged to be the most pivotal plant-based agricultural crop for the region. So much so, that crops of cotton are regarded as the cornerstone going forward, incorporating rotations of sorghum, rice, legumes, maize or other high value crops.

Whilst grower interest, land and water resources, and transgenic varieties are key ingredients for a future cropping industry, historical experience from other areas across Australia has shown that new industries have a high likelihood of failure, particularly if not preceded by appropriate R&D that seeks to understand local factors and tailor production systems accordingly.

This first edition of the Northern Australia Cropping Guide aims to deliver the developing industry's findings, highlights, and challenges to date.

Its purpose is to serve as a valuable resource guide for new and emerging farmers and provide a longer legacy for the broadacre cropping industry in northern Australia. The manual documents the knowledge derived from the collaborative work undertaken by industry bodies, partners and pioneer growers, and agribusiness in northern Australia. It also serves as a testament to the diverse research, development, and extension skills of many across this sector.

This guide is a foundational reminder that the journey to developing the north in this modern technological era is just beginning. Adopting innovation and technology can offer opportunities to drive this industry forward.

Simone Cameron
Director of Regions and Projects
NT Farmers Association



SECTION 1.

INTRODUCTION

PART A - Introduction to the Northern Australian Broadacre Cropping Field Manual

Northern Australia, the area north of the Tropic of Capricorn, has long been described as the next agricultural development frontier. Ash et al (2017) write that there has been a succession of public and private initiatives to either promote or initiate intensive agriculture in northern Australia, of which many have met with mixed fortunes, some ending poorly while others succeed and endure. The long-term success stories in broadacre cropping have generally been confined to smaller, dedicated regions such as the Ord River Irrigation Area in Western Australia, the Douglas Daly region in the Northern Territory and the Burdekin region in Queensland. In the last few seasons, however, a nexus appears to be forming between the long-held understanding of the potential for expansion of broadacre cropping in northern Australia, and tangible results in the paddock.

A catalyst for this watershed moment is the emergence of modern cotton as profitable and viable cropping option. Cotton is an anchor crop for rotational cropping systems, and the farming processes used to grow cotton facilitate the opportunity for farmers to produce other crops in rotation; crops that are historically successful and those that are emerging as new options for farmers.

In the past few seasons, there has been an increase in commercial trials, and commercial cropping of cotton and other broadacre crops. Despite the renewed energy and emergence of a new, modern and contemporary cropping industry, the scientific and practical knowledge about how to grow many of these crops in the north of Australia, particularly cotton, is still in its infancy. The unpredictable seasonality of the wet, the unknown threat from pests and disease, and the poorer soils all present formidable challenges.

This is in contrast to the industry in the eastern states, where there is decades of research, practical experience and cooperation among all industry stakeholders has resulted in a body of practical knowledge.

For northern cotton systems, several eminent manuals have emerged, such as NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region (Grundy, Yeates and Grundy 2012), NORpak – ORIA: Cotton production and management guidelines for the Ord Irrigation Area (ORIA) 2007 (Yeates et al 2007) and the annually published Australian Cotton Production Manual (CRDC and CottonInfo). These works set the standard for consolidating and effectively disseminating practical knowledge to the industry.

This manual has been aligned closely in design. It is designed as a repository for scientific, agronomic and practical lessons already learned in northern Australia. It can also be used as a catalyst for new trials and research and to progress to a critical resource for new and established

growers to use in making decisions during everyday farming operations.

The information in this first version of the manual can be categorised into three types:

- existing information from the industry in other parts of Australia that apply generally to the North,
- data and knowledge from historic trials and enterprise locally in northern Australia, and
- information gathered from trial work in the 2019/20, 2020/2021 and 2021/2022 seasons.

As knowledge and understanding about broadacre cropping evolves in northern Australia, so too will this manual. It is designed to be revised and updated as lessons are learned. It will also be used as the vehicle for collaboration by all stakeholders in the north Australian broadacre cropping sector.



PART B: Australian Cotton and Broadacre Crop Industries

The Australian agriculture sector has set an ambitious farm gate value of production target of $100 billion by 2030. Growth in value and volume of the broadacre cropping industry, including the cotton industry and its partner crops, will be critical to achieving this goal.

The Australian broadacre cropping industry is forecast to be worth more than $15 billion in farm gate value of production in 2022. The industry generates significant export revenue and makes up almost a quarter of the nation's total value of agricultural production. (ABARES 2021)

The modern-day cotton industry is a high-end, specialist fibre production sector that generates around $2 billion in export revenue annually, with almost the entire crop exported to markets around the world. The cotton industry employs 12,000 people across 1500 farms in Australia, 90% of which are family-owned. (Cotton Australia 2021)

Additional value is expected for livestock industries through the local availability of cotton seed and grains for the northern livestock industry.

With producers in eastern and southern states of Australia experiencing irregular climate patterns and water availability challenges, the expansion crop production into northern Australia will underpin the future growth and provide export product diversity to help offset any production issues in the eastern states.

The agricultural sector is a key pillar of the Northern Territory economy, contributing significantly to employment opportunities and economic prosperity, particularly in regional and remote areas. The agricultural sector, which also includes fodder and broadacre cropping, supports various downstream industries including retail and wholesale trade, manufacturing and transport. Cotton, as part of the broadacre sector, has the potential to become a reliable cornerstone crop.

Recent successful cotton trials in the north have increased interest from local and interstate growers and international investors who see the crop as a potential opportunity to diversify the agricultural sector. To capitalise on these successful trials, the industry wants to significantly expand its cotton production, with grower forecasts reaching around 400,000 bales in the next decade. (NT Farmers/PricewaterhouseCoopers Australia 2019, ii)

There is an immediate opportunity for new growers to enter the northern Australian cropping industry. The agricultural industry and government are working together to facilitate research, development and extension to provide a support network for new growers.

PART C: Why Grow Cotton in Northern Australia?

Northern Australia has enormous potential as a cotton production region. Cotton is a proven, established and profitable commodity with international export markets. The cotton seed produced is a financially and nutritionally valuable by-product of cotton production. It can provide significant benefits for local livestock industries in terms of live weight gain for cattle.

Cotton is a viable, environmentally friendly and profitable foundation crop in many family farming operations. The introduction of cotton to farming systems in northern Australia will facilitate the opportunity for growers to also introduce grain and pulse crops to these rotations, further adding to the production capability of the farms in these regions. Additional value is expected for livestock industries through the local availability of cotton seed and grains for the northern livestock industry.

The profitable financial forecasts for cotton, combined with weather related production challenges in the eastern and southern states, will be a driver for



continued expansion of production in Western Australia, Northern Territory and Queensland over the next decade.

Cotton gins are being built in the Northern Territory and Western Australia, with the commencement of the Katherine Cotton Gin construction in late 2021, to support the expansion of the cotton industry in those areas. This means producers will have significantly reduced transport costs while continuing to receive high returns for their product under current market conditions. They will also have more affordable access to the seed by-product.

In summary, cotton in northern Australia will be driven by:

- Available rainfall during the regular wet season,
- Trial work which will provide improved agronomic expertise in growing cotton in northern Australia,
- Infrastructure development – cotton gins, which will lower transport costs, and
- Proximity to expanding Asian markets.

Colour Tab Guide

For quick referencing information.

- Is Growing Cotton and Other Broadacre Crops for Me?
- Understanding and Committing to MyBMP
- Understanding and Committing to Best Practice Biosecurity
- Understanding Gross Margins for Northern Cotton
- Understanding the Northern Australian Climate
- Understanding Northern Australian Soils
- Introduction to the Cotton Plant
- Growing Crops: Planning Stage
- Growing Crops: Growth Stage
- Growing Crops: Harvest and Post-Harvest Stage



SECTION 2.

PREPARATORY KNOWLEDGE

Part A: Is Growing Broadacre Crops (Cotton) for me?

Sources: Adapted from:
• CottonInfo et al factsheet Tropical Cotton Production: Considerations for Northern Cotton Growers
• Cotton Australia, 2021, in Australian Cotton Production Manual, Ch 2, p 10

Northern cotton faces some very different challenges when compared to traditional temperate growing regions. Higher temperatures and rainfall, soils with lower water holding capacity that are prone to crusting, and the need to allow for compensatory growth after fruit shedding when climatic stresses occur (e.g., cloud, temperature extremes) need to be factored into management plans.

New growers should have a thorough understanding of their responsibilities before making the decision to grow cotton. There is no single recipe for producing a profitable and sustainable cotton crop, but to be successful you must approach cotton production with long term planning and commitment.

The Australian cotton industry operates in an extremely cohesive and cooperative environment, where a number of industry organisations exist specifically to support growers, from research extension to agronomy, community relations and advocacy. You will also find that your fellow cotton growers are prepared to willingly share their experiences and offer invaluable advice.

Here is a list of considerations for new cotton growers in northern Australia:

Cotton is a Complex and Challenging Crop
Cotton is a relatively complex crop to grow, requiring specific agronomic knowledge and some farming techniques that you may not have used before. A cotton crop will require timely and constant attention from planting to picking through to post crop management. To be successful you must apply good planning, thoroughness, timeliness and careful management to all your business and cotton production practices.

Industry Note:
"To manage evolving scenarios with changing conditions, managers must be constantly assessing the crop and adapting in-crop management methods to ensure sustainability. Production plans must also be flexible enough to incorporate the seasonal variability typical to the north. If all stakeholders acknowledge the risks, develop and adhere to best management practice and manage the variables within their control for the betterment of the entire industry, there are great opportunities to develop a productive and profitable cotton industry in northern Australia"
Luke McKay 2018 Nuffield Australia Scholar

Choosing a Cropping System
Cropping system should enable seasonal responsiveness and also manage for long term risks to ensure the system can be sustainable.
- Soil characteristics (eg

Plant Available Water Capacity (PAWC) and wet season trafficability) and climate (eg radiation and temperatures) are suitable for crops being considered.
- Water availability (rainfall and if relevant irrigation) matches crop requirements in terms of timing, total volume and peak water demand.

As well as planning to optimise individual crops, consider management including crop sequences and practices that will ensure long term sustainability of system, for example manage herbicide resistant weeds and maintain soil health.

Yield Potential
Profitable yields need the right combination of soil, climate and production system. Be realistic about initial yield potential and be aware that cotton is not necessarily suited to all of northern Australia. While cotton is a hardy and resilient plant well suited to tropical production, inexperience and the unexpected can quickly result in lost yield potential. During the last ten years, irrigated crop yields in northern Australia have varied from 5.5 - 12 bales/ha, with about 10 per cent of irrigated crops abandoned due to unforeseen events. Therefore, if considering tropical cotton, do not assume that you will achieve industry-reported average yields from southern Australia during your first attempts.

Ginning and Module Transportation
Complete your arrangements for ginning before you commit to planting cotton. Note: current biosecurity restrictions exclude ginning of cotton grown in the Northern Territory and Western Australia at any facilities in Central Queensland. Consider distance to the gin and whether or not the gin will be operating when your cotton arrives (out of season with the southern crop). Access to cost effective transportation for round cotton modules can be a major impediment for cotton production at distant locations, with backloads limited in some areas. Transportation costs have ranged from $60-$190 per ginned bale (not module) for growers in northern Australia depending on distances involved.

Suitable Equipment
Cotton is a new crop in northern Australia, meaning there are limitations on the amount of plant equipment required for producing cotton in these regions. These limitations pose a significant challenge to timely farming operations and must be considered carefully when planning a crop.

Successful cotton production depends on the ability to conduct timely agronomic operations, particularly during the wet season when the window for action can be very short between rainfall events. Weather interruptions and staff annual leave during summer can make services difficult to acquire. Also, spray contractors are often engaged with weed control with products that are incompatible with cotton during the wet season and a contractor will need to thoroughly decontaminate equipment which takes additional time.

Consider picking costs before you plant. Contract picking can be very cost effective but if the contractor has to travel large distances for a small area of cotton the additional costs might outweigh any potential rewards.

Also consider how you will destroy the crop when you are finished, as the licensing requirements to grow Bollgard® 3 cotton dictate specific crop destruction practices.

Crop Monitoring and Management Advice

Cotton is a relatively complex crop to grow, requiring specific agronomic knowledge. It will require timely and regular attention from planting to picking through to post crop management. The availability of crop consultants is limited across the North. These agronomists may have limited capacity to provide regular crop monitoring, support and advice. The geographical distance between plantings could also present challenges for regular (weekly) agronomic advice. Wet season cotton production requires agronomic practices that are suited to tropical conditions and some southern cotton production tactics (sowing, nitrogen, growth regulator and irrigation) are not directly transferable. The ability to contextualise advice to match local conditions is essential.

Chemical Use

The cotton industry takes the stewardship of chemical usage very seriously. The industry has reduced its use of synthetic insecticides by 97% since 1992 thanks to Integrated Pest Management (IPM) techniques. You must be prepared to apply the industry's Best Management Practices (BMP) for pesticide use, including using an IPM strategy and following the industry's resistance management plans. All chemical use must accord with the currently registered label or permit for that particular pesticide, crop, pest and region as well as requirements under relevant regulation.

Local Communication

It is your responsibility to ensure chemical drift is minimised on your farm and does not occur outside your property boundaries. Cotton is highly susceptible to phenoxy herbicides such as 2,4-D. The core best management practice for safe and responsible pesticide use is to develop a pesticide application management plan (PAMP) and discuss your plans to grow cotton with your neighbours so any concerns can be adequately addressed. Letting your neighbours, local resellers, spray contractors and aerial operators know that you have cotton can help minimise risk, particularly in new or isolated areas. Don't forget apiarists (beekeepers) as neighbours.

Biosecurity Restrictions

There are key pests, weeds and diseases that only occur in northern or southern Australia. Biosecurity practices that limit movement of these organisms between regions is critically important.

The Pink Bollworm that occurs naturally in WA and the NT has the potential to be a major pest if spread to Southern Australia. Similarly soil-borne diseases such as fusarium wilt, nematodes and resistant weed species that occur in Southern Australia have the potential to reduce cotton yield potential if they were introduced to the north. Implementing quarantine best practices to prevent the spread of these organisms by the movement of machinery, people and cotton modules is a key consideration. Monitoring for any unusual pests or crop symptoms is also critically important for cotton grown in northern Australia due to the closer proximity to Southeast Asia where several insect and disease threats reside.

Transgenic Cotton Requirements
Growing a genetically modified cotton means that you must sign a contract with the owner of the technology (Bayer). All commercial GM cotton technologies in Australia require compliance with resistance management plans that form part of the licence conditions. You should be aware of all the requirements of the resistance management plans and crop management plans for the respective products.
There are specific industry and government regulations that apply to production of transgenic (Bollgard® Roundup Ready Flex®) cotton in Australia. These can vary between regions, so talk with your relevant Bayer representative about receiving a licence to grow GM cotton and signing a Technology User Agreement (TUA).

Crop Inputs
You will need to source suppliers for farm inputs such as seed, fertiliser, herbicides, insecticides, growth regulators and defoliants. Check with existing supplier if they have the inputs they need for growing cotton.

Best Practice
The Australian cotton industry utilises the myBMP (Best Management Practice) system to demonstrate to the community the industry's improved farming practices and careful management of natural resources. All growers are incentivised to engage in this stewardship program.

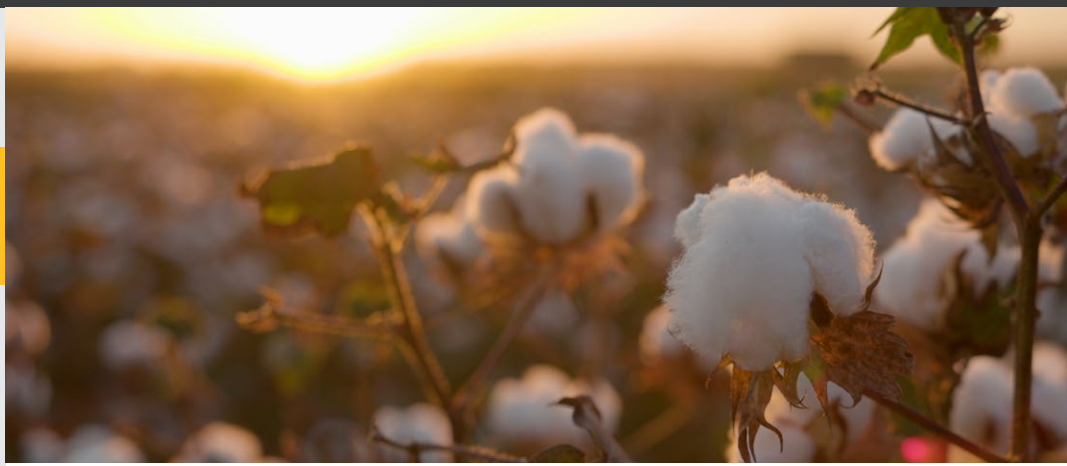
Expansion of cotton into new areas should consider and manage risks to water quality, local fauna, and natural vegetation.

Marketing
Cotton has unique marketing parameters based around fibre quality. Discuss premium and discount sheets as well as price with an experienced cotton merchant/marketer. For a list of Australian merchants, see www.austcottonshippers.com.au

Industry Support
There is no single recipe for producing a profitable and sustainable cotton crop, but to be successful you must approach cotton production with long term planning and commitment.

The Australian cotton industry operates in an extremely cohesive and cooperative environment, where a number of industry organisations exist specifically to support growers, from research extension to agronomy, community relations and advocacy. You will also find that your fellow cotton growers are prepared to willingly share their experiences and offer invaluable advice.

Entities such as industry associations (e.g., NT Farmers Association), Cotton Australia grower groups (Northern Cotton Growers Association) and Research and Development Corporations (CRDC) provide extensive peer and professional support and advice for new growers. CottonInfo is the Australian cotton industry's joint extension program and is a is a joint venture between three cotton industry organisations, Cotton Australia, the Cotton Research and Development Corporation and Cotton Seed Distributors Ltd. The CottonInfo website (www.cottoninfo.com.au) is a comprehensive source of information for new and existing growers.



Part B: Understanding and Committing to MyBMP

Source: Cotton Australia website and myBMP website

About myBMP
myBMP is the industry's assurance mechanism, a best management practice system for growers to improve on-farm production.

myBMP is the result of industry wide consultation with growers, researchers and industry bodies, taking into consideration the requirements of the cotton industry now and into the future. The initiative is supported by the Cotton Research Development Corporation (CRDC) and Cotton Australia.

Australia's myBMP-accredited farms produce cotton using responsible and efficient management practices. The myBMP program is an online self-assessment mechanism. It also has practical tools and auditing processes to ensure that Australian cotton is produced according to best practice (Cotton Australia 2021).

Through myBMP, all Australian cotton growers have a resource bank to access the industry's best practice standards, which are fully supported by scientific research and development, resources and technical support.

By using myBMP's tools, growers can improve on-farm production performance, by:

- Better managing business and production risk
- Maximising potential market advantages
- Demonstrating responsible and sustainable natural resource management to the community.

myBMP is the result of industry wide consultation with growers, researchers and industry bodies, taking into consideration the requirements of the cotton industry now and into the future. The initiative is supported by the Cotton Research Development Corporation (CRDC) and Cotton Australia.



Information is categorised into **10 key modules** for growers:

1. **Biosecurity**
For prevention, management and control of pests and diseases.

2. **Energy and Input Efficiency**
For more efficient energy inputs such as electricity, fuel and fertilisers.

3. **Fibre Quality**
For growing the best quality cotton possibles.

4. **Sustainable Natural Landscape**
For managing the vegetative and riparian assets on your farm.

5. **Integrated Pest Management (IPM)** For management of pests, weeds and diseases.

6. **Petrochemical Storage and Handling**
For managing fuels and lubricants on farm

7. **Pesticide Management**
For all aspects of pesticide management, storage and use on farm

8. **Water Management**
Covering water quality, efficiency of storage and distribution for both dryland and irrigated farming practices

9. **Soil Health**
For maintaining and/or improving soil quality and fertility

10. **Human Resources and Work Health and Safety**
Helps growers manage employees and contractors whilst providing a safe and compliant workplace.

Ginning and Classing modules are also available for the Australian cotton ginning and classing facilities.

myBMP Structure
myBMP is structured into modules. Under each module are key areas. Each key area has standards listed under these supported by checklists, additional information and resources.

Each checklist item is assigned a level. These levels are:
Level 1 - identified legal requirements (what you must do)
Level 2 - Industry identified best practice standards (what you should do)
Level 3 - Innovative practices (new cutting-edge practices)
(myBMP 2021)

These levels can be completed in stages, and a grower can commence growing cotton while completing the levels.



Part C: Understanding and Committing to Best Practice Biosecurity

Source: Adapted from the CottonInfo website

Biosecurity – Everyone Has a Role to Play
Farm biosecurity is a set of practices designed to protect farms and our industry from the entry, spread and establishment of pests, weeds and diseases.

Exotic and endemic pests and diseases can reduce yields, affecting the environment and changing the way we manage our crops and farms. For growers and crop managers, it's important to protect your asset – your farm – with a farm biosecurity plan, which integrates on-farm biosecurity practices that prevent or reduce the risk of pest, weeds and diseases entering or spreading.

Australia has a world-class biosecurity system. However, with increased international trade and people movements, there will always be a risk of new plant pests or diseases entering the country. There is also the additional possibility that pests can also be spread to Australia through natural means such as wind and water currents.

What Do You Need to Know?
Biosecurity is a shared responsibility between everyone in the community, including growers, consultants, contractors, industry members and visitors. Each person needs to play their part to reduce the likelihood of spreading pests, weeds and diseases. You do not need to know about all biosecurity risks, but you should know about biosecurity risks associated with the cotton industry, your business and day-to-day work, and even hobbies, and take reasonable steps to prevent or minimise these risks.

Defending Your Farm
Growers play a key role in protecting Australia's agricultural industry from pests, weeds, and diseases by implementing on-farm biosecurity measures. Implementing strong biosecurity measures on your farm will help protect your business, region and the industry from the introduction and spread of endemic and exotic pests, weeds, and diseases.

If a new pest or disease becomes established on your farm, it could affect your business through increased costs (for monitoring, changes in production practice, additional chemical use and labour), reduced productivity (in yield and/or quality) or loss of markets. Early detection and immediate reporting increase the chance of effective and efficient eradication.

Farm Biosecurity Management Plan
A farm biosecurity management plan is a risk assessment.

Developing a farm biosecurity management plan can help growers assess the biosecurity risks associated with their farms and businesses and decide on appropriate actions and

practices to mitigate and minimise these biosecurity risks.

Completing a risk assessment is not about completely removing every risk, it is about trying to minimise the risk by taking reasonable steps and actions.

A farm biosecurity management plan is available with instructions on how to use the template. For assistance in completing your farm biosecurity management plan, contact the NT Farmers Association, or the CottonInfo Technical Lead for Biosecurity.

Key Biosecurity Targets

People

If it can move, it can carry pests, weeds, and diseases. For this reason, it is important to never assume that people know the biosecurity measures and practices you have in place on farm. There are a number of ways of communicating your biosecurity requirements, both before and during a person's visit to your farm.

Crops

Regularly monitoring crops for the presence of pests, weeds or diseases (e.g., insects, mites, nematodes, pathogens (diseases) and weeds) or associated symptoms increases the likelihood of early detection of unwelcome intruders. Promptly reporting any sightings greatly increases the chances that new pests and diseases can be eradicated before they establish.

Growers, consultants and farm personnel are expected to report any sightings of exotic pests or anything unusual to a State/Territory Department Officer or by calling the Exotic Plant Pest Hotline on 1800 084 881 from anywhere in Australia.

Ratoon and Volunteer Cotton

Ratoon (regrowth/stub cotton) and volunteer (plants that have germinated and established unintentionally) cotton plants are a biosecurity risk. They harbour pests, carrying them from season to season and providing an inoculum source for early re-infection of the following year's crop. They are also a potential point of establishment for new pest and disease outbreaks.

Vehicles, Machinery and Equipment

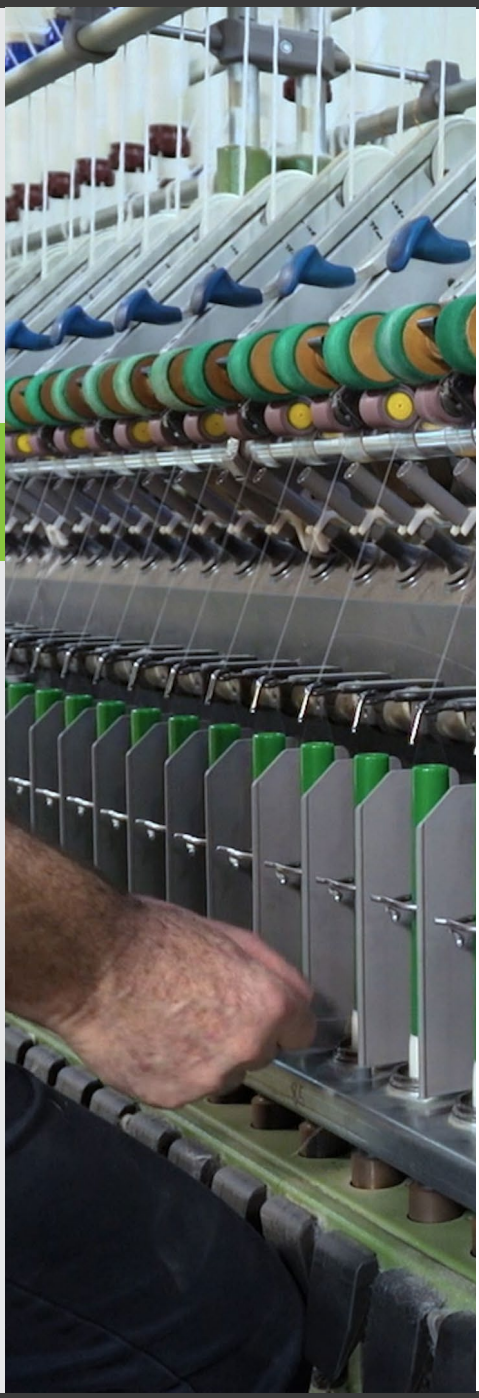
Vehicles and equipment such as pickers and tractors can carry soil and plant material, particularly weed seeds, to other areas or other farms. Come Clean Go Clean is one of the simplest, yet most effective ways of minimising the spread of pest, weeds and diseases by ensuring vehicles and machinery are arriving onto and leaving farms mud and trash-free.

What Should You Do on Your Farm?

- Develop a Farm Biosecurity Management Plan to assess the biosecurity risks associated with your farm and business, and the best actions to mitigate these risks.
- Ensure all farm personnel, consultants, contractors and visitors are made aware of farm biosecurity requirements – clear communication is critical for ensuring your biosecurity plan operates effectively
- Erect biosecurity signs. These signs are a useful tool to remind farm personnel and visitors about biosecurity practices and expectations.
- Monitor crops and fields regularly for signs of pests and disease, particularly any new or unusual insects, weed species or plant symptoms.
- Ensure all farm personnel are aware of the action to be taken in the event of identifying unusual pests or plant symptoms. If you spot anything unusual, call the Exotic Plant Pest Hotline 1800 084 881.
- Remove all cotton volunteers and ratoon plants from all cropping and no-cropping areas to reduce carryover of pests and diseases.
- Control volunteer and ratoon cotton to minimise the risk of harbouring pests and disease overwinter.
- Consider the risk from and inspect farm inputs e.g., seed, soil amendments, stock feed, and organic fertiliser.
- Practice Come Clean Go Clean. CottonInfo, together with NSW DPI, QDAF and the Grains Farm Biosecurity Program have developed a best practice 4-step wash down protocol for machinery, vehicles and equipment. This protocol involves the use of an agricultural detergent and decontaminant.

There are specific procedures and protocols to manage spread of pests and diseases in northern Australia. For best practice Come Clean Go Clean in these regions, contact your local government biosecurity authority.

For more information on biosecurity visit the myBMP Biosecurity module. (CottonInfo 2021)



Part D: Understanding Gross Margins for Northern Cotton

Source: Adapted from CottonInfo/Ag Econ's Northern Australia Cotton gross margin 2021 Analysis

Overview of Gross Margin Budgets

A gross margin (GM) represents the difference between gross income and the variable costs of producing a crop.

Variable costs within the budgets are those costs directly attributable to an enterprise. They vary in proportion to the size of an enterprise. For example, if the area grown to cotton doubles, then the variable costs associated with growing it such as seed, chemicals and fertilisers will also double.

GM budgets do not take into account risk, timing, overhead costs (such as depreciation, council rates and permanent labour) and do not calculate farm profit. A gross margin budget can assist with which crops to plant; indicate cash flow requirements; and if adjusted to actuals, create a useful record of operations and profitability of the enterprise for the season. (Revell and Powell 2021)

Your local extension officer or accountant can assist with gross margin analysis.

Gross Margin Analysis for Cotton in Northern Australia

The CottonInfo Northern Australia cotton gross margin (GM) budgets have been designed to give an

indication of the operations and costs required to grow a cotton crop in the emerging cotton regions in the north (QLD, NT & WA). There is a raingrown GM, and an irrigated GM. The GMs were based on inputs from farmers, researchers, agronomists and industry specialists across QLD, NT, and WA.

The indicative published GMs indicate that both irrigated and raingrown cotton can return positive gross margins at $1409 and $534/ha respectively for the 2020 year.

A key management consideration in these regions is the wet season. The timing of the onset of the wet season and the amount of rain it brings can affect planting dates, pest management, defoliation and importantly - the profitability of the crop. The published GM budgets can be used as a guide, however farm location, individual field management plans, movements in crop and input prices and changes in seasonal conditions will all change the required operations and costs of growing cotton. In all instances, operations should be tailored to the requirements of individual fields.

A GM represents the difference between gross income and the variable costs of producing a crop. GM budgets do not take into account risk, overhead costs (including permanent labour) and do not calculate farm profit.

Gross margins can be improved by either reducing variable costs or increasing income. Figure 1 indicates the range of results for changes in the raingrown GM. Figure 2 indicates the influence that a change in a key variable may have on the northern Australia gross margin for irrigated cotton. The axis (where the blue and green bars meet) indicates the value of the published gross margin. The length of the bar (blue and green together) indicates the size of impact the variable can have on the gross margin. The blue bars reflect downside risk, while the green bars represent upside potential.

The raingrown cotton analysis (Figure 1) indicates cartage as the operation with the highest scope for change in cost and therefore change to the gross margin. Changes in the cotton price also have a big influence on the gross margin and can potentially result in a negative gross margin. The analysis assumes no change in yield at 5 bales/ha. Sensitivity testing of the gross margins indicating yield and price combinations and the resulting change in gross margin can be found at the beginning of each gross margin.

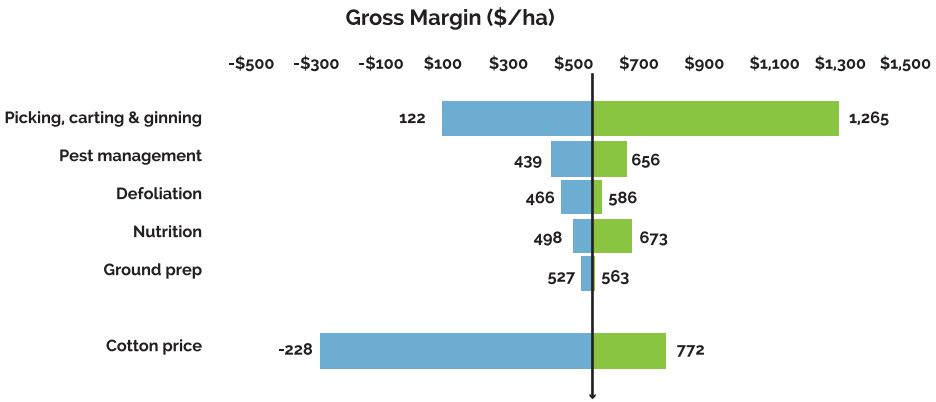


Figure 1. Raingrown Northern Australia Cotton. Key gross margin sensitivities (potential change in gross margin). Adapted from "Northern Australia Cotton gross margin 2021 Analysis", p. 2, by CottonInfo and AgEcon, 2021, Australia: Copyright 2021 by CottonInfo.

The irrigated cotton analysis (Figure 2) indicates some costs (i.e., cartage, nutrition) have more scope for cost reduction (green bars) which increases the gross margin and some variables (cartage, irrigation, cotton price) have the potential to further increase costs or decrease income, therefore reducing the gross margin (blue bars). The change in variables assumes no change in yield at 9.7 bales/ha.

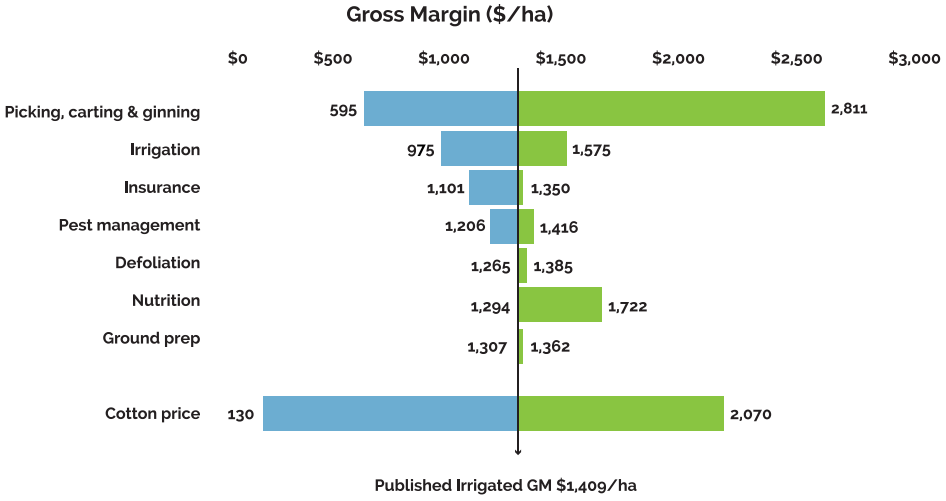


Figure 2. Irrigated Northern Australia Cotton. Key gross margin sensitivities (potential change in gross margin). Adapted from "Northern Australia Cotton gross margin 2021 Analysis", p. 1, by CottonInfo and AgEcon, 2021, Australia: Copyright 2021 by CottonInfo.

Picking, Carting and Ginning

Cartage: This key variable cost is calculated by distance to the gin, which is currently assumed to be 2680 km (based on Katherine to Emerald, noting biosecurity restrictions currently prevent NT cotton accessing Emerald processing facilities, meaning alternative ginning options in SE Qld are required), road train transporting 12 round bales per trip, 4.25 lint bales per round. The total cost of $550*/round bale (equivalent to $155 per lint bale in the GM). This represented 31% of raingrown costs (34% of irrigated total costs). Current costs can be as high as $855 /round bale, but with new gins under development, or ear marked for development in northern Australia, the cost could be reduced for locations to as low as $45*/round bale.
Raingrown Irrigated GM: $595*/ha - $2811*/ha
Dryland GM: $122*/ha - $1265*/ha

Picking and Ginning: Picking and ginning made up 31% of the raingrown cotton costs and 25% of total irrigated costs, however these operations are likely to have low variability in costs. The published GM assumes using a picking contractor. The cost of picking may be reduced with picker ownership (where scale allows). There is minimal variability in ginning price. Ginning transport associated cost will reduce significantly once the Katherine Gin comes on line in 2023. This will be a significant milestone for the development of the industry.

Crop Inputs

Nutrition: Optimal crop nutrition is a key management practice that needs careful consideration in a tropical climate. All fertiliser strategies should include comprehensive soil testing prior to sowing. Within the published GMs nutrition accounted for 15% and 14% of total expenditure for irrigated and raingrown crops respectively. Where testing results suggest reduced rates of fertiliser can be applied without yield compromise, this is a potential cost reduction to increase the both the raingrown and irrigated GMs. Cotton crop nutrition requirements are comprehensively covered in the Nutrition chapter in the annual Australian Cotton Production Manual.

Pest Management: Control of weed and insect pests will depend largely on the season and location. Use of a particular brand name or active ingredient in the published GM does NOT imply a recommendation. Insecticides and spray timing suggested in this budget are examples only and strategies will vary with individual circumstances. The examples given accounted for 5% and 8% of the total costs for raingrown and irrigated cotton gross margins respectively. Individual fields need careful monitoring to determine pest and beneficial insect populations. Use recommended thresholds for all pests. Avoid using broad spectrum sprays and continuously using chemicals from the same group. Follow the Insecticide Resistance Management Strategy (found in the Cotton Pest Management Guide) to protect the value of insecticide technologies for the future. Conserving and utilising beneficial insects is a key aspect of long-term effective pest management.

Always read chemical labels and follow directions, as it is your legal

** pricing indicative of 2021 season*

responsibility to do so. Application method assumes ground spray until the crop closes-over, ability for ground application will depend on rainfall, soil type etc. Increased use of aerial spray will increase costs and reduce GM.

Growth Regulator: Requirements (and number of applications) depends on climatic conditions, predominantly rainfall. The published GM example has four applications for the irrigated cotton and three applications for the raingrown, however this could be as many as six. The cost of growth regulant accounted for less than 1% of total costs in both the irrigated and raingrown cotton gross margins.

Defoliation: Good conditions are required to get the best performance from defoliation. The choice of defoliant, rate used and number of applications, depends on the moisture status of the plant, geographic location and seasonal conditions. Self-propelled ground rig is used in this example due to improved canopy penetration, however there can be trade-offs with damage to the crop. The published GM assumes 2 defoliations. Defoliation accounted for 1% and 2% of total expenditure for raingrown and irrigated cotton respectively.

Ground Preparation: The cost of ground preparation is influenced by the previous crop (or fallow) and the operations required to create a weed and insect free field for planting. This may involve a combination of farming operations including herbicide and pesticide sprays. Within the published GMs these costs accounted for 1% of total cotton expenditure. Preparation is important for yield maximisation and Figure 2 indicates potential variance in these costs have minimal impact on gross margin.

Gross Margin $975 - $1575*

Crop Pricing

Lint Price: The published GM includes sensitivity testing of crop income ($/bale inclusive of lint, seed and discounts). The change in gross margin is indicated for a per bale income range of $475 - $675. When expenditure and yield remained constant, the cotton gross margin remained positive down to $475 bale - well below the 20-year average lint price of approximately $500/bale plus an approximate additional $75 /bale for seed.

An 8% increase in income ($50*/bale) over $610*/bale, increased gross margin by 47% to $2039*/ha. An 8% decrease in income below $610 / bale decreased gross margin by 25% to $1069*/ha. These significant changes in gross margin indicate that in volatile world markets, sound, independent marketing advice is essential.

Management

Breakeven Price: Irrigated breakeven price was $465*/bale (inclusive of lint, seed and discounts). Raingrown breakeven price was $496*/bale (inclusive of lint, seed and discounts).

Breakeven Yield: Irrigated breakeven yield is 5.52 bales /ha. Raingrown breakeven price is 3.36 bales /ha.

** pricing indicative of 2021 season*

With a constant expenditure and price of $610*/bale (inclusive of lint, seed and discounts), a one bale (10%) increase in yield in the irrigated gross margin, increased gross margin by 24% to $1746 /ha. A one bale decrease in yield in the irrigated gross margin, decreased the gross margin by 26% to $1076*/ha.

Insurance: The published GMs assumed no crop insurance was taken. If insurance is required for risk reduction, this would be an increased cost and a reduction in GM. Insurance premiums are influenced by a variety of factors such as policy type, location, and estimated yield. Best practice is to get quotes from a couple of providers and compare like for like policies.

Calendar of Operations: Timing of cotton in northern Australia is based around a potential planting window. Planting windows will vary depending on the growing area and timing of the wet season.



** pricing indicative of 2021 season*

Average Annual Rainfall
30-year Climatology (1981 to 2010)
Australian Bureau of Meteorology

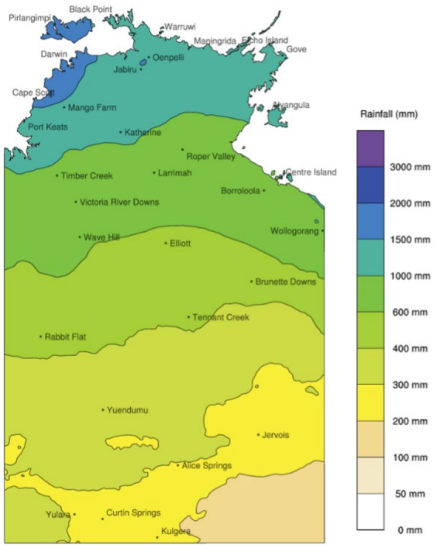


Figure 3. Northern Territory Average Annual Rainfall. Bureau of Meteorology. 2020 (http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp?period=an&area=nt#maps). Copyright 2020 by Commonwealth of Australia, Bureau of Meteorology.

Owner Operator v Contractor:
Contracted operations in the published GMs include picking, cartage and aerial spraying. Contract rates include variable, overhead and labour costs as well as a profit margin. Rates are also influenced by supply and demand in a season or valley, quality of equipment on offer and the size of the job (to ensure relocation costs are recouped). Contracting bills are a tax deductable cost. The cost of growing a cotton crop with all operations contracted may increase total costs in the range of $800-$1200*. However contracting costs would also offset the overhead requirement of labour and potentially the capital expense of specialist machinery. Using a contractor may be preferable particularly where labour is short, or cotton is grown as an opportunity crop.

General Notes

Bale: The industry term 'per bale', means a ginned 'lint' bale of 227kg. New picking technology picks the cotton and packs it into round bales (sometimes called round modules) on-farm, which is then transported to the gin.

Bt: A licence fee is paid to Bayer for cotton seed that uses Bollgard® technology (Bt). The technology licence fee for Bollgard3® stacked with Roundup Ready Flex® for 2018-19 is $390* per green hectare (GST exclusive). The dryland budget uses Bayer Cotton ChoicesTM Option 3, an end point royalty of $52.50*/bale ex GST.
The fully irrigated budgets use Bayer Cotton ChoicesTM Option 1, which provides a discount on the technology licence fees for up-front payment. The semi-irrigated budget uses option 2, which includes the option of 'Late Crop Removal', $420 per green hectare. For crops expected to yield less than 4 bales/ha the End Point Royalty is the most cost-effective option.

Crop Destruction/Pupae Destruction:
To further mitigate resistance follow the specific guidelines in your licence agreement.

Herbicides: The cornerstone of weed management and managing herbicide resistance risks is

** pricing indicative of 2021 season*

controlling survivors and preventing new weed seeds from entering the seed bank. To reduce the likelihood of herbicide resistance, rotate herbicide groups and weed management techniques. Chipping or spot spray can be used to control any surviving weeds as part of a robust Integrated Weed Management (IWM) plan. Aim to plant into clean fields. See the Herbicide Resistance Management Strategy (found in the Cotton Pest Management Guide) and Bayer's Roundup Ready Flex Cotton Weed Management Guide.

Labour: Labour costs an estimated $350-$400*/ha. Labour is assumed to be an overhead cost and is not included in this budget.

Levies: The Research Levy ($2.25*/bale) is a compulsory levy that is invoiced by the ginning organisation following ginning. The Cotton Research Development Corporation (CRDC) uses funds collected through this levy to finance vital industry research. The Cotton Australia Levy ($1.50*/bale) is a voluntary levy, which funds the peak industry body Cotton Australia that provides a valuable policy/advocacy role, farmer support and promotes the Australian cotton industry.

Machinery: The cost of each farming pass reflects variable costs only (fuel, repairs and maintenance). Labour and depreciation are considered overhead costs, so are not included in this budget.

Prices:
Input Prices: Chemical & fertiliser pricing information was collected across all cotton growing regions and averaged to give an indication of product pricing.

Cotton seed price per kg will vary with the time of ordering and seed treatments chosen. Price quoted in the budgets is for a preseason order of 746B3F.

Output Prices:
Lint: $597*/bale is the 12-month average published cotton lint price by Namoi Cotton Co-operative, base grade cotton.

Seed: The cotton seed price is given indicatively as a per bale value. $100*/bale for seed (prior to ginning costs being subtracted) is the equivalent of $400*/t, assuming an average of 250kg of cotton seed per bale of lint.

Rotation: Whilst cotton can be grown in various rotations, this budget assumes a two-year rotation of cotton- wheat- long fallow (a southern farming systems approach). Rotations for northern Australia are discussed in later chapters.

Row Configuration: The Dry land GM considers varied planting configurations, however solid 1m configurations have been widely trialled and adopted as common practice in the NT. Irrigated GM assumes the same solid 1m planting row configuration

Yield: Actual yields are a complex result of agronomic and environmental factors and as a result will vary

** pricing indicative of 2021 season*

between fields, farms and regions.
Dryland: Estimated yields are entirely weather and region dependant. We have used the yield matrix (based on Ozcott modelling of the Darling Downs Region) from page 18 of the Australian Cotton Production Manual 2019.

Irrigated: A yield of 12 bales/ha is achievable considering the long fallow, 'best practice' operations and the five-year average yield for the variety 746B3F in Cotton Seed Distributors (CSD) commercial trial results.

Refuge: Each grower is required to grow a refuge crop as part of preventative insect-resistance management. Refuge requirements have been reduced with the introduction of Bollgard3® cotton, however, remain a critical part of growing the technology to protect its longevity. With this in mind, refuge crop costs have been included as part of the gross margin budget. For the purposes of the irrigated budget examples, we have used irrigated pigeon peas at 2.5% of the Bt cotton area. Unsprayed conventional cotton at 5% of the Bt area is used for the dryland budget. Refer to the relevant Resistance Management Plan for more information on refuge crops and minimum requirements.

Refuge Removal: Pigeon peas should only be harvested or slashed after the Bollgard3® crop has been removed.

Looking for More Information?
For comprehensive gross margin analysis of both raingrown and irrigated cotton in northern Australia, visit the CottonInfo website and locate the Australian cotton industry gross margin budgets page.

For a complete guide to cotton management, see the Australian Cotton Production Manual.

Key research projects for both irrigated and raingrown cotton in northern Australia have been conducted by Dr Stephen Yeates:

Dryland: Yeates, S. Poulton, P. (2019). Preliminary Determination of Dryland Cotton Yield Potential in the NT: Preliminary climate assessment and yield simulation. Report to NT Farmers, Queensland Cotton and the Cotton Research and Development Corporation. CSIRO.

Irrigated: Yeates, S. (2008). Northern Australia Cotton Development & Coordination Leader, Final Report. CRDC Project CSP1602.

Additional information on northern Australian cotton production can be found in the below reports:
- CRCNA (2021). Broadacre Cropping in Northern Australia, Issue 2 March 2021
- CottonInfo Website. Tropical cotton production, Information for Northern cotton growers.
- Acres of Opportunity Northern newsletter's



Part E: Understanding the Northern Australian Climate

Climate for Growing Cotton
Ideal conditions for cotton entail sunny warm days with maximum temperatures spanning 27˚C–32˚C with overnight minimums of 16–20˚C. Light intensity, which is often irregular in tropical environments due to shading and cloudiness associated with the monsoon is also important for growth and reproductive structure development. This is particularly important from flowering.

Daytime temperatures in excess of 32˚C place additional stresses upon the plant which has to transpire more water to keep cool. Nighttime temperatures above 22˚C will begin to impede respiration processes whilst temperatures below 11˚C (cold shock) or above 36˚C (hot shock) will result in a shock to the plant that temporarily arrests development (Constable and Shaw 1988). Extended periods of low solar radiation (e.g., cloudy weather), too much or too little rain/water and excessively hot weather, particularly during flowering can impact on yields.

Northern Australia has a large amount of variation in climate across regions and within and between seasons. Planning and ongoing management needs to be adaptive and respond to climate.

Grower Insight: Douglas/Daly Region, NT - Cotton 2021 Growing Season

"Wet season cropping in this region can be challenging to say the least. However, if you give the crop the best start you can and monitor nutrition and pests then you can be well placed to cope with the coming season. It is also vitally important to be in the crop at least twice a week as insect and weed pests can manifest quickly in the tropics.

"During the 2021 growing season an average wet was experienced by the grower (1500mm rainfall). Approx. 100mm of rainfall pre-plant then 1400mm spread over the next four months from December 2020 planting to April 22, when the crop received its last beneficial rain.

"Our preferred method of crop establishment is to apply a pre-plant fertiliser to the plant line in Oct-Nov and let the grass and weeds grow to produce a cover of about 2-3t/ha of dry matter. This is the ideal amount, but any amount seems to be better than nothing. Although heavier covers can be problematic and will require careful management at planting. The cover crop is sprayed out with Glyphosate just prior to planting (2-5 days). The benefits of the cover are threefold, and this has been born out over several seasons now.

1. If a cover can be established on early season rainfall this will go a long way to reducing the speed of rainfall runoff and the consequential erosion. Also, by slowing down the runoff you are creating a greater opportunity for water infiltration into the soil.

2. If the cover is allowed to grow out to about 2-3t/ha equivalent of dry matter, then it will mostly be tall enough to provide good shade to a freshly planted seed and an emerging seedling. The ground temps in the region can reach 58˚+ at the surface on bare soil and still be as high as 45˚ at seed depth. Shading and the ability to plant during rain is important.

3. Whilst the cover can and will use some of the pre-plant fertiliser, the benefits will be repaid to the crop as the cover dies and breaks down into the soil as veg matter, giving a later injection of nitrogen and phosphorus. As the cover dies the capillaries left behind by the decaying roots will also provide an avenue for water ingress.

"December and January were commensurate with good growing conditions. i.e., lots of sunny days with regular morning or afternoon storms (temp range 18˚-32˚).

"February however gave only 10hrs of sunlight. This coming as 5hrs one afternoon and 5hrs the next morning. The expected outcome of all this overcast weather was to see a marked fruit drop. Surprisingly the crop seemed to suffer no ill effects and continued to grow quite well with the only noticeable effect being the leaf size. The size of the leaves grew to about a third bigger than normal as the crop tried to gather in more sunlight in the overcast conditions.

"Then, coming out of February into March, a hot period (2 weeks) of no rain and high temps and high humidity (37˚and 95% humidity) were experienced and this is believed to have caused a shock to the plants which then proceeded to drop fruit from nodes 10-14 leaving a hollow through the crop.

Later in March the rain came back again, and the crop went on to perform as expected with no further fruit loss."

Bruce Connolly,
Tipperary Station, NT.



Managing Your Climate Risk Using Forecasting Tools
Understanding how to use forecasting and weather analysis tools to assess climate risk can assist in better decision making (when managing nitrogen by irrigation decisions and determining crop selection) for the upcoming season. Factoring this information into your cropping plan provides valuable guidance on the use of expensive crop inputs and can also help prepare for extreme climatic events.

What Do You Need to Know?
Forecasting tools rely on imperfect information which can cause variations in reliability, but the trends suggested by a range of tools can provide a valuable source of information to consider in risk management decisions.

Relying on one particular model or information source is risky. Computer guidance can be very reliable at certain times of the year, but there may also be strengths or weaknesses with climatic influences that are not always clear to the user.

Seasonal Forecasts: Rainfall versus Temperature
Modelling and simulating rainfall convective processes in various layers of the atmosphere is a challenging science. The accuracy of rainfall seasonal predictions varies throughout the calendar year and by region. Temperature predictions based on air pressure patterns are generally more accurate than rainfall forecasts. Evaporation due to hot temperatures is an important component of the moisture balance sheet that should not be overlooked.

Above average temperature forecasts can be a good guide to approaching months of heat waves and extreme weather. Conversely models showing below average three-monthly outlooks can also signal increasing cloud cover and lower evaporation, and hopefully rainfall.

El-Niño Southern Oscillation (ENSO)
ENSO refers to the oscillation in the sea surface temperature and air pressure anomalies in the tropical Pacific Ocean. The Southern Oscillation Index (SOI) is an air pressure measurement calculated between Tahiti and Darwin. The SOI represents a 30-day average of a broad belt of air pressure in the Pacific Region. When the SOI is in a positive phase (La Niña), mean sea level air pressure is lower and historically conditions are more favourable for rain.
Generally, from January to May, temperature and rainfall in most summer cropping regions is poorly correlated with ENSO. However, during a definitive ENSO phase, related climate modelling shows stronger results in the winter cropping season and at the onset of summer crop planting.

Recent research has found that climate models have far greater accuracy during defined La Niña or El Niño events than they did in neutral phase years. Neutral years should not be confused with average years; variability will increase during ENSO neutral years, reducing the longer-term accuracy of seasonal models.

Indian Ocean Dipole (IOD)
The Indian Ocean Dipole is a Sea Surface Temperature index in the Indian Ocean. This is a secondary

moisture source during the winter and spring seasons in Eastern Australia. A negative Indian Ocean value is favourable for moisture supply. The IOD life cycle starts in June and typically ends in October and impacts southern growing areas from the Macquarie Valley south the most.

General Circulation Models (GCMs)
The Bureau of Meteorology's GCM is just one of around eight operational seasonal models available internationally. Identifying consensus from these models can give extra confidence in decision making. Variable results can also signal a conservative approach is required.

The GCMs indicate short and long-term precipitation and temperature outlooks, as well as seasonal forecasts.
Most climate models simulating Australian seasonal conditions will be heavily weighted with ENSO information.

Monitoring Seasonal Temperature Forecasts
When planning summer crops, a climate risk assessment can also include regular surveys of international seasonal temperature forecasts. These forecasts can assist in monitoring stored soil moisture and making decisions about likely evaporation rates through the spring and early summer period.

The Australian Bureau of Meteorology releases a seasonal temperature and rainfall forecast on a monthly basis. The results of this forecast should be considered in the context of other models such as leading US, European and Asian forecasts.

Global Circulation Models generally have higher accuracy predicting extremes in temperature than rainfall. A series of monthly seasonal forecasts of high temperatures may often coincide with low rainfall.



What Should You Do on Your Farm?
Stay informed about the latest climate risk management information through the CottonInfo Moisture Manager – a monthly summary of international forecasting models, climate indicators, expert opinion and local analysis delivered by CottonInfo.

Survey information sources widely. Look at a range of models to determine if there is a consistent pattern in the forecasts.



Part F: Understanding Northern Australian Soils

It All Starts with The Soil
Soil health is key to your farm's profit and production. It underpins the fertility and crop production of a farming enterprise, providing the cotton plant with support and access to water, oxygen and nutrients. An understanding how modern farming practices impact on the physical, chemical and biological properties of the soil is critical in making optimal soil management decisions.

(CottonInfo 2021)

What Do You Need to Know?
Source: CottonInfo website – Soil Health

The key components to soil heath are:

Soil organic matter and soil carbon
Soil organic matter is composed of dead and decomposing plant material, soil biota (fungi, bacteria, worms etc.) and animal waste. Soil organic carbon is a component of the soil organic matter and the role this carbon plays is important for all three aspects of soil fertility:

- Biological function: supplying energy for plant and microbial activity.
- Physical function: stabilising soil structure, improving soil aggregation and water movement.
- Chemical function: increasing cation exchange capacity (CEC), buffering pH and reducing the effect of salinity and sodicity.

Subsoil Constraints
Subsoil constraints are soil properties that limit or restrict the cotton plant from meeting its water and nutrient requirements.

An ideal soil for cotton production has good infiltration and internal drainage, high plant available water capacity (PAWC), good soil structure for root growth and development, optimum pH, low salinity, balanced nutrient availability, low sodicity and adequate soil biota.

Problems associated with subsoil constraints include compaction, soil dispersion, high or low pH and waterlogging. These problems can result in poor plant growth, loss of bolls and poor boll set, reduced yields, erosion, increased land management costs and other management issues.

Compaction
Compaction restricts root growth, reducing the availability of nutrients and water to the cotton plant. Soil compaction can also increase denitrification, further reducing the availability of nitrogen. Some compaction is an inevitable consequence of using heavy machinery on soils, but impacts can be minimised by implementing good management practices, minimum tillage, controlled traffic and guidance systems.

Waterlogging

Waterlogging can impact significantly on cotton production, causing problems such as denitrification, boll shed and reduced boll set. Water logging from wet season rainfall during vegetative or early flowering growth stages, can cause a crop to develop a shallow root system, making it sensitive to later moisture stress.

Many of the soils used for cotton production in Australia, are sodic or strongly sodic below a depth of 0.5m. This affects root growth and uptake of water and nutrients. Groundwater used for irrigation can cause sodicity problems particularly when the water contains high sodium levels relative to calcium.

Saline Soils

Saline soils contain excess salts in the soil solution (the liquid in soils held between the soil aggregates). When the concentration of salts in the soil solution exceeds that found in the plant roots, water flows from the roots back into the soil, so that the plant is unable to obtain sufficient water even though the soil is moist.



AM Mycorrhiza

Soil Mycorrhiza

Soil mycorrhiza (also referred to as AM) are soil-borne fungi that attach themselves to the growing roots of crops. They can allow roots to scavenge more effectively for nutrients, particularly phosphorous and zinc, which are immobile in the soil.

AM fungi survive well in dry soils but can decline if the soil undergoes cycles of wetting and drying without a host plant being present. AM can also be reduced in some systems following non-mycorrhizal crops like canola. Low AM colonisation is noted due to the experience of dry season weather lasting for several months after a wet season period, but is not a cause.

Common Soil Issues of Northern Australia

Sources:
- Grundy, Yeates and Grundy. 2012. NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region. Pg. 27.
- Yeates and Poulton. 2019. Determining Dryland cotton yield potential in the NT: Preliminary climate assessment and yield simulation. Pg. 4-5

Soil type can significantly influence agronomic practices required and field trafficability. From a production perspective, loam soils are generally easier for cotton production in wet years than clay soils.

Soils of the Northern Territory

Source: NT Department of Environment, Parks and Water Security. Soils of the NT Fact Sheet

In the NT, soils are an important natural resource for land-based agricultural industries. For comprehensive information about soils in the Northern Territory, including maps of soil types, visit the Northern Territory Department of Environment, Parks and Water Security (DEPWS) website: www,depws.nt.gov.au/rangelands/information-and-requests/land-soil-vegetation-information



Blain type soil (Kandosol) - cotton emergence

Common Soils of the Northern Territory

Kandosols

Often referred to as red, yellow and brown earths, these massive and earthy soils are important for agricultural and horticultural production. They occur throughout the NT and are widespread across the Top End, Sturt plateau, Tennant Creek and Central Australian regions. Also commonly known as Tippera and Blain type soils.

Tenesols

These weakly developed or sandy soils are important for horticulture in the Ali Curung and Alice Springs regions. They soils show some degree of development (minor colour or soil texture increase in subsoil) down the profile. They include sandplains, granitic soils and the sand dunes of beach ridges and deserts.

Hydrosols

These seasonally inundated soils support both high value conservation areas important for ecotourism as well as the pastoral industry. They generally occur in higher rainfall areas on coastal floodplains, swamps and drainage lines. They also include soils in mangroves and salt flats.

Rudosols

These are very shallow soils or those with minimal soil development. Rudosols include very shallow rocky and gravelly soils across rugged terrain such as the Arnhem Plateau but also pure sand soils in deserts.

Chromosols

These are soils with an abrupt increase in clay content below the topsoil. They are generally restricted to small occurrences across colluvial and alluvial plains.

Vertosols

These cracking clays or black soils are critical to the pastoral industry. They are common across coastal floodplains of the Top End, the Barkly Tablelands and basalt and alluvial plains of the Victoria River District.

Calcarosols
These are soils with calcium carbonate often formed on limestone. They are restricted to small pockets in Central Australia, the Victoria River District including Gregory National Park and the Katherine and Mataranka Districts.

Dermosols
These are soils with highly developed structural characteristics. They occur in the Tindal area and other parts of the Daly River Basin.

Ferrosols
These are iron rich soils generally formed on basalt. They are restricted to volcanic landscapes of the Victoria River District and to a smaller extent in the Roper River Catchment.

Less Common Soils of the Northern Territory

Sodosols
Dispersive soils high in sodium with an abrupt increase in clay content between the topsoil and subsoil. They are restricted to small occurrences in the southern region.

Anthroposols
Resulting from human activities. i.e., urban environments, industrial areas and mine sites.

Organosols
Organic and peaty soils in coastal floodplain back swamp environments.

Soil pH
Soil pH is a measure of the acidity, neutrality, or alkalinity of the soil solution. pH directly influences the availability of soil nutrients to the cotton plant. For example, most cracking clay soils are alkaline (pH 8.0 to 8.5), which affects the availability of many micronutrients.

Sodic Soils
Sodic soils have too high a proportion of sodium. This excess of sodium in soil reduces the strength of bonds that hold clay particles together within aggregates. The sodium also attracts water molecules more readily than other cations, which forces the clay particles apart, causing what is known as dispersion, which causes the soil structure to collapse.



Tippera soil profile

Table 1
As an example, the table shows a summary of the challenges and management options for cotton production on the broad soil groups of the lower Burdekin, Queensland.

Further R&D is required to understand this relationship with NT soils specifically and cotton production.

Note. Summary of the challenges and management options for cotton production on the broad soil groups of the lower Burdekin. Adapted from "NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region," by P. Grundy, S. Yeates and T. Grundy, 2012, p27. Copyright 2012 Cotton Catchment Communities Cooperative Research Centre.

Soil group	Positives	Challenges	Management options
Cracking clays	Suitable provided drainage is good. Highest plant available soil water (PAWC). Reasonable levels of Phosphorous (P) and & Potassium (K) may be available Soil test to confirm.	Waterlogging if drainage is poor. Generally sodic at depth — rooting depth and PAWC limited if sodicity is near the soil surface. Ca:Mg ratio may be limiting to structure as many soils are <2, particularly deeper in profile. Trafficability after wet weather. Can be difficult to wet soil surface in the centre of the bed during irrigation. This can be a constraint for activating soil surface-applied liquid nitrogen fertiliser to the centre of the bed.	Ensure good drainage e.g., tail drains designed to exit runoff water quickly. Reasonable slope 0.1%. Avoid run lengths >600 m. High beds about 15 cm above furrow. Use a gypsum program similar to other crops if the Ca:Mg ratio is low. Appropriate nitrogen management is essential.

Gradational clays	Suitable for cotton.	Waterlogging if poorly drained.	Similar to cracking clays.
Levee/alluvial	Best suited for wet season trafficability. Deep root exploration (180 cm) can capture leached nutrients, reducing additional fertiliser requirements.	Surface crusting is a risk where silt is present and soil has been cultivated. Furrow irrigation can be inefficient if beds crust or if water infiltration is too high. Water soluble nutrients such as nitrate are easily leached.	Needs careful management of nitrogen and sulphur. Soil test for other nutrients (e.g., Zn may be required). Controlled traffic + minimum tillage (zero tillage of bed top preferable) with trash retained on soil surface. Better suited to overhead or drip delivery systems.



Two main soil groups suitable for cropping occur in the Top End and Sturt Plateau; Tippera clay loams and Blain sandy loams these have the following characteristics:

- Low inherent fertility particularly N, P and many micronutrients. Organic carbon is also low.
- Mostly low plant available water (80 to 125 mm to 160 cm) although some blain soils are higher being deep (>3m) with a clay loam texture below 1m. The better dryland cotton areas in NSW and Qld have self-mulching clays with 250 to 350 mm of plant available water.
- High susceptibility to surface crusting after ploughing.
- Easily erodible particularly the Blain.
- High soil temperatures will kill establishing seedlings. Surface mulch cover is the best protection.
- Nitrogen as NO3- is easily leached below the root zone or lost in runoff water.

Clay Soils

Where the climate could be suitable for cotton significant areas of heavy clays occur in the Bains and Roper catchments and the Barkley Tableland. Experience at the Ord and Burdekin has demonstrated limited wet season trafficability and water logging are major constraints of clay soils.

Many top-end soils hold only 80 to 125 mm of plant available water in the root zone. The end of the wet season occurs from mid-March to mid-April in most localities. An actively growing crop grown on a soil providing 90 mm of water will extract approximately 6 mm of water per day when actively growing, hence will begin water stress avoidance in 8 to 10 days and sever stress after another 15 days. (Yeates and Poulton 2019, 4 -5)



Soil core sampling in NT cotton

Part G: Introduction to the Cotton Plant

Sources: Adapted from:
• Williams and Bange, 2021, in Australian Cotton Production Manual, Ch 1, p 7–9.
• Grundy, Yeates and Grundy. 2012. NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region. Pg. 84

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

Cotton fibre forms on developing seeds inside a protective capsule called a boll. When seed is mature the boll ruptures and opens, allowing the fibre to dry and unfurl. A cotton plant's primary purpose is to produce seeds – in uncultivated cotton, the fibre is just a by-product which the plant produces to aid in seed dispersal.
When cotton is picked, both the seed and the attached fibre are harvested, compressed into modules and transported to a gin where the seeds and contaminants (leaf and twigs) are separated from the fibre. The fibre is then compressed into 227 kg bales, classed according to fibre quality, and exported around the world to textile mills. A by-product of the ginning process is cotton seed and oil, which are also valuable commodities.

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

Perennial Growth Habits
In its native habitat as a perennial shrub, cotton can survive year after year. Therefore, in situations where the cotton crop has inadequate resources (moisture, solar radiation, nutrients) it will drop or 'shed' some flowers or small bolls (also called fruit). This is a way to guarantee its survival by using the limited resources available to support its leaves, branches, roots and the remaining fruit. This is why extended periods of low solar radiation (e.g., cloudy weather), excessively hot weather, or limitations on root systems (e.g., soil compaction and water stress), particularly during flowering, can lower yields.
But being a perennial, the cotton plant has an indeterminate growth habit. This means that the plant develops fruit over an extended period of time, so in many cases the plant can often compensate after a stress event (i.e., pest attack, physiological shedding), by continuing to grow and produce new fruit if time permits.

Day Degrees (DD)
Generally speaking, a cotton plant grows in a predictable pattern, which allows crop development to be predicted using daily temperature data, which is then calculated into "day degrees". Day degrees are fundamental to understanding crop growth, development and can assist with management interventions. Monitoring of squaring nodes, fruit retention and nodes above white flower (NAWF) will help keep track of how a crop is progressing compared to potential crop development. Furthermore, understanding the stage a crop is at will help in predicting crop water use, as peak water demand occurs during peak flowering.

This accumulation of DD has been calibrated with specific targets for a range of cotton development events (Table 2). The term 'cold shock' refers to when minimum temperature <11˚C, and cotton development is delayed. The DD requirement for first square and first flower increases by 5.2 every time a cold shock occurs.

This new approach to estimating crop development, also known as '15-32 system' is being delivered alongside the existing approach on the Cotton Seed Distributors website day degree calculator (www.csd.net.au/ddc, membership may be required, or Facts on Friday: "New Day Degree Calculator to Assist in Crop Development"). This approach is based on recent research that found that a function that has a base temperature of 15.6˚C (instead of 12˚C) and an optimum of 32˚C can better predict crop stages when there are more extreme conditions, with no need to accommodate for cold shocks. For further information watch "Using Day Degrees in Cotton Production" on CottonInfo YouTube channel www.youtube.com/cottoninfoaust

Table 2
Cotton growth stages with typical DD

Note: Cotton growth stages with target DD. Adapted from "Australian Cotton Production Manual 2021," by S. Williams and M. Bange, 2021, p7. Copyright 2021 CRDC and CottonInfo.

Cotton stage	Notes	Cotton development	Accumulated DD (base 12) after planting
Germination	Germination will start as a seed takes in (imbibe) moisture and temperatures are warm enough.	Base 12	DD1532
Emergence	The two cotyledons (seed leaves) break the soil surface and unfold.	(3-5 days depending on soil moisture and temperature)	

Cont. next page

Vegetative Growth	A cotton plant adds a new node every 42 DD or 2-4 days. This rate will slow as the crop approaches cut-out.		
First Square	A square is a flower bud. The first square occurs on the first fruiting branch at approximately 5-7th nodal position above the cotyledons, about 4-6 weeks after emergence. Initiation of the first 'pinhead' square normally occurs when the true leaf on node 4-5 is unfurled and signals the beginning of the reproductive phase.	505	339
First Flower (15-20 days)	The first square will develop into the first flower within.	777	584
Boll Filling	After the flower petals fall off, a fertilised boll (fruit) is visible. In 20–25 days this boll will reach its maximum boll size. After fertilisation, the boll begins to develop. The boll is divided into 3-5 segments called locks, which contain lint and 6-9 seeds. The number of locks is determined by the time a square has reached a 'pinhead' in size.	1087 (Total time from fertilisation to an open pickable boll is about 50-60 days)	
First Open Boll	Under optimum conditions it takes 1527* about 50 days from flowering to having an open boll.	1527*	1077

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

Cut Out	Occurs when the plant's demand for assimilate (products of photosynthesis) finally exceeds supply so that further growth and production of new squares virtually ceases. It normally occurs when the plant reaches about 3-4 NAWF. Earlier set bolls will start to open and measurements of the number of nodes above the most recent cracked boll (see below) should be used to determine the date of the last irrigation and defoliation. Crop maturity occurs when all bolls have completed fibre development. Generally defoliation begins just prior to full maturity so that the complete loss of leaves coincides with the opening of the last pickable boll.		

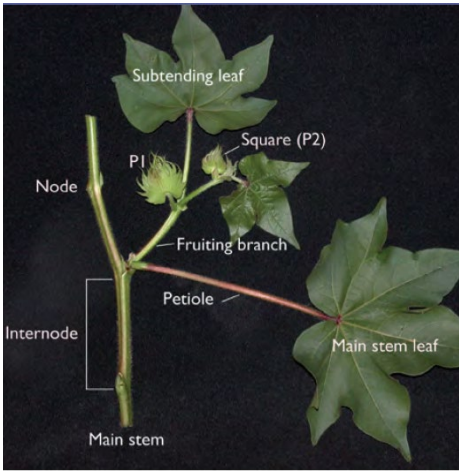


Figure 4. A developing fruiting branch and associated structures. Photo by Paul Grundy. Adapted from "The Cotton Plant", by S. Williams and M. Bange, in Australian Cotton Production Manual 2021, (p. 8), 2021: CRDC and CottonInfo. Copyright 2021 Paul Grundy, Qld DAF.

Cotton Growth

During cotton plant growth and development, two types of branches, vegetative (monopodial) and fruiting (sympodial) will arise. Having only one meristem (growing point), vegetative branches grow straight and look much like the main stem. Vegetative branches can also produce fruiting branches. The first fruiting branch will generally arise from nodes 6 or 7 (position will depend on preceding temperature conditions and variety). With the potential to grow multiple meristems, this branch will grow in a zig-zag pattern and produce multiple fruiting positions. Figure 4 shows a fruiting branch that has formed above a main stem leaf. This branch has produced two fruiting structures along with their subtending leaves. The pattern of development and growth of the plant as a whole is described in Figure 5, where the development of new fruit occurs at the top of the plant on new fruiting branches as well as along older fruiting branches.

Maintaining vigorous vegetative growth before flowering is important as it is these leaves, branches and roots that will support/supply the future boll load. Monsoonal weather can affect the early growth of crops planted in the wet season of northern Australia (December and January planting). The plant has the ability to compensate for this growth during periods of sunny weather.

As a cotton plant develops, new leaves grow and expand, producing carbohydrates to allow new growth of leaves and the developing roots. Once reproductive structures begin to develop, vegetative and root growth will normally slow down as the plant begins to supply resources to the developing fruit. When there are excess resources to the needs of the developing fruit, the rate of vegetative and reproductive growth continues. Good crop management aims to keep the reproductive and vegetative growth in balance for as long as the season allows, timing cut-out to maximise the number of mature fruit (bolls) at harvest. The longer the period of fruit production before cut-out generally translates into higher yields. At cut-out the supply of carbohydrates, water and nutrients equals the amount needed by the developing bolls and new growth ceases.

During crop growth certain growth parameters (e.g., node production and fruit retention) should be measured and recorded to help with management decisions for maximum yield.

Some situations where there is plenty of water and nutrients, excessive vegetative growth can occur. Growth regulators such as Mepiquat Chloride can help manage this growth. Measuring Vegetative Growth Rate (VGR) is an effective technique used



to assist with these decisions. See Managing crop growth Chapter for further information.

Approaching cut-out, bolls grow and they become larger sinks for carbohydrates, water and nutrients, leaving less available for new growth. NAWF (Nodes above white flower) is the number of nodes from the uppermost first position white flower to the terminal. This number will naturally decrease as the season progresses as growth slows from the terminal, and as flowering progresses in a pattern up the plant, the NAWF will decrease. Cut-out occurs when NAWF approaches the top of the plant and flowering ceases (NAWF = 4 or 5). More information on measuring NAWF and cut-out can be found in Preparing for Harvest Chapter of the Australian Cotton Production Manual 2021.

Just as flowering progresses in a pattern up the plant, so does the maturation and opening of bolls. Therefore, measuring the number

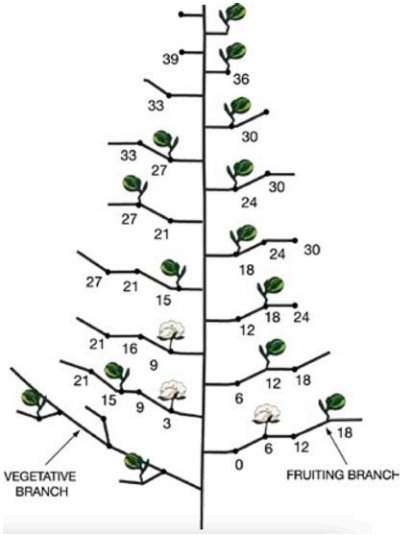


Figure 5. Rate of development of fruiting sites on a cotton plant, adapted from Oosterhuis 1990. Numbers represent days from appearance of first square to the production of new fruiting site. Adapted from "The Cotton Plant", by S. Williams and M. Bange, in Australian Cotton Production Manual 2021, (p. 8), 2021: CRDC and CottonInfo. Copyright 1990 Oosterhuis.



of nodes from the uppermost first position cracked boll (NACB – nodes above cracked boll) to the terminal is an effective way to determine crop maturity. Crops are considered mature and ready for defoliation decisions if they have reached 4 or 5 NACB. More information on measuring NACB can be found in the Australian Cotton Production Manual. Harvest Chapter.





SECTION 3.

GROWING CROPS

PLANNING, GROWTH AND HARVEST STAGES

Part A: Planning Stage

Planning for Your Crop

Source: Adapted from CSD and Bayer et al. 2020. "Northern Newsletter, Pre-Season." Acres of Opportunity.

Planning and preparation in advance of growing cotton, or any rainfed crop, in northern Australia is critical. Some key activities to consider prior to planting are:

Organise Your Contractors, Inputs and Suppliers Early

You will need to source farm inputs such as seed, fertiliser, herbicides, insecticides, growth regulators and defoliants. You are required to sign a Cotton Seed Distributors (CSD) Grower Agreement to purchase seed and if you plan to grow cotton containing Bayer GM technologies you will also need a Bayer Technology User Agreement (TUA), which is a regulatory requirement. There are several CSD Agents and Bayer Technology Service Providers in northern Australia.

Most cotton growers engage outside assistance to help manage their crop. This can include a crop consultant (agronomist) to assist with decision making throughout the season, and contractors for time sensitive farm operations (Eg:, planting, picking and spraying).

Similarly, it is important to have suitable contractors engaged and ready to work when you need them. It is common for planting, spraying and picking of crops to be handled by contractors. In northern Australia particularly, it is important to have suitable transport options secured early in the season to transport cotton rounds to the gin.

The Paperwork - CSD Planting Seed Agreement (Grower Agreement) and Bayer Technology User Agreement (TUA)

Growers must have a Grower Agreement in place before seed can be dispatched from your local agent or reseller. The Grower Agreement is an annual agreement that sets out the rights and responsibilities of CSD, the CSD agent and the grower, with respect to the supply and stewardship of cotton planting seed.

Growers must also sign a TUA. A TUA is a legal agreement between Bayer Australia Pty Ltd (Note: Bayer Crop Science trading as Monsanto Australia Pty Ltd) and a grower, which gives the grower a limited license to use the respective Bayer GM technologies contained in the seeds and describes stewardship guidelines and obligations for the Bayer traits. A TUA can be completed with your Technology Service Provider (TSP).

For more details download the 2021 CSD Grower Information Guide.

Consider the Costs

In terms of budgeting and gross margins for growing cotton, there are a number of things to consider. Although the majority of costs come in-crop and at the back end of the season for a cotton crop, there are still costs related to ground preparation,

fertiliser, seed etc. which come before planting. See Part D: Understanding Gross Margins for Northern Cotton

Consider your Ginning and Marketing Options
It's also important to investigate cotton ginning and marketing, prior to planting. Remember that you will produce two commodities with each cotton crop - the lint and the seed - both of which can provide lucrative returns if marketed wisely.

For a list of Australian merchants visit the Australian Cotton Shippers website (http://www.austcottonshippers.com.au/)

The Bollgard® 3 Resistance Management Plan (RMP)
Insect resistance poses a serious threat to transgenic cotton, as the insecticide toxins it contains are expressed all season long.

The cotton industry has taken a proactive approach to resistance management to ensure the longevity of thetechnology. As a regulatory requirement of the Australian Pesticides and Veterinary Medicines Authority (APVMA) registration of Bollgard® 3, all growers are required to implement the Resistance Management Plan (RMP). Taking into account the unique environment in northern Australia, Bayer, in conjunction with the cotton industry has developed a Bollgard® 3 Northern Australia RMP. The RMP outlines key management strategies that growers must put in place, in order to grow cotton containing the Bollgard® 3 technology. Further details on implementing the RMP is provided in the accreditation program.

For more information refer to the Bollgard® 3 Northern Australia Resistance Management Plan. www.crop.bayer.com.au/products/biotechnology-traits/bollgard-3-with-roundup-ready-flex-cotton#tab-4

Accreditation
Prior to planting any of Bayer's technologies, including Bollgard® 3, growers must complete an accreditation course. The accreditation course provides information on the process required to grow the technology and outlines the key strategies within the RMP. Growers only need to complete an accreditation once for each cotton technology, prior to planting.

What is a Cotton Planting Window?
Cotton planting windows are a resistance management technique that restricts the period in which planting can occur, with the aim of restricting the number of generations of Helicoverpa spp. exposed to the proteins in Bollgard® 3 cotton each season.

For more details refer to the Cotton planting windows and key RMP timings for Northern Australia Guide.

Is Your Current Machinery Suitable to Grow Cotton?
If not, you will need to engage the services of a contractor to assist.



Some field operations - particularly planting - are time sensitive, so there is tangible value in having machinery serviced early. Having machinery ready to go when planting conditions are right and having the capacity to cover the ground quickly will minimise the chance of missing the opportunity when it arises.

Choosing Your Cropping System

Source: Adapted from CottonInfo. Tropical Cotton **Production:** Consideration for Northern Cotton Growers factsheet.

Wet or Dry Season?

Historically, crop production in northern Australia usually occurred during the dry season, but cotton is more likely to succeed as a wet season sown (summer) crop. With genetically modified cotton now used almost exclusively by the industry, planting windows are dictated to the grower under the Technology User Agreement (TUA), meaning that cotton must become exclusively a wet season crop.

Wet season cropping can throw up significant challenges for both experienced and new growers, including:

- **Reduced availability of products and people** The wet season is a traditional 'downtime' period, and securing labour, contractors or agronomic inputs is more difficult.
- **Field trafficability** Have alternative strategies in place to that allow flexible application of crop inputs such as nitrogen when fields cannot be easily driven on.
- **Water availability** Annual closure of irrigation supply schemes for maintenance or riverine flooding can prevent access to water for irrigation. Ensure that you have

a strategy in place to be able to irrigate at short notice during the wet season if conditions suddenly turn dry.

- **Nitrogen (N) management** High losses (>65 per cent) of N can occur due to leaching and volatilisation if large rainfall events occur before the crop root system has established. Growers should delay applying the majority of N until the start of the peak crop uptake period (about 30-50 days after planting) or apply fertilisers that have been modified to delay oxidisation to the soluble nitrate form. Unless the crop is severely deficient, avoid applying N after mid flowering as this will delay maturity.
- **Remember to expect the unexpected!** No two wet seasons are the same - what worked last year may not be suitable this year. Flexibility and lateral problem-solving are essential in a wet season environment.

Wet Season Cropping

Source: Adapted from Yeates and Poulton 2019.

Growing dryland crops in the tropical 'Top End' is very different to traditional summer cropping areas in south-eastern Australia.
That is:

- There is a clearly defined wet and dry season
- The crop must be grown using in-crop rainfall with minimal reliance on stored soil water as soils are well drained mostly with low moisture holding capacity; not heavy self-mulching clays that can store water over a fallow period. By the end of the dry season (October – November) the soil has almost no plant available moisture.
- Early in the wet season rainfall is extremely variable and air and soil temperatures are very high.
- The optimal sowing window is usually tight as it is a balance between sowing early enough to reliably establish a crop and capture as much in-crop rainfall as possible during the wet season. While not planting too early and expose maturing / open bolls to pre-picking rain which will downgrade fibre colour and can reduce yield via boll rot.
- Yields usually decline rapidly as planting is delayed after the optimal window. Zero-till systems with good soil mulch cover increase the number of planting days within the optimal window.
- Cotton yield is largely determined by boll number (70%) which is proportional to the length of the growing season. The other contributor to yield (30%) is boll weight which requires favourable climatic conditions after flowering (water, solar radiation, temperature).
- Cotton requires nitrogen and in the absence of other stresses yield is proportional to the amount of N taken up by the crop in the first 90 days of growth. Nutrition needs to be managed in a similar way to other wet season crops. In-crop application is usually the most efficient for wet season grown cotton with application most effective between 30 and 55 days after planting. (Yeates and Poulton 2019, 4)

The table 3 is data collected from a trial commercial crop in the Douglas Daly region of the Northern Territory during the 2020/21 season. The information in this table is a guide for the conditions and management

activities of growing raingrown cotton in this area during the wet season. The best yield achieved in this trial crop was 7.28 bales/hectare.

Note: the information in this table is indicative of one crop, in one paddock, on one farm, in one location; it must be understood that conditions during the northern monsoonal season can vary dramatically even down to paddock-to-paddock scale.

Dryland/Raingrown Cotton

A combination of low water holding capacity soils, a strongly seasonal rainfall pattern (December to March) and high temperatures makes tropical 'dryland' cropping very different to southeastern Australia where cotton is grown on deep clays with high available moisture following a fallow and sowing occurs during the cooler spring months.

- **Sowing date** Dryland/raingrown tropical cotton depends heavily on timely in-crop rainfall. Achieving acceptable yields requires a 140 - 150-day period when rainfall is reliable. There is a very narrow sowing window; too early risks rain on maturing cotton causing boll rots and fibre discolouration; too late and the crop can be water stressed before bolls are mature, reducing yield and fibre quality.
- **Crop establishment** High soil temperatures and surface crusting impede crop establishment. Place seed on moisture and cover with loose soil. Avoid soil firming press wheels.
- **Row spacing** Skip row configurations are unlikely to be required in tropical dryland/raingrown cotton as root system development usually occurs mid wet season when rainfall is most reliable, although this requires further research.
- **Nitrogen** Applying the majority of fertiliser in-crop 30 - 50 days after planting significantly increases the efficiency of fertiliser uptake by cotton and reduces up-front costs.
- **Zero Tillage** Combined with uniform surface mulch cover (or planting directly into a cover crop such as millet, jarra or cavalcade) reduces runoff, improves soil water availability, moderates soil temperatures, and improves planting date flexibility. This system has been shown to increase dryland sorghum yield at Katherine by up to 80%.



Tipperary Cotton

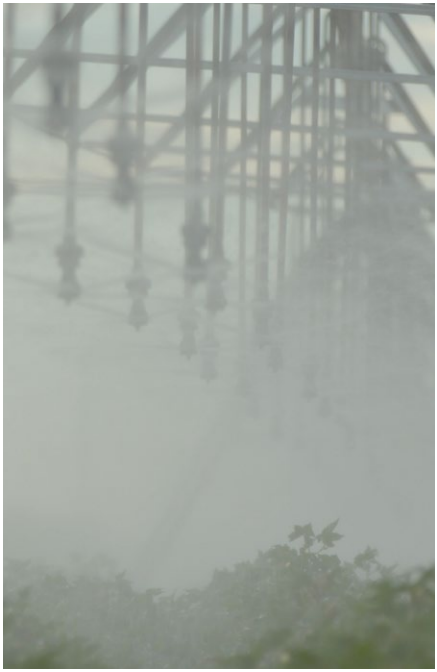
Table 3
Crop summary of a 2020/21 season cotton crop in the Douglas Daly region

Note. Crop summary of a 2020/21 season cotton crop in the Douglas Daly region. Adapted from "Variety Trials", by Cotton Seed Distributors 2021. www.csd.net.au/variety-trials Copyright 2021 Cotton Seed Distributors.

Crop Summary	
Planted	6/1/21
Seed imbibition date	8/1/21
Establishment method	Rain Moisture
Previous crop	Long Fallow Cavalcade
Row configuration	Solid 1m
Planting speed (km/hr)	7
Planting depth (cm)	3
Monitor rate (seeds/m)	7.5
Soil temperature at planting (˚C)	29.3
Defoliation date	10/5/21
Days to defoliation	122
No. of defoliation	2
Rainfall (mm)	916
Effective Rainfall (mm)	
Picking date	24/6/21

In-crop irrigations	0
Total nitrogen (kg/ha N)	120
Pre-plant nitrogen (kg/ha N)	50
Post-plant nitrogen (kg/ha N)	70
Phosphorus (kg/ha P)	35
Potassium (kg/ha K)	55
Zinc (kg/ha Zn)	1.6
Flowering pix applied (L/ha)	0.6
Cutout pix applied (L/ha)	1.8
Total pix applied (L/ha)	2.4
Helicoverpa sprays*	1
Mirid sprays*	2
Mite sprays*	1
Whitefly sprays	0
Total sprays	4

*Disclaimer: Always follow label directions



Irrigated Cotton
Source: Adapted from CottonInfo. Tropical Cotton Production: Consideration for Northern Cotton Growers factsheet.

Depending on location, cotton can be irrigated to supplement wet season (summer) rainfall or be fully irrigated during the dry season (winter), but not both in a calendar year. Considerations include:

- **Sowing date selection** Aim to ensure critical flowering and boll filling stages occur during periods of reliable long sunny days, with mild night temperatures (15 - 23˚C) that are followed by reliable dry weather for picking. Spring planting (used in temperate Australia) is high risk in the tropics due to low radiation during flowering and high rainfall on maturing bolls (January to March) leading to boll rots and fibre discolouration. Sowing date must fall within the allowable planting window for the region.
- **Plant populations** Vigorous early growth leads to larger plants, so lower plant populations (6 - 10 plants/m2) are preferred. At higher establishment rates the plants will compete for light, exaggerating internode expansion and crop height.
- **Crop establishment** Planting deeper than 3 - 4 cm is risky if intense rainfall follows on soils with the potential to form surface crusts. Soil firming press wheels can exacerbate crusting. Avoid placing N fertiliser with or underneath seed; band to the side, particularly if using DAP.
- **Growth regulation** Use of growth regulators must achieve a balance between suppressing vigorous early growth and not inhibiting the production of later fruit if required for yield compensation.
- **Irrigation scheduling** During the transition from the wet to the dry season, scheduling will depend on prior rainfall and the size and depth of the root system. Root system characteristics can vary greatly between seasons, and it is possible for crops to become water stressed in less than a week after rain. Large yield losses have occurred at the Burdekin due to this scenario.
- **Mepiquat chloride (Pix®)** recommendations from temperate Australia based on internode length DO NOT WORK in tropical production systems. Yield reductions of up to 26% in wet and 16% in dry seasons occur when excessive Pix application prevents plant recovery from

environmental stresses. Local R&D has developed, and validated crop monitoring systems based on maintaining an optimum height range relative to the overall height, node number and crop boll load as the crop develops by only using low rates of Pix (repeat dosages when required) and/or other management (e.g., irrigation).

Northern Australia Cropping Calendar - Cotton

Sources: Adapted from:
- Yeates and Poulton 2019
- Bayer. 2020. "2020/2021 Grower Guide." Growing Cotton in Northern Australia.

Choosing a Planting Date

Dryland, or raingrown, tropical cotton depends heavily on timely in-crop rainfall. Achieving acceptable yields requires a 140 - 150-day period when rainfall is reliable. There is a very narrow sowing window; too early risks rain on maturing cotton causing boll rots and fibre discolouration; too late and the crop can be water stressed before bolls are mature, reducing yield and fibre quality.

Assuming average temperatures, cotton planted in the wet season will require at least 100 days to produce its first open boll then depending on the flowering period will continue to grow and open bolls for about a month provided soil water is available. Planting too early in the wet season could increase growing season length but increase the risk poor crop establishment and rain at maturity. Hence the length of the growing season for dryland cotton in the NT will depend on the duration of the wet season following planting and the amount of soil available water to finish boll growth after the 1st boll has matured. (Yeates and Poulton 2019, 6)

Many top-end soils hold only 80 to 125 mm of plant available water in the root zone. The end of the wet season occurs from mid-March to mid-April in most localities. An actively growing crop grown on a soil providing 90 mm of water will extract approximately 6 mm of water per day when actively growing, hence will begin water stress avoidance in 8 to 10 days and severe stress after another 15 days. (Yeates and Poulton 2019, 6)

The likely best planting windows for cotton at 4 locations in the NT was identified by:

1) Calculating thermal time values (Degree Day sums) derived at the Burdekin to predict the date of critical crop stages.

2) Calculating half monthly rainfall variability and comparing this with growth stages for different planting windows to define the best balance of wet or dry conditions for crop establishment, yield, boll rots or fibre discoloration of maturing bolls. (Yeates and Poulton 2019, 6)

For Tipperary and the Douglas Daly Region:

- Planting 1 to 15 December will expose a cotton crop to large volumes of rain during early boll maturity (mid–March).
- Planting in late-December to mid-January will provide rain during flowering with a lower risk of rain at maturity.
- Planting in early February avoids rain on maturing bolls but greatly reduces the likelihood of rainfall during flowering and boll growth risking lower yield. A soil with higher-than-average plant

available water will be required to reliably produce acceptable yields when sown at this time. (Yeates and Poulton 2019, 6)

In the Katherine and Larrimah Regions:

- The rainfall pattern is similar to Tipperary and Douglas Daly with lower rainfall volumes per half month.
- Rainfall variability is extreme between late December and late March.
- Lower rainfall volumes will increase the risk of within season water stress and reduce the risk of boll rot and fibre colour down grade due to prolonged rainfall near maturity.
- The planting window will be similar to Tipperary and Douglas Daly with the greater likelihood of water stress and high temperature reducing planting opportunities in mid-December and yield when planting occurs on or after mid-January.
- Fibre discoloration and boll rots at or near boll maturity will be less likely in late March and early April. (Yeates and Poulton 2019, 8)

Yeates and Poulton (2019) conclude that:

- The planting window for dryland cotton that is most likely to balance yield with avoidance of rain damage to maturing cotton was mid-December to mid-January.
- However, when planted within the optimal window the median simulated dryland yield varied between 1 and 5 bales / ha: the range due to differences in available water between soils, soil nitrogen availability including N fertiliser management, and the amount and type of soil much cover.
- When a legume mulch contributed 20 to 30 kg N/ha to nitrogen supply yield was maximised by applying 100 kg/ha of N split 50:50 between sowing and 30 days after sowing. Applying 150 kg N/ha marginally improved yields as other factors were limiting (water, solar radiation).
- This analysis demonstrated the need to target soils with higher water availability for dryland cotton production. (Yeates and Poulton 2019, 16)

When using Bollgard® 3 (or any licenced product) planting dates must fall within the relevant planting window.

What is a Planting Window?

Source: Adapted from Bayer. 2020. "2020/2021 Grower Guide." Growing Cotton in Northern Australia.

A planting window is a resistance management technique that restricts the period in which planting of a cotton crop containing Bollgard® 3 insect control technology can occur, with the aim of restricting the number of generations of Helicoverpa spp. Exposed to Bollgard® 3 crops each season. Planting windows are an important part of the Bollgard® 3 Resistance Management Plan (RMP), regulated by the Australian Pesticides & Veterinary Medicines Authority (APVMA).

How Do Planting Windows Work?

Planting within a window reduces the length of time that Bollgard® 3 cotton will be in the ground and thus limits the number of generations of Helicoverpa spp. exposed to the Bt proteins

contained in Bollgard® 3 cotton during this time.

The greater the number of generations exposed to the Bt proteins, the greater the opportunity for resistance to develop.

Cotton Planting Windows for Northern Australia

For more information including region specific planting windows, which requires all Bollgard® 3 cotton crops to be watered up or planted into moisture by the designated date, unless otherwise advised by a "Bollgard® 3 Planting Window, refer to Bayer's Cotton planting windows & key RMP timings for Northern Australia resources www.crop.bayer.com.au/-/media/bcs-inter/ws_australia/use-our-products/product-resources/cotton-traits/planting-windows-in-northern-australia-quick-guide.pdf

Northern Rotation Crops

Source: Adapted from NT Farmers Association. 2020. Northern Territory Plant Industries Economic Impact Analysis.

There are a number of crops currently grown successfully and profitably in northern Australia that have potential as rotational crops with cotton. These include sorghum, maize, mung bean, pulse crops such as cowpea, peanuts, sesame, hay and fodder crops. Some of these, such as hay crops, have proven to be effective cover crops within a cotton-based cropping system. Further detail on cover crops is provided in coming sections.

NT Farmers have identified three key crops that are likely to be successful in northern Australian farming systems, with production to expand quickly.

These crops are:

Peanuts

Peanuts are a highly important crop to plant-based agricultural and horticultural crop producers in the NT, given their high gross margin and suitability to the region.

Peanuts, while traditionally grown on red clay loams, can be grown on a wide range of soils, including sands, sandy loams and silty loams. Soils with loose and friable surfaces, such as sandy levee and Blain sandy loams, are favoured as they are both easier to dig, and are able to produce a clean, light-coloured shell.

Despite peanuts often being classified as drought tolerant, the highest quality and yields are often obtained from areas with reliable rainfall, and with access to irrigation. As such, irrigation management is critical to obtaining a high yielding economically viable crop.

A regular rotation of crops with peanuts is encouraged, to avoid



Forage sorghum used as windbreak to assist with peanut crop establishment

building up weed, disease and insect problems associated with any mono-culture system. The ideal crops to include with peanuts include cereal crops, such as maize and sorghum, sugar cane or a grass pasture phase. There is a significant opportunity to expand the production of peanuts in the NT. Australian growers only supply a fraction of the local domestic demand and prices remain relatively stable throughout the year.

Currently, there are no shellers/ processors in the NT, resulting in all produce being freighted to Queensland. Peanut Company Australia (PCA) remain interested in peanut production in the NT as a post farm gate handler.

Rice

Rice, similar to peanuts, has shown potential for incorporation into an economically viable crop rotation in the NT, specifically the Douglas Daly region. So much so that, in 2019, trials of wild rice were planted in close proximity to Darwin.

The soil and water resources of the NT are sufficient to develop the minimum scale required for post farm gate processing of rice, in rotation with peanuts and mung beans.

The most suitable rice crop variety for the region is likely aromatic rice, given its significant gross margin and sizeable market size and competitiveness. There is significant growth potential associated with the development of an aromatic rice crop, in rotation with other crops, as Australia imports around 200,000 tonnes at an estimated value of $130 million per year.
Australia's main rice marketer, SunRice, purchased a rice mill in Burdekin during 2016 for aromatic rice production, signalling the potential growth and economic viability of a plant-based agricultural precinct with rice-production capabilities.

There is also strong support from the Federal Government for the production of rice production across northern Australia. The Government established a $4 million program in 2016 to support the expansion rice production in the region and provided $1.8 million of funding to the Charles Darwin University to develop a commercially viable native rice



NT grown rice

industry. The development of a plant-based agricultural precinct would support the production of aromatic rice, or other suitable varieties, in the NT. Aromatic rice, in rotation with other crops such as peanuts and mung beans, is a biologically sustainable and economically viable agricultural production model.



Industrial Hemp

Industrial Hemp

The development of industrial hemp presents plant-based agricultural and horticultural producers with a significant growth opportunity, following the momentum and traction it has gained in the past decade.

Industrial hemp is a fast growing, annual herbaceous plant with a deep tap root. Industrial hemp is a short-day plant, thus requires a set number of successive days for flower initiation.

To achieve a viable gross margin, the production of industrial hemp must occur on a broad acre basis. As such, the farming operations will likely need to be comparable to that of other broad acre crops, such as sorghum, cotton and soybean.
Industrial hemp is well suited to fertile, neutral to slightly alkaline, well drained clay loam or silt loam. The plant is largely intolerant to wet, flooded or waterlogged soil, thus should be sown at a 4cm to 5cm depth in non-crusting soils to achieve rapid germination. Furthermore, adequate moisture is required during active growth to obtain an economically viable yield.

Investigation into industrial hemp has concluded that, once infrastructure is established, the crop has potential to compete with other broad acre crops in terms of farm gate returns. Therefore, the construction of a processing facility will provide further opportunities for industrial hemp production. The development of a plant-based agricultural precinct would support the production of industrial hemp in the NT, likely resulting in the realisation of the crop's vast growth potential and scalability for the future. (NT Farmers Association 2020, 29-30)

R & D trials on hemp are being undertaken by the DITT at the time of publication. Results and learnings from these trials will be included in future editions. Market opportunities for hemp material is a significant contributor to the development of this emerging industry. AgriFutures has identified hemp as one of the priority industries. The recent formation of the Australian Hemp Council to develop a Hemp RDC demonstrates the positive advancements hemp has made in recent times.

Broadacre cropping Research

Across northern Australia four broadacre cropping projects and one specific commodity (spices) cropping project are being co-funded by the CRC for Developing Northern Australia (CRCNA), Grains RDC (GRDC), Cotton RDC (CRDC), and other organisations

and companies in the North. The CRCNA has co-invested with the Grains Research and Development Corporation (GRDC) in four broadacre cropping projects, three of which are in far north Queensland. The fourth project is a partnership between the CRCNA, GRDC and the Cotton Research and Development Corporation (CRDC) in the Northern Territory.

Further, the CRCNA has partnered with Central Queensland University and several producers to deliver a commodity specific cropping project in central Queensland and the Northern Territory. Each of these five projects take a different emphasis to the issue of bringing broadacre cropping to diversify existing pastoral and farming enterprises of northern Australia. More information www.crcna.com.au/resources/publications/broadacre-cropping-northern-australia-newsletter-vol-2A planting window is a resistance management technique that restricts the period in which planting of a cotton crop containing Bollgard® 3 insect control technology can occur

- The aim is to restrict the number of generations of Helicoverpa spp. exposed to Bollgard 3 crops each season
- Planting windows are an important part of the Bollgard 3 Resistance Management Plan (RMP), regulated by the Australian Pesticides & Veterinary Medicines Authority (APVMA) and are unique to each valley
- All valleys must agree upon an 8-week planting window between 1 December and 30 May

Compliance with the Bollgard 3 Resistance Management Plan (RMP) is essential to ensure the longevity of the technology.

The RMP is based on five key principles:

- Planting Windows
- Refuge Crops
- Control of volunteers and ratoon cotton
- Pupae busting/trap crops
- Spray limitations

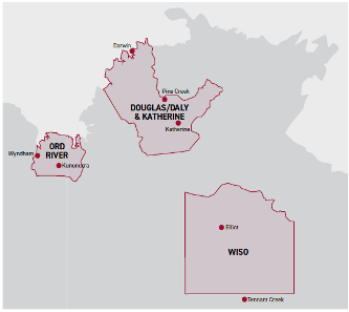
The RMP can be downloaded at www.bollgard3.com.au

Bayer Websites

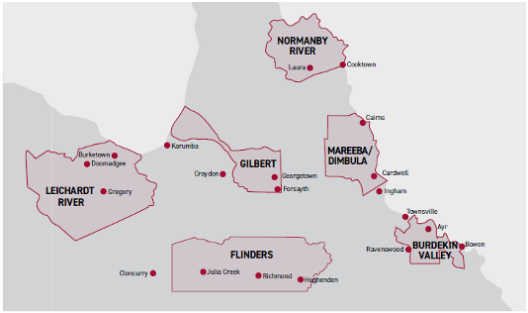
- www.crop.bayer.com.au
- www.bollgard3.com.au

Acres of Opportunity website

- www.acresofopportunity.com.au



Planting window NT/Ord Valley



Planting window North Queensland

What is the Process for Setting a Planting Window?

Prior to planting cotton in northern Australia, growers must check their valley planting window dates. To set planting window dates, the following process should be implemented:

If there is a Cotton Grower Association (CGA) in place:

- The valley's Cotton Grower Association should determine an 8-week window that best meets the needs of growers.
- The CGA should apply to the Transgenic and Insect Management Strategy (TIMS) via written notice of the desired planting window dates.
- If approved, TIMS will notify Bayer.
- Bayer will communicate the window to growers and Technology Service Providers (TSPs) via a "Planting Window Notice" specifying the dates for that valley.
- Growers must comply with this notice.

If there isn't a Cotton Grower Association in place:

- Growers should contact their local TSP or Bayer to notify of preferred planting window dates.
- Bayer will work with local TSPs and TIMS to set a window that meets the needs of the majority of growers.
- Bayer will communicate the window to growers and TSPs via a "Planting Window Notice" specifying the dates for that valley.
- Growers must comply with this notice.

Growers must understand and always refer to their TUA for their obligations under this agreement when it comes to key activities, such as sowing, refuge crop establishment etc.

Northern Australia Cropping Calendar – Other Crops

CSIRO has published a comprehensive study of the agricultural opportunities for crops across three major catchments in northern Australia (Mitchell Catchment in Qld, Darwin Catchment in the Northern Territory and the Fitzroy Catchment in Western Australia). These studies include a cropping calendar of crops broadly suited to production in these regions.

The Darwin catchment is indicative of potential sowing, growth and harvest stages for a number of crops in the northern regions. Figure 7 provides an overview of the cropping opportunities for the Darwin catchments, and is a useful guide for planting, growing and harvesting times for each potential crop.



Regional hay production (Jarra grass)

Crop Type	Crop	Crop duration (days)	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Irrigation Management		
															Rain Fed	Supplementary irrigation	Full Irrigation
Cereal	**Maize**	100-140													•	•	•
	Rice**	90-160+															•
	Grain Sorghum	110-140													•	•	•
	Barley	100-140															•
Pulse	**Mungbean**	70-85													•	•	•
	Chickpea	90-100															•
Oilseed	**Sesame**	100-120													•		
	Safflower																
Legume	**Soybean**	90-100													•		•
	Butterfly pea	90-110													•		
	Pigeon pea	100-120													•	•	•
Forage Legume	**Cavacade**	150-180													•		•
	Lablab	100-120													•	•	•
	Cowpea	100-120													•	•	•
Forage hay silage	**Millet**	60-80													•		•
	Sorghum	90-110													•		•
	Rhodes Grass	60-80 Perennial															•
	Jarra Grass	Perennial													•		
	Maize	80-120													•	•	•
Root crops	**Peanuts**	100-140															•
	Cassava	180-210															•
Emerging crops	**Cotton**	120-150													•	•	•
	Hemp*	70-120															•

*Emerging crops, further northern R & D required
**irrigated variety only, new forage varieities require northern R & D

Crop growing period

Suggested planting window

Suggested planting window for perennial crop

Figure 7. Annual cropping calendar for agricultural options in the Darwin catchments. Adapted from "Chapter 4: Opportunities for agriculture and aquaculture" by Ash A, Irvin S, Philip S, Poulton P, Watson I and Webster T, 2018, In: Water resource assessment for the Darwin catchments. A report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, by Petheram C, Chilcott C, Watson I and Bruce C (eds), 2018, p. 177, part of the National Water Infrastructure Development Fund: Water Resource Assessments. Copyright 2018 by CSIRO, Australia.

Field and Soil Preparation

Sources:
• Peachey, Alex. In CSD and Bayer et al. 2020 "Northern Newsletter, Pre-Season Edition". Acres of Opportunity.)
• CSD and Bayer et al. n.d. "The Dozen Deeds for Northern Australia." Acres of Opportunity.

Mulch Cover Protection for Cotton

Expert Comment:
"The cotton seed is actually very fragile; it will die in hot soil. Planting a cover crop, such as Jarra grass first, harvesting it, then planting cotton into the Jarra stubble is much more effective than planting into bare soil. Unless there is cloud cover and rain at planting soil temperatures without a stubble are just too hot for the cotton seed in the NT. "

Steve Yeates, leading northern Australia cotton researcher, presenting cotton research data from a range of cotton trials in Australia's tropics at a Northern Territory mulch cover workshop in October 2020.

Expert Comment:
"Trial work done in at Katherine Research Station has clearly shown conservation farming and planting into a mulch or stubble has multiple benefits for helping a cotton crop get established"

Fergal O'Gara, Katherine agronomist, presenting at a Northern Territory mulch cover workshop in October 2020.

Expert Comment:
"Mulch cover is part of a minimal till farming system, also known as conservation farming. Conservation farming is any farming system that aims to conserve soil and moisture.

Other benefits of planting into mulch or stubble from a previous crop is more water infiltration into the soil profile and an increase in water holding capacity of the soil. Mulch cover also protects the soil from intense storm rain crusting the soil surface and preventing the seedling from establishing. There is also evidence of reduced need for herbicide as a minimal till system does not disturb the weed seed bank as much as a conventional till system.

"There are more planting opportunities with mulch cover due to greater soil water and planting can be done in two passes, without losing time cultivating while saving on diesel fuel. There is also less erosion and loss of topsoil."

Alex Peachey, Senior Extension Agronomist, NT Dept. of Industry Tourism and Trade

Maintaining a cover crop is critical for the benefit of:

- Aiding in crop establishment, in providing a mulch layer to:
  - Preserve moisture in seeding zone.
  - Insulate against high soil surface temperatures during planting.
- Reducing rain splash, helping to retain moisture and reducing the possibility of runoff and erosion.
- Creating a micro-environment which promotes early season growth, and a habitat for beneficial insects.

Using Minimum or Reduced Tillage

Research and commercial practice on dryland grain crops in the NT during the 1990's clearly demonstrated the huge benefit of zero or reduced tillage into mulch cover provided any nitrogen tie up by non-leguminous mulches could be managed. The key benefits where a greater number of planting days within the optimal window, higher yields in dry years, lower soil temperatures, reduced soil crusting, greater infiltration of rainfall and slower drying of the soil surface when the crop is young. (Yeates and Poulton 2019, 15)

Selecting Seed

Source: Adapted from CSD and Bayer et al. n.d. "Dryland Cotton Guide". Acres of Opportunity.

Selecting a cotton variety that has the right regional and production type fit is a very important decision. Cotton Seed Distributors (CSD) has a range of varieties available, which should be selected based on:

1. Potential yield in your area and production type
2. Disease tolerances
3. Resilience in fibre quality
4. Technology choice:
   a) Conventional: cotton is non-GM.
   b) Roundup Ready Flex®: can be sprayed over-the-top with Roundup Ready® Herbicide with PLANTSHIELD® and / or Roundup Ready® PL Herbicide with PLANTSHIELD® Technology. This technology has revolutionised cotton production by reducing the need for residual herbicides, in-crop chipping, cultivation and shielded lay-by applications.
   c) Bollgard® 3: is the latest generation insect control technology that offers excellent control of helicoverpa, the main cotton pest within Australia. It offers three different protein toxins for control and reduces the need for broad spectrum insecticide sprays.
5. Other varietal characteristics such as determinacy, leaf shape and season length should also be considered

Part B: Growth Stage

Crop Establishment

Source: Adapted from Quinn and Roughley. 2021. In Australian Cotton Production Manual 2021. Ch 15, p 87-88

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. Establishment in northern regions is especially challenging given extremes in heat and rainfall, as well as wet season limiting planting opportunities within the 8 week window.

If the crop has a strong start, obtaining yield potential is much easier.

Plant 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

Planting Rate

The cotton planting rate calculator (www.csd.net.au/planting-rate-calculator membership maybe required) 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; and,
- 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.

The seed size and germination data for the variety grown will have a large impact on the final planting rate. On average, there are between 10, 000 and 11, 000 seeds per kilogram; however, there are differences between varieties, which can impact significantly on the final kilograms per hectare planting rate. The seeds per kilogram information for cotton planting seed can be obtained via the AUSlot number and QR code on your bag of seed. This will link you directly to access your statement of seed analysis from CSD's website (www.csd.net.au/auslots membership maybe required).

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 rate 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 seven-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.

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 a seed sample submission, please contact your preferred agent.

Planter Setup

Ensure planter is well serviced and operating well before planting time because breakdowns in the field can rob you of time:

- Check CSD's planter maintenance checklist at www.csd.net.au/resources/69-planter-maintenance-checklist (membership may be required)
- Ensure the planter is level.
- Check that discs and press wheels are uniform and engage the soil in the correct manner.
- Check that monitors are calibrated and working correctly.
- Chains and cogs need to be properly adjusted and lubricated.
- Spray lines and filters should be cleaned to stop blockages when planting herbicides or in-furrow sprays are to be used.
- During the operation, 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.
- Keep a kit of spare parts (seed tubes, press wheels, scrapers, monitor cables, chains, and nozzles) in the cabin to allow for quick minor repairs.
- Planter seeding rates should be calibrated as well as granular insecticide rates if used.

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.

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 shown that planting at depths of more than 5 cm can compromise establishment, even under ideal conditions. Typically in northern Australia planting deeper than 3 - 4 cm is risky if intense rainfall follows on soils with the potential to form surface crusts.

Planting Speed

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. Note that soil firming press wheels can exacerbate crusting caused by intense wetseason rainfall.

One of the keys to plant stand uniformity is planter speed. The aim should be to plant with precision, not speed. Results from trials conducted by Cotton Seed Distributors on traditional MaxEmerge planters show an ideal planting speed of around 8 to 10 km/hour. The average population decreased when the planter sped up past 10 km/hour and slowed down below 8 km/hour.

Do I Need to Replant?

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 6 to 10 plants per metre of row, distributed along the row as uniformly as possible. Potential yield declines as planting is delayed.

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.

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 and whether there is sufficient time in the planting window. 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 there a risk of extreme heat?

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.

Soil moisture status: In seasons where irrigation water is such a limiting factor, the soil moisture status is critical in determining whether or not a replant is justified:
- Is flushing or rainfall going to get dry seeds up?
- What implication does this have to the water budget for the rest of the planted area?

Dry seeds: Seeds can survive in soil for a long time. Consider if a stand will be improved if rainfall or irrigation germinates these dry seeds.

Variety selection: If the replant means you are planting late in the window, choose a variety which has performed well in late planted scenarios in your area. These are typically the more determinant variety with inherently longer, stronger, and mature fibre as cooler conditions at the end of the season can negatively impact on fibre quality. Check CSD's variety guides for suitable varieties.

The Implications of Not Replanting
Sometimes sticking with the plant stand you have is a better option than replanting. There are some considerations of managing a low plant population:

Lower yield potential: If possible, prioritise resources to fields with a better plant populations and higher yield potentials. This is particularly relevant in limited water situations.

Weed populations: Low plant populations with gaps may encourage weed problems later in the season due to lack of competition. A plan for their management should be devised early. (Quinn and Roughley 2021, 87-88)

Cotton Nutrition Requirements and management
Ensuring the crop has adequate nutrition is critical to maximising yield, but with fertiliser application making up one of the highest variable cost line items and numerous downsides from over fertilising (eg. rank growth) nutrient efficiency is a key management consideration. Cotton crop nutrition should not occur in isolation but should be planned with consideration of other management practices such as:
- Crop rotation.
- Stubble/cover crop management.

- Tillage practices.
- Use of legumes, manures and composts.
- Soil chemistry (salinity, sodicity) that may limit root development and
- exploration.
- Water availability and timing of wet season rainfall.
- Soil physical condition

High yielding cotton in the Australian production system typically leads to the removal of large amounts of nitrogen (N), phosphorus (P) and potassium (K) from the soil in the harvested seed-cotton (Table 1). An average 11 bale/ha crop will remove 136 kg N/ha, 25 kg P/ha and 39 kg K/ha

Major Nutrients are:
- Nitrogen (N)
- Phosphorous (P)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Sulphur (S)

Micro-Nutrients are:
- Boron (B)
- Chloride (Cl)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Zinc (Zn)
- Nickel (Ni)
- Cobalt (Co)

Nutrient removal at various yield levels in bales/ha. The green shaded area represents macronutrients, yellow shaded area represents micronutrients (note a change in units of measurement).

Yield	N	P	K	S	Ca	Mg	Na	B	Cu	Zn	Fe	Mn
b/ha	kg/ha							g/ha				
4	33	11	12	4	2	7	0.13	8	11	56	91	18
5	50	13	17	5	3	8	0.14	18	13	64	99	24
6	65	15	22	6	3	9	0.15	28	15	73	109	30
7	81	17	26	7	4	11	0.15	36	18	85	122	36
8	95	19	30	8	5	12	0.16	43	20	97	138	42
9	109	21	33	9	5	13	0.17	49	22	112	156	48
10	123	23	36	10	6	14	0.18	55	24	128	176	54
11	136	25	39	11	6	15	0.18	59	26	145	199	60
12	148	27	41	12	6	16	0.19	62	28	164	224	66
13	160	29	43	13	7	18	0.20	65	30	185	252	72
14	171	31	45	14	7	19	0.20	66	32	207	283	78
15	182	33	46	15	7	20	0.21	67	34	231	316	84
16	192	35	47	17	7	21	0.22	66	36	257	352	90
17	201	37	48	18	8	22	0.22	65	38	284	390	96
18	210	39	48	19	8	24	0.23	62	41	312	431	101
19	219	41	48	20	8	25	0.24	59	42	343	474	107

The management of highly soluble negatively charged nutrients such as nitrates and sulphates has always been challenging in the tropical wet season. Large rainfall events can occur at any time and have the capacity to leach or erode significant amounts of these nutrients from the root zone or the field. Nitrogen can be converted to nitrous oxide when the soil becomes waterlogged and be lost to the crop by volatilisation. All forms of nitrogen, whether sourced from fertiliser, manures, plant residues, or soil organic carbon can be easily lost by these processes. Organic matter from previous crop stubble will decompose (mineralise) rapidly in this wet and warm environment. Legume stubble either from grain or cover crops is high in nitrogen and particularly susceptible to rapid mineralisation. When converted to nitrate this nitrogen can be
leached below the root zone or into the furrow to be lost in tail water.

Considerations for nutrition in northern systems

- Rooting depth. Prolonged wet weather will suppress root exploration and roots will only access nutrients near the soil surface. It is important to know where both the roots and nitrogen are in the profile during the season
- Previous crop. Reserach found nutrient depletion by proceeding crops (from high to low) is sugar > maize > grain soybean > grain mungbean. Mungbean/soybean or millet cover crops (where the grain is not harvested) have the least impact. A full sugar cycle (plant cane and 3-4 ratoons) will deplete the soil of N, S and potentially other nutrients, including organic carbon. Although legume cover crops provide nutrients, rapid stubble breakdown means there is a risk of quick mineralisation and losses to leaching or runoff.
- The time between the previous crop and cotton. Mineralisation of the remaining stubble and roots after sugar and maize can be very slow due to a high proportion of carbon to nitrogen (C:N ratio) and significant amounts of N can be 'tied up'. The longer the break between cotton and these crops, the more efficiently fertiliser N will be used by the cotton crop (meaning less fertiliser will be required). On the other hand, legume crops can break down too fast for the cotton crop to capture the released N before losses might occur.
- Soil type. Leaching of N below the roots is more likely in sandy or loamy textured soils. Stubble breakdown is usually faster in sandier textured soils than clay soils. Fertiliser rates and timing research across different soil types and climatic zones remain a focus for industry going forward..

Planning seasonal nitrogen requirement

To estimate the total nitrogen fertiliser requirement for the coming cotton season, knowledge of the previous crop, the inherent fertility of the soil, seasonal rainfall outlook and the time and management between harvesting the previous crop and sowing cotton is required. The predicted total nitrogen requirement can be adjusted with mid season nitrogen application once crop growth and climatic conditions can be better determined.

Nitrogen application (based on Burdekin research)

*best practice nitrogen management for NT soils is still a focus for research. Splitting of nitrogen fertiliser application so the majority is applied between 25 and 50 days after sowing is the most efficient and effective way to apply nitrogen, and reduces the risk of fertiliser burn to seedlings on sandy soils. Flexibility is required in the method of application of in-crop nitrogen to reduce the risk of wet ground preventing machinery entering the field.

Clay soils: apply between a third and half the total required nitrogen at sowing. This is because in seasons receiving average or above average rainfall during January and February the efficiency of uptake of nitrogen fertiliser applied at sowing is generally low (20-40%).

- If the previous management of the field is favourable to soil nitrogen and field layout (good drainage or controlled traffic) permits entry by machinery within a week of significant rainfall, then apply a third of the total nitrogen required.
- Where entry to a field is more likely to be delayed by rainfall apply half the total nitrogen required. The efficiency of this pre-plant fertiliser could be poor so anticipate that increased nitrogen may need to be applied incrop.

Sandy or loam soils: the amount of nitrogen applied at sowing is determined by the risk of fertiliser burn to seedlings. Applying as little as one third of the total required nitrogen at sowing will minimise fertiliser burn provided there is separation between the seed and fertiliser. Because N uptake efficiency at sowing is usually higher (35-60%), there is less chance of running out of nitrogen before the second application is made. Good trafficability on these soils reduces the risk of late application of the remaining fertiliser.

Pre-plant fertiliser banding at depths >120 mm (common in other regions) is a risky strategy if it is likely wet season rainfall could result in shallow root systems that may not reach the fertiliser, particularly on heavy clay soils in wet years. Loss of available nitrogen can also occur via leaching in sandier soils and de-nitrification in clays, leading to early season deficiencies. If plant roots penetrate deeper during drier conditions on sandy soils, they may encounter leached bands of nitrogen, stimulating late season vegetative growth or reducing gin turnout.

Apply in-crop nitrogen fertiliser 25-50 days after sowing. Some flexibility may be required to respond to seasonal conditions, particularly on clay soils, and nitrogen fertiliser could be applied 5 days earlier or later if needed. It is preferable to apply in-crop nitrogen prior to flowering (about 45 days after sowing). Only apply nitrogen later during flowering if the crop is showing deficiency symptoms or to capitalise on a positive seasonal forecast and very sunny weather. Crops showing nitrogen deficiencies after flowering will rapidly reach cut-out, and any decision to fertilise must be implemented quickly. Nitrogen applications at or after cut-out will not be taken up by the plant and risk crop regrowth at a later time.

A small strip of cotton left without nitrogen fertiliser at planting can be

used as an indicator for when in-crop nitrogen is required. Ensure any other required nutrients (e.g. as identified by a soil test) are applied across both the main paddock and indicator strip to prevent other deficiencies confusing the result.

Growth Management

Source: CSD and Bayer et al. 2020. "Northern Newsletter – Establishment to Flowering". Acres of Opportunity.

Excessive growth can lead to reduced penetration of insecticides, as well as a reduction in sunlight penetration into the crop canopy that can reduce the expression of Bt toxins and exacerbate boll shedding. However, the use of growth regulators must achieve a balance between suppressing vigorous early growth and not subsequently inhibiting the production of later fruit if required for yield compensation.

Mepiquat chloride (Pix®) recommendations from temperate Australia based on internode length DO NOT WORK in tropical production systems. Yield reductions of up to 26% in wet and 16% in dry seasons occur when excessive Pix application prevents plant recovery from environmental stresses.

Local R&D has developed and validated crop monitoring systems based on maintaining an optimum height range relative to the overall height, node number and crop boll load as the crop develops by only using low rates of Pix (repeat dosages of 200-400 mL/ha when required) and/or other management (e.g., irrigation).
The approach is to moderate growth over time, leaving room to change tactics should the weather or other factors post-application work against



Nitrogen nodulation

you. Once applied Pix will have an effect on the crop for approximately 10 days after application and therefore once applied it cannot be removed. During the transition from wet to dry season conditions it can be difficult to predict field conditions more than several days ahead and therefore it is prudent to make repeat applications of Pix at a lower rate if required than use a larger one-off dose. The impact of Pix can be excessive if the weather changes from wet and overcast to sunny and hot. Also keep in mind that Pix may also reduce root system expansion.

Integrated Pest Management – What Is It and How Do You Do It?

Contributed by B. Thistleton, Department of Industry, Tourism and Trade, Northern Territory Government

Integrated pest management (IPM) refers to a management system for pests which integrates a number of different control methods: **biological, cultural and chemical.**

Biological Control

This consists of controlling insect and mite pests of plants using organisms which prey on (predators), parasitise (parasitoids) or infect (pathogens). Collectively these organisms are known as biological control agents (or biocontrol agents).

Biocontrol Agents

- Predators are animals (often insects or spiders) which kill and feed on their prey. Examples are lacewing larvae, hoverfly (syrphid) larvae and ladybirds, all of which feed on aphids, mealybugs and other sucking insects, spined predatory shield bugs which feed on caterpillars and predatory mites which feed on pest species of mites.
- Parasitoids are usually insects (tiny wasps or flies) which lay their eggs in or on the pests. The larvae which hatch develop inside the hosts eventually killing them. Parasitoids can attack all stages of an insect and are then known as egg parasitoids, larval parasitoids and pupal parasitoids.
- Insect pathogens cause diseases inside the insect and kill them – fungi, bacteria, viruses and nematodes. Examples are the fungi Metarhizium anisopliae and Beauveria bassiana, the bacterium Bacillus thuringiensis (e.g., Dipel®), nuclear polyhedrosis viruses (NPV) of Helicoverpa spp. (ViVUS®) and fall armyworm (Fawligen®) and entomopathogenic nematodes. Bollgard® cotton has Bacillus thuringiensis genes incorporated into the plant, these cause the plant to produce the bacterial toxins which kill caterpillars such as Helicoverpa spp.

Types Of Biological Control

Biological control can be divided into three main methods: conservation, augmentative and classical biocontrol.

- Conservation biocontrol refers to fostering those biocontrol agents which are already present in



the crop. By providing the right environment (e.g., flowering plants to give nectar for adult parasitoids, or refuges where parasitoids and predators can build up) and avoiding the use of broad-spectrum chemicals which will kill them, these biocontrol agents can be conserved and will naturally increase in numbers.

- Augmentative biocontrol refers to those situations where a particular parasitoid, predator or pathogen is either not present or is not in high enough numbers to give control when required. In this situation these biocontrol agents can be purchased from biocontrol agent suppliers and released into the crop. In the case of pathogens, the virus (e.g., ViVUS®, Fawligen®) or bacterium (Dipel®) are formulated so that they can be sprayed.
- Classical biocontrol refers to the situation where a new pest has established and has arrived in the country without the biocontrol agents that normally keep it under control overseas. In this situation a search is made in the pest's country of origin and effective biocontrol agents selected and introduced. This process often takes many years as it involves surveys and trials to determine suitable biocontrol agents in the country of origin, and host specificity testing in the country of origin and under quarantine in Australia to verify that the biocontrol agent will not attack other insects besides the pest. An example of classical biocontrol is the parasitoid of the spiralling whitefly, both of which are originally exotic. Classical biological control is also often used for control of weeds, when plant feeding insects are introduced to control the weed. In these cases, host specificity testing is very important to avoid unwanted side effects when the plant feeding insect is released.

Cultural Control

This refers to actions that we take in growing the crop that can have an effect on pest populations. It covers a whole range of interventions including time of planting, use of resistant varieties, crop hygiene, crop rotation, removal of secondary hosts and planting of refuge or trap crops.

Chemical Control

One misconception with IPM is that it consists only of biological and cultural control. While these are indeed key components of the strategy, it does not mean that chemicals cannot be used at all. But chemicals should be selected carefully and only applied when necessary. This involves monitoring the populations of the pests and only spraying when required using softer or selective chemicals that kill the pests without killing the predators and parasitoids. A good maxim is to spray as little as possible, but as much as necessary.

Upsurges and Outbreaks

Often pests such as fall armyworm, American serpentine leaf miner, silverleaf whitefly, melon thrips etc. develop resistance to broad spectrum insecticides (insecticides that kill many different groups of pests). At the same time the parasitoids and predators do not develop resistance, so these are killed. The pests therefore survive the insecticide spray and in the absence of the biocontrol agents which normally keep them under control

their populations increase rapidly. This phenomenon is called pest upsurges. In addition, in the absence of the predators and parasitoids which control them. outbreaks of other pests can occur.

How To Control Pests With IPM

Firstly, it is necessary to know what pests and beneficials (biocontrol agents) are present in your crop. Pests and beneficials can be identified by using factsheets and field guides produced by the NT Department of Industry Tourism and Trade. For example, there is a field guide on Pests, Beneficials, Diseases and Disorders of Mangoes and another one on vegetables. Similarly, there is a field guide to insect pests of cotton available through CottonInfo - Pests and Beneficials in Australian Cotton Landscapes. Specimens can also be submitted the entomology team in DITT for assistance with identification.

Then it is necessary to monitor the pests and beneficials in the crop at regular intervals and make decisions whether it is necessary to spray and, if so, what chemicals to use. Chemical choice should be made based on what is registered or has permits for the crop, which is known to be effective on the pests – and this can change if the pests develop resistance – and what is soft on the beneficials. Extra pests on the crop should be considered which might outbreak if their parasitoids and predators are killed by insecticides targeted at other pests. It is incorrect to say that you are using IPM for a certain pest on a crop. Instead, you are using IPM for the whole pest complex of a crop, because what you spray on one pest can affect the populations of another pest.



Zig zag beetle, Menochilus sexmaculatus. on mungbean (Beneficial - aphids, scale)

For cotton the use of Bollgard® 3 cotton results in caterpillars, especially Helicoverpa spp., being killed by the Bacillus thuringiensis toxins produced by the plant. It is therefore no longer necessary to spray as frequently as before for caterpillars, but sometimes sprays will be needed for pests such as mirids. In cotton, it is also a requirement to produce Helicoverpa adults which have not been exposed to the toxins and for this unsprayed refuge crops need to be planted. The recommendations for doing all these things change yearly as more information come to hand and are published in the CRDC and CottonInfo annual Cotton Pest Management Guides.

Key pest control considerations for Northern Australia:

- Only grow transgenic cotton varieties e.g. Bollgard® 3.
- Minimise insecticide inputs. Use only when necessary as indicated by pest abundance and damage thresholds. Take into consideration population trend and presence of beneficial insects as well as crop stage when making control decisions.
- Avoid early-season insect control sprays prior to flowering. Early squares are often lost to weather-related shedding, and higher mean rainfall poses a much greater run-off risk for pesticides to potentially enter a water course.
- Monitor regularly for insects (twice per week) and ensure that correct identification of pests is made. There are many insects that are beneficial that can be confused with pests. Your advisor will be able to do this for you.
- Select insecticides based on IPM compatibility. Give preference to narrow-spectrum products
- and avoid broad spectrum organophosphate and pyrethroid products. The application of dimethoate in Northern Australia (NQ & Kununurra) has resulted in secondary outbreaks of cotton aphids due to high levels of resistance in this pest.
- Use ground rig spraying wherever possible for better placement accuracy and to reduce the risk of drift.
- Strictly adhere to the protocols and recommendations of the Bt Resistance Management Plan (RMP). This strategy is updated each year to reflect scientific advances and/or changes in pest resistance levels.

The exotic pest, fall armyworm (Spodoptera frugiperda) was detected for the first time in Australia during 2020 and has since become well established throughout the tropics. So far crop inspections indicate that cotton is not a preferred host of fall armyworm and in instances where moths lay eggs in crops, the Bt proteins present in Bollgard® 3 varieties will provide good control efficacy. While there are numerous products registered for the control of various cotton pests; many insecticides, if used at the wrong time, can cause more problems than they solve by disrupting the balance of natural pest enemies ('beneficials').

This can subsequently flare secondary pests, which may then require further, often harsher methods of control. This has been the case across northern Australia for crops treated with dimethoate (often used for mirid control). At a number of locations dimethoate usage has been followed by outbreaks of cotton aphid (Aphis gossypii).

Testing of these aphids from NQ (various locations) and Kununurra have found extreme levels of resistance to organophosphates. The use of dimethoate in these instances have suppressed natural enemies and given resistant aphids a 'leg up' allowing sever outbreaks to occur several weeks later.

Likely insect pests of concern specifically in cotton (but not limited to) in northern Australia will include:

Pest	Susceptible Crop Stage	Comments
Principle Pests		
Green vegetable bug (Nezara viridula)	First flower to 60% open bolls	Typically appear at the end of wet season as surrounding weeds dry out. This pest may reinfest crops several times during flowering and boll filling. There are no genuine soft options for this pest. Neonicotoid may be advantageous in providing some residual control and being less likely to flare aphids or mealybugs.
Red banded shield bug (Piezodorus oceanicus)	First flower to 60% open bolls	As above. Note that these are very difficult to kill with pyrethroids providing minimal efficacy. Damage by this pest is equivalent to 1/3 of a green vegetable bug.
Cluster caterpillar (Spodoptera litura)	First flower to boll opening	Often active during wet season and until May/ June. This caterpillar is naturally tolerant of Bt proteins found in Bollgard® 3. This pest may become abundant if crop stress (cloud, heat, drought) causes Bt expression to lower. Pest status is not clear and is the subject of new research.

Aphids (Aphis gossypii)	First flower to defoliation	Often more active at the end of wet season. Likely to have extreme resistance to organophosphate. Use of these products for the control of other pests will flare aphids.
Mealybug (Phenacoccus solenopsis)	All season	More common in back-to-back cotton fields or in weedy pre-plant fields. Outbreaks can be severe when poor farm hygiene is coupled with early season use of broad spectrum insecticides. Management depends on farm hygiene and conservation of natural enemies.
Occasional/future pest concerns		
Mirids (Creontiades spp.)	Squaring to cut out	Mirids typically migrate into crops during squaring and flowering and often during the early transition to the dry season. Consider using more selective insecticides options for this pest.
Pale cotton stainer (Dysdercus sidae)	Peak flower to 60% open bolls	Have been uncommon in most crops. Typically seen from late April onwards as bolls mature. Adults and nymphs can feed on developing seed and on seed in open bolls. Feeding can cause boll loss or staining of cotton in open bolls.
Silverleaf whitefly (Bemisia tabaci)	First flower to 60% open bolls	Often more common April onwards as surrounding weeds dry off. To date this pest has not reaches threshold numbers in tropical crops throughout Australia.

Leafhoppers (Siphanta patruelis)	All season	This insect was abundant in Ord river crops during 2017 & 2018. Glasshouse studies were subsequently conducted with this insect which found that this sap feeder is not a pest of cotton. Feeding by up to 8 nymphs per boll for 25 days did not cause boll shedding or loss of lint yield. Excreted honeydew maybe a contaminant but field numbers have been too low to cause this problem.

Insect Pests of Northern Australian Broadacre Cropping

Sources: Adapted from;

- Grundy, Yeates and Grundy. 2012. NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region. P 53-64.
- Mckay, Luke. 2020. TROPICAL COTTON PRODUTION SYSTEMS. Issues relevant to cotton production in Northern Australia. Sydney, NSW: Nuffield Australia. P 38-39
- Cotton Catchment Communities Cooperative Research Centre. 2011. Pests and Beneficials in Australian Cotton Landscapes. P 37.
- CSD and Bayer et al. n.d. "The Dozen Deeds for Northern Australia." Acres of Opportunity.)
- Contribution by Dr Brian Thistleton and Dr Frezzel Praise Tadle, NT Dept. Industry, Tourism and Trade



Figure 8. FAW egg mass. Contributed by NTFA

Fall Army Worm (FAW)

Contributed by Dr Brian Thistleton and Dr Frezzel Praise Tadle

Fall armyworm is native to tropical and sub-tropical America. It was detected in Africa in 2016 and then spread through more than 30 countries, recently (late 2019) moving through Southeast Asia towards Australia. In early 2020, it was found in the northern Torres Strait Islands and has subsequently established at many sites in north Queensland. At the end of March 2020 its presence was



Figure 9. FAW larvae in sweet corn. Contributed by B. Thistleton and T. Frezzel, NT DITT.



FAW egg mass on sorghum



Figure 10. Male FAW adult moth, resting position. Contributed by B. Thistleton and T. Frezzel, NT DITT. Copyright by D. Visser ARC-VOC.

confirmed at several locations in the Northern Territory.

The adults are capable of flying long distances of up to 100 kilometres in a night. They can also spread by movement of infested produce by air, road or sea. Fall armyworm can cause significant economic damage in a short space of time and produce several generations in a season.

Hosts

Worldwide, fall armyworm has been recorded feeding on more than 350 species of plants. However, its main host plants are grasses (Gramineae or Poaceae) and in the NT it has been recorded on maize, sweet corn, sorghum, millet, rhodes grass. There are also records of the species feeding on watermelon and conventional cotton, but these are uncommon. The young larvae will feed on Bollgard® cotton in the laboratory but the BTh toxins kill them very quickly. In Queensland it has become a significant pest of capsicum.

Surveillance

Adult fall armyworm (Spodoptera frugiperda) can be trapped using bucket traps containing attractants for the male moths. These attractants are synthetic chemicals designed to be similar the pheromones produced by female moths to attract the males. The traps also contain an insecticide which kills the moths so that they are retained for further study.

Currently two lures are used with slightly different chemical blends. P061 Frugilure from Chemtica in Costa has the lure on a plastic card while Trécé Phercon lure is on a rubber septa. Both lures will catch by-catch – other related moths which also react to the attractant – and, since the

scales on the wings are often rubbed off and the diagnostic markings are no longer visible, it is usually necessary to dissect the moths to examine the diagnostic characters on the genitalia, and/or conduct molecular diagnoses.

Control

FAW has developed resistance to many of the commonly used insecticides. There are a number of registered products and minor use permits available for various insecticides on various crops and this is constantly increasing. Details of these can be found on the Australian Pesticides and Veterinary Authorities website (https://portal.apvma.gov.au/pubcris and https://portal.apvma.gov.au/permits) or contact DITT entomology for the latest advice.

The use of IPM, where biological, chemical and cultural control methods are integrated to manage pests on a crop, should be used wherever possible (see separate article in this publication). Studies are currently being conducted across the north of Australia, in a collaborative Hort. Innovation funded project by NT DITT, WA DPIRD and QDAF, to identify parasitoids of FAW already present in the areas, which could be conserved for biological control.

More Information

For advice on insect identification and control contact DITT entomology:
Email insectinfo@nt.gov.au
Phone (08) 8999 2258.

Bucket Trap



Bucket Trap deployed



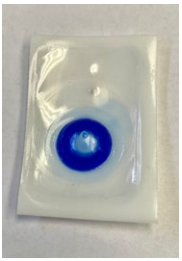
Trap locations of FAW in NT



Lures



Lures



Bucket Trap with moths



Figure 11. Surveillance methods and locations of FAW trappings in the NT. Contributed by B. Thistleton and T. Frezzel, NT DITT.

All pesticides should be used in accordance with label instructions and the NT Control of Use legislation.

For advice on pesticide use contact:
Email chemicals@nt.gov.au
Phone (08) 8999 2344.

American Serpentine Leaf Miner
American Serpentine Leaf Miner poses a serious threat to Australia's horticulture, nursery production, and agricultural plant industries. The larvae of these flies are tiny maggots which burrow between the upper and lower layers of leaves of vegetables and soft leaved decorative plants. When these larvae mine between the leaf layers, it can cause damage to the leaf and the plant, which is why the species is considered a plant pest. It was first found in northern Australia in 2021, with the first case in the NT confirmed in August.



American Serpentine Leaf Miner Adult



Damage from an American Serpentine Leaf Miner



Mealybug (Solenopsis)

Mealybug (Solenopsis)
Mealybug can affect plant growth at all stages and in severe infestations plant death can occur. Heavy infestations, of greater than 500 Mealybug in the top eight nodes at cut out, have been found to result in around 80% reduction in harvestable bolls. Honeydew excreted onto the leaves is high in melezitose sugar, which is very sticky and can promote the development of sooty mould as well as contaminate ginning equipment (Cotton Pest Management Guide 2019, as quoted by Mckay, 2020, p 38).

There are currently only limited chemical controls available for mealybug, meaning Integrated Pest Management (IPM) is the most effective method available. There are currently insecticides available on permit that offer control of mealybug, but these can disrupt or damage beneficial predators. Targeting other pests during the season, like mirids, with harsh chemistry, may assist mealybug build-up and establishment through reduced predator numbers. (Mckay 2020, p38-39).



Silverleaf Whitefly (SLW)

Silverleaf Whitefly (SLW)
SLW is a major pest in cotton. It has the ability to contaminate cotton lint with honeydew, has a large host range, can rapidly reproduce and can develop resistance to many insecticides. Silverleaf Whitefly (SLW) feed on the phloem vessels that transport the sugar rich products of photosynthesis around the plant. During digestion, a proportion of plant sugars (sucrose, glucose, fructose) are altered into new sugars e.g., trehalulose and melezitose, resulting in a combination of sugars passed out of the SLW in the form of honeydew.

Compared with aphid honeydew, which is evident as thick, wet, sticky honeydew coating leaves and bolls, SLW honeydew often dries to an almost lacquer-like consistency and though visible on the leaves and bolls, may be dry to touch. This is deceptive – the main sugar, trehalulose, has a low melting point and is hydroscopic (attracts moisture).

In the spinning mills, visually "clean" cotton can cause problems as heat generated through friction causes the trehalulose to melt. It then attracts moisture and sticks to machinery, eventually necessitating shutdown for cleaning. Consequently, cotton producing regions that develop a reputation for supplying honeydew contaminated lint risk incurring significant discounts. It is important that the Australian cotton industry upholds best management of SLW to maintain its reputation for producing uncontaminated, high-quality cotton. Greenhouse whitefly (Trialeurodes vaporiorum) and Australian Native Whitefly (Bemisia tabaci) are present in cotton but not considered pests as they rarely build to significant populations and are easily controlled, often by insecticides targeted against other pests. As a consequence, SLW tends to dominate in sprayed cotton crops.

Management of SLW requires a year-round Integrated Pest Management (IPM) approach as SLW numbers can rapidly increase, especially if natural enemies are reduced by insecticides and hot seasonal conditions favour fast SLW development. (CottonInfo 2018, p 1).

Pink Boll Worm
Pink Boll Worm is only found in the NT and north of WA where it is a pest of cotton. Larvae are up to 18mm long and are yellowish pink with a dark brown head and rows of darker markings along the back. Moths are 12mm long, dark grey or silvery-grey and hold their wings over the body when at rest.
Larvae hatch from small eggs and tunnel into large squares, flowers or bolls. Mature larvae pupate in bolls, stems or surface trash. The life cycle takes about 6 weeks, but usually only one generation of pink spotted bollworm occurs during late January-March in conventional cotton.

The pink spotted bollworm does not have an overwintering diapause. However, larvae can remain alive for long periods and survive by feeding

on dry cotton seed in trash. Live larvae have even been found in seed cotton in modules awaiting the gin.

Larvae bore into green bolls feeding internally and to a lesser extent into squares and flowers. This results in damaged lint due to feeding and the entry of boll-rotting fungi.

Effective management of cotton crop residues will help minimise subsequent infestation in cotton. In northern Australia growing cotton in the dry season avoids major damage from pink bollworm.



Seed eating bugs, Melanerythrus mactans (Stal) commonly found in sorghum, mungbean, cowpea and cotton

Disease Pathogens
A disease occurs when a pathogen is exposed to a susceptible host variety and the environment is favourable for an infection to take place. A disease can be controlled by excluding or eliminating the pathogen, growing a resistant variety or by modifying the environment.

If pathogens aren't present in an area, don't introduce them! Always practice good farm hygiene and insist that vehicles, machinery and equipment - even your boots – are clean before moving on or off farm: Remember to "be a good mate and leave it at the gate".

All cotton seed in Australia is supplied with a standard fungicide seed treatment for the control of seedling diseases. The seed also undergoes a rigorous process to ensure that disease cannot be transmitted on the seed.

Wet and humid weather is usually a significant factor in disease development. There are several leaf pathogens than can infect cotton and cause various leaf spots, and even defoliation, when a crop is exposed to an extended period of wet weather.

The most common of these observed in northern Australia is Alternaria leaf blight. This disease is rarely a problem for healthy crops but can cause significant leaf damage in later planted crops which are exposed to cool overnight temperatures and dewy conditions. The simplest way to avoid this disease is to ensure that peak boll load occurs during autumn as opposed to mid-winter. Alternaria may also be present during the wet season, but damage has tended to be limited to the lower canopy, with senesced leaves rapidly replaced at this time of year.

Common Diseases found in Northern Australian Cotton Growing Regions (Burdekin)
No major diseases other than Alternaria leaf spot have been reported on cotton growing in northern Australia. For disease to occur, three conditions must be met; both the microorganism responsible and a susceptible host must be

present, and environmental conditions must fall within a certain range for the pathogen to germinate, grow and develop.

The following summarises cotton pathogens known to occur in the Burdekin, and other potential disease threats that may affect the development of a future cotton industry in the region.

Alternaria leaf spot
(Alternaria macrospora and/or alternata) is the most prevalent and serious disease of cotton in northern Australia. Disease severity can be high, particularly in cooler wet years and where potassium may be limiting. Symptoms begin with small brown necrotic lesions, 1-2 mm diameter, surrounded by a purple halo. The lesions may extend up to 2-3 cm in diameter in some cases with the impact more severe on okra leaf types, where a lesion on the mid-rib can cause leaf necrosis for the remainder of the leaf blade below the lesion. A marked yellow halo surrounding the necrotic lesion is common on mature leaves. Under suitable conditions, the fungus will sporulate and take on a black sooty appearance. As the disease progresses the tissue at the centre of old lesions will turn grey, dry and may crack and fall out giving a 'shot hole' appearance. Premature defoliation and senescence of the lower plant canopy is the most noticeable symptom of Alternaria leaf spot. However, in northern Australia, Alternaria leaf spot is also common in the upper canopy.

There is limited information regarding control of Alternaria leaf spot on cotton, probably because it has not been a major disease in established cotton growing areas. At present there are no fungicides registered for the control of Alternaria on cotton in Australia. Potassium deficiency can exacerbate the severity of Alternaria leaf spot.



Alternaria leaf spot

Grey Mildew

Grey mildew detected in the Northern Territory. Northern Australia cotton growers (NT, Nth Qld, WA) are encouraged to monitor and report any unusual symptoms in their crops, following the recent confirmation of grey mildew disease, caused by the fungal pathogen Ramulariopsis sp.

Grey mildew of cotton is a foliar disorder caused by Ramulariopsis sp. It produces distinctive fungal growth like other mildews and can be easily identified by the presence of white to greyish coloured spores on the underside of the leaf.

White or grey powdery growth may occur on the upper surface also. The infection generally starts in the more humid lower canopy but spreads to upper leaves and the entire plant may be affected. The affected leaves dry up from margin and cup inward. Leaves turn yellowish brown and fall off prematurely. There is a notable distinction between Ramulariopsis and other mildews such as powdery mildew of cucurbits. Ramulariopsis sp. is known as a 'false mildew', as it can grow on nutrient media without the presence of a living host. Because of this ability to live on non-living organic residues, Ramulariopsis sp. can persist on decomposing plant material.



Grey Mildew

Boll Rots

Boll rot is a generic term referring to a number of diseases whereby bacteria and fungi cause damage to bolls, lint and seed.
Many species of microorganisms, mostly fungi, have been implicated as causes of boll rots. Many are opportunistic wound pathogens that cause rots following insect damage or other wounds to bolls. Others are secondary invaders of already-diseased tissue. However, a few are described as primary pathogens, and are capable of entering intact bolls directly or through natural openings.

The majority of the damage in Australia can be attributed to: Alternaria macrospora, Fusarium spp., Lasiodiplodia threobromae, Phytophthora spp., and Sclerotinia spp. Rhizopus sp. and Botrytis sp. produce profuse grey fungal growth over bolls that have been damaged by insect attack.

The first record of cotton boll rots caused by the fungal pathogen Nematospora coryli were made in the Burdekin during 2010. This pathogen is unique in that it is always transmitted by sap sucking Heteropteran insects. This fungus causes several serious diseases of cotton including seed rot, internal boll rot (stigmatomycosis) and tight lock. In the USA fibre losses of 40-60% have been reported. Insect control is the best way to prevent infection, although improved cultivar resistance may be possible. This was the first record of Nematospora coryli on cotton in Australia.

ALL GROWERS - If you see anything unusual, call the Exotic Plant Pest Hotline: 1800 084 881

Weed Control

It is important to control weeds, in order to reduce competition for the crop and maximise yield potential, as well as removing plant species which are capable of hosting pests and diseases. There are a number of tools available to manage weeds during a cotton season. The cotton plant can also become a weed itself, if not controlled properly following harvest. It is essential to control both volunteer and ratoon cotton before, during and after the cotton season, as part of the Bollgard® 3 Resistance Management Plan (RMP) and also for general farm hygiene. Volunteer and ratoon cotton plants can harbour unwanted pests and become very difficult to control if not acted on when they are small. The Roundup Ready Flex® Weed Resistance Management Plan details strategies that can be implemented to minimise the risk of glyphosate resistance developing in weeds on-farm.

Consult the Roundup Ready Flex Cotton Weed Management Guide (WMG) for clear recommendations for weed control practices in a Roundup Ready Flex cotton crop. The guide includes a range of herbicides which offer different modes of action throughout the season, reducing the risk of glyphosate resistance developing on your farm and saving you time and money in the future. A key part of the RMP for growers of Bollgard® 3 cotton is the control of volunteer and ratoon cotton. It's important to act on early season weeds (including cotton volunteers) when they are small, and ensure cotton is fully destroyed post-harvest as it can become a woody weed (ratoon). It is also important to implement appropriate cultural methods and herbicide strategies to control volunteer cotton.



FAW in sorghum. Contributed by NTFA

Part C: Harvest and Post-Harvest Stage

Defoliation

Source: Adapted from Grundy, Yeates and Grundy. 2012. NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region. Pg. 68

Defoliation is the process by which a cotton crop is treated with a combination of harvest aid chemicals that remove the leaves and hasten the opening of bolls in preparation for machine picking. Hormone defoliants such as thidiazuron, when applied to cotton crops, increase the ethylene concentration within the leaves which in turn triggers a layer of cells at the base of the leaf petiole to die. This results in the abscission of the entire leaf complete with petiole. If done correctly the leaf will drop from the plant before it actually dies. Boll openers/conditioners such as ethephon specifically enhance ethylene production which leads to the quicker splitting and opening of mature green bolls

The effectiveness of defoliation chemicals depends on:

- Using appropriate combinations and rates of defoliant and boll openers
- Timing their application appropriately to crop maturity
- Taking into account likely temperatures post application.

In fields with a compensatory top crop, the age difference between bolls spread over the top 8-10 nodes can be greater than initial impressions may suggest. To assess physiological maturity, locate the last cracked boll that is on the first branch position from the top of the plant. Then count up 4 nodes from the branch with the cracked boll. Any first position fruit above this level (i.e., 5 nodes or above the upper-most cracked boll) will still be immature and difficult to open under cool humid conditions.

A general rule of thumb is that when a crop is close to being ready for defoliation wait a few more days before applying defoliant products. Often okra leaf varieties such as Siokra 24BRF can be defoliated with one pass if a little more time is allowed before applying defoliant When the crop reaches 4 nodes above cracked boll (NACB), the top boll will have reached 'effective' maturity, where fibre development on all bolls is complete and defoliation can occur without risk of reducing yield and quality.

Timing

Source: Adapted from CSD and Bayer et al. 2021. "Northern Newsletter – Cutout to Picking".

Defoliating too early can lead to immature cotton fibres, which has the potential to downgrade fibre quality during classing and may lead to discounts in bale prices. Your consultant can assist with the timing and application rates of defoliants through varying methods. It is often better to use a combination of the methods below to determine maturity:

- 4 Nodes Above Cracked Boll (NACB). Physiologically, the last harvestable boll is mature when the boll four nodes down has begun to open up (cracked).
- When the crop reaches 60% open. This is determined through simply counting the number of open bolls compared to the total number of bolls.
- Cutting bolls and looking for

mature seeds. Bolls should be firm to cut even with a sharp knife; the contents of the seed should be fully formed, and the seed coat turned from translucent to tan or black.

In northern Australia, it can be common for crops to be top heavy, with a greater proportion of the fruit being within the top half/third of the plant and much less on the earlier fruiting, lower nodes. Timing of defoliation for these crops can be somewhat tricky, in that crops can appear to be more mature than they actually are. These crops require careful assessment using the NACB technique and boll cutting to determine the ideal timing to commence defoliation. If the crop is variable across the field, it may be necessary to wait a bit longer until the less mature field sections are ready. Leaf drop is readily straight forward for northern crops, but bolls can be difficult to open particularly if they are not quite ready.

Application

Speak to your consultant (agronomist) about the best products and application rates to use when defoliating. Defoliation utilises products which cause the leaves to drop from the plant and products which encourage unopened bolls to open. It is normal for irrigated crops to have two, or sometimes even more defoliation applications, depending on the season. Depending on the plant's growth, different rates and products may be required for each application. Be cautious about rates and products that are used, in order to ensure that leaves do not 'freeze' onto the plants. Products and rates used should not be off-label or include products not registered for use at defoliation. The use of Dropp® UltraMAX has not been necessary for many research crops over the last decade in northern Australia. Do not add diuron to defoliation mixes, not only is this practice off label, but under northern conditions it has been observed to cause serious leaf freezing, resulting in greater trash contamination of picked lint.

Harvesting/Picking

Source: Adapted from Grundy, Yeates and Grundy. 2**Source:** Adapted from CSD and Bayer et al. July 2021. "Northern Newsletter – Pre-Season". Acres of Opportunity.

Pay attention to the upper fruiting branches and the rate of boll opening. Once ready, pick the crop on time and without delay. Cotton has the ability to weather some adverse climatic conditions but can be prone to downgrades in fibre quality. In recent seasons, some northern Australia cotton crops - particularly dryland crops, have also been prone to cotton locks falling out of bolls once they are open. This is another reason why timeliness of picking is important. Cotton should not be picked if there is a heavy dew or moisture from recent rainfall, or at any time when moisture levels are above 12%. Picking wet cotton and baling or building modules under wet conditions can lead to fibre quality issues, especially if there is any length of time before the cotton is processed at the gin. Cotton, if picked too wet, can result in spontaneous combustion while in storage, and fires in machinery. Pay attention to conditions. In some locations it may not be appropriate to commence picking until late morning if there has been heavy overnight dew. Some signs that cotton is too wet to pick are:

- If moisture is evident on your vehicle/machinery

- If you can see or feel moisture at all on the bolls
- Seeds inside the lint do not crack if bitten
- You are experiencing picker head door blockages, or the picker is throwing cotton out the front
- Depending on your location and the time of year at picking, moist air and heavy dews can occur anytime between sundown and sunrise and may take some time to dry out after sunrise.

The best outcome for the crop is to have good quality cotton post ginning, which has minimal downgrades and a good turnout (the percentage of lint to seed from the raw product). Well timed and effective defoliation, as well as picking under the right conditions will contribute to this.

Pickers versus Strippers

It may be necessary to consider using a cotton stripper, rather than a picker when yields are low, and bolls are tight. A stripper will take almost everything off the plant, even bolls which are tight and likely to be missed by a picker, however this may also be detrimental in some situations, where those remaining bolls are poor in fibre quality. Stripped cotton is also often quite trashy and harder to gin, and you will also be transporting much more crop matter to the gin (e.g., stems). Strippers are not recommended to be used in the Ord Irrigation Area or the Northern Territory, due to the risk of transporting pink bollworm.

Picking Contractors

It is important to contact your picking contractor as early as possible, so they can time their arrival when your crop is ready to be picked. Communication is essential to ensure that you have a picker available, when necessary, as there may be a number of other crops in the region and limited availability for contractors. Talk to your local grower groups if you require contact details for picking contractors.

Workplace Safety During Harvest

It is vital that all contractors and farm staff go through a safety induction prior to cotton harvest. The key to managing farm safety during harvest is to involve all staff in identifying potential hazards and implement a plan to manage these safety risks. It's equally important for contractors as well as farm staff. Developing a set of procedures of how you would like the harvesting operation to progress will ensure that all involved are aware of correct and safe operation of equipment.

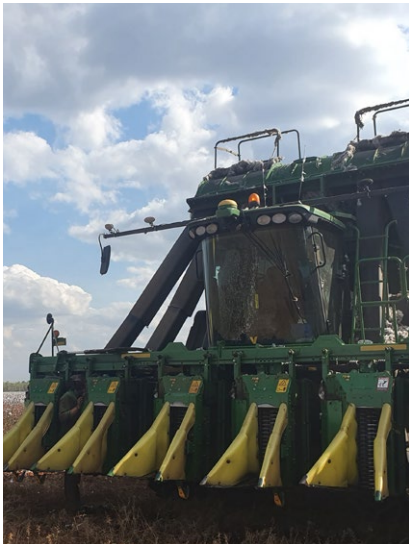
Biosecurity

Biosecurity plays a very important role throughout the cotton industry and is even more critical in emerging cotton regions and those with high biosecurity risks. There are a number of pests, weeds and diseases that affect the cotton industry, some of which are unique to northern Australia and every effort must be made to avoid their spread. It is essential that 'come clean, go clean' protocols are adhered to at all times.

One pest of particular concern is pink bollworm (Pectinophora gossypiella), which is present in the Ord Irrigation Area and Northern Territory. This pest is the reason why cotton picked in these regions cannot be ginned in Central Queensland and must be transported further south. There are a number of measures which are recommended in order to prevent the spread of pink bollworm and other pests, which are outlined in the biosecurity risk management plan linked below.

There is a recommendation in place for the Ord Irrigation Area and the Northern Territory that if unsprayed, non-Bt cotton is grown as a refuge for a Bollgard® 3 crop, this refuge should NOT be picked, as it has a very high risk of hosting pink bollworm. Pink boll worm pupae can be easily incorporated into modules during picking. Although not registered for control of pink bollworm, Bollgard® 3 cotton has a very high efficacy on pink bollworm, so the presence of pupae is very unlikely compared to non-Bt cotton.

Refer to the Biosecurity risk management plan for transportation of cotton modules from Western Australia and the Northern Territory to Southern Queensland for ginning 2020 for further information.



Post-Harvest Field Management

Sources: Adapted from:
• CSD and Bayer et al. "Dryland Cotton Guide". Acres of Opportunity.
• Adapted from Grundy, Yeates and Grundy. 2012. NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region. Pg. 71

End of Season Crop Destruction

Ensure all cotton plants are destroyed post picking. Note: All Bollgard® 3 crops must be slashed and mulched within 4 weeks of harvest. As a perennial crop, cotton can regrow into ratoon plants post defoliation/picking, and can:

1. Act as a weed, robbing moisture and nutrients,
2. Act as a bridge to host insect pests and diseases,
3. Lead to resistance build-up,
4. Be costly to control.

Conduct a pupae-busting operation, if required under your resistance management plan. This pass can be utilised for additional purposes such as planting another crop or remedial action to repair soil constraints such as compaction, or to place immobile nutrients such as potassium and phosphorus deep into the soil profile.

This can be achieved through:

- Root pulling/cutting and mulching using a purpose-built power take off driven implement.
- Mulching and cultivation.
- Mulching and treatment of any regrowth cotton with appropriate herbicide.

The most optimal method will depend on the equipment available and what type of crop will follow (e.g., grains or sugarcane). (Grundy Yeates and Grundy 2012, 71)

For other crops, a mechanical method that either pulls the roots or cuts the main stem at or below ground level is highly recommended, as cotton is difficult to control with herbicides in short term grain rotations. When root cutting cotton, ensure that the stub will not regrow by severing the main stem below where the cotyledons were attached. (Grundy Yeates and Grundy 2012, 71)

Controlling ratoon cotton or seedlings between seasons is an essential part of effective pest management. Allowing plants to grow between season creates a 'green bridge' for a number of insects pests. It allows resistant sucking pests to survive on farm between seasons and can expose Bt toxins to pests in the environment, potentially accelerating the development of resistance to these toxins in Bollgard II® transgenic varieties on which tropical cotton production depends. (Grundy Yeates and Grundy 2012, 71)

For more information about crop destruction under a TUA, refer to the Bollgard® 3 Resistance Management Plan (RMP) for Northern Australia or consult with your seed provider or local agronomist.

Refuge Destruction

Source: Adapted from CSD and Bayer et al. July 2021. "Northern Newsletter – Cutout to Picking". Acres of Opportunity.

Destruction of refuges must only be carried out after the Bollgard® 3 has been harvested. Soil disturbance of refuge crops must only occur when the trap crop is being destroyed.

Trap Crop Destruction

Source: Adapted from CSD and Bayer et al. July 2021. "Northern Newsletter – Cutout to Picking". Acres of Opportunity.

The trap crop must be destroyed 2-4 weeks (but not before 2 weeks) after final defoliation of the Bollgard® 3 cotton crop, (slash and pupae bust - full soil disturbance to a depth of 10 cm across the entire trap crop area).

RMP Requirements

Varying seasonal conditions could mean slashing or mulching alone will not be enough to prevent Bollgard 3 from ratooning or re-growing. Wherever relevant growers must implement additional cultural and/or registered chemical control measures to ensure Bollgard 3 does not ratoon post-harvest. Irrespective of sowing data, all Bollgard 3 cotton must be destroyed by October 15



Rhodes grass. Contributed by NTFA



SECTION 4.

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SECTION 5.

APPENDICES



Part A: Companion Reference Publications

1. Australian Cotton Production Manual
2. Cotton Pest Management Guide
3. NORpak: Cotton production and management guidelines for the Burdekin and north Queensland coastal dry tropics region.
4. NORpak – ORIA: Cotton production and management guidelines for the Ord Irrigation Area (ORIA) 2007
5. Pests and Beneficials in Australian Landscapes

Part B: Information

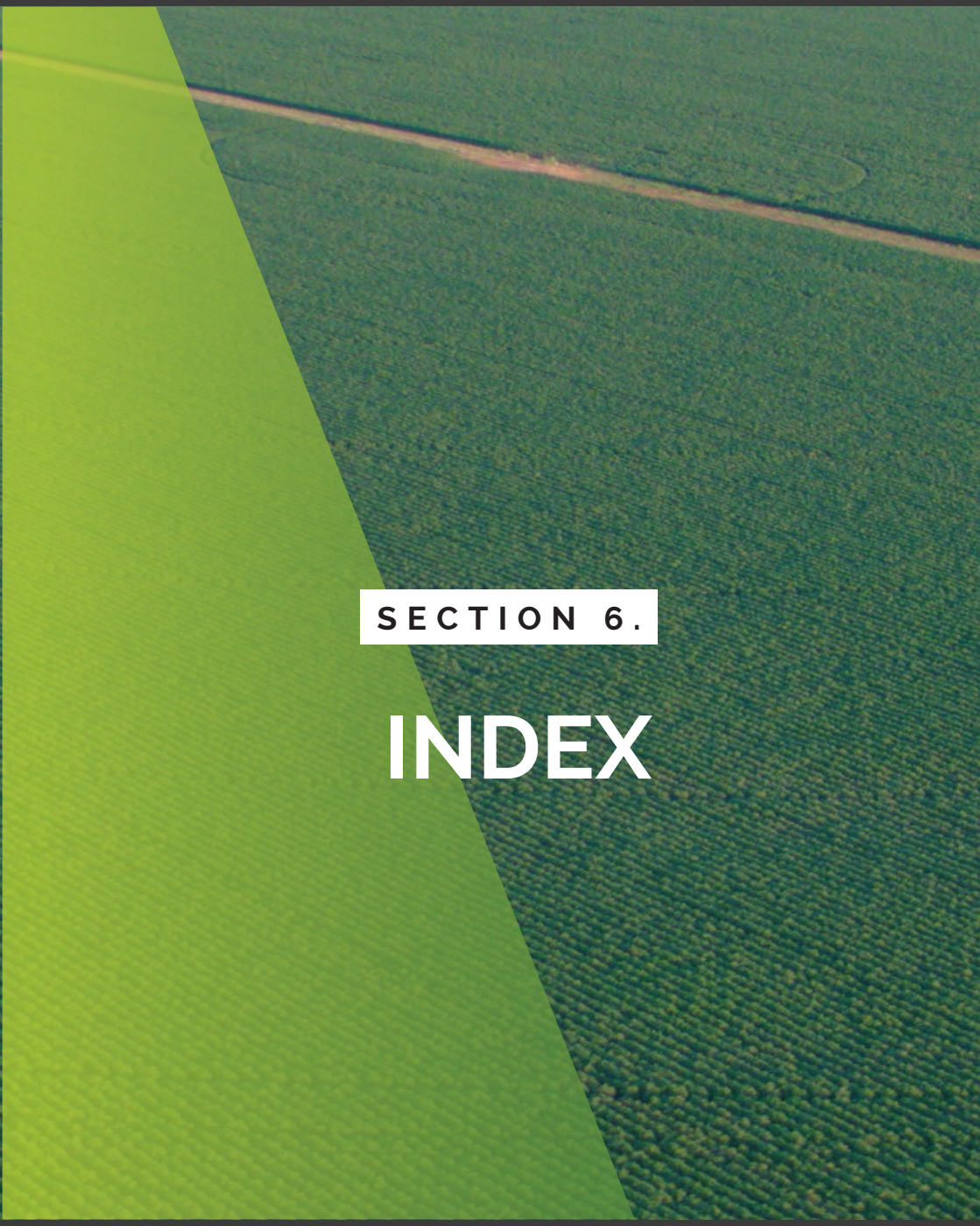
1. Come Clean Go Clean Poster https://www.cottoninfo.com.au/publications/come-clean-go-clean

Part C: Useful Links

1. Australian Cotton Industry Gross Margin Budgets: https://cottoninfo.com.au/publications/australian-cotton-industry-gross-margin-budgets
2. www.crop.bayer.com.au/products/biotechnology-traits/bollgard-3-with-roundup-ready-flex-cotton#tab-4

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NORTHERN AUSTRALIA BROADACRE CROPPING MANUAL

Northern Territory Farmers Association Inc
T: (08) 8983 3233
E: admin@ntfarmers.org.au
www.ntfarmers.org.au
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