



Australian Cotton Production Manual

2013



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Foreword

By **SUSAN MAAS (CRDC)**

Welcome to the 2013 Cotton Production Manual. This publication serves as a key document to reference best cotton production practices, and as such, is an important resource for all cotton producers. In response to interest from growers this edition includes an 'Introduction To The Cotton Plant', so an understanding of cotton physiology can help to make your agronomic decisions. This edition of the manual has been divided into four sections.

- **Cotton For Profit** – In the quest to continue to maximise profitability, growers need to improve yield while managing input costs. This section outlines some key production issues for the 2013/14 crop, with a particular focus on input efficiencies.
- **Better Farming Future** – Profitability needs to be maintained into the future, and this section outlines key production issues that will not only impact on the current crop, but also on the future of the industry. The chapters in this issue cover the principles of managing long term.
- **Cotton For The Customer** – Australian cotton is viewed worldwide as an excellent fibre. Cotton quality is something that can be influenced throughout the season. This section covers management issues relating to quality, as well as chapters explaining post farm gate issues.
- **The Business Of Cotton** – This business of cotton can be complex. This section identifies issues across a range of topics including economics, marketing, finance, insurance, as well as the safety and management of the human resources involved in cotton.

This publication is one of a series of key products proudly brought to you by the cotton industry's Development and Delivery Team. This team is a Joint Venture partnership between Cotton Research and Development Corporation, Cotton Australia and Cotton Seed Distributors and is responsible for delivering a high quality research adoption program to the cotton industry to encourage the early and maximum uptake of new research and innovation, leading to higher economic performance with a reduced ecological footprint.

Thanks again to the researchers, industry and the Development and Delivery Team, who have contributed to reviewing and updating the 2013 Cotton Production Manual.

This resource is supported by additional information on best practice at www.myBMP.com.au.



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So give us a call or visit your local CGS Branch to get your "Rain grown cotton pack". It contains most of the information you will need to get started, or come back to, the cotton industry!



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Introduction To The Cotton Industry

By Michael Bange (CSIRO)

The cotton fibre is unique in generating a host of products that sustain and make life more comfortable and aesthetically appealing. Australian cotton is viewed worldwide as an excellent fibre. It is generally purchased with the intention of producing high quality yarns for use in the woven and knitted apparel sector in the Asia-Pacific region. China is also significant market. Australian cotton is often purchased for a premium as it meets many of the spinners' requirements on the basis of quality and consistency. It has the specific fibre qualities required to spin high-quality combed, ring-spun yarn and produce desirable high value textile products.

Cotton fabrics dating back to 3000BC are proof of the long history of the cultivation of cotton and its importance as one of the most popular natural textiles around the world.

Two cotton species are grown in Australia, *Gossypium hirsutum* and *Gossypium barbadense*. The cottons are called New World cottons and originated in Central America. *Gossypium hirsutum* (called Upland) represents more than 90% of Australia's and the world's cotton production as it is most productive and has suitable fibre properties for modern textile production. *G. barbadense* cottons have a number of names – Pima, Egyptian, Peruvian, Sea Island, and so on. These cottons have very good fibre properties demanding a significant price premium from spinners for manufacture of fine garments. It has lower yield and narrower climate requirements – requiring specific management. In Australia, Pima production has been limited to western NSW locations such as Bourke, Hillston and Tandou.

The First Fleet brought cotton with them to Australia in 1788, however the first plantings in the Sydney area were disappointing, due to the unfavourable climate. Early production was then confined almost entirely to Queensland, with the first commercial crops grown at Moreton Bay Queensland in 1840.

Australia's 'modern' cotton industry as we have come to know it today was started in the early 1960s, largely in the Namoi Valley of NSW. From these modest beginnings, the industry has expanded the growing region as far south as Hay and Griffith in NSW to Emerald in Queensland.

The Australian cotton industry is one of the nation's biggest rural export earners and is vital for the prosperity of many regional communities. Despite exposure to



(Photo: Cotton Australia: Jenni Seigmeier)

droughts and floods, the industry responds proactively and as a result, communities continue to prosper with cotton farming. Much planning, investment, and effort is being undertaken by all sectors of the industry to address current and future challenges to ensure the industry remains prosperous and resilient.

The industry has also invested heavily and relied upon vast experience and research in the development of industry best management practices. **'myBMP' is a key tool growers can use to help achieve best practice in growing cotton sustainably and responsibly.** It can also be used to help direct growers to the latest information from the industry and the cotton research community on specific issues relating to cotton farming as a whole.

Go to the **myBMP** website – www.mybmp.com.au for more details and to register.

Cotton Research and Development Corporation www.crdc.com.au

Cotton Australia www.cottonaustralia.com.au

Department of Primary Industries NSW www.industry.nsw.gov.au

Qld Department of Agriculture Fisheries and Forestry www.daff.qld.gov.au

CSIRO www.csiro.au

Alternatively to receive the latest industry information and publications, add your details to the Cotton Industry Mailing list by contacting Dave Larsen – david.larsen@industry.nsw.gov.au or 02 6799 1534.

Cotton Industry Organisations

Cotton Australia

After more than 40 years of service, Cotton Australia continues to support and represent the interests of Australia's cotton growers.

Cotton Australia determines and drives the industry's strategic direction, retaining a strong focus on R&D, promoting the value of the industry, reporting on its environmental credibility, and implementing policy objectives in consultation with its stakeholders.

Cotton Australia works to ensure an environment



conducive to efficient and sustainable cotton production. It has a key role in the cotton Best Management Practices (BMP), an environmental management program for growers.

Cotton Australia pushes for better funding for rural R&D and provides grower-driven feedback to the CRDC on where it should invest its research dollars. The organisation helps to safeguard the industry by remaining vigilant and prepared for risks like biosecurity threats and exotic pest incursions.

One of Cotton Australia's key roles is that of advocacy, positioning the industry within the political framework to reduce the regulatory burdens on cotton growers and advancing their interests at all levels.

The organisation lobbies hard on a huge range of political issues that confront growers and defends the industry from the impacts of new legislation, often dealing directly with senior politicians and policy makers in both Federal and State Parliaments. A good example is Cotton Australia's leading role in the very heart of the water debate for over a decade, fighting hard on all fronts for growers' rights and coordinating industry responses alongside other groups such as the National Farmers Federation.

Cotton Australia also works to ensure an environment conducive to efficient and sustainable cotton production. Attending to grower issues at a local level, Cotton Australia's Regional Managers often provide a direct pathway for growers to ensure that policy is directed to the areas that matter most. Cotton Australia has expanded its team of Regional Managers, offering a broader service across the major cotton growing areas.

It has recently increased its resources to promote the cotton industry to the Australian community, and works hard to position the industry in a positive way.

Cotton Australia is funded by a voluntary levy of \$2.00 per bale of cotton and growers can be confident of an efficient and truly grower-representative structure.

Cotton Australia will continue to work with and on behalf of growers to Advance Australian Cotton.

To learn more about Cotton Australia, visit www.cottonaustralia.com.au

CRDC – Science underpins the success of the Australian cotton industry

Cotton Research and Development Corporation (CRDC) invests in research and development for the world leading Australian cotton industry. As a partnership corporation involving equally the industry and government, CRDC is focused on a better farming future for Australian cotton growers.

CRDC plays a key leadership role in working with industry to set and manage the strategic direction of the R&D that keeps the Australian cotton industry competitive. In doing so it is accountable to the industry, through Cotton Australia and also to the Australian Government, through the Minister for Agriculture,

Fisheries and Forestry. For their part, growers influence the direction of industry R&D through their membership in Cotton Australia.

All cotton farmers pay an R&D levy of \$2.25 for each 227 kilogram bale of cotton. This is collected by cotton ginners on behalf of the Australian Government. The Australian Government then provides CRDC with the resultant growers' levies together with R&D funding.

From 2013 to 2018, CRDC intends to invest \$100 million in a balanced portfolio of research, development and extension projects. The main themes of focus are farmers, industry and customers. Balancing these major programs are focus themes of people and performance. In the next five years, up to five per cent of investments in R&D will seek answers to industry's future success in 'blue-sky' R&D. CRDC partners with and collaborates with a broad range of publicly funded research organisations and commercial providers to provide world-leading research findings. All investments are selected on the basis of improved environmental, social and economic benefits to the industry and the nation.

The CRDC participates in a joint venture with Cotton Australia and Cotton Seed Distributors to provide support to the Australian Cotton Industry Development and Delivery Team (D&D) for the effective delivery of campaigns and research to the industry that supports improved practices, R&D communications and responsiveness to emerging or emergency issues.

In addition CRDC produces a range of publications about corporate activities and disseminates research outcomes through industry media and the Corporation's website.

For more information go to www.crdc.com.au

Key research partners

Rural Research and Development Corporations

CSIRO

Universities

Cooperative Research Centres (CRCs)

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State Government Departments

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Introduction To A Cotton Plant

By Sandra Williams & Michael Bange (CSIRO)

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

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

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

Cotton plant physiology

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

Perennial growth habits

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

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

Cotton development

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

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

DD is described by the following equation:

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

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

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

TABLE 1:

Cotton growth stages with target DD

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

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



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

FIGURE 1:

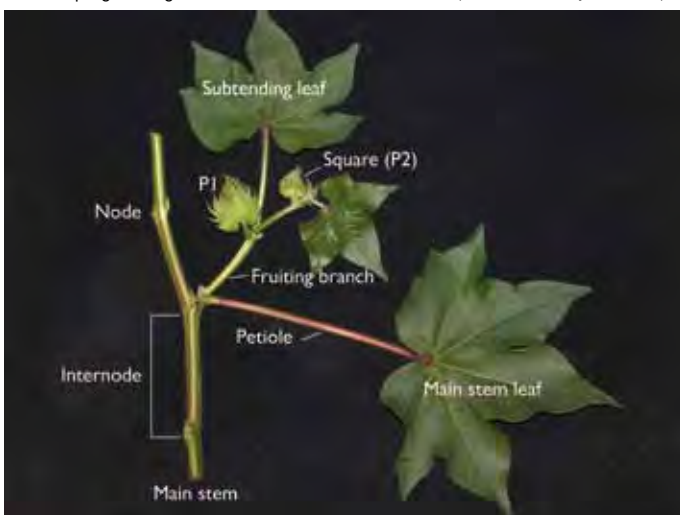
Progression from square to boll. (Photo: Paul Grundy, DAFF QLD)



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

FIGURE 2:

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



Cotton growth

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

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

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

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

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

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

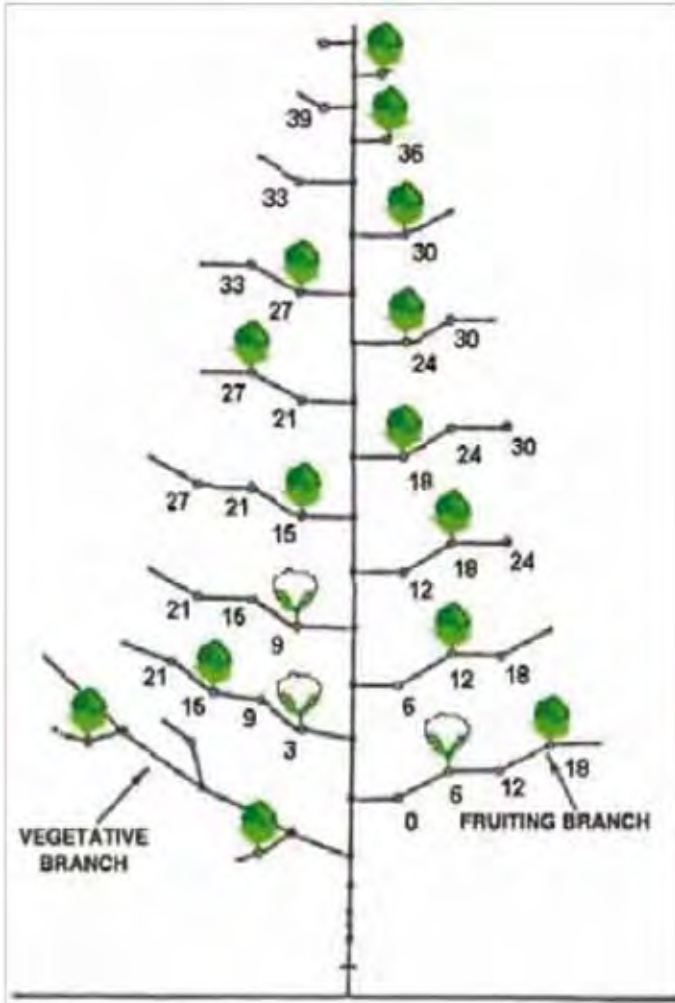


FIGURE 4:
A diagrammatic representation of the internal structure of an individual fibre. (Source FIBREpak Figure 3.3)

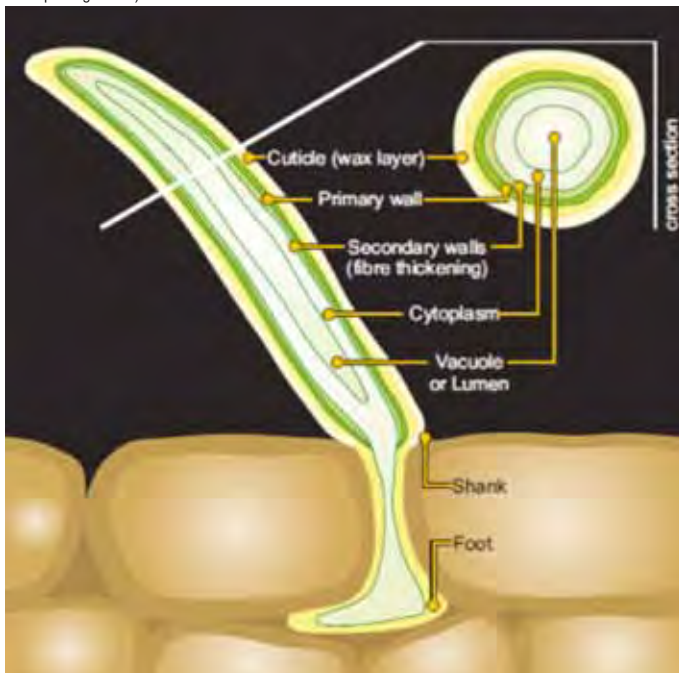


TABLE 2:
Cotton fibre development

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

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

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

Cotton fibre biology

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

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

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

- FIBREpak
- CottASSIST Crop Development Tool
- NORpak



Common terms for cotton growth and monitoring

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

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

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

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

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

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

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

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

Square. The flower 'bud'.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Lint is cotton fibre that forms around the developing seeds.

myBMP

Participation is the focus,
certification is optional

By **JIM WARK** (Cotton Australia)

The Australian cotton industry's *myBMP* web-based management system provides all Australian cotton growers a centralised location to access the industry's best practice standards which are fully supported by scientific knowledge, resources and technical support. It represents a complete rejuvenation and extension of the original BMP system providing growers with tools to

Help improve on-farm production performance

- Better manage business risk
- Maximise potential market advantages
- Demonstrate 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 and Cotton Australia.



***myBMP* provides the tools required to improve production performance, better manage business risk, maximise potential market advantages and demonstrate responsible and sustainable natural resource management to the community.**

New *myBMP* features

Part of the ongoing improvement program there have been a number of changes to the *myBMP* program that include

- Master documents – allows the quick uploading of key resources such as induction plans
- Light bulbs – additional resource that allows user to see suggestions or helpful information
- Useful short cuts – can't find something, this link can help find commonly used functions
- Let Us Know – allows users to easily email information to the *myBMP* admin office

Why use *myBMP*

- **A simplified program** – being web-based, *myBMP* has done away with clunky manuals and paper based assessments. All information is lodged electronically and stored confidentially. *myBMP* allows the user to upload documents relevant to their *myBMP* practices in one easy to manage on-line filing cabinet.
- **Tailored by you for you** – *myBMP* allows you to work through the program modules in the order and to the levels that suit your business priorities whether you just want to check the identified legal requirements or conduct a farm self-assessment. *myBMP* has been designed to accommodate all users – from the seasoned BMP user to growers who have never grown cotton or used BMP before
- **Focus on continual improvement** – for the Australian cotton industry to remain competitive in the world market, continual improvement and increased efficiencies will be important and *myBMP* can help in the delivery and dissemination of new research and information that helps makes this continual improvement possible.
- **Resources** – every practice is linked to its own reference source that provides definitions, explanations, templates, calculators and links to further information. No more need for Google searches because *myBMP* provides access to all the latest information and research results in one easy to access place
- **Certification** – those growers who choose to seek certification will find the new and streamlined auditing process easier to manage

Getting started is easy

- ***myBMP* can be accessed via www.myBMP.com.au** – once on the home page, selecting the "Register Here" text will take you through the registration process (Tip – the "Demonstrations" tab will allow you to access a video tutorial, showing you how to complete the process – once registered you can watch virtual tours of all of the *myBMP* features from the Grower Home Page)
- **Support** – If at any time you have questions about *myBMP*, you can either email the *myBMP* Service Manager via admin@myBMP.com.au or call 1800 COTTON for over the phone support and training.

For more information go to www.myBMP.com.au

What time is it?



Planning

- Assess energy use (Ch10)
- Manage diseases & pests(Ch16, 13)
- Plan for dryland cotton (Ch9)
- Plan to maximise your cotton quality (Ch20)
- Rate your risk of herbicide resistance (Ch15)
- Review whole farm water use (Ch8)
- Review your cotton business (Ch24, 25)
- Select variety/biotech (Ch3)
- Soil test & develop fertiliser plan (Ch7)
- Staff training & safety updated (Ch26)
- Select and get to know your fields (Ch11, 17)
- Weeds & ratoon/volunteer control (Ch15, 18)

Planting/ Emergence

- Check soil moisture (Ch8, 9)
- Come Clean Go Clean (Ch16)
- Get to know your local D&D (backpage)
- Planting and establishment (Ch4)
- Pre-irrigate or water up? (Ch4, 8, 16)
- Reduce risk by using cottonmap (Ch12)
- Stay soft early for season long IPM (Ch13)
- Survey for disease and symptoms (Ch7, 16)
- Use planting window & establish a refuge (Ch14)

Harvest/Post Crop

- Come Clean. Go Clean. (Ch16)
- Crop preparation before harvest (Ch21)
- Harvest & Deliver quality cotton (Ch22)
- Harvest Safely (Ch22, 26)
- Manage cotton stubble (Ch14, 16, 18)
- Map yield to plan for the future (Ch11)
- Pupae bust (Ch14)
- Understand post farm processing (Ch23)

In Crop

- Monitoring informs management (Ch5,6,7,8,13,21)
- Maximise your natural resources (Ch19)
- Manage irrigation efficiently (Ch8)
- Best practice crop protection (Ch13, 14, 15, 16)
- Record for benchmarking (Ch7, 8, 10)
- Survey for disease and symptoms (Ch16, 7)
- Apply sprays efficiently (Ch12)
- Adhere to IRMS & RMP (Ch14)

2013 Australian Cotton Production Manual
Timely advice throughout the year
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www.mybmp.com.au

New Growers' Checklist

By **SALLY DICKINSON** (CottonInfo Team)

Information provided by Cotton Australia
<http://cottonaustralia.com.au/cotton-growers/resources/new-growers>

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 highly profitable and sustainable cotton crop, but you will find that to be successful you must approach cotton production with long term planning and commitment. The good thing is that once you have made the choice to grow cotton, you will not be on your own.

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 lobbying. You will also find that your fellow cotton growers are prepared to willingly share their experiences and offer invaluable advice.

Some questions for first time cotton growers

- **How committed are you to cotton?**
To be successful you must apply good planning, thoroughness, timeliness and careful management to all your business and cotton production practices.
- **Who will harvest your crop?**
Cotton picking machinery is expensive. Most new growers employ picking contractors to harvest the crop, but in good seasons contractors can be in short supply.
- **Have you planned for cotton?**
Among the critical factors in growing cotton are; fitting cotton into your crop rotation program, sound weed management, good soil management, integrated pest management strategies and effective stubble management after harvest. Review relevant chapters in this manual to help plan and inform your decisions.
- **How much of your time does cotton require?**
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 constant attention from planting to picking and through to post crop management.
- **How do you feel about using chemicals?**
In the last decade, the Australian cotton industry has reduced its reliance on insecticides by more than 90%, however, some chemical usage may be required. You must be prepared to apply the industry's Best Management Practices for pesticide use.
- **How do you feel about complying with GM cotton regulations?**

Growing a genetically modified cotton means that you must sign a contract with the owner of the technology. 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. Refer to the stewardship chapter.

- **Have you talked to your neighbours?**
It is your responsibility to ensure chemical drift is minimised on your farm and does not occur outside your property boundaries. The web based application Cotton Map enables cotton growers to map their fields so that people in the neighbouring areas can see that there is cotton in the vicinity (www.cottonmap.com.au).
- **How will you finance your crop?**
Hail presents a significant risk to summer crop production including cotton which can have high growing costs. This may affect your financial position in relation to growing costs and marketing positions. It is important to discuss hail insurance coverage with an experienced specialist. Refer to Chapter 25.
- **Who will buy your cotton?**
Cotton has unique marketing parameters based around fibre quality. Discuss premium and discount sheets as well as price with an experience cotton merchant/ marketer. For a list of Australian merchants, please see www.austcottonshippers.com.au
- **Is your current machinery adequate to grow cotton?**
Can you adapt your existing machinery? Or will you need to engage the services of contractors? Minimise machinery acquisitions until you are sure about your long term commitment to cotton growing.
- **Have you contacted a consultant?**
Seek the services of a cotton consultant early for management advice and crop planning, particularly if you have limited cotton agronomy experience. Speak to experienced local cotton farmers for advice on the selection of a well reputed consultant, your local Cotton Grower Association is a good place to start or for more information, contact the Crop Consultants Australia at www.cropconsultants.com.au
- **Have you contacted a spraying contractor?**
Unless you plan to do all of your own spraying you should discuss your requirements with an aerial and/ or ground rig operator before the season commences. Ensure you use a reputable and accredited spray contractor with adequate insurance coverage.
- **Have you contacted a farm inputs supplier?**
You will need to source suppliers for farm inputs such as seed, fertiliser, herbicides, insecticides, growth regulators and defoliants.

For further information:

Cotton Australia www.cottonaustralia.com.au

Cotton Grower Associations www.cottonaustralia.com.au/ca/members/

Agronomic adviser/consultant www.cropconsultants.com.au

Cotton Development and Delivery Team see inside back page

myBMP Information www.mybmp.com.au

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Best Practice



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Selecting The Seed
Crop Establishment
Monitoring To Manage
Mepiquat Chloride
Nutrition Efficiency
Irrigation Efficiency
Dryland Cotton
Energy Efficiency
Precision Ag – Tools To Improve Efficiency
Efficient Spray Application

Selecting The Seed

By **ROBERT EVELEIGH (CSD)**

There are a large number of varieties that can be selected and grown. Varieties are generally chosen based on yield, quality and disease resistance characteristics. However other traits such as determinacy, leaf shape and season length may also be important. The full range of cotton varieties available are outlined on the CSD web page. www.csd.net.au

Yield

In irrigated production systems yield is the primary selection characteristic. Some varieties are widely adapted and can perform in a range of environments. Varieties in the Sicot 71 family have demonstrated exceptional yield performance in a wide range of environments. Sicot 74BRF has set a new yield benchmark in full season environments. Other varieties such as the Sicot 43 family only perform well in specific short season environments.

Dryland production systems require varieties that yield well in water limited situations. The best dryland varieties are generally very indeterminate and have robust fibre characteristics. Siokra 24BRF is a variety specifically bred for dryland and tropical irrigated production. Other irrigated varieties with good fibre length can also be grown under dryland conditions. Sicot 74BRF has also performed very well as a dryland variety in full season environments.

The relative performance of cotton varieties can be compared online at www.csd.net.au using the variety comparison tool and the latest variety guide should be consulted to assist in selection.

The final yield of any variety is the product of its yield potential limited by the environment. It is worth your time to select the best performing variety for your farm. In fact different fields on your farm may require different varieties to achieve the highest yields. Varieties can be selected on past performance but most new varieties will have to be selected on their results in variety trials. Historically cotton growers change varieties rapidly to grow the higher yielding replacements. Cotton varieties bred in Australia have demonstrated a 1.8% increase in

BEST PRACTICE

- In addition to yield potential, consider quality traits, disease ranking and leaf shape when selecting variety.
- If planning to access biotechnology traits, contact a Technology Service Provider (TSP) to find out more about requirements and stewardship.

average yield per year, so newly released varieties may be the best choice for your farm

Quality

Australian cotton is regarded as some of the best in the world. Apart from lack of contamination the intrinsic fibre characteristics have been improved by breeding. Fibre length has been increased significantly in the last few years. Fibre strength has also been increased and micronaire values adjusted down to the premium range. Some varieties such as Sicala 340BRF have exceptional quality and may achieve premiums. However Pima varieties have the best quality and generally command a higher price for lint. There is an inverse relationship between yield and most fibre quality traits but through careful selection, breeders have been able to get high yielding varieties with good fibre quality.

Some fibre quality traits are more important in particular environments. In the hotter regions selecting varieties with lower relative micronaire may assist in minimising discounts and achieving premiums. In dryland situations selecting varieties with the best fibre length will reduce the chance of length discounts. Variety selection can also impact on grades. Okra leafed varieties sometimes achieve slightly lower grades than normal leaf varieties due to the leaves 'catching' on the plant and contaminating the lint. Careful defoliation and ginning will limit any grade loss.

Disease

Breeding has provided the main method of managing our major diseases such as verticillium and fusarium wilt. The industry has developed a ranking system (F rank for fusarium and V rank for verticillium) to allow growers to compare the disease resistance of varieties. The ranking systems use a number system to compare new varieties to a standard. A rank of 200 would indicate the variety is immune to fusarium wilt and verticillium. The best commercial varieties available currently have an F rank of about 136 and a V rank of around 112. Breeding aims to improve the disease resistance over time and new varieties generally have improved F rank.

By selecting varieties with the highest disease resistance in fields with significant disease pressure, yields will be maximised. In the case of fusarium and verticillium, selecting the most resistant varieties can reduce spore numbers in the soil, thereby reducing its impact on subsequent crops.

The latest disease rankings are available in the CSD Variety Guide and online at www.csd.net.au.

Refer to Chapter 16 Cotton Pest Management Guide for more information on disease management

Okra leaf shape

The 'okra' leaf shape has been used in some Australian varieties since the early 1980s. It is a useful trait that has demonstrated some resistance to heliothis, mites and

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more recently whitefly. Varieties with 'okra' leaves have also been shown to be more water use efficient. However the trait requires careful breeding to achieve equivalent yields to the best normal leafed varieties.

For more information about cotton varieties go to www.csd.net.au or contact CSD



CSD variety trial

Biotechnology

Today there are two broad classes of cotton biotechnology traits which are approved and available in Australian cotton varieties providing either insect protection, herbicide tolerance or in varieties which are 'stacked' with a combination of both traits.

Bollgard II® technology provides control and aids the management of *Helicoverpa* species in cotton. It expresses two specific proteins isolated from *Bacillus thuringiensis* (Bt) which are efficacious against *Helicoverpa armigera* and *Helicoverpa punctigera*. One of the key benefits of Bollgard II has been the significant reduction in insecticide use which has allowed for an increased adoption of IPM principles as well as providing growers with a consistent platform to manage insect control costs.

Roundup Ready Flex® technology confers full season tolerance to glyphosate herbicides. The ability to use Roundup Ready® herbicide in crop to control a wide range of weeds in crop allows growers to design weed control programs that can target individual fields and specific weed problems. The technology has reduced the reliance on pre-emergent herbicides and has allowed growers to more effectively use minimum tillage techniques and reduce manual weed chipping costs.

Liberty Link® cotton confers tolerance to Liberty® (glufosinate ammonium) herbicide which is registered to control a range of broad leaf and grass weeds in crop. This technology utilises the herbicide glufosinate which has particular strengths including the ability to control hard to kill weeds including weeds like peach-vine which are not well controlled by glyphosate. Liberty herbicide also provides useful control of glyphosate tolerant cotton volunteers.

Accessing biotechnology traits

The access to the various traits is governed by the major technology companies who develop and commercialise the technology via an annual license called a 'Technology User Agreement' (TUA). The TUA forms the basis of the relationship between the grower and the technology company. Its primary purpose is to clearly define the terms and conditions associated with use of the technology in a particular cotton season. It covers a broad array of matters and includes the prices, payment and risk management options for the technology. It also includes stewardship requirements particular to a technology.

In practicality, the actual licensing process is managed by Technology Service Providers (TSPs) on behalf of the technology companies. TSPs are primarily well known local and national retailers of crop protection products and cotton planting seed. Growers should direct initial enquiries about access biotechnology to their local TSP's.

All cotton biotechnology traits commercialized in Australia are supported by an appropriate stewardship program which forms part of the annual TUA between technology owners and growers. The stewardship programs are a product of collaboration between the cotton industry and the developers of the technologies with an aim of supporting their long term sustainable use. This is important to ensure the traits continue to provide value to growers and more importantly provide a basis for the introduction of new novel traits. See Stewardship chapter.

A list of current TSPs can be located at:

www.monsanto.com.au/products/cotton/

www.bayercropscience.com.au/



Crop Establishment

By JAMES QUINN (CSD)

Target plant population

To optimise yield you should aim for an evenly spaced plant population from 5–13 plants per metre. You need to avoid gaps greater than 50cm. This has been verified by many years of experiments in Australian conditions.

There are some situations where growers should target the upper or lower end of this range.

Aim for the lower end of the range when:

- Planting dryland, and;
- Where you normally grow a larger plant size that can compensate well into spaces (e.g. in wetter, warmer climates and good soil types)

Aim for the higher end of the range when:

- Early crop maturing is essential (e.g. southern and eastern regions), and;
- Where you normally grow a smaller plant size that cannot compensate well into spaces (e.g. tight soils)

Planting rate

The key considerations when determining how much seed you need is your desired plant stand, the seed size and seed quality for the variety you are growing, and how many seeds survive.

On average there are about 10,000 seeds/kg, but there will be slight differences between varieties. The average seeds/kg for each variety is printed on the bag and also available on the CSD website.

Seed quality: All CSD seed has a minimum germination of 80% at the point of sale (most is a lot higher than this). Germination percentages for individual lots are available on the CSD website or contacting CSD's lab.

Seedling survival is rarely 100% so you can never bank on seeds/ha and plant/ha being the same.

Bed condition: Uneven or cloddy beds can result in

BEST PRACTICE

- Planting outside the ideal planting window for your district may require special management.
- Some varieties have lower seedling vigour and require careful management in terms of seed bed, soil temperature, and planter set up and operation.
- Replant decisions should be based on good field information about the current population, its health and the cause of the stand loss. A low and gappy plant stand can be very costly and difficult to manage. Replanting Bollgard II needs to occur within the planting window.



Aim to avoid gaps greater than 50cm – they have a large impact on yield.

uneven seed depth and seed/moisture contact, resulting in a staggered germination and gaps in the plant stand.

Soil insects: Particularly wireworm, can attack young seedlings. Seed treatment insecticides will control them but because the insect needs to feed on the plant before it dies, some plant loss can still occur.

Soil temperature: Ideal soil temperatures for cotton establishment are 16°C–28°C. Temperatures below this result in slow emergence and increased chance of soil diseases.

Seedling diseases: such as rhizoctonia, pythium and fusarium can kill young plants during and after emergence. This will be more prevalent at low temperatures, where there is high levels of crop residues and in fields with a history of disease.

Many of these factors are unavoidable and the best and easiest way to manage them is to increase the seeding rate.

There are more disadvantages in having a plant population that is too low than there are to having one too high.

Planter setup

Ensure planter is well serviced and operational well before planting time because breakdowns in the field can rob you of time and allow surface soil moisture to further dry away.

- 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 when 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.

SPEED OF PLANTING VERSUS ESTABLISHMENT

Location	Speed of planting	Seeds planted per metre	Plants established per metre	Per cent establishment
Dalby dryland following sorghum	9.5 km/hr	15.2 seed/m	10.2 plant/m	67.1 %
	7.5 km/hr	15.2 seed/m	11.1 plant/m	73.0 %
St Ruth dryland; millet stubble	12 km/hr	9.8 seed/m	4.2 plant/m	42.8 %
	8 km/hr	9.8 seed/m	5.8 plant/m	59.2 %
Theodore, pre-irrigated, back to back	12 km/hr	13.0 seed/m	10.7 plant/m	82.3 %
	8 km/hr	13.0 seed/m	12.0 plant/m	92.3 %
Emerald, watered up back to back	9 km/hr	11.2 seed/m	8.7 plant/m	77.7 %
	7.5 km/hr	11.2 seed/m	8.7 plant/m	77.7 %

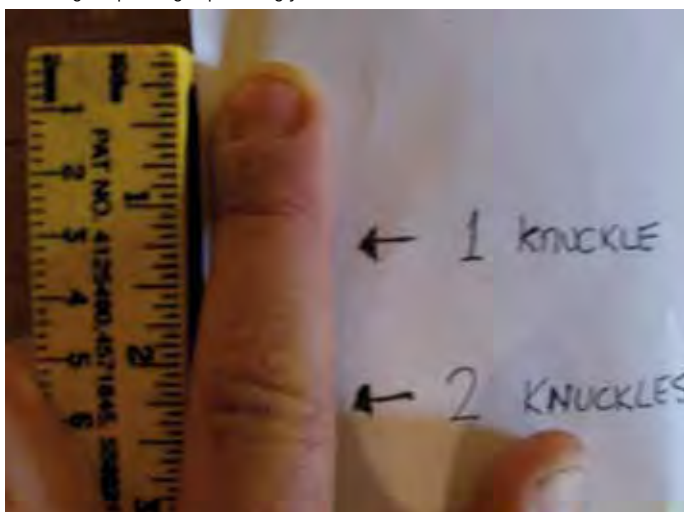
Attention to detail is very important at planting, especially with the small seeded varieties such as Sicot 74BRF. CSD trials with Sicot 74BRF have shown speed of planting can make a difference in establishment.

Planting depth

The depth you want your seed depends on the method and soil conditions you are intending to establish your crop. Many people like to use the 'knuckle' as a quick and easy measurement tool in the field (Figure 1).

FIGURE 1.

Checking the planting depth using your knuckles.



Establishment method	Ideal depth
Planting into moisture (rain or pre-irrigated)	2 ½ and 4 ½cm (1 to 1 ½ knuckles)
Planting dry and watering up	2½cm (1 knuckle)



Particularly when planting on rain moisture, beware of uneven moisture throughout the bed which will cause variable crop development.

Important considerations

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

Check the consistency of the soil above the seed. If the pressure from the press wheels on the planter are set too high, you can get a compacted zone above the seed and the young seedling will have a tough time getting out.

Some dry soil above the seed slot is useful to prevent losing moisture from around the seed, but if there is too much, a rainfall event after planting will turn this dry soil into wet soil, and increase the depth for which the young seedling needs to push through.

This method has advantages in hot climates, because it cools the soil and crop establishment is rapid. However, consider pre irrigating when:

- There is a large seed bank of difficult to control weeds; and,
- The soil is very dry and temperatures are high.

Any shallower than 2½cm and the plant doesn't have the chance to scrape off the seed coat at germination and growth of that plant will be quite slow until that coat is thrown off.

When planting dry, it's very importantly to be aware of the consistency of the seed bed. A poorly consolidated (or cloddy) hill can collapse when the water hits it and dropping the seed down to great depths, resulting in a poor or variable strike. This is especially important for crops coming out of sugarcane or corn.

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



Planting into moisture.

Planting time

The ideal planting time will vary between seasons and districts.

Start time: Planting should not occur until minimum soil temperatures at seed depth are maintained at 14°C or more for three days and rising. Planting at temperatures below this will diminish root growth, reduce water and nutrient uptake and the plants are much more susceptible to seedling diseases and insects.

History shows the incidence of replant has been much higher in situations where soil temperatures have been lower than ideal.

End time: Agronomically, the end date is more important in short season areas where early crop maturity is essential. This is evident by the comparison of ideal planting times for northern, central and southern regions (See figure 2.)

The adoption of Bollgard II cotton has helped eliminate some of the desire for very early planting because:

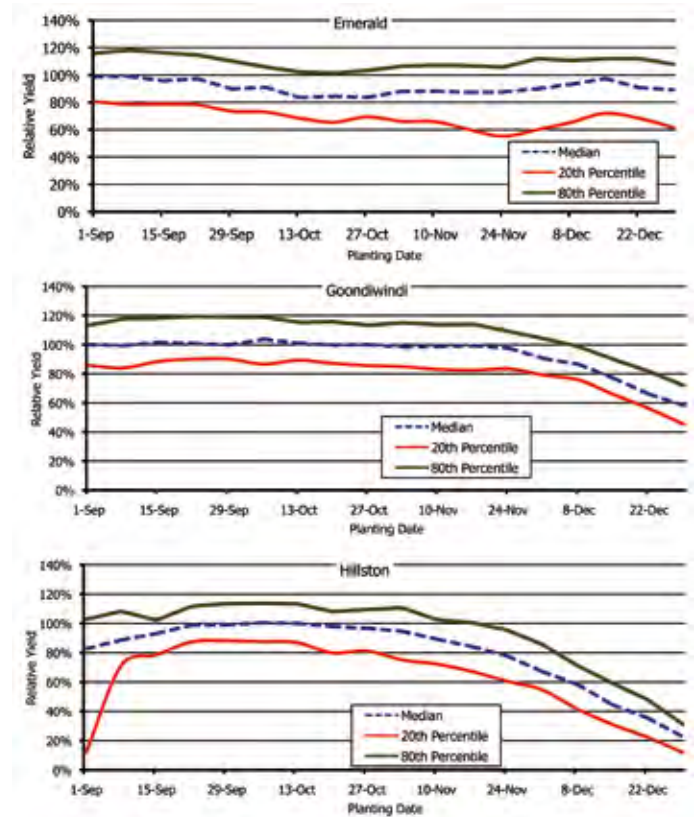
- These crops tend to retain more early fruit and hence a quicker time between planting and picking.
- The season-long *Helicoverpa* control offered by this product diminishes the risk of high late-season insect numbers and control costs associated with conventional cotton.

Where season length allows, planting slightly later has a lot of advantages:

- It will increase the likelihood of warm temperatures at planting, resulting in increased seedling survival and vigor.
- A crop established under warm conditions has the potential to produce bigger plants, hence greater leaf and stem area to sustain boll development later in the season.
- Later planting will delay the peak flowering period past the hot conditions often associated with late December/early January period. This can reduce the likelihood of premature cut-out and high micronaire.

FIGURE 2.

Yield potential by sowing date for Emerald, Goondiwindi and Hillston.



Data generated by CSIRO using the OZCOT model assuming soil Plant Available Waterholding Capacity (PAWC) of 200mm (Emerald and Goondiwindi) and 150mm (Hillston), Irrigation deficit of 70mm, Water allocation for the season of 8ML/ha.

Note: Planting 'slightly later' will mean different things in reach region, depending on season length:

- In cooler areas in the south and east it may mean planting in mid October.
- In central regions it may mean mid mid to late October.
- In northern and western regions it may mean mid October to early November.

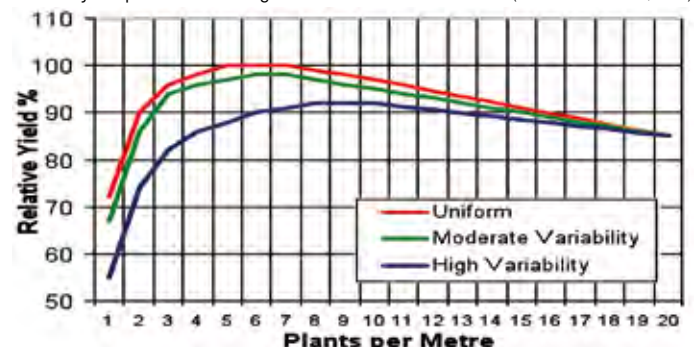
Other factors that need to be considered in determining planting date:

- Late maturing crops may be more susceptible to pests such as silverleaf whitefly and aphids.
- Availability of harvest machinery if a crop is much later than others in the district.

In all cases, people growing Bollgard II cotton need to

FIGURE 3:

Relative yield potential at a range of Plant Stand Uniformities. (Source: G Constable, 1997)





Cereal stubble is important in the establishment of dryland crops – it improves moisture infiltration and protects the young seedlings from sandblasting.

plant within the planting window for their district. This information is available in the Bollgrad II Resistance Management Plan.

Planting on rain moisture

Although this is what dryland growers do every year, many irrigators also aim to establish their crop on rain moisture to save water on pre-irrigation or watering up.

There are a number of factors that will improve the likelihood of success with planting into rain moisture and some cautionary points for those attempting it on irrigated country.

Stubble

The presence of standing stubble will increase the chance of seedling survival in moisture planting situations dramatically because it increases the amount of infiltration and hence moisture available to the seedling, it reduces surface evaporation and it protects the young seedling from the elements.

Bare fallows in irrigation country

This is a risky practice and often results in replants if conditions are not ideal. Fields hilled for irrigation are designed to shed water so you need to check whether moisture has infiltrated to any depth into the seed zone.

In cloddy seedbeds the fine materials may be wet but the larger clods may be dry and may draw moisture away, drying the seed bed.

Check across a field to see whether the rainfall has been uniform.

When planting, check soil moisture levels in the seed zone regularly.

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

Do I need to replant?

The decision as to whether to replant or not is sometimes a straightforward decision, and other times not. The obvious question is “will I achieve a better result with the plants I’ve got or should I start again?”

The decision needs to be made carefully, based on good field information on the current population, its health, the cause of the stand loss, the implications of replanting and the implications of managing a low plant stand.

Some factors to consider:

Measure your plant stand

Figure 3 demonstrates the relative potential yield of plant stands that are variable or non-uniform compared with a uniform stand. A plant stand with high variability is one having 2 or more gaps greater than 50 cm in length every 5 metres of row. The data also shows that 5–10 plants/m of row has the best yield potential; variable stands will reduce yield for all plant populations.

Causes of the plant loss

Establishing the cause of the stand loss is important so you can determine whether further plants will die and also if you choose to replant, whether the crop will succumb to the same problem again. Often stand loss is due to a combination of factors.

Insect damage: If insects such as wireworm are the cause of plant loss assess whether they are still present and continuing to kill plants. If you replant, use an in-furrow insecticide or a robust seed treatment at a higher planting rate.

Diseases: If seedling disease is the cause of the stand loss consider whether plants are still dying and likely to reduce the plant stand further. Generally higher soil temperatures will reduce their incidence when replanting.

Soil characteristics: In sodic or hard setting soils, seedlings may be slow in emerging or get stuck under a crust. Sometimes the mechanical breaking of this crust to allow the young seedlings through may be more effective than replanting.

Herbicide damage: If planting herbicides washing into the root zone has injured or killed young seedlings, consider whether this will reduce the population further and whether it will impact on replanted plants.

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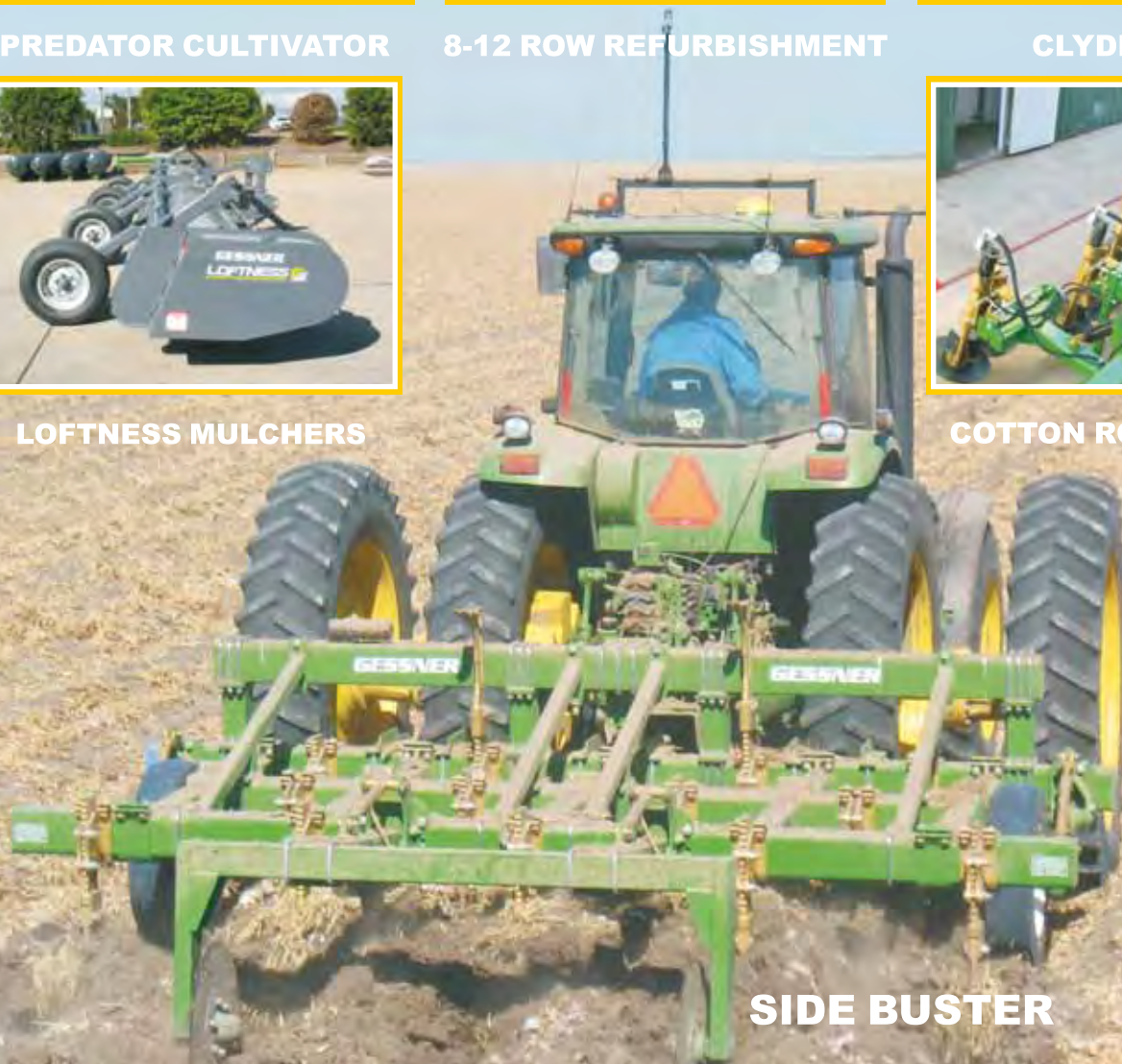
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Avoid planting into fields with established weeds – they will draw moisture out of the profile so it's not available to the young seedlings.

Fertiliser burn: If ammonia burn has killed young seedlings, the replant should be off-set from the original problem so it does not reoccur.

Hail or sandblasting damage: Try and determine whether the surviving seedlings will regrow.

The implications of replant

Replanting date: Relative yields decline by late October in warmer growing regions and earlier in cooler regions (Figure 2). This reduction in yield potential should be factored into replant decisions, as a low population or gappy stand may have a greater yield potential than one which could be replanted.

Soil moisture status: In seasons where irrigation water is such a limiting factor, the soil moisture status is a critical factor 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 acreage?

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 variety guides for suitable varieties.

Remember, any replanting of Bollgard II varieties needs to be completed within the planting windows for Bollgard II. There are no restrictions on planting date for non Bollgard II 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.

Further information: www.csd.net.au



Monitoring to Manage

Compiled by **Susan Maas** (CRDC)

A key part to successful management of cotton is making informed management decisions based on crop measurements and other indicators. The following outlines some measurements which will assist in optimal management based on industry best practice.

Monitor to Manage:	Post Harvest	Pre-planting/ Emergence	Planting to 1st flower/ metre	1st flower to 1st open boll/metre	1st open boll/metre to harvest
Diseases and Disorders		Where there is seedling death or stunting try to determine the cause by inspecting roots and plant. Dig rather than pull plants out.	Monitor plants for symptoms including reduced leaf area, tip damage, leaf or stem discolouration, plant stunting and other signs of non uniform growth, such as short internodes and plant stress such as cavitation (boll dangle) or parrot beak bolls. Refer to Cotton Symptoms Guide		
Energy	Review whole season Energy Use Efficiency indices. Refer Chapter 10.	Keep records of fuel and power usage and each field operation to allow energy usage to be estimated. Refer Chapter 10.			
Irrigation	Review whole season Water Use Efficiency indices. Refer Chapter 8.		Monitor soil moisture using probes to inform scheduling decisions. Monitor plant symptoms, and measure growth and retention to also provide supporting information. Refer Chapter 8.		
Nutrition	Sample soil for nutrition in a representative part of the field. Record date and time of sampling, as well as GPS location. Use a nationally accredited (NATA) laboratory. Refer Chapter 7.		Sample petioles to monitor nitrate-N up to flowering. At this stage petiole testing is not recommended for other nutrients. Refer Chapter 7.	Sample leaf tissue twice (at flowering and cut out) to monitor all nutrients including micronutrients. Refer Chapter 7.	Yield maps overlaid with other information sources such as soil maps, can help identify fertility trends and subsoil constraints. Refer Chapter 1.
Pest & Beneficials		Monitor using industry guidelines for species and numbers of pests and beneficials at least twice weekly, in addition IPM decisions should consider plant damage and health (e.g. retention) Refer to chapter 13 and the Cotton Pest Management Guide for details.			
Plant Growth		Monitor plant establishment per metre as well as the distance between plants (gappiness) within the plant stand for replant decisions. Refer Chapter 4.	Monitor fruit retention and plant growth to help with agronomic and pest management decisions (See box on next page) Measure Vegetative Growth Rate (VGR) by comparing the change in the height to node ratio over time. Refer Chapter 6 and Crop Development tool on CottASSIST.	NAWF (Nodes Above White Flower) measure is used to assess health. At 1st flower the NAWF should be above 8. To maximise yield potential try to keep the NAWF >4.5 for as long as possible. Once the NAWF falls below 4 this is termed cut out and signals the end of reproductive growth. Refer Chapter 6.	In uniform crops NACB (Nodes Above Cracked Boll) measurement is used to determine the time required before the crop reaches maturity. When the crop reaches the '4-5 NACB' stage, the uppermost boll will have reached 'effective' maturity. In non-uniform crops NACB is not reliable indicator of maturity. Refer Chapter 21 for more information on defoliation decisions.
Weeds	Assess weed species and load to plan IWM. Refer Chapter 15..	Monitor for weed survivors, post herbicide application. Refer Chapter 15.			

Using Mepiquat Chloride (Pix)

By SANDRA WILLIAMS, MICHAEL BANGE & GREG CONSTABLE (CSIRO)

Acknowledgements: Dave Kelly, John Barber, Bernie Caffery, James Hill, Brad Cogan and Steve Warden (cotton consultants).

Once a cotton plant has flowered, competition for water, nutrients and carbohydrates between vegetative and reproductive growth commences within each plant. This is normally well regulated by the plant itself, but in some situations can become unbalanced. It is in these situations when the need for growth regulators like Mepiquat Chloride (Pix) should be considered.

When excessive vegetative growth has been prevented, Mepiquat Chloride can improve yield. This is a result of increases in canopy light penetration and air circulation reducing in physiological shedding, increasing fruit retention. Mepiquat Chloride is also credited for a range of responses including inducing cutout, achieving earliness, reducing attractiveness to late season pests and improving crop uniformity.

This chapter explains Mepiquat Chloride's mode of action and how to make the decision on whether an application is needed.

Mode of action

Mepiquat Chloride reduces the production of Gibberellic acid (GA) in a plant by partially inhibiting one of the enzymes involved in the formation of GA.

GA belongs to a group of plant hormones, Gibberellins, which are natural growth regulators in plants. They

BEST PRACTICE

- Mepiquat Chloride manages excessive vegetative growth by shortening internodes and reducing leaf area to restore the balance between reproductive and vegetative growth.
- There are many factors that should be considered when making the decision to apply Mepiquat Chloride.
- Simple observations of height will not necessarily identify accurate Mepiquat Chloride response.
- **Caution:** Some defoliant products containing Ethephon, such as Prep, are labelled as a 'Growth Regulator'. Ethephon on a growing cotton crop has devastating consequences. Ethephon is used for preparing the crop for harvest and may cause significant fruit loss if used at inappropriate times.

play an important role in stimulating plant cell wall loosening which allows stretching of the wall by internal pressure. This is known as cell expansion and is one mechanism allowing a plant to grow. In addition to GA, cell expansion is driven by a number of factors including water availability, humidity and temperature.

Impact on cotton growth

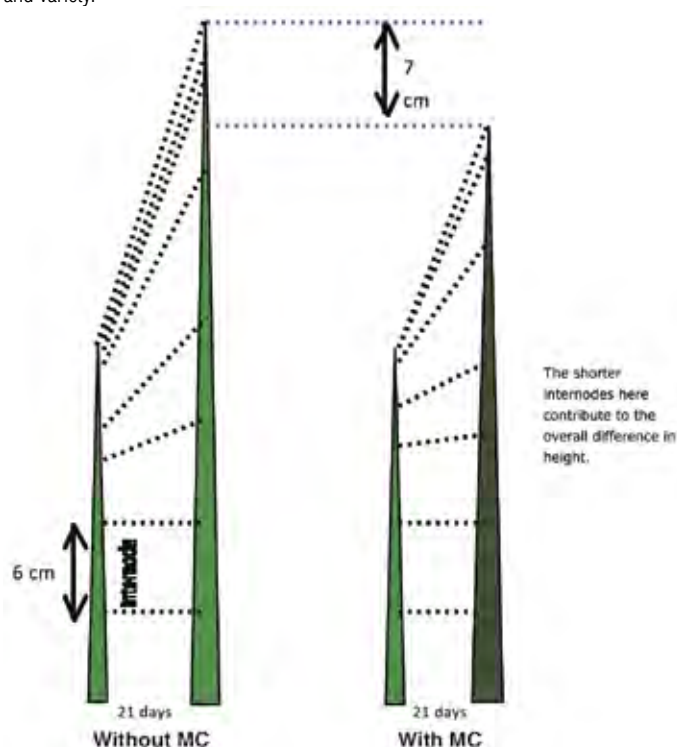
When cell expansion is inhibited following an application of Mepiquat Chloride, any new plant growth will normally have shortened internode length (refer to Figure 1) and smaller, thicker leaves. As cells are smaller and denser, and because the green coloured chlorophyll molecules are sitting closer together, the leaf colour is generally a darker green.

Even though Mepiquat Chloride is rapidly distributed throughout the entire plant, it only significantly limits the cell expansion in new growth. So generally it is only the top 3 or 4 internodes that will be shortened. The concentration of Mepiquat Chloride becomes diluted as growth continues and the formation of GA and normal cell expansion resume at the growing point. Thus larger plants growing more rapidly will require higher rates of Mepiquat Chloride to slow cell expansion.

Figure 1 is an example of the impact of Mepiquat Chloride on an actively growing plant terminal. The

FIGURE 1:

An example of an actively growing cotton plant terminal over a period of 21 days with and without a Mepiquat Chloride (MC) application. In this example the total reduction in plant height after 21 days is approximately 7cm less than a plant that hasn't received an application of Mepiquat Chloride. This calculation is based on the plant's current fully expanded internodes being an average length of 6cm. Following the application of Mepiquat Chloride, differences in plant height will be a result of responses of plant growth to field and environmental conditions, boll load and variety.





plant on the right has been treated with Mepiquat Chloride. In this example, after a period of 21 days the overall height difference is not large as the production of new nodes continues on the treated plant. However this difference in height will become larger over time unless the vegetative/reproductive imbalance is addressed. The treated plant can resume normal growth if the fruit load is enough to keep the vegetative growth in check.

Vegetative growth

Maintaining vigorous vegetative growth before flowering is important as it is these leaves, fruiting branches and roots that will support its future boll load. After flowering this vegetative growth will normally slow down as the plant prioritises its resources to the boll (water, nutrients and carbohydrates). Only when there are excess resources to the needs of fruit growth does vegetative and reproductive growth continue. Eventually, when all of the resources are allocated and there is no excess, further growth (both vegetative and reproductive) ceases and the crop will cutout.

Competition for water, nutrients and carbohydrates between vegetative and reproductive growth is constantly occurring within each cotton plant. This is normally well regulated by the plant itself, but in some situations can become unbalanced. It is in these situations when the need for growth regulators like Mepiquat Chloride comes about.

When fruit is lost, such as shedding during prolonged cloudy weather, very high temperatures, or due to insect attack, the resources that were being used by the fruit are now available for other growth. If growing conditions are good, the plant will respond by growing larger leaves and more stem. New fruiting sites will continue to be produced.

Similarly in conditions where there is abundant moisture, humidity, heat, ample nutrients, no soil constraints etc, there may be an excess of resources above the needs of the developing bolls. The crop will respond by growing more lush vegetative growth. Excessive vegetative growth can be a symptom of too much nitrogen, or too frequent irrigations. All cotton varieties have a similar response in vegetative growth.

Yield

Research conducted in the USA has shown that Mepiquat Chloride, applied at early flowering can have a positive effect on boll retention in the lower part of the canopy if there was excessive vegetative growth. Excessive vegetative growth (leaf area and stem growth) can result in canopies which limit penetration of light into lower parts of the plant. This results in leaf shading (sometimes referred to as self shading) reducing photosynthesis and reducing retention or growth of lower bolls; and increase humidity in the canopy predisposing leaves and bolls to disease.

The use of Mepiquat Chloride in these circumstances essentially acts as a 'brake' on vegetative growth, allowing better penetration of light into the canopy and allow fruit growth to 'catch-up' and re-establish

the crops ability to balance its own vegetative growth, and then continue to meet the needs of further fruit production.

Maturity

An effect of Mepiquat Chloride is to assist earlier cutout and thus crop maturity. Restricting vegetative growth means that there are less assimilates (products of photosynthesis) produced by the plant from new leaves to continue new growth at optimal rates thereby causing the plant to approach 'cutout' more rapidly. The time of cutout is generally directly related to maturity. Applications late in the season to reduce unnecessary vegetative growth can assist in maturing the crop for a timely harvest. Applications applied at early flowering (to control excessive vegetative growth) to allow fruit growth to 'catch-up' will also help the crop reach maturity at a normal rate. Although in this case, optimal nitrogen and water are also important factors to consider in assisting earlier crop maturity.

In shorter growing regions close attention to appropriate and timely use of Mepiquat Chloride is required to ensure no delays in maturity.

Crop uniformity

On occasions a crop can become patchy with excessive vegetative growth, for example when the crop has had a pest infestation that has not affected all plants, cases of uneven soil types, or head ditch and tail drain effects. In these situations Mepiquat Chloride applications can assist in making the crop more uniform allowing for uniform defoliation and timely harvest. Crops that do not have uniform maturity can be attractive to late season pest infestations, and are susceptible to fibre quality issues such as lower micronaire (due to increased numbers of immature bolls) and increased leaf trash.

The use of variable rate technology in these situations can offer significant opportunities to optimise the effectiveness of Mepiquat Chloride applications.

Making the decision at early flowering

Cotton's response to Mepiquat Chloride application/s depends on a range of factors, the most critical being whether there are other sources of stress already controlling growth, and the rate and timing of the application. Since GA plays an important role in cell expansion, preventing the plants production of GA can be detrimental to plant growth. Hence using a high rate of Mepiquat Chloride at an inappropriate time can result in yield reductions.

In making a decision as to whether Mepiquat Chloride can help, it is important to consider causes behind any excessive growth such as those described previously. In assisting these decisions at early flowering one should consider information on vegetative growth rate (VGR), field history, fruit retention, irrigation scheduling, current and future weather conditions, and cotton variety.

Measuring VGR – early flowering

Vegetative Growth Rate (VGR) is an effective technique to monitor vegetative growth. VGR is the rate of change of plant height relative to the rate of node development. The VGR measures the rate of internode increase and is better able to capture situations where crops are moving from optimal to poor conditions, or vice versa. This method is also able to identify the need for canopy management before crops are excessively vegetative. Simple observations of height will not necessarily identify accurate Mepiquat Chloride response.

$$\text{VGR (cm/node)} = \frac{\text{This week's height (cm)} - \text{Last week's height (cm)}}{\text{This week's node number} - \text{Last week's node number}}$$

Measurements should commence as the crop approaches first flower, which is normally late November for many regions and the plant has roughly 12 mainstem nodes. The monitoring should continue during the first half of the flowering period as rapid increases in growth rate can occur at anytime in this period.

Plant height and node information can be entered into the CottASSIST Crop Development web tool which calculates the VGR and compares this number to the ideal range for the crops growth stage.

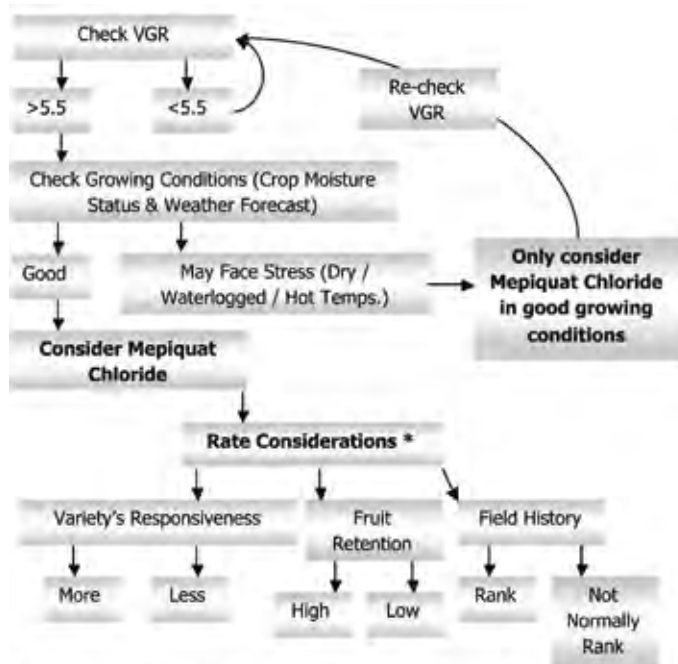
During early flowering, if the VGR is over 5.5 then applying Mepiquat Chloride should be considered. However before deciding on the timing and the rate, other factors need to be taken into consideration (refer to flow chart 1).

Field history/soil type

Knowing how the cotton is likely to grow in each field is the key factor in making the decision to apply Mepiquat Chloride

FLOW CHART 1 – EARLY FLOWERING DECISION TREE:

This flow chart incorporates all of the factors and the decision processes that should be considered when making the decision to apply Mepiquat Chloride early in the season around flowering.



* Use Table 1 and Figure 2 for assisting with decisions regarding Mepiquat Chloride rates.

Chloride. Some fields, often due to lighter textured soil types allow better access to soil water and nutrition; and have a tendency for rank growth. In these situations you would expect to get a positive response from Mepiquat Chloride application/s, although it is still important to monitor these fields to determine the correct application rate and timing.

Fruit retention

After flowering the cotton plant will naturally become committed to giving more and more of its resources to the developing bolls. Therefore a high fruit load may already reduce the tendency for a crop to produce excess vegetative growth, hence a reduced need for Mepiquat Chloride. Caution should be applied to crops with early high fruit retention (like many Bollgard II crops) as research has shown any limitations to canopy size early in flowering will impact yield more than crops with lower fruit retention. Crops with larger boll loads will need larger canopies to support the growth of fruit. Refer to the Crop Development Tool on CottASSIST site.

Future stress events

It is always important to ensure that crops are not stressed for at least a week after the Mepiquat Chloride application as additional stresses can substantially limit vegetative growth and thus limit yield. Hot weather and/or water stress from being unable to irrigate the crop on time are examples.

Stress, especially moisture stress, will reduce vegetative growth and production of new fruiting sites allowing existing fruit on the plant to develop. This may lead to early termination of flowering and a probable yield reduction.

In cases of severe stress (water, prolonged period of cloudy weather, or a period of very high temperatures) fruit loss may occur. In these cases a symptom can be excessive vegetative growth once stress has been removed. Crops should be monitored closely following these events. Strategies to apply Mepiquat Chloride in anticipation of stress events that cause these affects are not recommended as the growth regulator could add to the stress or the event may not eventuate and therefore limit vegetative growth needed for continued fruit growth.

Variety

Research has shown that our Australian cotton varieties vary in their yield responsiveness to applications of Mepiquat Chloride (see Table 1). Varieties may differ in the response to Mepiquat Chloride because of determinacy (ability to regrow), rate of canopy development or fruit production, or because of differences in their architecture. Less responsive varieties may still require Mepiquat Chloride, so monitoring their VGR and taking into account all other factors remains important.

TABLE 1:

Yield responsiveness between varieties under irrigated conditions

More responsive	Intermediate responsiveness	Less responsive
e.g. Siokra 24BRF, Sicot 75, Sicot 70BL, Sicala 340BRF	e.g. Sicot 74BRF, Sicot 72BL, Siokra V-18BL, Sicot 730	e.g. Sicot 71BRF, Sicot 71RRF, Sicot 71, Sicala 43BRF, Siokra V-18BRF

Rate considerations at early flowering

Figure 2 has been designed to take all factors into consideration when deciding on the rate of Mepiquat Chloride to apply. The following examples will explain how to use the graph.

Example one: A crop has a VGR Measurement of 8, low fruit retention and the field is normally prone to rank growth. Information from the seed company has indicated that the variety is moderately responsive to Mepiquat Chloride, so using Figure 2 the application rate may be at a higher rate (For example 600-1000mL/ha).

Example two: A crop has a VGR of 6, good fruit retention, the field has no history of rank growth and information from the seed company has indicated that the variety is not greatly responsive to Mepiquat Chloride, therefore using Figure 2 applying Mepiquat Chloride may not be a benefit, although monitoring should continue.

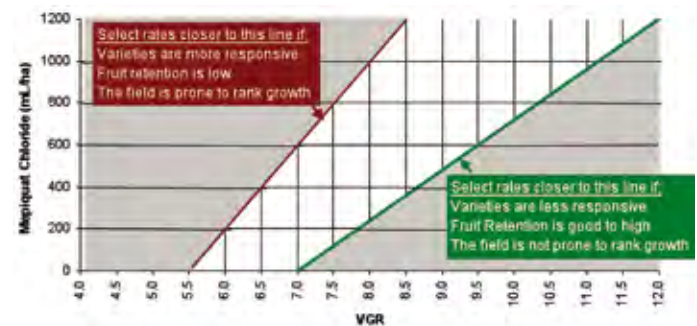
Making the decision before cutout

Given the right conditions, cotton will continue to grow late in the season. This late growth can increase the crops attractiveness to late season pests and can also increase the number of immature (low quality) bolls at harvest. This is when Mepiquat Chloride maybe considered in order to slow down further vegetative growth. It is also important that if earlier or timely cutout is to be achieved water and nutrient management should specifically aim to meet only the requirements of the fruit that will be taken through to harvest.

Decisions regarding a late application of Mepiquat Chloride are based on whether or not the crop is already

FIGURE 2:

Mepiquat Chloride requirement graph incorporating VGR and other factors. Rates assume Mepiquat Chloride formulation of 38 g/litre. (Source: CSD)



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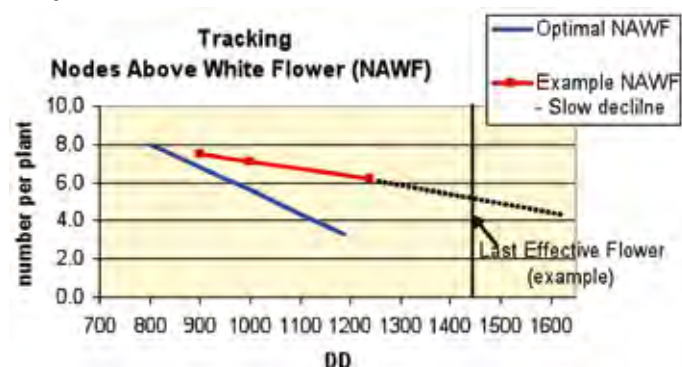
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FIGURE 3:

An example of using the number of Nodes Above White Flower to forecast the timing of cutout.



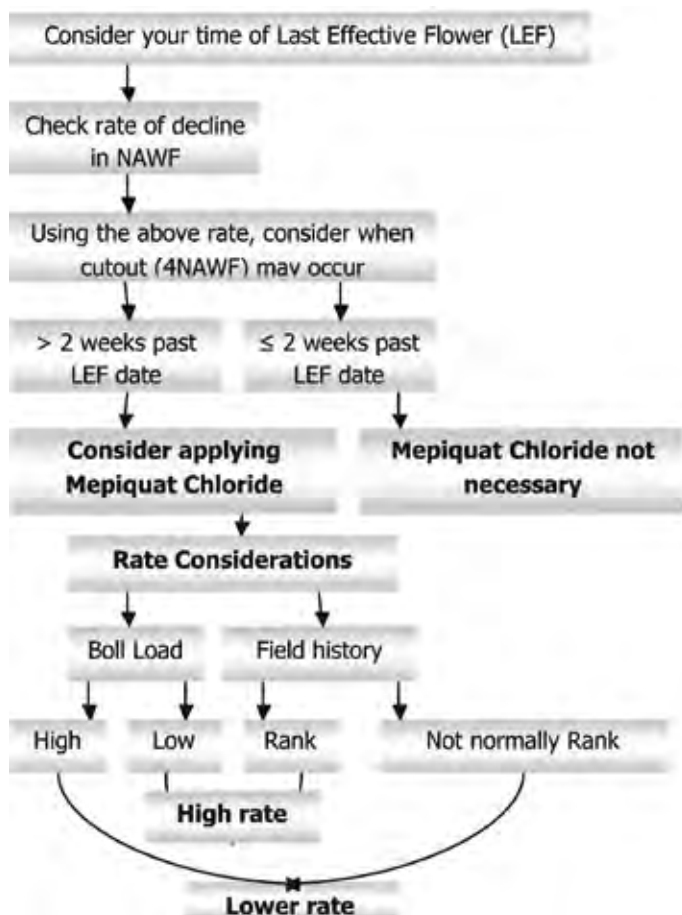
approaching cutout at an acceptable pace. These decisions are generally made in late January for most regions or about 3 weeks before the last effective flower (LEF) date. The LEF date can be determined by using the CottASSIST Last Effective Flower Tool (LEFT) or from local experience.

Monitoring NAWF – late season

An effective technique used to assess how quickly cutout is approaching is monitoring the number of Nodes Above the White Flower (NAWF). This measures the position of first position white flowers relative to the plant terminal.

FLOW CHART 2 – CUTOUT DECISION TREE:

This cutout chart is designed to help with late season decisions to apply Mepiquat Chloride.



The closer a white flower is to the terminal means that there has been less nodes produced since that particular flower was initiated as a new square.

NAWF: Count the number of mainstem nodes above the uppermost white flower in the first fruiting position. These counts are typically collected weekly from first flower until cutout. Monitoring should occur post cutout to ensure that any regrowth is identified and managed if necessary. NAWF counts can be entered into the CottASSIST Crop Development web tool to plot the rate of decline on a chart and compare this with the optimal rate of decline.

In an optimal situation, the NAWF should fall at the rate of one per 55–65 Day Degrees. Where there is a slow rate of NAWF decline and the forecast cutout (4 NAWF) is beyond the LEF, then applying a cutout rate of Mepiquat Chloride should be considered. Figure 3 compares an optimal rate of NAWF decline with a slow rate of decline. In this example the forecast of cutout (shown with the dotted line) will go beyond the LEF date, hence a cutout rate of Mepiquat Chloride should be considered.

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

- FibrePAK
- CottASSIST (Crop Development Monitoring and Last Effective Flower Tool)



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Get the latest information on Australian cotton varieties at www.csd.net.au

Nutrition Efficiency

By **DUNCAN WEIR** (Qld DAFF) &
IAN ROCHESTER (CSIRO)

Acknowledgements: Nilantha Hulugalle (NSW DPI), Mike Bell (Qld DAFF)

Nutrients and soil constraints that impact cotton

Crop nutrition management not only requires a sound knowledge about plant nutrient requirements and demands but also requires an understanding about soils, soil chemistry, soil health and the complex interaction between the plant and soil.

Nitrogen

Nitrogen is a mobile nutrient both in the soil and in the plant and should be monitored throughout the production season to maximise production. Deficiency symptoms include stunted plants with pale yellow leaves, few vegetative and fruiting branches. Excessive supply of N will induce rank vegetative growth, shed young bolls, delayed fruiting and crop maturity, hamper defoliation and reduce lint yield and profit.

Cotton sources most of its N as nitrate-N from the mineralisation of soil organic matter. Mineralisation is a biological process within the soil which results in the release of nutrients in a form which is available for crop uptake. Only about 1/3 of the crop's N needs are derived from N fertiliser but this is critical to maximising production.

Nitrogen can be lost from the system in several ways and must be considered when preparing a nitrogen management plan. These include:

- **Denitrification** – A biological process especially under low oxygen conditions such as during water-logging where nitrate N is converted into a nitrogen gas and lost to the atmosphere.
- **Leaching and runoff** – Nitrates can be washed through the soil profile and out of the root zone or removed in runoff water.
- **Volatilisation** – Nitrogen in the form of ammonia is lost to the atmosphere. Particularly important when solid fertilisers are applied and are not incorporated properly or in a timely manner.
- **Removal of seed cotton** – most of the crop N removed from the system is found in the cotton seed and can be significant, particularly in high yielding crops.
- **Burning stubble** – The heat from fire destroys organic matter in the surface soil, and much of the N, P and S contained in the soil organic will be lost to the atmosphere during burning. Burning stubble is not common in modern cotton farming systems.



Excess nitrogen can have a detrimental impact.

While insufficient nitrogen will impact on yield, excess nitrogen can also have significant detrimental impacts on cotton. Rank vegetative growth, boll shedding, delayed full boll load and crop maturity, small fruit, increased disease problems such as boll rots, difficulties in defoliating, harvesting problems and reduced fibre quality are all problems associated from over fertilising. All these impacts have considerable economic costs associated with them and result in reduced yields, quality down grades, increased production costs as a result of increased use of growth regulators and defoliant, higher fertiliser costs and reduced N efficiencies. Recent research on Nitrogen Use Efficiency (NUE) by Dr Ian Rochester has identified that there may be opportunities to improve NUE in the cotton industry. www.mybmp.com.au has useful strategies to assess nitrogen use

Anhydrous ammonia (82% N) and Urea (46% N) are the two major nitrogen fertilisers used in the cotton industry. The N released from both fertilisers become available to plants within days, depending on the amounts applied. Urea has the advantage of being able to be applied in different ways using different application methods and at different times. It does need to be incorporated quickly after application to prevent significant losses through volatilisation.

There are several different approaches to how and when N is applied. If all N is applied prior to planting:

- Apply after July to reduce substantial losses through denitrification and leaching.
- Allow sufficient time after application and before planting (3 weeks) to prevent seedling damage.
- Depth and position is also critical to prevent unnecessary losses and seedling damage.
- If N applications are to be split there are two main methods (side-dressing and water run) of application in crop. Side-dressing should occur prior to flowering to help reduce crop damage through root pruning and allow sufficient time for the N to become available to the plant. Water run urea provides more flexibility and reduces crop damage, however in really wet years, opportunity to get nitrogen on may be limited..

Anhydrous ammonia (NH₃) is the most popular option for irrigated cotton, especially where high rates of N are required. Specialised equipment and training is required when applying NH₃. It must be applied deeper than 15 cm to reduce losses however soil conditions impact greatly on this. Very dry soils will allow gas to escape through voids and air spaces while very wet soils will allow gas to escape through the application furrow if it is not closed properly.

Legumes

Incorporating a legume into your crop rotations can significantly improve soil nitrogen fertility through their capacity to fix atmospheric nitrogen into a plant available form. Legumes can also have beneficial effects on soil structure and plant disease management. The amount N fixed and residual soil N of various legume crops can be seen in NUTRIpak.

Recent work has shown significant financial and agronomic benefits of including legumes into the rotation.

Phosphorus

Phosphorus (P) plays an important role in the energy transfer process in plants cells, used in DNA and RNA and some regulation of plant metabolism. Plant deficiency causes reduced seedling vigour, poor plant establishment and root development, delayed fruiting and maturity. Plants will appear stunted and with red/purplish colour.

Phosphorus is a highly immobile nutrient in the soil and despite many soils having a high total P content they can have very low P availability especially under alkaline conditions. P in soils can be classified into 3 pools:

- Available P (phosphate in soil solution that can be used by plants, limited in quantity but readily replenished from labile P).
- Labile P (moderately available P that move in and out of solution, acts to buffer the available P in solution).
- Non labile P (very insoluble P unavailable to plants).

Actively growing cotton plants take up available P from the soil solution. As this supply is depleted, labile P replenishes and maintains the available P. i.e. acts as

a buffer. With continued cropping, the level of labile P declines and is less able to replenish and maintain available P. When P fertilisers are applied to soils, much of the P ends up as labile P. P is normally applied pre plant as a starter with N to enhance growth and increase efficiency.

Mono Ammonium Phosphate, MAP (N:P:K – 9:22:0) and DiAmmonium Phosphate, DAP (N:P:K – 18:20:0) are the most commonly used P fertilisers. Banding of these fertilisers is the preferred method of application as the P remains in solution for a longer period. Although it is considered that P fertilisers are only 30-50% efficient, it is not lost to the system but is immobilised or fixed and may become available later.

P is relatively immobile within the soil so increasing soil-root contact can increase the uptake of P by the crop. Mycorrhizal fungi (VAM) found in the soil have an association with cotton and assist in accumulating and making P available to the plants. Low VAM populations have been attributed to long fallow disorder and need to be considered when growing cotton following long fallow periods or after non-mycorrhizal crops such as canola. Tillage is the main contributor to low VAM populations.

Potassium

Potassium (K) is a mobile nutrient within the plant and has a role in energy transfer, osmotic regulation (maintaining turgor), protein synthesis and nitrogen metabolism. Adequate K nutrition has been linked to reducing the incidence or severity of plant diseases and improving yield and fibre quality.

Deficiencies are first seen in the lower leaves as necrotic lesions and leaf death which moves up the plant, bolls don't develop and fail to open, and as premature senescence can occur.

There are several forms of K in the soil with varying levels of availability to the plant.

Potassium chloride (muriate of potash) is the most widely used fertiliser. It should be banded away from the seed row to prevent seedling damage. Foliar fertilisers can be effective when deficiencies have been identified in petiole and leaf analysis.

Other essential nutrients

Zinc: Zinc is essential in small amounts for enzymes and plant harmony. Deficiencies can be seen as interveinal chlorosis, stunting, and will affect yield, maturity and fibre quality. Zinc sulphate is the most effective and inexpensive form to apply zinc to soil or crop, whereas zinc oxide is very insoluble in the soil but can be dissolved by plant roots. Zinc can be broadcast and worked into the soil, with shallow cultivation. Zn can also be successfully applied to crops as a foliar spray; it can alleviate symptoms and supply sufficient zinc to meet crop needs.

Iron: Iron is an essential nutrient required in very small



amounts in chlorophyll synthesis and some enzymes. Plant symptoms include interveinal chlorosis of the young growth and yellowing of the leaves. Most of the iron in soils is unavailable to plants. Availability is greatly affected by the presence of manganese and P and Zn fertiliser can also reduce iron uptake. Water logging can also lead to deficiencies in alkaline soils. Deficiencies can be managed through both foliar and soil applications.

Other essential nutrients such as copper, boron, calcium, magnesium, sulphur, manganese and molybdenum all have very specific roles to play in meeting the nutritional needs of a cotton crop. Required in very small amount, deficiencies are very rare.

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

- NUTRIpak
- FIBREpak
- SOILpak
- Vetch Fact sheet
- Nutrients removed in harvested seed-cotton
- CottASSIST Nutrilogic

Subsoil constraints

Soil provides the cotton plant with water, oxygen, nutrients and support. An ideal soil would have good infiltration and internal drainage, high plant available water capacity (PAWC), good soil structure for root growth and development, optimum pH, low salinity, balance nutrient availability, low sodicity and adequate soil mycorrhiza and other soil biota. Subsoil constraints are those soil properties or characteristics which limit or restrict the cotton plant in meeting its requirements. Problems associated with subsoil constraints include compaction, soil dispersion, high or low pH, water logging and erosion. These soil related problems can result in poor seedling emergence, poor plant growth, loss of bolls and poor boll set, reduced yields, erosion, increased land management costs and other management issues.

Understanding how modern farming practices impact on and effect the soil, it's chemical and physical properties, is a critical role in how we develop and manage our production systems. For example, as much as 1.5 tonnes of salt per ha is deposited onto soil and into the root zone each time a crop is irrigated. This can be significantly higher when bore water is used rather than river water. The accumulation of salts in the root zone can lead to sodic soils causing soil structural problems, soil dispersion, water logging and hard setting soils.

What is a sodic soil?

A sodic soil is one which has too much sodium associated with the negatively charged clay particles. Large quantities of sodium in soil, reduces the strength of bonds holding clay particles together in aggregates. The sodium also attracts large numbers of water molecules helping to force the clay particles apart. This is known as dispersion and causes the soil structure to collapse. The level of sodicity can be quantified by determining the

exchangeable sodium percentage (ESP) during a soil test. Many of the soils used for cotton production in Australia, are sodic or strongly sodic below a depth of 0.5 m. This affects root growth and water and nutrient uptake. Ground water, used for irrigation can cause sodicity problems particularly when the water contains high sodium levels relative to calcium.

What is a saline soil?

A saline soil is one with excess salts in the soil solution. Soil solution is 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. In this situation the plant is unable to meet its water demands even though the soil is moist. Salinity occurs as a result of ground water rising to within 2mtr of the soil surface, or by irrigating with saline water, or by applying salts via: fertilisers; lime or gypsum. Salinity is measured by testing the soil solutions electrical conductivity (EC).

Meeting the challenge of sodic soils

Calcium can be applied to soils to ameliorate sodic soils. The best form of calcium to use is determined by the pH of the soil. If the soil is alkaline, gypsum will give the best results while if the soil is acid, lime should be used. In this case, lime also has the added benefit of raising the pH of the soil.

The addition of organic matter to soil can also help to reduce the effects of soil sodicity. Organic matter helps hold the soil aggregates together, stabilises soil chemistry, reduces dispersion and improves soil structure.

Source: "Salinity and Sodicity – what's the difference?" By David McKenzie *The Australian Cottongrower* Feb-Mar 2003

Other important soil constraints

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

Waterlogging: Water logging particularly following surface irrigation can impact significantly on cotton production. Denitrification, boll shed and reduced boll set are some of the impacts of water logging, resulting in yield loss. refer to Chapter 8 for more information on waterlogging.

Soil pH: Soil pH is a measure of the acidity, neutrality or alkalinity of the soil solution. It directly influences the availability of soil nutrients to the cotton plant. Most cracking clay soils are alkaline (pH 8.0 to 8.5) affecting the availability of many micronutrients. This should be considered when calculating fertiliser programs.

Soil mycorrhiza: Soil mycorrhiza (also referred to as AM), are beneficial soil-borne fungi that attach themselves to the



Alternative crop rotations can increase organic inputs.

growing roots of crops. They allow roots to scavenge more effectively for nutrients especially those nutrients which are immobile in the soil and have poor solubility such as P and Zn. Low AM levels are associated with long fallow disorder when cotton crops perform poorly particular in long fallow dryland cotton systems or following non mycorrhizal crops such as canola. Refer to Chapter 16.

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

- WATERpak
- NUTRIpak
- SOILpak

Soil organic matter and soil carbon

Soil organic matter is composed of dead and decomposing plant material, litter, soil biota (fungi, bacteria, earthworms etc) and decomposing animals and their waste material. It includes everything that is of biological origin; by definition, soil organic matter is rich in carbon.

Soil organic carbon can be divided into four fractions.

1. **Crop residue and particulate matter:** Organic materials which have started to quickly decompose.
2. **Microbial biomass:** Microscopic living organisms that decompose organic materials.
3. **Humus:** Organic material whose structure is unrecognisable from its original form. Changes its form slowly.
4. **Charcoal:** Stable organic material and relatively inactive and unlikely to undergo further decomposition.

Soil organic matter is normally quantified by measuring the soil organic carbon content of the soil. An assumption is made that organic matter contains ~60% carbon. Hence, a soil containing 1% carbon will have approximately 1.7% organic matter. The soil carbon content reflects both the organic and inorganic carbon sources. In alkaline soils, carbon is found in inorganic forms as CaCO₃ (limestone) and as CaMgCO₃ (dolomite)

but these carbon forms are normally excluded from soil carbon analyses.

Importance of soil organic matter

Soil organic matter plays an important role in all three aspects of soil fertility:

1. **Biological functions:** Supplies nutrients for plant growth and provides energy and nutrients for soil micro-organisms.
2. **Physical functions:** Stabilises soil structure and promotes soil aggregation, improves soil water storage and infiltration.
3. **Chemical functions:** Increases soil cation exchange capacity, buffers soil pH, reduces effects of salinity and sodicity.

Organic matter losses

Organic matter can be quickly depleted if soils are not managed carefully. Soil organic matter losses result from excessive cultivation, excessive nitrogen fertiliser application, wind and water erosion of top soil, crop stubble removal (silage, hay or burning), and high soil temperatures (bare fallow in summer).

Managing soil organic matter

Soil organic matter levels in many cotton fields have declined significantly since the fields were developed. Arresting the decline and rebuilding soil organic matter should be an important consideration to ensure soils remain fertile into the future. This means balancing the addition of organic materials with their decomposition, by either adding more organic matter (crop residues and other organic materials) and or reducing the loss of carbon from the soil.

Inputs of organic materials can be increased by:

- Retaining stubble;
- Growing cover crops and green manure crops;
- Alternative crop rotations;
- Adding composts;
- Animal manures; and,
- Bio-solids.

Losses can be reduced by changing management practices:

- Reduce tillage operations;
- Employ controlled traffic and use permanent bed systems; and,
- Stop burning or baling crop residues.

It may be difficult to achieve this balance in every cotton production system, due to soil type, environmental conditions and agronomic constraints.

Some of these practices may have conflicting impacts. For example, retaining crop stubble on the surface increases soil water infiltration and storage, reduces soil erosion and protects the soil. However, a significant amount of carbon is lost to the atmosphere as carbon dioxide (CO₂) as soil organic matter decomposes. In contrast, stubble



incorporation can increase organic carbon retention and may be combined with pupae busting operations. Cultivation can promote loss of soil water and expose the soil to erosion. Research has shown that a strategic, targeted tillage operation to incorporate stubble and control pupae, can help increase soil carbon.

Most of a crop's nutrient requirements are met from the recycling of soil organic matter and the nutrients released during the decomposition of this material. Inorganic fertilisers are required when the soil is unable to meet a crop's nutrient demand and are critical in optimising production. Manures and composts can be a very important source of organic matter for soils as well as a valuable supply of nutrients. However there is a time lag between the applications of these materials and when nutrients become available to the crop. The nutrients are slowly released to the soil and assist the supply of nutrients to the crop.

In irrigated cotton systems, research has shown that soil organic carbon levels can increase with changes to conventional cropping systems. By eliminating deep tillage operations, soil structure can be maintained and by incorporating stubble, soil health is promoted. Other management practises including reducing fallow periods and optimising water and nutrient applications can also play important roles.

Monitor to manage – nutrition efficiency

Application of fertilisers to meet crop demand is only a part of developing a crop nutrition plan. Consideration must be given to other very important factors such as crop rotations, fallows, stubble management, tillage practices, legumes, manures and composts, soil chemistry, salinity, sodicity and irrigation water. The development of a considered, balanced nutrient management plan for the crop will maximise yields, optimise nutrient use efficiencies, minimise nutrient losses and improve soil health and physical properties.

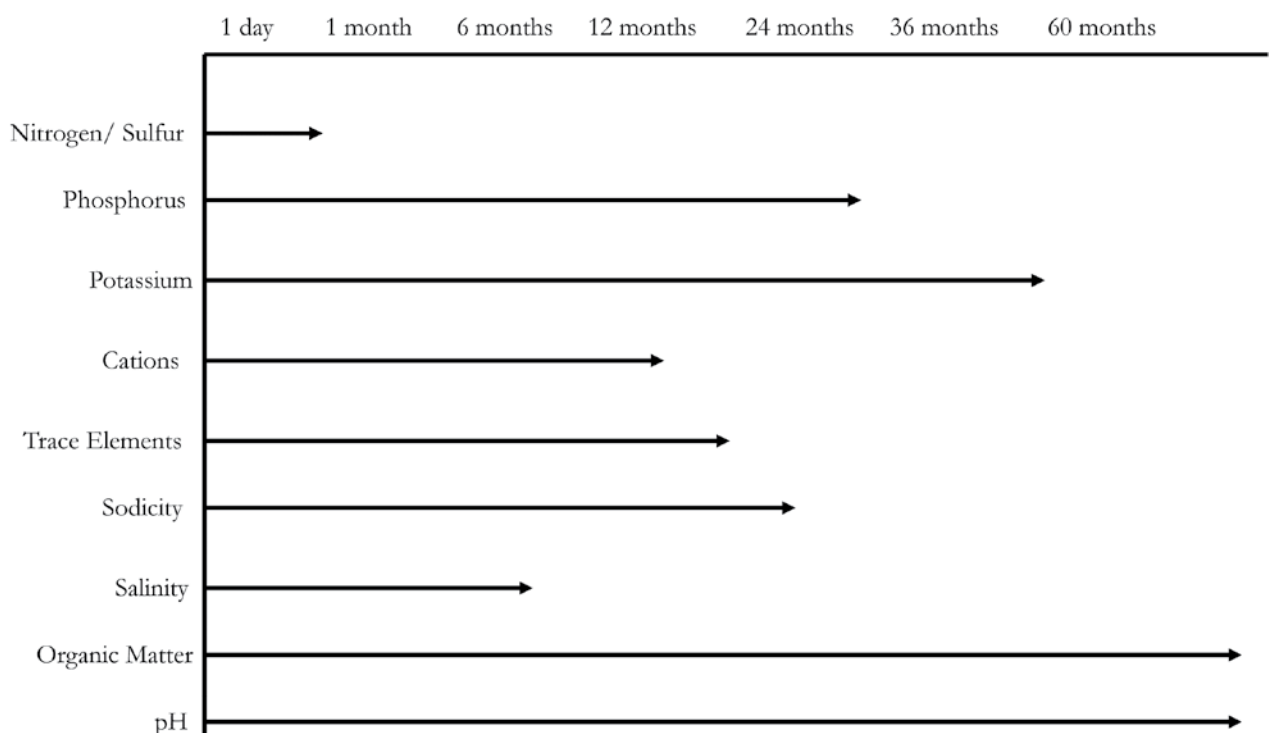
Most of the nutrients taken up by cotton from the soil are derived from the decomposition of previous crop residues, soil microorganisms and soil organic matter. Nutrients are continually being cycled between the crop and soil, as occurs in all biological systems. However, because of the high rates of nutrient removal in seed cotton (Table 1), our inherently fertile cotton-growing soils can become depleted in nutrients.

The removal of nutrients depletes soil fertility and fertiliser application may be needed to increase the supply of these nutrients to subsequent cotton crops. Hence, we can either replace these nutrients as they are removed or wait until each nutrient successively becomes limiting to cotton production, then commence a fertiliser program to overcome the nutrient deficiency. It is important that this program begins before nutrient supply limits crop production.

TIME TO DETECT SIGNIFICANT CHANGE IN SOIL PROPERTIES FROM TYPICAL FERTILISER APPLICATION

When developing a crop nutrition plan, consider how frequently should soil be tested for different nutrients.

Source: Healthy soils for sustainable Farms, Understanding Soil Testing short course. (Source: Cotton CRC Healthy Soils for Sustainable Farms, Understanding Soil Testing Short Course)



In developing a fertiliser program a grower needs to consider the following strategies and integrate them according to their own farm's needs:

- Determine soil nutrient status using pre-season soil testing.
- Calculate expected crop nutrient requirement taking into consideration expected yield, cropping history, cropping system and nutrient losses, crop use efficiencies, plant nutrient recovery and uptake, soil condition and characteristics – decision support programs such as NutriLOGIC can assist here.
- Develop a fertiliser use plan that minimises nutrient losses.
- Monitor crop through petiole (early season) and leaf analysis (flowering to defoliation) to determine if the crop has sufficient or inadequate nutrient levels.
- Develop a long term management program which maintains or improves soil health.

Determine soil nutrient status: soil sampling and analysis

A fundamental requirement in meeting the nutritional needs of a cotton crop is determining nutrient level in the soil before planting. By using soil analysis as a routine part of management, it can provide an indication of the fertility level in your soil at that point in time. Do-it-yourself soil sampling kits are commercially available through accredited laboratories or, service providers can be engaged to sample, analyse and provide recommendations for fertiliser application.

Soil sampling kits provide instructions on how and where to sample the soil in order to provide a representative sample. There are often differences in soils and soil types within any given field. To gain the most benefit from soil tests it is important to take these differences into account when sampling. Precision Ag technology such as EM surveys can assist to understand this variability. Crop performance throughout the season can also provide insight into areas worthy of investigation. Good records can allow for the monitoring of nutrient status over time. Follow sampling instructions carefully; accuracy of the results can be impaired if the samples are not taken and handled correctly.

Refer to the Precision Ag section of this book for more details on EM surveys.

When choosing a laboratory to conduct your testing, ensure that it is accredited to Australian Standards and registered by the Australian Association of Testing Authorities. Unfortunately laboratories express results differently so it is important that the tests being conducted are going to provide the information that is required and in a form that can be used.

Calculate expected crop nutrient requirement

Interpreting soil tests can be complicated and it is recommended to seek professional advice from service providers or use an interpretation program such as

NutriLOGIC to determine fertiliser requirements. NutriLOGIC is a user friendly decision aid for fertiliser management. It is a component of CottASSIST, a suite of web tools developed by CSIRO, Cotton CRC and CRDC to provide the cotton industry with access to the latest research.

NutriLOGIC provides an assessment of nutrient/fertiliser requirements, independent of fertiliser manufacturers and resellers.

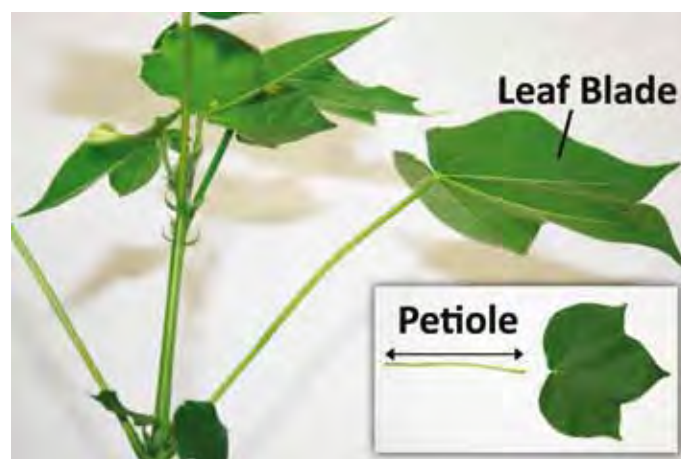
NutriLOGIC estimates the fertiliser required for a cotton crop based on years of field experiments conducted in Australian conditions, supported by industry funding. Inputs required are soil test data, the cotton growing region and the month the sample was taken. The program makes allowance for soil factors (texture, compaction and predisposition to water logging). Losses of N through denitrification and leaching during the crop-growing season are also built into the web tool.

Develop a fertiliser management plan

A fertiliser plan outlines how, when and in what form the fertiliser inputs that are required by cotton crops are managed. This requires working through a number of considerations, all of which depend on each other.

Which fertiliser to apply: There are different types or forms of fertiliser that can be used i.e. manures and composts, granular fertilisers, anhydrous ammonia (gas), liquid fertiliser or foliar fertiliser. The type of fertiliser may be limited by the capacity to apply it. Composts and manures need to be spread and incorporated, anhydrous ammonia (gas) needs to be applied using specialized equipment by trained staff, and foliar fertilisers need to be applied evenly and in a timely manner, i.e. in response to nutrient crop demand.

When to apply: The timing of fertiliser application is determined by the production system and the type of fertiliser being used. Composts and manures need to be spread and incorporated in advance of planting and when used in minimum tillage systems may need to be combined with other processes. Anhydrous ammonia (gas) fertiliser cannot be applied too close to planting.



Leaf and petiole testing can inform cotton nutrient status.
(Photo: Duncan Weir, Qld DAFF)



as seedling damage may occur from ammonia burn. When applying all the nutritional requirements “up front” there are reduced efficiencies and greater losses from the system to be considered. Split applications can improve efficiencies and the application rates can be adjusted to meet changing crop demands. Timing of split applications is critical, irrigation and rain can impact on the capability to apply fertilisers in a timely manner hence increasing the risk of crops being nutrient deficient at a critical time.

What rate to apply: The fertiliser rate will depend on the type of fertiliser being used and when it is being applied. The composition of the fertiliser (percentage of each nutrient in the fertiliser) will dictate just how much of the product needs to be applied to meet the crop requirement. If all the fertiliser is being applied up front, an adjustment must be made to take into consideration losses and inefficiencies. On the other hand, if a starter fertiliser is being used at planting with later in-crop applications, the rate of fertiliser must be adjusted. The rate is determined by soil analysis in the winter prior to planting the crop and can be modified by leaf and petiole analyses performed in-crop.

Where to apply it: Most fertilisers are best applied to the soil. This normally occurs pre-plant, at depth, off the plant line. Applying fertilisers too close to the plant line may cause seedling damage due to the salt or toxicity effect. Nitrogen, contained in fertilisers can be lost to the atmosphere through ammonia volatilisation and should be applied below the surface and buried. Other fertilisers e.g. P, K, Zn etc can be broadcast and then incorporated later to maximise contact between the roots and fertiliser. The amounts of nutrients that can be applied to the foliage is quite limited and the benefit short term. Foliar fertilisers can be used to help meet crop nutrient requirement when a nutrient has been identified and the quantity of nutrient required is small.

Fertiliser plans need to be flexible and have the capacity to be modified through the season if conditions change or if leaf and petiole analyses identify a problem and indicate a change to the nutritional requirement of the crop and subsequent fertiliser program.

Monitor the crop

Often, nutrient deficiencies are not identified until symptoms appear, by which time, some yield reduction will have occurred despite remedial fertiliser application. Plant analyses can provide information about the nutritional status of a crop and indicate nutrient deficiencies which, if identified early enough, may be rectified by applying the appropriate fertiliser with little or no impact on the crop.

Petiole analysis is ideal for monitoring nitrate-N and potassium concentrations up to flowering. For Australian cotton, petiole tests have been calibrated for nitrate and potassium but are not recommended for other nutrients. Three samplings approximately 10 days apart (600, 750 and 900 day degrees) are required to give a good

indication of the rate of change in the nitrogen and potassium in the petioles.

Leaf analysis can be used to monitor all nutrients including micronutrients. Sampling leaf tissue twice (at flowering and cut out) produces the most useful information.

Follow sampling direction carefully, results can only be as good as the sample provided. Tips for leaf blade and petiole sampling:

- Ensure samples are taken at a similar soil moisture and time of day and record stage of growth (day degrees).
- Do not sample when the crop is not stressed (eg. during water logging or cloudy weather).
- Sample at least 50 petioles or 50 leaf blades from the youngest mature leaf, normally 4th or 5th unfolded leaf from the top of the plant.
- Leaf blades must be immediately removed from the petiole
- Collect samples with clean, dry hands or clean gloves, as sweat and sunscreen can contaminate.
- Samples should be loosely packed in a paper bag and stored in a cool place (refrigerator) immediately and transported to laboratory as soon as possible.

NutriLOGIC can be used to assess both petiole analysis (early crop nutrient monitoring) and leaf analysis (flowering to defoliation crop nutrient monitoring).

Develop a long term management program which maintains or improves soil health.

Compaction, sodicity, poor soil structure, low fertility and salinity are just some of the critically important reasons to develop long term production programs and systems. Sodicity and salinity are naturally accruing constraints in many soils used for cotton production. They are covered in more detail in the Subsoil Constraints section below.

Reduced, minimal or zero tillage practices, crop rotations, cover crops, legumes, composts, stubble incorporation, manures and controlled traffic are just some of the management practices which can be introduced into a cropping system that can have beneficial impacts on soil health and soil fertility as well as reduce costs and improve productivity.

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

- NutriPAK
- SoilPAK
- Nutrients removed in harvested seed-cotton
- CottASSIST NutriLOGIC
- Cotton Symptoms Guide

Irrigation Efficiency

By LANCE PENDERGAST (Qld DAFF)

Plant response to water

Too little – water stress

Cotton has an indeterminate growth habit (that is, it is a perennial that keeps growing), and therefore, under favourable conditions, the number of leaves, new nodes, fruiting branches and squares can increase rapidly, unlimited by a phenological time frame, and continue to be produced while conditions remain favourable.

During the pre-flowering stages of growth, production of carbohydrates (through photosynthesis) exceeds demand, and as a result vigorous vegetative growth occurs. As plant growth continues, the demands for carbohydrates by the component plant parts such as bolls increase, and production becomes limited by environmental conditions. Boll growth exerts large demands for carbohydrates and it is through the balance between boll demand and leaf production that vegetative growth is restricted.

Water stress can restrict both vegetative and boll growth. It has been shown that no matter what degree of water stress is imposed on a crop, the proportionality between vegetative growth and boll development remains relatively constant. Similar results have been achieved with crops receiving different amounts of nitrogen. This

FIGURE 1.

The changing scale of water use by the cotton plant as it moves into each stage of growth

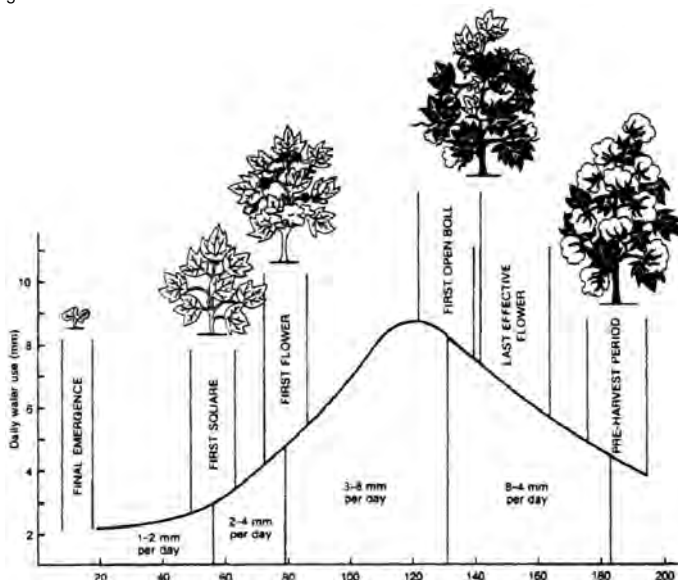


TABLE 1:

Yield loss (%) per day of water stress (extraction of >60% plant available water) (WATERpak Table 3.1.3)

Growth stage	Past conventional*	Bollgard#
Squaring	0.8	1.1
Peak flowering	1.6	1.7
Late flowering	1.4	2.7
Boll maturation	0.3	0.69 [^]

[^]14 d post cut out
Source: Yeates et al. 2010#; Hearn and Constable 1984*

implies that, independent of water or nutrient supply, the plant will always attempt to form a balance between vegetative growth and boll development.

Too much – water logging

The major and immediate effect of waterlogging is a reduction in the transfer of oxygen between the roots and the soil atmosphere. Plant roots may become so oxygen deficient that they cannot respire normally. As a consequence, root growth and absorption of nutrients is decreased leading to less overall plant growth. A reduction in node numbers leads to a reduction in the number of fruiting sites and consequently a reduction in the number of bolls produced.

Cotton is most susceptible to waterlogging during the early stages of flowering as this is when the plant is setting the fruit load that will dictate final yield. As the plant gets older there will still be effects there but they won't be as severe because the fruit is basically established on the plant.

Plants exposed to rainfall induced waterlogging may also suffer from the reduced sunlight availability associated with overcast conditions. Under these conditions the plant cannot fix enough carbon to maintain normal functions and may shed fruit as occurs under any other form of stress.

In addition to the immediate physiological impacts of waterlogging on the crop, there are also significant impacts on nutrient availability and uptake. Waterlogging increases the rate of denitrification and plant uptake of Nitrogen (N), Iron (Fe), Zinc (Zn) (reduced) and Manganese (Mn) (increased) are directly affected by a decline in soil oxygen. Irrigation strategies designed to avoid potential waterlogging events not only contribute towards improved yield and water use efficiencies but can also benefit crop nutrient efficiencies. Waterlogging also tends to decrease the plants ability to regulate sodium uptake and, although cotton is reasonably tolerant of salinity, exposure to increased concentrations does impinge on yield potential.

Optimized irrigation system designs allow delivery to the head-ditch, run-times and tailwater collection / return such that exposure to waterlogging and deep drainage are minimised.

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Monitor to manage – irrigation efficiency

Water is a production tool just like any other management input. Regardless of how growers manage their water or how much water is available the goal is to optimise water use efficiency (WUE). Improving water use efficiency involves a whole farm water management plan.

The first step is to have a water budget. Water budgets consist of components such as crop/plant requirements, and potential water sources. Budgeting requires knowledge of all water sources; fallow rainfall and fallow efficiency, reliable in-crop rainfall, irrigation allocation and reticulated water. Water losses, such as by deep drainage and leaching in-field and through evaporation and seepage from on-farm storages and channels, should also be considered.

In the planning process, decisions about cropping and what area to sow can be made seasonally, dependent on expected water availability. Tools such as CropWaterUse – a web based application is available to help growers calculate the theoretical daily and seasonal water use of a crop. (<http://cropwateruse.dpi.qld.gov.au>)

The overall production target must suit the type of irrigation system and the available water resource.

A successful philosophy to follow from the start is 'measure to manage'. The use of both water meters and soil moisture probes enables the fine tuning of management strategies that can lead to improved efficiencies. There is also benefit in monitoring crop response such as NAWF. Refer to Chapter 5.

Dryland growers can use HowWet?, a Windows based program which uses farm rainfall records to estimate how much plant available water has been stored in the soil and the amount of organic nitrogen that has been converted to an available form during a fallow (non-crop period). HowWet? tracks daily evaporation, runoff and soil moisture using estimates of weather conditions and rainfall input by the user. Accumulation of available nitrogen in the soil is calculated based on soil moisture, temperature, soil type and age of cultivation.

<http://www.apsru.gov.au/apsru/Products/HowWet/how%20wet.htm>

BEST PRACTICE

- Monitoring the conditions, the plant, and soil moisture will help in scheduling irrigations to meet crop demands and avoid plant stress.

Pre irrigation

The decision for the cotton grower to pre-irrigate or water up the crop is, like so many others, a decision that has to be made specifically to suit a particular farm. In certain situations it can be beneficial to combine the two options: pre-irrigate to plant into moisture and give the crop a quick watering to ensure good plant stands (WATERpak page 91).

Every farm is different and a range of questions need to be considered before making a decision e.g. is it likely to rain before/during/after planting?, what are the implications associated with the different tactics in relation to seedling disease and weed control, am I set up for dry or moisture planting?

Scheduling in-crop irrigations

Irrigation scheduling is the decision of when and how much water to apply to an irrigated crop to maximise crop productivity. Good scheduling should provide plants with water that is within a desired range and should limit over or under irrigation so that balanced growth is achieved. For Bollgard II varieties insufficient available water prior to and during flowering will reduce plant size and lead to early cut-out while too much water can lead to rank growth or waterlogging.

The first irrigation plays an important role in setting up for plant growth, fruit retention, fibre quality and boll weight. Its timing is perhaps the most difficult irrigation scheduling decision as it is a balancing act between not stressing the plant while stored water is fully explored by the developing root system.

The demands of high fruit retentions afforded by Bollgard II cotton, in conjunction with tight water scenarios which growers and consultants have been faced with for the past few seasons, has seen the timing of first irrigation become a key management issue.

Irrigating too early can increase potential for exposure to waterlogging. Irrigating too late will incur yield penalties due to the impact of stress on plant development. Like many crops cotton has stages of development at which it is particularly sensitive to stress. Irrigation scheduling should strive to avoid exposure to stress during flowering and early boll filling stages. Research by Steve Yeates and Dirk Richards, CSIRO, in both BollgardII® and conventional cotton, has shown similar losses in yield attributed to being late on the first irrigation. Delaying the 1st irrigation will place the plant under stress which will impact on the performance of the crop. Results have shown a dramatic reduction in yield (up to 23%) due to stress in the lead up to flowering. Recent research by Marcelo Paytas and Steve Yeates has shown for BollgardII crops that when conditions are hot and dry irrigation up to 2 weeks prior to flowering on clay soils will increase yield provided there is no water stress after flowering.

It is important to tailor your irrigations to meet the needs of high retention crops to optimise yield and water use



efficiency. High boll load early in flowering can lead to premature cut-out and lower yields.

Subsequent irrigation scheduling

One of the most important things besides monitoring your soil moisture is monitoring crop development. Keep a check on squaring nodes, first position retention and NAWF. Use the CottASSIST Crop Development Tool to help keep track of how the crop is progressing.

Research by Yeates has shown that low deficit scheduling or frequent watering eg 40 to 50mm deficit or 6 to 7 day intervals (Wee Waa clays) increased Bollgard II yield by 17% and WUE by 8% when conditions were hot and dry during flowering. Trials showed where mild growing conditions were experienced, generally associated with higher in-crop rainfall and less evaporative demand, scheduling irrigations to a greater deficit maximised yield and WUE, by allowing the opportunity to capture more in-crop rainfall rather than irrigating at a 40mm deficit. Irrigation scheduling based on small deficits requires skill and a system that can apply water quickly. Otherwise application efficiencies will be lower and the crop waterlogged.

When irrigation water is limited, save water for the flowering period. Bollgard II crops with high fruit retention are most susceptible to water stress late in flowering and at Cut-out. Yeates and Richards have measured a yield decline of 2.7% per day of stress compared with 1.2% per day for conventional cotton at this stage of growth.

Scheduling: Final irrigation

Ideally the last irrigation will provide sufficient water to optimise final yield and fibre quality, adequate soil moisture to facilitate efficient take-up and function of applied defoliant, and a soil profile that is sufficiently dry enough to enable harvest without causing soil compaction.

End of season water requirements can be estimated from the date of the last effective flower (“cut-out”). Although location specific it takes about 50 days from cut out to maturity. Given reduced daily water use late in growth and a full profile, a crop should be able to rely on stored soil water for up to 30 days, on most clay soils depending on the rate of evapotranspiration experienced. Hence irrigation water is required for the first 20-25 days after last effective flower – possibly two irrigations would be required during this time. The last harvestable bolls take 600 to 650 day degrees to reach maturity. Crop water use during this period will vary, at the time of first open boll, water use may be 5–7 mm/day, and may decline to around 3–4 mm/day prior to defoliation.

There are a number of methods available to accurately time final irrigation and defoliation: Measuring Nodes Above (last) Cracked Boll (NACB), is most commonly used, (refer to FibrePAK). On average, bolls will sequentially open at a rate a node every three days. This will depend on a number of factors, particularly climatic conditions.

The prime objection of the last irrigation is to ensure that boll maturity is completed without water stress, (WATERpak pg 93). Once a boll is 10–14 days old, the abscission layer responsible for boll-shed cannot form. Consequently late water stress (beyond cut out) does not significantly reduce boll numbers and therefore yield. However, fibre quality can be more seriously affected by late water stress. Crops that come under stress prior to defoliation (60% bolls open or 4 boll carrying NACB), can suffer some fibre quality reduction, especially micronaire. The degree of reduction obviously increases the earlier the stress occurs.

Scheduling: With limited water

More recently, in the face of reduced water allocations that preclude normal (full) irrigation practises, irrigators have also employed skip row strategies into their production systems. (CSD, 2009). As with dryland production, the number and timing of irrigations in skip row planted cotton will vary with location, soil type, previous history, and weather conditions, with the interval between irrigations increased with skip row plantings. Ideally the irrigation deficit used should be the same as for normal planting configuration. See Furrow irrigation considerations and configurations.

The author would like to acknowledge that this article relies extensively on original contributions to WATERpak by Nilantha Hulugalle, Michael Bange, Steve Yeates, Dirk Richards, Guy Roth, Dallas Gibb and Stefan Henggeler

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

- WATERpak
- FIBREpak
- CottASSIST Crop Development Tool



(Photo: Cotton Australia: Karen Sullivan)

Monitor to manage – whole farm water balance

By **JIM PURCELL** (Aquatech Consulting)

A successful and profitable irrigation enterprise is one that manages precious water at both the crop root zone level (soil moisture monitoring and irrigation scheduling) and at the whole farm level (how much water do I have? what are my losses? and therefore how much do I have left for crop production?).

This section discusses the whole farm water management area. The tools for whole farm water balance have progressed greatly in the last 10 years. The use of commercial tools and water management consulting services has steadily grown as irrigators strive to improve their profitability with less water.

Below is a step by step process to better manage water at the whole farm level. In summary:

Phase 1

- Measure and record the basics.
- Complete a simple seasonal whole farm water balance
- Review the results.
- Fix the easy stuff.
- Repeat until happy.

Phase 2

- Stop at Phase 1 if you are happy with your WUE or move to daily water balance. Daily water balance allows prediction forward of water requirements before and during the season.

Phase 1 – Seasonal whole farm water balance

Step 1 – Measurement

Measurement is essential for any good management and water management is no different. To achieve good measurement start with the following:

- Ensure all water meters are installed correctly and measuring accurately. Check them with another meter.
- Survey all storages to establish accurate depth to volume to surface area characteristics. Ensure all tailwater and buffer storages are included. Storage surveys can now be done with water in the storages!
- Fit storage meters in all storages. Gauge Boards are a start but don't really do enough. It is very difficult to measure the volume of a stormwater harvesting event with gauge boards unless the gauge boards are read just before and just after each event and recorded. Irrimate™ Storage Meters have been developed over the last 5-6 years. They read and log water level, storage volume and water surface area at any required interval (normally 30 minutes but can be changed). This not only allows water volume to be accurately monitored in real time but also provides flow rates

into or out of the storage. A storage meter also records the water surface area which allows the calculation of water volume loss from seepage and evaporation. Telemetry is now optional with information available by internet (read your storage volume, depth and surface area with your mobile phone or laptop while on a holiday overseas!).

- Take strategic measurements of soil seepage characteristics and storage and channel evaporation characteristics. This allows calculation of the seepage and evaporation losses in each storage, channel and drain. Irrimate™ Seepage and Evaporation Meters can be hired from Aquatech Consulting or any Irrimate™ Agent. These meters measure both seepage and evaporation characteristics. It is not necessary to measure every storage or every channel and drain to get meaningful results. Default values are available without measurement as a start.

Step 2 – Record keeping

The next step is basic record keeping. The aim is to record enough basic information to calculate how much water the crop actually needed during the particular season and how much water was made available to grow that crop.

In simple terms, the total measured available water, less the calculated actual crop water requirements for the season, equals the water lost to production. It should always be remembered that it is impossible to produce an irrigated crop without some losses. The real question is “How much water did I lose and how much could I save and use to increase production and profit?”

To establish this, it is necessary to be able to split up the total water lost to production into components:

- Storages losses (wet-up, seepage and evaporation).
- Channel system losses.
- Drainage system losses.
- In-field losses.
- Operational losses (stuff-ups resulting in water lost out of the system).

The records needed for a seasonal whole farm water balance include:

- Meter readings from all inflows – (river, scheme channel and/or bores).
- Storage volumes at the start of the season.
- Storage volumes at the end of the season.
- Harvested water volumes (land surface diversions) measured using the Irrimate™ storage meters or similar.
- Rainfall on fields.
- Field number or name and area.
- Crop yield.
- Reference Evapotranspiration for each day during season based on weather data (automatically provided in WaterTrack™).
- Field soil type (menus provided).



- Field soil moisture deficits (mm) at the start of the season and end of season (estimated or from soil probes if available).
- Crop emergence date and end date (when crop stops transpiring e.g. cotton defoliation).
- Dates of each field irrigation.

Step 3 – Seasonal water balance

The whole point of completing a whole farm water balance is to find out where water is being lost, whether those losses are ok and what is required to reduce the losses and increase production.

The Seepage and Evaporation Assessment with an Irrimate™ Meter allows the calculation of soil seepage losses from storages, channels and drains. Similarly, the measured evaporation characteristics from the same measurement allow calculation of evaporation from storages, channels and drains. If a farm has two different soil types, then it “may” be necessary to complete a second Seepage and Evaporation Assessment in each soil type.

Calculation of actual crop water requirements is based on daily Reference Evapotranspiration (Eto) values for particular farm and season and crop factors. Eto can be sourced from a weather station on the farm or normally from the Bureau of Meteorology SILO database. If WaterTrack™ is used for the whole farm water balance, the program automatically obtains and updates daily Eto from the Bureau of Meteorology. All that is required is to provide the farm Latitude and Longitude from Google Earth.

Step 4 – Review the results

All irrigation farms will lose water; it is inevitable. The question is “Where are the losses and are they OK?”

WaterTrack Divider™ will complete a simple seasonal water balance and provide Water Use Efficiency Indices required for *myBMP* and Water Management Plans.

Irrigation consultants can advise whether the losses are typical, good or bad and can advise on the type of works and cost to reduce losses. WaterTrack Divider™ even provides a basic economic calculator. This can determine if the proposed capital works are economic and how long the pay back period is from the extra production.

There is a network of commercial consultants from Emerald, Queensland to Keith in South Australia who can provide the equipment, software and consulting support to their clients in Water Management. Experience is showing significant increases in farm profit from increased water use efficiency.

Step 5 – Repeat seasonal water balance next season and so on, until happy with reduced losses and water use efficiency performance

For more detailed accuracy and predictions undertake Phase 2.

Phase 2 – Daily whole farm water balance

Step 6 – Comprehensive daily whole farm water balance

Rather than waiting until the end of the season to check how water management went, it is also possible to set up the daily water balance model, WaterTrack Optimiser™.

WaterTrack Optimiser™ models each element of an irrigation farm in sections and in individual fields daily. The computer model replicates each action taken by the irrigator in their daily routine and calculates the losses in each segment of channel and drain, each storage and each field daily.

The results are much more comprehensive than those achieved by completing a seasonal water balance but more effort is required with data collection and data entry. Essentially, every action done with water on the farm is also done on the computer.

The value of the extra effort is the ability to manage water at each irrigation and make changes then rather than waiting until next season. WaterTrack Optimiser™ also allows forward prediction at any time to check whether there is enough water available (including losses) to completely irrigate those fields in production.

Typically, prediction is done:

- Before planting.
- Mid November or early December to decide which fields shall remain irrigated.
- As many times as required in February to determine which fields shall be finished.

The effort required to complete this modelling can result in very significant profit increases by maximising the yield potential of the remaining water. Most irrigators use commercial consultants to complete this modelling. The consultant is then able to work with the irrigator on alternative strategies.

Further information on whole farm water balance can be found at www.myBMP.com.au

For more information reference waterpak contact: Aquatech Consulting 02 6792 1265 (www.aquatechconsulting.com.au, www.irrimate.com.au or www.watertrack.com.au)

Furrow irrigation considerations and configurations

By **LANCE PENDERGAST** (Qld DAFF) & **CSD EXTENSION TEAM**

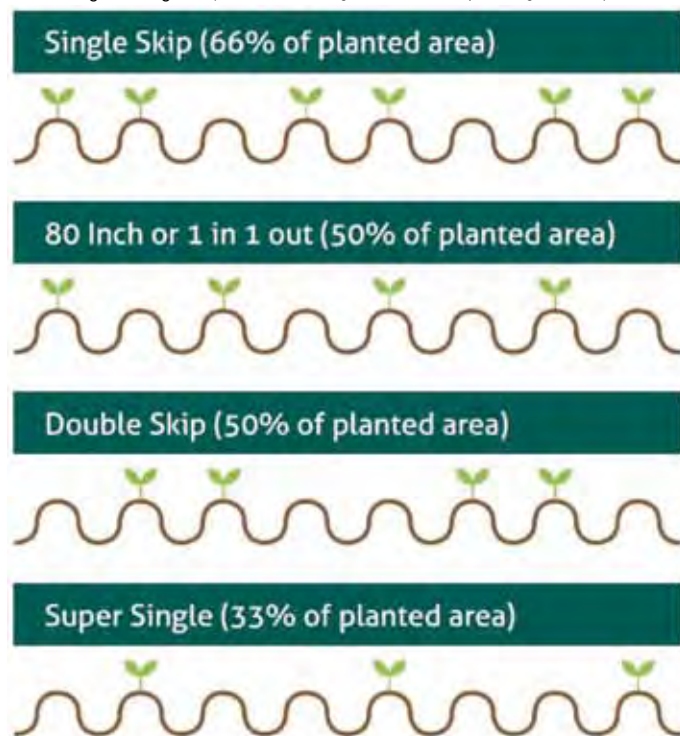
Acknowledgements: **Michael Bange (CSIRO)** and **Dave Kelly (Macpherson Agricultural Consultants)**

Furrow considerations

Furrow irrigation remains the dominant irrigation method in Australia. Typically about 60–70% of the water that reaches the field is used by the crop, and the remainder is recycled as runoff or lost to deep drainage. Over recent years some operators have made considerable improvements in the efficiency of furrow irrigation in response to the increasing demand for limited water supplies. Significant improvements in

FIGURE 1:

Row configuration guide (Source: CSD Getting the most out of skip row irrigated cotton)



BEST PRACTICE

- Measuring field efficiencies will enable informed decisions about management options to improve irrigation efficiencies.
- Wider row spacing configurations can be used to manage risk in dryland and semi-irrigated situations but will limit yield potential. Carefully assess the benefits of reduced costs and improved fibre quality to determine best fit for your system.

water use efficiencies have been achieved through furrow optimisation evaluations using advance meters, siphon meters and SIRMOD.

Optimal furrow irrigation performance requires understanding of application efficiency (amount of water applied in irrigation that is available to the crop for use) and distribution uniformity (how evenly infiltration occurs across the over the field) and the methods for improving both. Adequate management and maintenance of all components between the head ditch and the tail drain is important for furrow irrigation systems. Improving furrow irrigation performance involves careful management of flow rates and irrigation duration and appropriate timing (scheduling) of irrigation events. Refer to monitor to manage irrigation efficiency.

A number of modifications can be made to improve furrow irrigation performance. Design changes include modifying furrow slope and geometry, although these parameters have very little effect on irrigation performance. Changing field length has a larger impact on performance, but typically the most significant improvements are possible through management changes. Increasing or decreasing compaction in furrows will modify the infiltration characteristic (for example, wheel tracks) and can improve efficiencies. The most common changes to improve furrow irrigation system performance are an increase in flow rate and corresponding decrease in irrigation duration. It is vital that measurements are taken before implementing changes so that current performance can be identified and appropriate changes can be implemented. For more information see WaterPak 4.2.

Semi irrigated – Row configurations

There are a range of different configurations being used by growers across the cotton industry in semi-irrigated situations. These include single skip, 1.5m and 2m (60 and 80 inch), double skip, super single and some non-uniform configurations. The positive and negative features of each configuration, including the relative water use efficiencies, depends on the individual situation. What works best in one farming system may not in another due to differences in soil type, environment, cropping history, available equipment, water availability and other factors.

Growers contemplating:

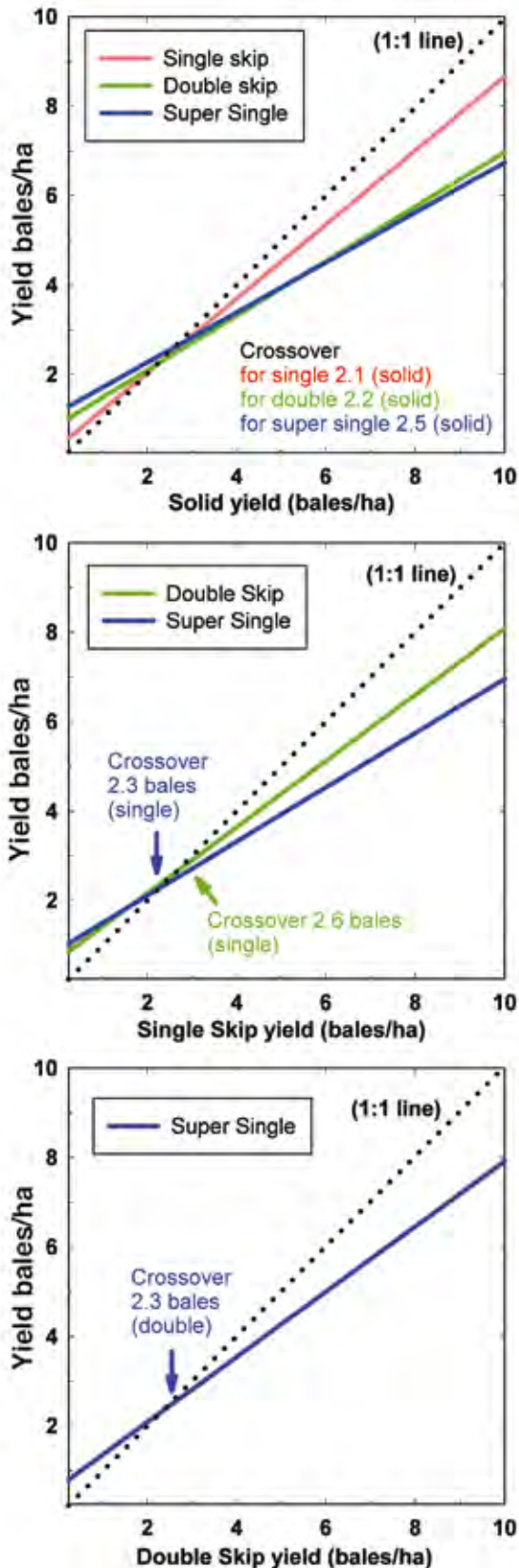
- Whether they would benefit from using skip row configurations; and,
- Which skip row configuration they would use ...should consider the following points.

The yield/cost/fibre quality mix of each configuration

Extensive research has shown that while skip row cotton does limit yield potential (Figure 2), the combination of reduced fibre length discounts and variable cost savings in growing skip row cotton often lead to a better risk/return proposition.

FIGURE 2:

Comparison of average yields of various combinations of row configurations. Responses are generated from controlled comparisons undertaken over many seasons. Crossover refers to the average yield potential at which there is no further improvement in the yield of a particular configuration compared to the configuration stated on the bottom of each graph. For example in the middle graph, when comparing double skip to single skip, the average yield potential at which single skip outperforms double skip is 2.6 bales/ha. Compiled by M. Bange (CSIRO 2012).



Semi-irrigated single skip (3 irrigations) left and solid plant (fully irrigated) on the right. (Photo: CSIRO)

To use these graphs, growers need to consider their yield potential, based on all the factors discussed later in this chapter.

Single Skip has the lowest risk of losing yield when conditions are favourable. It will however also use its moisture profile the quickest. Having a plant row 50cm one side and a one metre skip row to the other, this configuration will enjoy some benefits of ‘partial root zone drying.’ It is best suited to situations on heavier soil types with high PAWC and more irrigation water availability.

While **one-in-one-out (1.5m or 2m)** cotton has not been included in these comparisons, grower experience and some trial work has shown its yield potential to be similar to or slightly higher than double skip but possibly more prone to fibre quality discounts because it does not have the advantage of mild early stress. Detailed research is currently being undertaken to investigate this issue. A more uniform growth habit in one-in-one-out cotton can reduce lodging; allow better spray penetration and defoliation processes when compared to double skip.

Double Skip provides more insurance against lower yields when compared to single skip especially when conditions are less favourable. Having a plant row 50cm one side and a 1.5m skip row to the other, this configuration provides the benefits of ‘partial root zone drying’ which toughens the plant up. Plants can be prone to lodging, especially vegetative branch fruit which takes advantage of the extra light available in the skip area. It is best suited to drier profiles and hotter environments.

Some growers have tried **Super Single** (one-in-two-out) in semi-irrigated situations. The widely spaced plant rows 3 metres apart means the yield potential and potential upside in a good season is severely limited. However, this configuration may be an option with a full soil moisture profile at planting and minimal irrigation water resources where there is a high chance of severe water limitations during flowering and boll fill. This configuration allows growers to minimise growing costs as well as limit the likelihood of fibre quality discounts.

Non uniform configurations have been tried in some circumstances but can lead to variability in maturity, and subsequent difficulties in management.

Skip row configurations function by increasing the volume of soil that plants have to explore thereby providing a bigger reservoir of available moisture and thus allowing the plants to hold on for longer during dry periods.

Skip row cotton provides an 'in between' option for increasing the area of cotton which can be grown, allowing some upside in production if conditions improve and far less downside in potential fibre quality discounts if the season deteriorates.

In some cases, inherent growing characteristics such as soil type and location may mean there is minimal advantage in adopting skip row practices.

Planting row configuration effects on cotton gross margin

The vigorous tap root of the cotton plant allows for wider exploration of the soil profile for moisture and nutrients, particularly when compared with fibrous root type crops. This characteristic has led to the use of wide row configurations that increase the total amount of soil moisture available to the plants. This extends the time before in-crop rainfall is required and therefore makes the crop less reliant on in-crop rainfall particularly in the first 2-3 months of its life. Narrower row configurations such as single skip are more popular in higher rainfall areas while the wider row configurations such as super single are used in the lower rainfall western areas.

The wide row spacings provide greater surety in yield and maintenance of base grade fibre quality. There is a strong relationship between row configuration and fibre quality, especially for fibre length. In row configuration trials, fibre quality improved with wider row configurations. Therefore the row configuration chosen in combination with the seasonal conditions experienced will have an influence on the likelihood of quality discounts being incurred on delivery of the cotton.

Savings in variable costs of inputs such as planting seed, insecticides, defoliant and the picking operation are likely with wider row configurations. Taking this into account, a lower yielding wider row configuration crop can at times give a better gross margin than a higher yielding crop on a closer configuration. In many ways growing skip row cotton really emphasises that gross margin is not just a function of the yield produced, but very much a combination of yield and costs associated with the row configuration chosen.

How does the planting row configuration affect variable costs?

Cotton has a couple of big ticket items which make up the majority of the growing costs, these being picking and technology licencing fees. In wide row configurations, efficiencies in picking can be made through not trafficking every pass, with some contractors altering machinery or charging on a green hectare basis.

The biotechnology licence fee can either be based on a green hectare rate, or end point royalty scheme where the licence fee paid is related to the yield achieved. This not only works as a risk management tool but also in wider planting row configuration where the green hectare rate and yield potential is lower, it is also a cost management tool because the grower pays less.

For more information on using wider row configurations in irrigated cotton, see the publication 'Getting the most out of skip row irrigated cotton', available from Cotton Seed Distributors.

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

• WATERpak

Alternative Irrigation Systems

By **LANCE PENDERGAST** (Qld DAFF)

Over the bank siphons / furrow irrigation is, and will remain in the foreseeable future, the dominant mode of irrigation used by the Australian cotton industry. As a result of extensive efforts the industry has achieved significant improvements in the performance of siphon / furrow irrigation. When optimised under appropriate conditions this method can produce high levels of performance. There are however a range of factors inherent in siphon irrigation that have driven efforts to develop alternative options. Competition for labour and water resources, and increased yields, are principal drivers. Increased automation, the ability to deliver precise amounts to meet crop demand in a timely

BEST PRACTICE

- Evaluate full potential performance of existing system (e.g. furrow) when considering change to alternative system (e.g. to overhead, drip etc).
- When assessing the viability of an alternative investments the following need to be considered: Yield & prices risk, the extent of water savings and risk of water availability, likely impact of changing energy costs, and availability of labour. Note that pipes through the bank system still subject to issues associated with furrow irrigation e.g. relationship between run- time, flow rate, field length and their impact on distribution uniformity etc Design to meet site specific conditions. Identify site specific constraints of existing infrastructure and design accordingly (see pipe through bank case study)
- Cost of professional advice is invariably returned manifold
- Successful operation requires ability to change mindset from furrow irrigation techniques. Full potential of systems such as overhead and drip are achieved via ability for greater control (which requires more refined scheduling)
- Inquiries to cotton D & D team will assist access to growing body of knowledge regarding optimising system / crop performance.



manner, and energy efficiencies underlie most ongoing efforts to develop alternatives.

Centre Pivots/Lateral Moves (CPLM)

Centre pivot and lateral moves (CPLMs), have been around since the 1950s. Early experiences with CPLMs were often poor.

Typically early Australian system designs were incapable of delivering the application rates required by cotton growing under Australia conditions, a problem exacerbated by the relative lack of knowledge regarding peak crop water use. They operated at high pressure using overhead knocker sprinklers and were prone to poor hydraulic design. Operating costs were high, water use efficiencies low and a great deal of time was spent just keeping the systems going.

Much has changed since those early days. Pressure on water availability and environmental sustainability, as well as economic and political factors, have contributed to increasing attention to the viability of CPLMs.

Design and operating protocols have come a long way in the past decade. Systems capable of operating efficiently over a wide range of soil types and environmental conditions now efficiently irrigate an increasing area of cotton.

Before replacing a current surface irrigation system with a CPLM system you should assess the performance of the existing system. This will ascertain potential improvements before considering the alternative irrigation systems. Optimisation of an existing furrow system could significantly reduce potential gains expected from investment in an alternative system.

It is not possible to make a 'rule-of-thumb' statement that the investment in CPLMs is or is not profitable – every farm business differs and so do the water savings and yield benefits for the many crops that can be grown with these machines.

- A 'with' and 'without' scenario analysis approach with support from a suitably qualified agri-business financial advisor is a robust method to assess the economic and financial performance of investment in CPLMs. This approach involves the following steps.
- Prepare a steady state profit analysis at the whole farm scale for the current farming system (the 'without' scenario) and the one with the CPLM investment (the 'with' scenario).
- Undertake a financial analysis over the life of the investment for the 'with' and 'without' scenarios.
- Complete an economic analysis to calculate and compare the Internal Rate of Return and the Net Present Values for the 'with' and 'without' scenarios.
- Perform a marginal analysis to calculate the marginal return and payback period for the CPLM investment.

Growers considering purchasing CPLMs should look, listen and learn from those with experience with these machines. One of the most consistent messages is the importance of obtaining a 'site specific' system

design – CPLM designs must be tailored to match the environment (e.g. soil characteristics) in which it will be operating. Field by field considerations often result in system design varying considerably between machines operating in close proximity to each other.

A well designed CPLM should:

- Maximize the amount of water placed into the crop root zone from water pumped;
- Distribute the water uniformly across the field;
- Be capable of meeting peak crop water use; and,
- Have minimal energy and labour inputs.

Fortunately the industry has matured since its early days when disappointment could often be traced back to inappropriate designs sold and built by overly 'optimistic' providers. Growers can now access providers with a proven track record of delivering machines that perform as promised. A range of tools has been developed to assist grower's initial decision making process, to verify system performance, and to plan ongoing machine operation.

While irrigation efficiency for CPLM is often higher (85–90%) than for furrow (about 75–85%), there is still the potential for losses due to evaporation and increased foliar diseases. Improved designs of both machines and sprinklers, and innovations such as the use of low energy precision applications have led to some operations increasing water use efficiency to exceed 90% (with associated improvements in application uniformity). Successful operation of CPLM requires a different mindset to furrow irrigation. Existing equipment can be audited to help improve this understanding and identify opportunities for modifications that can improve uniformity of application.

Useful resources:

The cotton industry publication **WATERpak** provides a useful discussion of alternative irrigation systems, including CPLMs.

A comprehensive CPLM training package, developed and delivered by the National Centre for Engineering in Agriculture (NCEA) with funding from CRCDC and the CRC-IF.

A Centre Pivot and Lateral Move one day workshop available through Growcom.

OVERSched – an on-line CPLM management tool for visualising soil moisture deficits and irrigation scheduling options.

Subsurface Drip Irrigation (SDI)

SDI is an alternative irrigation system for improving water use efficiency. SDI is the application of water below the soil surface through emitters with a discharge equivalent to crop water requirements – to meet the crop evapo-transpiration demand. It is a low pressure, low volume irrigation system that uses buried drip tubes. SDI tape is laid permanently and has been documented lasting for 10-15 years. Recent developments in SDI technologies and materials have increased system affordability and reliability with systems now capable of achieving irrigation efficiencies as high as 90-100%.

Capital investment and labour costs are, therefore, low compared to surface drip where tape needs to be placed,

TABLE 1:

Impact of drip irrigation on Water Use Efficiency Indices (bales/ML) on three Darling Downs drip irrigation demonstration sites.

	Gross Production Water Use Index (GPWUI)		Irrigation Water Use Index (IWUI)	
	Furrow	Drip	Furrow	Drip
Site 1 (1m drip)	0.84	1.11	1.58	2.60
(2m drip)	0.84	1.04	1.58	2.41
Site 2 (solid)	1.22	1.30	2.20	2.80
(skip)	1.32	1.50	2.19	2.66
Site 3 (60')	1.13	1.82	1.66	2.69
(skip)	0.92	1.15	2.24	3.17

removed and then replaced after each crop. It has a number of potential benefits over furrow irrigation:

- Water savings, control of runoff and deep drainage, increased rainfall capture, and reduced soil surface evaporation.
- Reduced incidence of disease and weeds.
- Enhanced fertiliser efficiency.
- Reduced labor demands.
- Field operations possible even when the irrigation is turned on.

As was the case with CPLM historically SDI irrigated cotton systems provided disappointing results. Their failure to produce the anticipated improvements in yield and water use efficiencies (which had been critical components in the initial decision to outlay the considerable required installation capital) may be attributed to a range of factors. Again, as with early CPLM installations, poor design or adherence to design at installation, and insufficient operator expertise, so often associated with application of any new technology, did little to produce expected outcomes. Just as a high performance engine behaves atrociously when out of tune, SDI systems perform poorly if not operated correctly, even if their design is excellent.

Trials conducted by the Cotton Catchments Communities CRC, in collaboration with a tape manufacturer and three irrigators on three sites, (see Table 1) showed a range of yield impacts of drip irrigation on cotton. The average yield decreased with the use of drip at one site (although here drip out-yielded furrow irrigated cotton in the first year of installation), and increased at the second (a 10% yield increase on average over furrow irrigation with 1m drip) and third sites (where yield increases ranging from 20 to 34% for drip over furrow irrigation were recorded). The average reduction in applied irrigation for drip irrigation over furrow irrigation ranged from 15 to 31% across the three demonstration sites.

The impacts of the yield increases and reduction in water use, as captured in the Water Use Efficiency Indices (IWUI– bales/ML), showed significant improvements in water use efficiency from the investment in drip irrigation. However, for an increase in profitability from the installation of drip the water savings must be

significant enough to enable an expansion in cotton area and an increase in yield sufficient to increase profits over the existing furrow irrigation system.

It is also important that there is reliability in water supply from year to year to justify the significant capital investment. It is critical that best management practices in design, installation, management and maintenance of drip irrigation systems are followed – if not, then profitable investment in these systems is unattainable.

Useful resources:

CRDC funded, NCEA produced publication: Alternative Irrigation Systems for the Australian Cotton Industry by Raine, Foley and Henkel remains a very informative reference for both SDI and CPLM. Ask your local cotton or water use efficiency extension officer for access to a copy.

More Profit Per Drop (<http://moreprofitperdrop.wordpress.com>) website has a range of articles discussing SDI.

Articles discussing SDI can also be accessed at <http://www.cottonandgrains.irrigationfutures.org.au> including WATERpak provides a useful discussion of alternative irrigation systems, including SDI.

Bankless Irrigation Systems

By **LANCE PENDERGAST & NIKKI PILCHER**

Bankless channel systems are designed to remove the need for siphons, with the field split into bays. The field is designed to be watered at a high flow rate with all furrows in a bay irrigated at once.

There are several types of bankless channel systems in use in Queensland and NSW. The original bankless channel system is the 'roof-top' system. In the roof-top system the bay is graded from both ends on a reverse slope forming a peak in the centre of each bay. Innovations in design are being made with this design with the most recent version in the St George area eliminating the roof top configuration.

Bankless irrigation systems are being used by broad acre irrigators seeking to improve farm efficiencies. The main motivation is the labour savings that can be made with such a system.

Pros

- Reduced labour requirements through removal of siphons.
- Improved machinery efficiency – no need for traditional management operations such as rotobuckling and drive through ditches for spraying and harvesting operations.
- Ability to better manage crop water use in response to hot, dry weather and pending rainfall events.
- Limited maintenance – tail drains are graded every 2–3 years but no need to do head ditches.

Cons

- Not suitable for paddocks with varying soil types.
- Current efficiency and uniformity evaluation methods not suitable to assess bankless systems.
- Need suitable slopes.



- Installation costs – suited to properties in the developmental phase as opposed to converting old siphon fields to bankless systems.

For more information contact Lance Pendergast,
E: lance.pendergast@daff.qld.gov.au Mob: 0448 601 842.

Pipes Through The Bank

Efforts over the last decade to optimise the efficiency of siphon irrigation have resulted in significant improvements. In some situations fully optimized siphon irrigation systems now achieve performance levels (e.g. distribution uniformity, application efficiency and requirement efficiency) approaching those more typically associated with overhead and drip systems. There remain however a range of factors fueling considerable interest in options that provide alternatives to the traditional methodology of siphon irrigation. Innovative implementation conducted over the last five years by one grower and his consultant in the St George area has produced very encouraging results with the pipe through the bank system.

Although the potential for water savings were originally regarded as the main goal it is now recognized that labour savings was in fact the principal motivator. Labour savings of 50%, increased yields and a 25% water saving achieved by this grower attest to the potential of pipes through the bank systems as a viable alternative option to some fields currently irrigated via traditional over the bank siphons. These results have been attributed to the ability to adjust the inflow rate which, when used



Cotton being irrigated with pipe through the bank system.

FIGURE 1:
Cross-section view of PTB irrigation system

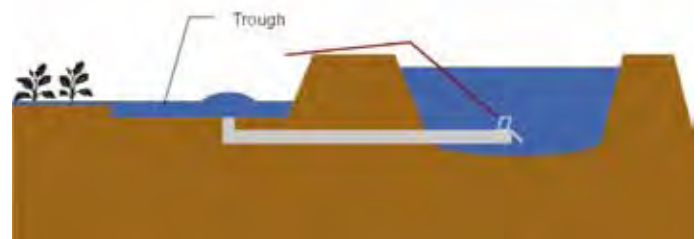


FIGURE 2:
erial view of PTB irrigation demonstrating pipe outlet situated in Guess row away from wheel tracks



in conjunction with optimization programs available, allows for delivery of irrigations adjusted to meet crop specific requirements.

Acknowledgement: This article, based on a More Profit Per Drop publication, would like to acknowledge all of the information provided by Craig Saunders, Saunders (Farming Pty Ltd) and Justin Schultz, (WaterBiz) in the development of that case study (at http://www.moreprofitperdrop.com.au/wp-content/uploads/2011/12/saunders-pipes-through-the-bank-case-study_final.pdf).

Dryland Cotton – Risk & Potential

By Michael Bange (CSIRO)

This chapter presents information to assist in establishing differences in yield potential, reliability and risks for dryland cotton between row configurations and regions. Extensive field research has been utilised including the use of the OZCOT crop simulation model coupled with historical climate records. Dryland cotton growers need not take uncalculated risks. History can often serve as our best guide to the potential risks and benefits of different cropping strategies. The use of crop simulation models is a powerful, and often the only way, to address such issues without suffering the consequent pain and real life experience when misfortune strikes. CSIRO at Narrabri has used long-term climatic records (1957 onwards from the Bureau of Meteorology) and the OZCOT crop simulation model originally developed by Brian Hearn CSIRO Plant Industry, to study the prospects for dryland cotton production in different regions. The OZCOT crop simulation model uses historical weather data, basic soil parameters, and defined management options to give estimates of potential crop

yields. The model has been comprehensively tested across both commercial dryland (including skip rows) and irrigated crops throughout the industry (Figure 1). The intention behind skip row configurations is to provide slowly available soil water to the planted rows to allow continued growth during dry periods. In practice, the benefits lie primarily in:

FIGURE 1:

Predicted lint yield (bales/ha) versus observed lint yield for commercial dryland cotton crops with various row configurations grown in southern Queensland and northern New South Wales. Also shown is the 1:1 line. In this comparison, the closer points are clustered around the 1:1 line drawn on the graph, the better the predictions made by OZCOT. The 1:1 line is the position on the graph where the simulated yield equals the predicted yield. (published Bange et al., 2005; AJAE (45 pp. 65–77))

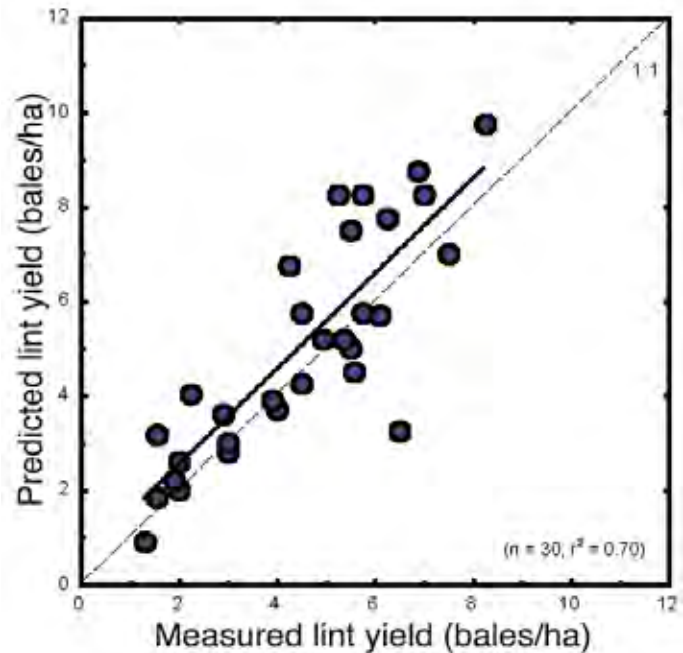


TABLE 1:

Average rainfall for cotton producing regions between the months of October and April as well as between December and March. (Source: Australian Rainman)

Region	Rainfall October to April (mm)	Rainfall December to March (mm)
Hillston	212	121
Narromine	303	183
Warren	310	194
Gunnedah	407	253
Coonamble	326	205
Wee Waa	391	251
Bellata	409	263
Moree	396	258
Croppa Ck	404	265
Goondiwindi	426	281
Dalby	488	319
Biloela	534	373
Emerald	489	356

BE AWARE OF

- Soils with a greater plant available soil water holding capacity reduce risks associated with dryland production. As with all dryland crop production, full profiles also significantly reduce year to year variation in yields.
- The optimal sowing window in most regions is 15th Oct to 15th Nov.
- Skip row configurations reduce the potential 'downside risk' in years with low rainfall.
- Double skip is more suitable for soils with lower plant available water holding capacity.
- Average fibre length is improved with skip configurations compared with solid.
- Seasonal climate outlooks such as the El Niño – Southern Oscillation (ENSO) phenomenon should also be considered as it can lead to differences in potential yield and associated risk.
- Be aware of average rainfall and variability between October and April in your region.
- Be aware of the ability of crops to access moisture in skip rows. Some soil types will limit root growth.



- A reduced risk of negative effects of water stress on fibre quality;
- Reduced yield variability; and,
- Better economic returns due to production costs being reduced more than the yield relative to solid planted cotton.

Rainfall

Obviously the main consideration for dryland production and a source of variability across regions is rainfall. Regions differ greatly in the average total amount of rainfall as well as the variability between and within seasons. Generally, the risk of less rainfall between the months of October and April is greater in the southern cotton growing areas (Table 1). The traditional dryland cotton growing areas have higher average rainfall during these months, coupled with higher rainfall during the December through March period when flowering and boll filling occur.

Predicting dryland cotton yield potential

The information presented in this chapter uses the OZCOT crop simulation model developed by CSIRO Plant Industry. Some assumptions used in this study were:

- Cracking clay soils storing 200mm or 250mm of available soil moisture in 1.5 m profile. A full profile at sowing.
- Siokra (Bollgard II) variety.
- Crops sown on the 30th October.
- Row spacing set at 1 m.
- Established population of 7 plants per metre of row.
- Nitrogen non-limiting.
- Climate data 1957–2010.

The model simulates potential yield. It does not

TABLE 2:

Probability of failing to sow based on the sowing rule (defined above) for different periods starting 15th September.

Region	Probability of failing to sow (%)			
	15th Sep to 15th Oct	15th Oct to 15th Nov	15th Nov to 15th Dec	Overall 15th Sep to 15th Dec
Gunnedah	43	15	14	24
Wee Waa	49	18	25	31
Bellata	55	21	13	30
Moree	42	16	18	25
Croppa Creek	36	18	17	30
Goondiwindi	39	17	24	27
Dalby	52	10	10	25
Biloela	52	18	10	27
Emerald	50	33	17	33

account for the affects of insect pests, diseases, weeds, management failures, and soil nutrient limitations other than N. The model also does not simulate the effects of climate and management on fibre quality, which is another important consideration when growing dryland cotton.

Sowing opportunities

The risk of failing to obtain a sowing opportunity was assessed for three, 30 day periods starting the 15th of September. A sowing opportunity was defined in terms of adequate soil moisture and temperature and there was no account for Bollgard II sowing window restrictions.

A sowing opportunity was considered to occur when there was:

- 25 mm (1") of water in top 100 mm (4") soil; and,
- 18°C mean temperature for 3 consecutive days

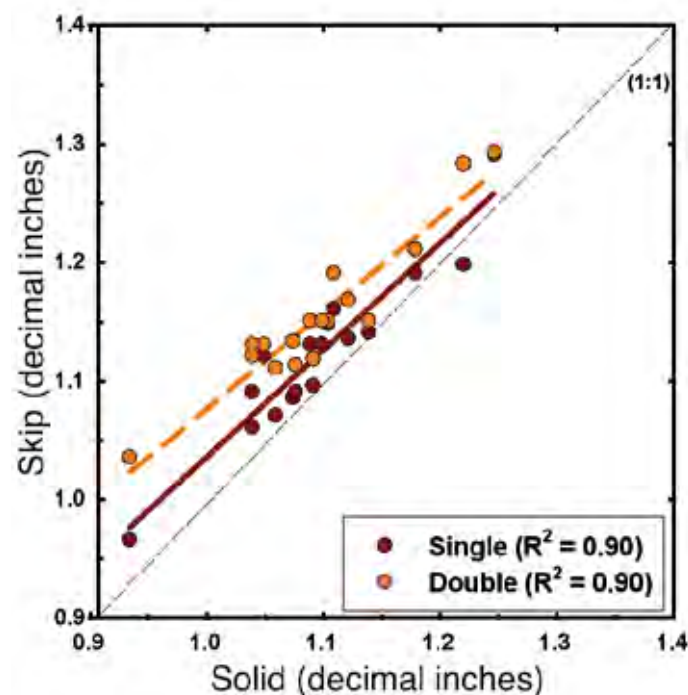
The Darling Downs, Moree and Gunnedah were found to have a slightly lower risk of failing to sow for the 90 day period starting 15th September for dryland cotton production than for most other areas especially for the period 15th October to 15th December (Table 2). Experience in these regions is commensurate with these findings.

Dryland regional yield potential and row configuration

A number of field studies have been conducted to compare the relative yield of skip row configurations compared with solid 1 m plant configurations. They

FIGURE 2:

Fibre length of skip row configurations compared with solid row configuration in dryland cotton systems. As points approach the 1:1 line, fibre length of the skip configurations equals that of the solid configuration (M. Bange, CSIRO). Note that this data is not simulated data.



generally show that when yields of solid configurations are high, skip row configurations have a penalty; however when yields of solid configurations are low the difference in yield between skip rows and solid configurations are small. It should also be noted that there are also significant fibre quality advantages attained from skip row configurations. Figure 2 shows data from experiments to highlight this point.

In Tables 3, 4, and 5 the average potential yield from three different row configurations (solid, single and double) is presented on a regional basis along with the associated 'Probability of exceedence' values. Probability of exceedence is used to indicate yield variability that exists with different seasonal climatic conditions experienced

TABLE 3:

OZCOT predictions, *solid* row configuration – effects of two plant available soil water holding capacities on potential yield (bales/ha) and variability of yields, expressed in terms of probability of exceedence. Soil profiles are full at sowing.

Region	200mm Plant Available Soil Water			250mm Plant Available Soil Water		
	Mean	80%	20%	Mean	80%	20%
Gunnedah	3.1	1.9	4.6	3.9	2.5	5.5
Wee Waa	3.3	2.0	4.8	4.0	2.7	5.7
Bellata	3.4	2.2	4.7	4.1	2.8	5.4
Moree	3.1	2.0	4.4	3.8	2.7	5.3
Croppa Ck	3.4	2.1	4.9	4.1	2.8	5.5
Goondiwindi	3.3	1.9	4.7	3.9	2.5	5.4
Dalby	3.4	2.0	4.7	4.1	2.8	5.2
Biloela	3.4	2.5	4.5	4.3	3.2	5.5
Emerald	3.5	2.4	4.4	4.2	3.1	5.2

TABLE 4:

OZCOT predictions, *single skip* row configuration – effects of two plant available soil water holding capacities on potential yield (bales/ha) and variability of yields, expressed in terms of probability of exceedence.

Region	200mm Plant Available Soil Water			250mm Plant Available Soil Water		
	Mean	80%	20%	Mean	80%	20%
Gunnedah	3.3	2.4	4.3	3.8	3.0	4.8
Wee Waa	3.4	2.4	4.4	4.2	3.2	5.0
Bellata	3.6	2.6	4.8	4.3	3.4	5.0
Moree	3.3	2.2	4.4	4.0	3.0	5.0
Croppa Ck	3.6	2.4	4.8	4.4	3.2	5.5
Goondiwindi	3.4	2.4	4.3	4.1	3.4	4.9
Dalby	3.6	2.5	4.4	3.9	3.1	4.6
Biloela	3.5	2.7	4.0	3.9	3.0	4.6
Emerald	3.5	2.5	4.5	4.3	3.1	5.2

in each region. For example an 80% probability of exceedence means that there is an 80% chance of at least achieving the yield presented for that region.

Generally across all regions, yields were improved with single skip and overall yield variability was reduced. Yield was also lower and more variable for solid. Mean yield across most regions was slightly less for double skip compared with single skip however, there were more chances (i.e. higher 80% and lower 20% probability of exceedence) of attaining better yields with double skip in soil with a lower plant available water holding content (200mm vs. 250mm).

Time of sowing

The length of sowing windows in dryland crops is often longer than for irrigated crops as the length of growing season is less for dryland cotton. While there is a trend for yields to slightly increase until late October, the optimum sowing time for most regions based on mean yields was from 15th October to the 15th November. In all regions mean yields of crops grown in single skip configuration were less when crops were sown early before the 30th September (Figure 3). The latest sowing date where there was no substantial penalty to average yield was the 15th November for all regions with the exception of the Darling Downs, where yield reduced after the 30th October. Later sowings within this window can give the crop more time to capture rainfall when the crop needs it most. Sowing times outside this window not only reduce mean yield but also increase potential yield variability (Table 6). Consideration must also be given to the timing of crop maturity, which may be influenced by sowing, as rainfall at harvest can affect lint quality considerably.

Seasonal climate forecasts to assess risk

TABLE 5:

OZCOT predictions, *double skip* row configuration – effects of two plant available soil water holding capacities on potential yield (bales/ha) and variability of yields, expressed in terms of probability of exceedence.

Region	200mm Plant Available Soil Water			250mm Plant Available Soil Water		
	Mean	80%	20%	Mean	80%	20%
Gunnedah	3.2	2.5	4.0	4.0	2.9	4.9
Wee Waa	3.4	2.3	4.6	4.2	2.7	5.2
Bellata	3.6	2.6	4.6	4.3	3.1	5.4
Moree	3.3	2.4	4.3	3.4	2.5	4.2
Croppa Ck	3.3	2.3	4.5	4.3	3.1	5.9
Goondiwindi	3.4	2.3	4.3	3.6	2.8	4.3
Dalby	3.2	2.2	4.0	4.0	2.7	5.2
Biloela	3.4	2.6	4.0	4.2	3.3	5.1
Emerald	3.4	2.4	4.2	4.1	3.1	5.2



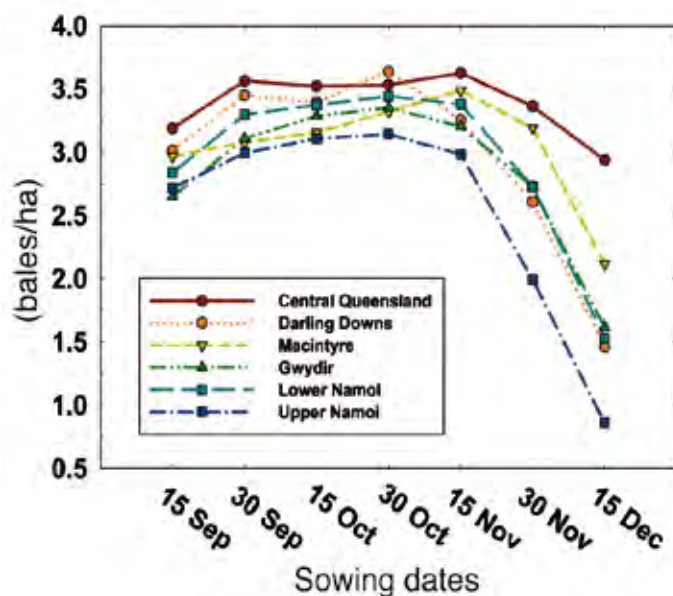
(Photo: Cotton Australia: Phil Davis)

Seasonal climate forecasts, based on the El Niño – Southern Oscillation (ENSO) phenomenon, may offer opportunities to adjust crop management in the light of probable future weather trends.

A useful way of interpreting seasonal forecasts is by identifying similar years in the climate history for the site of interest. Seasonal patterns in 'similar' seasons can be used as a guide for the potential risks and outcomes for the seasonal forecast. Outcomes of management decisions can then be assessed in terms of rainfall probability, average yields and the risks associated in achieving these yields for the coming season. While

FIGURE 3:

Change in expected mean crop yield with sowing date. Yields have been predicted using a single skip configuration and plant available water holding capacity of 200mm.



there are a number of ways of grouping similar years, one of the most successful approaches for partitioning historical records has been using the Southern Oscillation Index (SOI). The SOI is an index of the difference in atmospheric pressure between Darwin and Tahiti. It is a key indicator of the El Niño – Southern Oscillation (ENSO) phenomena. At present, we divide seasons into five groups, depending on the value and the rate of change of the SOI (SOI phase) at the time of forecast. The SOI phase is derived from the change in the SOI from last month to the SOI value at the time of the forecast. Phase I – SOI is consistently negative; phase II – SOI is consistently positive; phase III – SOI shows a rapid fall; phase IV – SOI shows a rapid rise; phase V – SOI is consistently near zero. Every month of the past 120 years

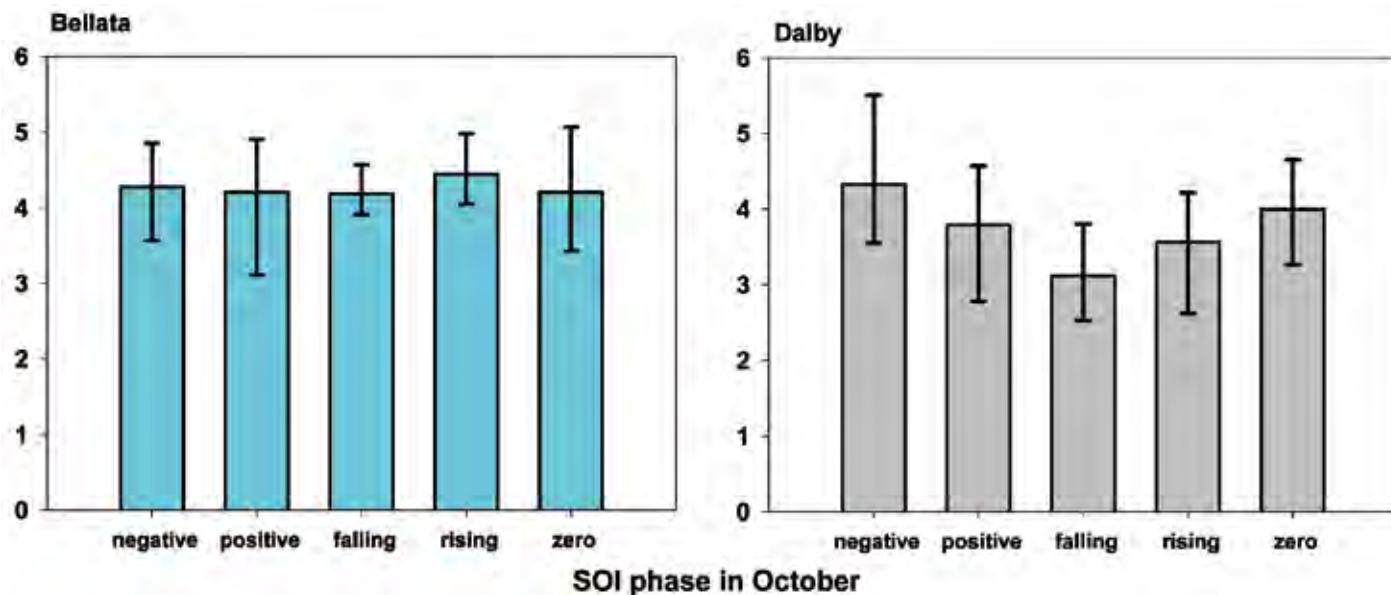
TABLE 6:

OZCOT predictions, *single skip* row configuration – effects of sowing date on potential yield (bales/ha) and variability of yields, expressed in terms of probability of exceedence.

Region	15 Sep	30 Sep	15 Oct	30 Oct	15 Nov	30 Nov	15 Dec	30 Dec
Central Qld.								
Mean	3.2	3.6	3.5	3.5	3.5	3.6	3.4	2.9
80%	4.0	4.4	4.5	4.0	4.4	4.5	4.5	3.6
20%	2.3	2.6	2.6	2.7	2.6	2.7	2.4	2.1
Darling Downs								
Mean	3.0	3.5	3.4	3.6	3.6	3.3	2.6	1.5
80%	4.3	4.4	4.2	4.4	4.6	4.2	3.6	2.3
20%	2.0	2.3	2.4	2.5	2.4	2.4	1.7	0.4
Macintyre								
Mean	3.0	3.1	3.2	3.4	3.3	3.5	3.2	2.1
80%	3.6	3.8	3.9	4.3	4.2	4.1	4.0	2.7
20%	2.1	2.1	2.2	2.4	2.6	2.7	2.1	1.4
Gwydir								
Mean	2.6	3.1	3.3	3.3	3.4	3.2	2.7	1.6
80%	3.3	3.8	4.4	4.4	4.4	4.1	3.5	2.5
20%	2.1	2.3	2.2	2.3	2.4	2.4	2.0	0.6
Lower Namoi								
Mean	2.8	3.3	3.4	3.4	3.4	3.4	2.7	1.5
80%	4.1	4.5	4.4	4.4	4.7	4.3	3.5	2.4
20%	1.8	2.1	2.4	2.4	2.5	2.3	1.8	0.5
Upper Namoi								
Mean	2.7	3.0	3.1	3.3	3.1	3.0	2.0	0.9
80%	3.9	3.9	4.2	4.3	3.9	3.7	2.6	1.7
20%	1.9	1.9	2.1	2.4	2.3	2.2	1.1	0.0

FIGURE 4:

Forecasted average dryland cotton lint yields (simulated using OZCOT using the details on the previous page for a 250mm plant available soil water profile) for single skip row configurations at Bellata (NSW) and Dalby (Qld) across for different phases of the SOI in October. The bottom of the error bar is the 80% probability of exceedence, while the top is the 20% probability. For a 200mm plant available soil water profile, average yields are less than for a 250mm profile and there is considerably more variability estimated for the negative, positive and zero phases. Average yields are considerably less for the rapidly falling and rising phases, but have less variability.



has been categorised into one of the five phases that takes into account the value and change in SOI.

Crop models can be linked with climatic data to help assess potential yields and risks of production in different years. Similar to seasonal rainfall, estimates of cotton yield for each year in a climate record can also be associated with the SOI phase at the time of forecast such as land preparation or sowing time. Simulation models such as OZCOT, when used in conjunction with the SOI can therefore provide opportunities for growers to tailor their management decisions more appropriately to potential impending seasonal conditions. Information of this nature has been used successfully to assist wheat growers in Southern Queensland in their variety choice and nitrogen management based on expected rainfall and predicted risk of frost.

Figure 4 illustrates how using OZCOT with analogous (similar) years of SOI phases in October identified from the historical climate records can be related to yield in the forthcoming season. It shows that compared to Dalby, Bellata is less affected by SOI and that average yield is slightly better when SOI is rising. For Dalby average yield is best when SOI is negative (but highly variable) and less when SOI is falling. In addition to row configuration as an option to reduce risk other management options could also be considered. One of these is nitrogen fertiliser management. In those years where the SOI phase is associated with potentially higher yields, more nitrogen could be applied to take advantage of the opportunity. Conversely, when the conditions were less favourable, lower inputs of fertiliser may reduce possible financial losses.

Conclusions

It is important to note that these analyses act only as a general guide to the potential yield and risks of dryland production for different regions. The outcomes and interpretation may change depending on a number of farm specific factors, for example: soil water holding capacity, starting soil moisture and costs. Most benefit comes from simulating growers' specific conditions using their own soil type and costs. Further comments on management and financial considerations of dryland cotton and different row configurations in dryland cotton production follow in this manual.

The growing of dryland cotton is subject to relatively large risk, not only in achieving yields but also because costs are a high proportion of income. Therefore the potential and risks associated with dryland production need to be calculated. Crop simulation models such as OZCOT provide a useful tool to help evaluate the risk.

Sources of information:

Whopper Cropper risk management software can compare the effects of different management options to help farmers to better manage production and economic risks. <http://www.backpaddock.com.au>

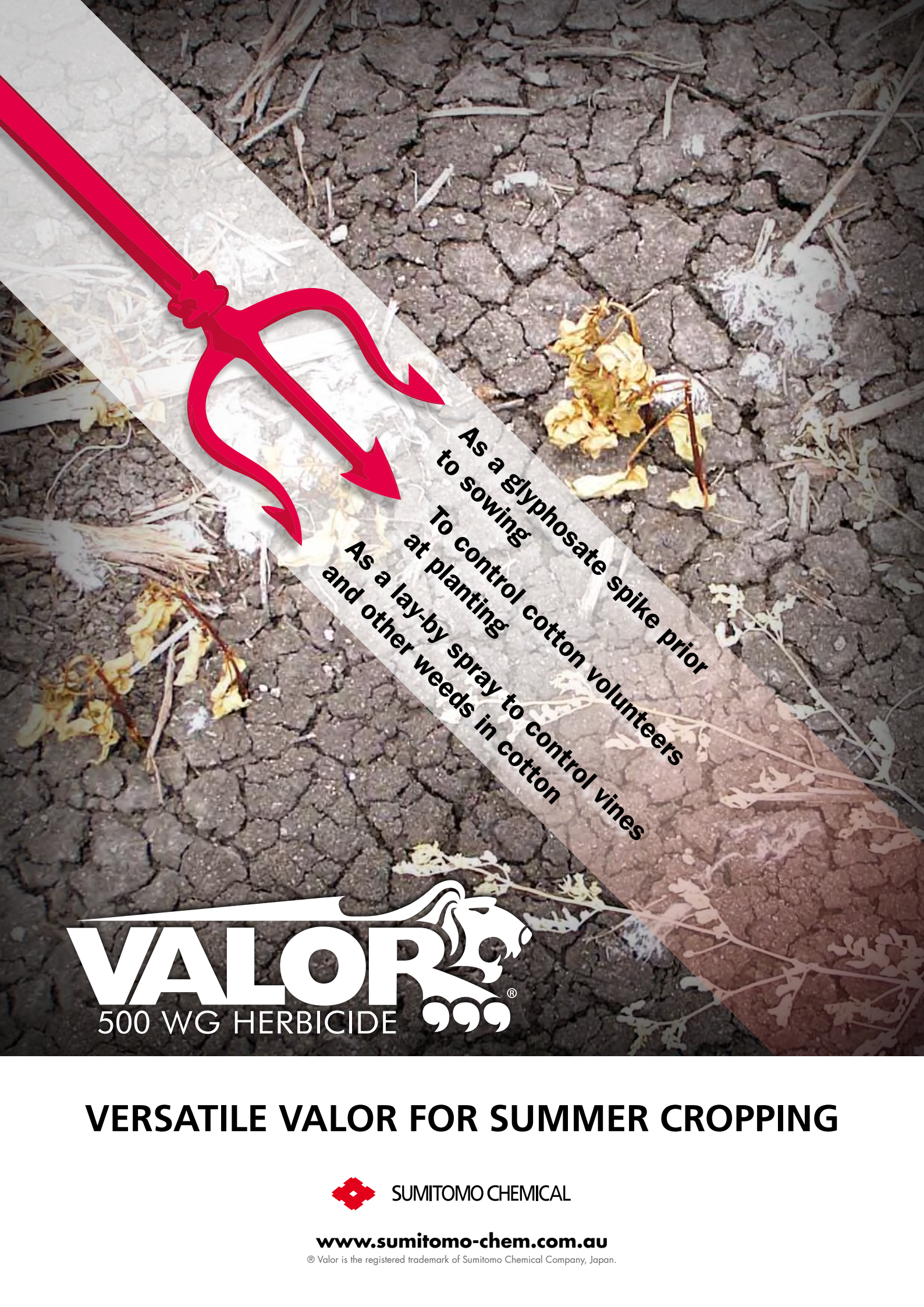
HowWet is a Windows based program that provides a simple method of using rainfall records to estimate storage of rainfall in the soil. <http://www.apsim.info/How/HowWet/how%20wet.htm>

Rainman StreamFlow software enables users to analyse detailed historical climate data and predict rainfall at a specific location within a specified time period. <http://www.daff.qld.gov.au/26-15734.htm>

The Bureau of Meteorology is Australia's national weather, climate and water agency, providing regular climate forecasts, warnings, monitoring and advice – www.bom.gov.au

Reference:

Bange, M.P., Carberry, P.S., Marshall, J. and Milroy, S.P. (2005) Row configuration as a tool for managing rain-fed cotton systems: Review and simulation analysis. *Australian Journal of Experimental Agriculture* 45(1): 65–77.



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Energy Use Efficiency

By **CRAIG BAILLIE (USQ)**

Energy inputs represent a major cost and one of the fastest growing cost inputs to primary producers. The Australian cotton growing industry is highly mechanised and heavily reliant on fossil fuels (electricity and diesel). Within highly mechanised farming systems such as those used within the cotton industry, machinery inputs are significant and can represent 40–50% of the cotton farm input costs. Direct energy use is a major component of these costs. Given the major dependence on direct energy inputs and rising energy costs, energy use efficiency is an emerging issue for the Australian cotton industry.

Previous work undertaken by the National Centre for Engineering in Agriculture (NCEA) has studied direct on farm energy use involving a number of case study cotton farms to understand the range, costs and contributions of energy use to cotton production and greenhouse gas emissions. The results from this work showed that energy use varies depending on the cropping enterprise and the farming system and that there are significant opportunities to reduce energy and costs. In comparison the GHGs from direct energy use can be similar and in fact greater than the GHGs generated by soil/fertiliser/water interactions. Improving on farm energy use would appear to be as important as improving nitrogen efficiency.

In the cropping sector a number of practice changes and technology developments have been, or are being, adopted which can be expected to reduce fuel/energy use or energy use intensity. Examples include minimum/zero tillage, controlled traffic, a range of precision ag technologies, planting of GM crops, some water use

efficiency measures and use of legumes in crop rotations.

Within highly mechanised agricultural productions systems such as the Australian cotton industry direct energy inputs (i.e. diesel and electricity) represent a major cost to the grower and potentially a significant proportion of the total GHG emissions. Previous studies by Baillie and Chen (2008) have reported significant savings in energy for both a refinement in current practices (i.e. up to 30% for individual operations) and a change in practice (10–20% across the farming system) through energy assessment.

Rational and efficient use of energy is essential for sustainable development in agriculture. At the current market condition, 1 Gigajoule (GJ) of energy would typically cost Australian farmers \$20 to \$25. Previous work (Chen and Baillie, 2007) including irrigated cotton production has shown that total energy inputs are influenced by management and farming methods, and ranged from 3.7 to 15.2 GJ/ha; at a cost of \$80 to \$310/ha and 275 to 1404 kg CO₂ equivalent/ha greenhouse gas emissions. Dry land cotton production in comparison is expected to be at the lower end of this range.

Monitoring to manage – assessing on farm energy use

An energy assessment determines how efficiently energy is being used, identifies energy and cost saving opportunities and highlights potential improvements in productivity and quality. This may also include potential energy savings through fuel switching, tariff negotiation and managing energy demands. Practically the main purpose of conducting energy assessments and maintaining records is to identify opportunities for significant cost savings which will lead to reduced GHGs. The concept of energy assessments in the cotton industry is relatively new with ongoing work being continued within the industry and linkages to *myBMP*. Starting to monitor energy use can be as simple as collating fuel and electricity costs and tracking them over time. As growers start to look at energy they will find that the more information collected will help to identify opportunities to produce more crop per Gigajoule.

Preliminary assessment

(Overview of the total energy consumption on-site, whole farm approach)

- This is the simplest & cheapest form of assessment. No additional tools are required.
- Collate total fuel (diesel, petrol & other fuels), and total electricity energy consumed, from farm receipts. Divide total energy use by total farm production (e.g., bales of cotton; head of cows) or area.
- The main purpose of a preliminary assessment is to benchmark overall energy consumption over time and to allow for comparing the relative performance of similar enterprises

BEST PRACTICE

- Record farm energy usage to identify how efficiently energy is used and where the most energy is consumed
- Explore ways to reduce energy use by focusing on high energy input areas and investigate opportunities to reduce energy inputs by changing practice or by doing the same operation more efficiently
- Maintain machinery and equipment and ensure any modifications do not affect their efficiency.
- Consider impact on energy use efficiency when making any changes to farm practices or new investments.

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Standard assessment

(Itemised farm approach, practice based)

- This is a practice based assessment which includes a desktop study of the energy breakdown or itemised account of energy usage across the farm.
- Energy usage for key farming processes is determined from data easily available from the site (i.e. record of practices, some fuel use data), calculated from machine specifications or based on published data for specific farming practices. Site specific information including electric motor sizes, pumping equipment, tractors and vehicles is collated to calculate energy use.
- This assessment provides much more detail than a preliminary assessment and aims to reach an accuracy of $\pm 20\%$.
- In addition to whole of farm benchmarking, helps to identify target areas and operations requiring further investigation.
- EnergyCalc Lite has been developed by the National Centre for Engineering in Agriculture to undertake agricultural energy assessments. EnergyCalc Lite also converts direct energy inputs into greenhouse gas emissions. Both the methodology and software requires some instruction however a record of farming practices and equipment or detailed bowser and electricity meter-box type measurements for all farming operations form the basis of an energy assessment. For more information go to www.mybmp.com.au

Advanced assessment

(Itemised farm approach, measurement based)

- This is a comprehensive measurement based assessment of energy usage across the farm.
- An advanced assessment utilises site specific data either gained from on-site measurement or through data and records maintained over time. An advanced assessment may include simple record keeping or more sophisticated equipment to extract energy usage for specific items of plant. Measurements would normally include bowser and electricity meter-box type measurements for all farming operations and processes.
- This assessment provides much more detail and accuracy (aims to reach an accuracy of $\pm 10\%$).
- In addition to whole of farm benchmarking, this information helps to identify target areas and operations requiring further investigation. EnergyCalc Lite can also help with this type of assessment. For more information go to www.mybmp.com.au

Detailed assessment of high energy use farming practices

(Specific operation investigation)

- The aim of a detailed assessment is to investigate ways to improve the efficiency of a specific operation and most likely requires specialised advice. Ideally this would focus on where the greatest energy consumption has been identified from standard or advanced assessments.

- This will usually involve a range of different sensors to measure the performance (energy efficiency) of different machinery. Examples of sensors used may include pressure (irrigation head pressure), flow rate, engine RPM, tractor travel speed, torque, load and temperature etc. A data logger may be required to record data for a considerable period of time to determine performance and to identify optimised machine settings (i.e. pumping).



Detailed assessments of specific tractor based operations have identified potential savings in diesel use of 30% can be achieved depending on how the tractor is operated. Tractor Performance Monitors (TPM) which are standard features in most modern tractors are useful for choosing the appropriate gear and engine speed that maximises fuel efficiency.

Assessing greenhouse gas emissions (GHGs) from direct energy inputs

With the increased community concern on global warming and climate change, the greenhouse gas emissions from the fuel use of agricultural production can be easily determined. This is particularly important in highly mechanised production systems as direct energy use contributes a significant proportion of the total GHGs and may be similar to biologically generated emissions (i.e. soil/water/fertiliser interactions). This may have strategic use to the cotton industry in the future through product labelling or where a price on carbon is established. Conversion of direct energy use (i.e. fuel, electricity etc) to greenhouse gas emissions can be determined by calculations and factors outlined in the National Greenhouse Accounts Factors published by the Department of Climate Change & Energy Efficiency.

On farm energy use and GHGs

Previous work has shown that on farm energy use varies significantly between different farming enterprises. Chen and Baillie (2007) reported on farm energy use to range from 3.7 to 15.2 GJ/ha costing \$80 to \$310/ha. All farms included in the study covered a range of farming regions and farming practices (e.g., conventional tillage, minimum tillage, dryland farming, and irrigation) in both NSW and

Queensland. Diesel energy inputs ranged from 95 to 365 litres/ha, with most farms using 120 to 180 litres/ha.

GHGs associated with this direct energy use was estimated to be between 275 and 1404 kgCO₂-e /ha. Dry land cotton production is expected to be at the lower end of this range. It is important to note that these calculations only relate to GHGs from direct energy use, and has not included the (biological) effect due to soil tillage/disturbance and applications of nitrogen fertiliser which can be determined by the Cotton Greenhouse Gas Calculator.

For irrigated cotton, average energy related greenhouse gas emissions can be equivalent to emissions from fertiliser use. A focus on improving on-farm energy use efficiency can be as important in irrigated cropping systems as improving nitrogen use efficiency. For example, data contained in the Australian Governments submission to the UN Framework Convention on Climate Change May 2010 (Australian Government, 2010) suggests that, in irrigated cotton, average energy related costs and greenhouse gas emissions (0.712 t CO₂-e/ha) appear to be equal to average costs and emissions from fertiliser use (0.67 t CO₂-e/ha).

Energy saving practices

Generally lower energy use on farm is a function of the number and intensity of farming operations and the requirements for pumping irrigation water. In cotton systems, water pumping is often the major energy use operation (20–70%). Significant efficiency gains (and in some cases crop productivity gains) can be made by optimising pump performance to provide reductions in diesel costs and in some cases improved pump efficiency can lead to increased water flow, more timely irrigation and improved crop yield.

It has been shown that if a farmer moves from conventional tillage to minimum tillage, there is a potential saving of around 10% of the fuel used on the farm, plus other production advantages.

It has also been found that energy use associated with picking is also significant and may contribute 20–50% of



Significant cost savings as well as energy efficiency gains can be made by optimising pump performance.

the total direct energy use (more so in dry land cropping systems). Ensuring equipment is well maintained and operated efficiently is particularly important for these high energy use operations.

In 2009 the NCEA conducted a case study (Baillie, 2009) to benchmark the energy use reductions resulting in the adoption of reduced tillage systems on the cotton farm 'Keytah' in the Gwydir Valley. The study showed that adoption of a minimum tillage system had reduced energy costs (and greenhouse emissions) by 12% since 2000 and developing a 'near zero till' system had the potential to reduce this to 24% less than 2000 energy costs. The integration of diesel–gas systems to reduce reliance on diesel fuel on this farm also shows considerable promise.

Compared with cotton, the energy use of other rotational (grain) crops is usually lower. Cotton generally has a greater number of farming operations, more intensive energy use associated with harvest (i.e. picking) and higher irrigation demands.

For further information and support relating to assessing your energy and greenhouse gas emissions, refer to the energy and greenhouse gas module in *myBMP* (www.mybmp.com.au).

References:

CRDC – Spotlight Magazine winter edition 2009 – www.crdc.com.au

Australian Government (2011), National Greenhouse Accounts Factors, Department of Climate Change and Energy Efficiency.

Australian/New Zealand AS/NZS 3598:2000. Energy Assessments.



EnergyCalc Lite
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Precision Ag – Tools To Improve Efficiency

By **ANDREW SMART & BROOKE SAUER**
(Precision Cropping Technologies)

Cotton growers in Australia are not only familiar with the term Precision Agriculture (PA), but are also very familiar with the concepts, solutions, and products that are available. Justifiably, PA is often described in terms of the primary enabling technologies, the Global Positioning System (GPS), and Geographic Information Systems (GIS). However, for the PA practitioner, mastery of the technology is only a small part of a successful on-farm implementation.

Broadly, PA refers to productivity enhancing concepts such as tractor and machine control, site-specific input placement, improved product efficacy, and increased irrigation efficiency (Precision Irrigation). More specifically, we can divide PA into two main areas:

1. Spatial Control – this includes guidance, as well as remote monitoring and control
2. Spatial Agronomy and Management (SAM) – analysis of spatial data which is decision based.

Spatial Control products have been widely adopted. In general, implementation is reasonably straightforward and benefits are easily quantifiable. SAM is more complex, requiring each value proposition to be understood at a local level. It is an agronomic and management strategy that brings together multiple data sources to allow the agronomist and manager to build knowledge and make better crop production decisions based on in-field variability. SAM comprises 3 main steps:

BEST PRACTICE

- Discuss precision ag ideas with your agronomist.
- Consider training to help interpret and utilise precision ag data.
- Where possible use multiple layers of information, such as several years of yield data with an EM survey to better inform management and agronomic decisions

1. Measurement and capture of data
2. Interpretation and analysis of data, and
3. Implementation of a management response.

PA has generally aided profitability in cotton farming systems by understanding and then improving the varying links between inputs (particularly water and varieties) and their interaction with soil production capabilities.

Crop variability

Variability in cotton farming systems can be categorised as stemming from these main factors:

- **Climate** – Overall crop yields on a national level are controlled mostly by what the climate delivers. (Major events such as flooding and hail are also climate related but the outcomes of overall yield will generally only affect individual farms.)
- **Farm** – Location or valley specific incidents as previously mentioned will affect overall farm performance. Individual farm management and ownership will also impact.
- **Field** – In-field variability will be determined by a number of factors including soil types, terrain, and the impact of historical practices.
- **Agronomic** – Variety choice, pest management, irrigation timing, location of checking, and individual interpretation of events, etc
- **Management** – Timing and type of farming practices, historical decisions, and general farm practice.

It is rare that you can attribute in-field variability to any single factor. It is far more likely that a complex relationship between several of the above factors is driving cotton production patterns. It is therefore important to consider all potential drivers in variability and comprehensively understand what site-specific combination of factors is present.

While there are many ‘tools’ available to measure variability in cotton production systems, there are several that have proved to be consistently reliable in the majority of circumstances. These include:

- EM surveys
- Remotely sensed images
- Elevation maps (including derivatives such as slope and wetness maps).
- Yield maps

Measuring variability

EM soil survey

Electromagnetic induction (EM) surveys are methods of measuring apparent soil electrical conductivity (ECa) by inducing an electrical current into the soil. These surveys have become very popular for a variety of reasons, including speed of data gathering, interpretability, and excellent correlation with real world observations.

Soil ECa is highly correlated to a combination of soil properties including water content, clay content, and salt

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Contact Mike Bange for more information.

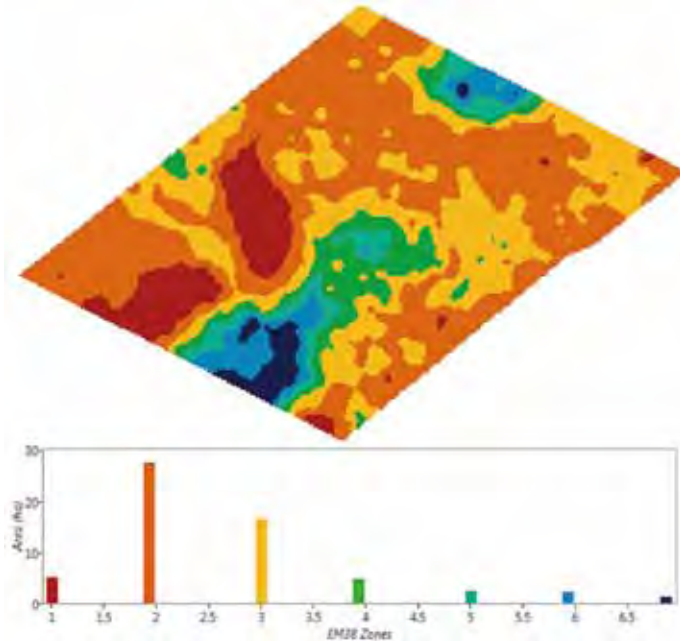
☎ 02 6799 1500 michael.bange@csiro.au

Best Practice



IMAGE 1:

EM38V survey captured with full moisture profile where red = low conductivity and blue = high conductivity. Low EM zones represent lower clay, water holding capacity and salts. High EM zones represent higher clay, water holding capacity and salts.



content. In non-saline soils ECa variations are most often a function of soil texture and moisture content. In general EM is most successfully used in areas where a single dominant factor is the cause of soil variability as recorded maps will then directly reflect that property. The main uses for EM surveys are:

- Forming soil type maps for the farm.
- Creating crop-specific yield-potential zones (all crops extract varying levels of nutrients and water from the soil).
- To optimize location of moisture probes relative to the majority of the field.
- To direct soil sample placement to best understand subsoil limitations.
- To understand yield potential in dryland systems by relating EM and soil sample data to plant available water capacity (PAWC).
- To locate deep drainage or leakage areas in storages and channels.

Biomass imagery

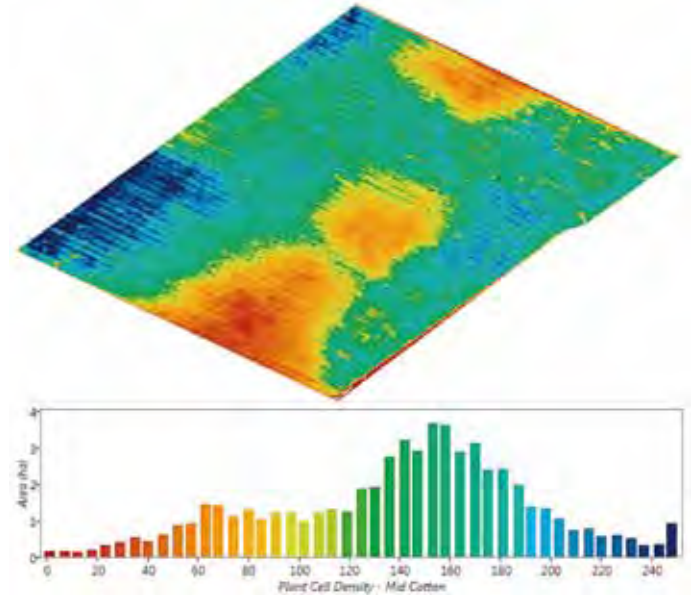
Airborne or satellite multispectral imaging systems measure the sunlight reflected off crops. Simply put, chlorophyll containing crops have strong reflectance in the green wavelength range and low reflectance in the red and blue wavelengths.

Plant Cell Density (PCD) and Normalised Difference Vegetation Index (NDVI) are indices which use the red and near infra-red (NIR) bands and have been used extensively in cotton farming systems for:

- Plant stand evaluation;
- Variable rate growth control;
- Variable rate fertiliser;

IMAGE 2:

Airborne imagery captured on 15th December 2002 where the relative PCD values on the X axis indicate the amount of biomass: Red = low biomass and blue = high biomass. NB. At this time in the season this map is mainly used for in crop growth management.



- Late season watering decisions; and,
- Variable rate defoliations.

Elevation and landscape change

The relationship between topography, soil water infiltration, and subsequent yield is quite complex because often where terrain changes so does soil type. Topography is however a primary determinant of the movement of water and subsequent infiltration, and its measurement and management can yield strong benefits. Fortunately, elevation maps can be created as a by-product by most RTK tractor guidance systems.

IMAGE 3:

Slope% Map created from an RTK tractor steering system where the X axis shows soil level above or below a "plane of best fit (0)" as a percentage (i.e. 15ha of this field is 0.05% above the plane).

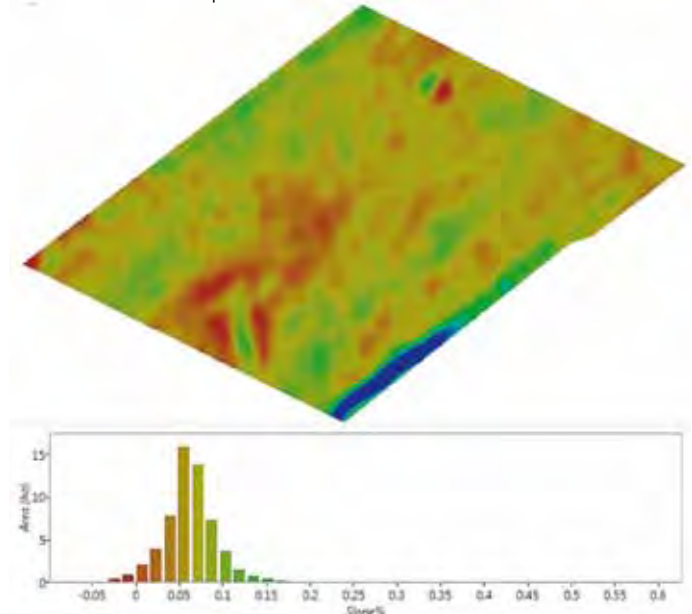
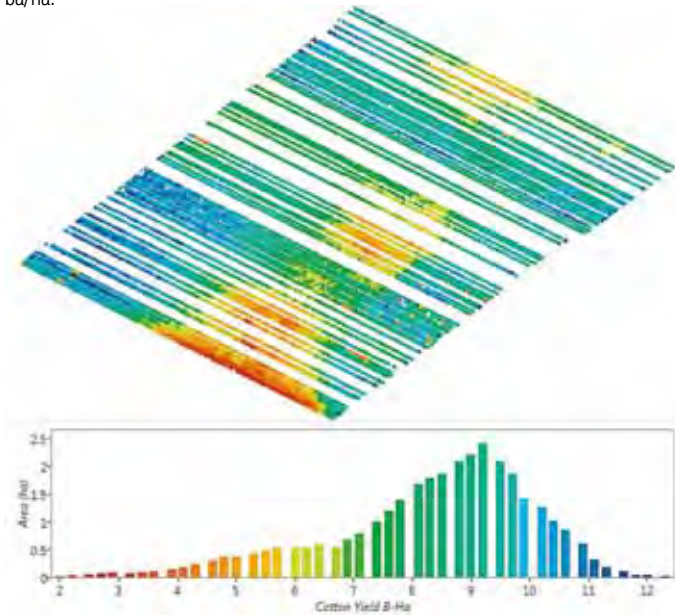


IMAGE 4:

Cotton yield from an actual cotton yield monitor, where the x axis shows yield in ba/ha.



Variations of soil type and topography combine to create differing growing environments and in the presence of subsoil constraints the relationship becomes even more complex. Elevation data coupled with EM surveys provide valuable information about the likelihood of waterlogging within irrigated fields. High EM and low elevation areas of the field will often be subject to prolonged waterlogging which has severe detrimental effects on cotton production.

The main uses for elevation data are:

- Locating moisture probes to avoid to areas in the field where water may lay or shed excessively (in combination with EM maps).
- Prioritising areas for remedial earthworks.
- Designing surface drainage to improve trafficability.
- Designing farm layouts to manage water flow and erosion.

Yield

Recording actual yield response is critical as a starting point for developing information about inherent field variability. Even if the information is merely anecdotal, it still remains as one of the simplest and most economical ways to monitor variability (and the integrated effect of environmental factors that influence yield). Recent technology improvements have enabled the accurate and effective monitoring of cotton yield. Subsequently yield monitors are becoming more commonly used in cotton pickers.

Outside of simple visual inspection, the main uses of yield maps rely on having other layers of information for combined analysis. These analysis outcomes include:

- Determining which soil types yield highest and lowest.
- Prioritizing management efforts with respect to soil types.
- Calculating which fields or parts of field are viable for earthworks.

- Calculating yield loss from areas in dryland fields that are water logging, and therefore the viability of surface drainage.
- Overlaying in-season imagery to build knowledge of yield outcomes at certain stages of crop growth for future crops.
- Building yield-potential zones with actual yield data for more accurate pre-crop fertiliser application.
- Calculating the viability of using gypsum in dryland or irrigated fields.

Using a simple correlation analysis method we can investigate cotton yield on a zone level based on EM value. Figure 1a shows Cotton Yield in 2002 (y-axis – right) is compared within EM zones (x-axis). In this situation the highest yielding zones (i) are also our higher area zones (y-axis- left) (b) and low EM zones. This indicates water was managed well in this irrigated field.

Further analysis showing profit/ha (b) identifies areas that have made money vs. areas that have lost money – the higher EM zones (in this case investigation in the field revealed high salt levels) are negative profit but only encompass a total area of approximately 3ha.

Using zones rather than ha basis, profit, revenue and costs are tightly aligned, but show a cumulative value for each zone based on the calculated ha's in each zone.

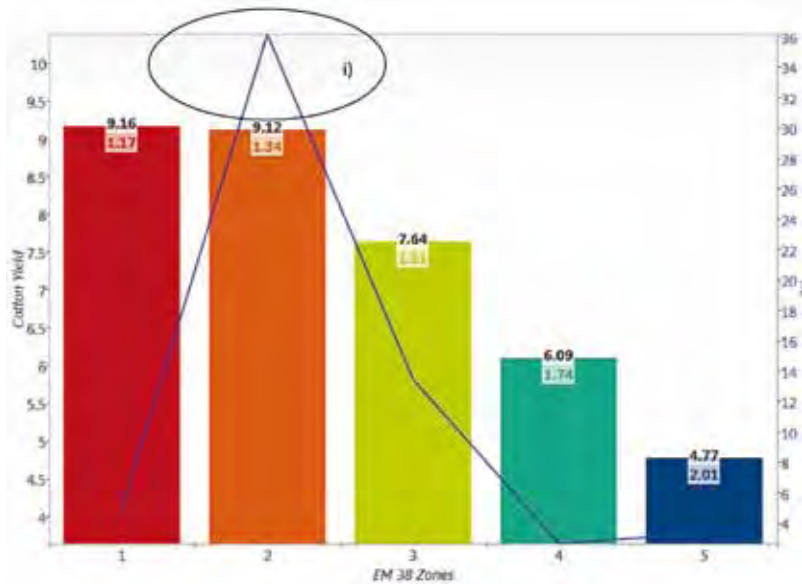
Summary

Growers all across the cotton producing regions of Australia are starting to realise the benefits of PA. For some the benefits flow quickly, while for many a lead time of data collection, analysis, and knowledge enhancement is required before realistic management plans can be implemented to manage spatial variability. Over the past decade personnel at Precision Cropping Technologies have observed and aided a wide variety of successful PA outcomes. Most agronomic solutions are, by definition, site specific, and require local knowledge and expertise. All growers are advised to discuss their ideas about PA with their agronomist.

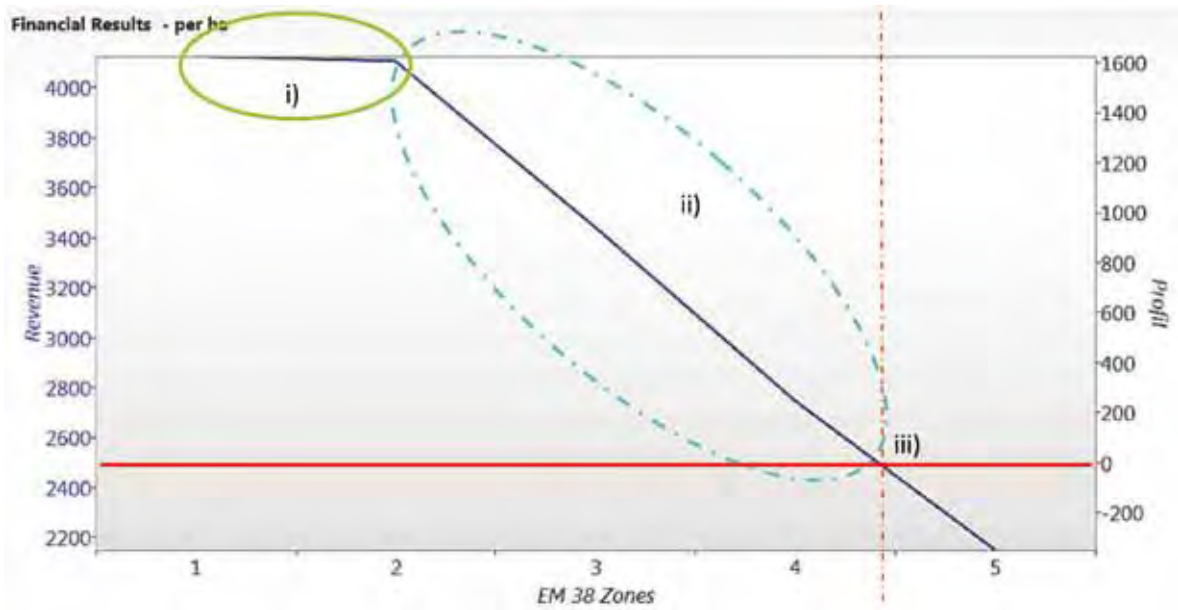
FIGURE 1:

Correlation between cotton yield (ba/ha) and EM zones (a), showing financial results per ha (b) and per zone (c) where revenue, costs and profits were based on receiving \$450/bale and the cost/ha was \$2500.

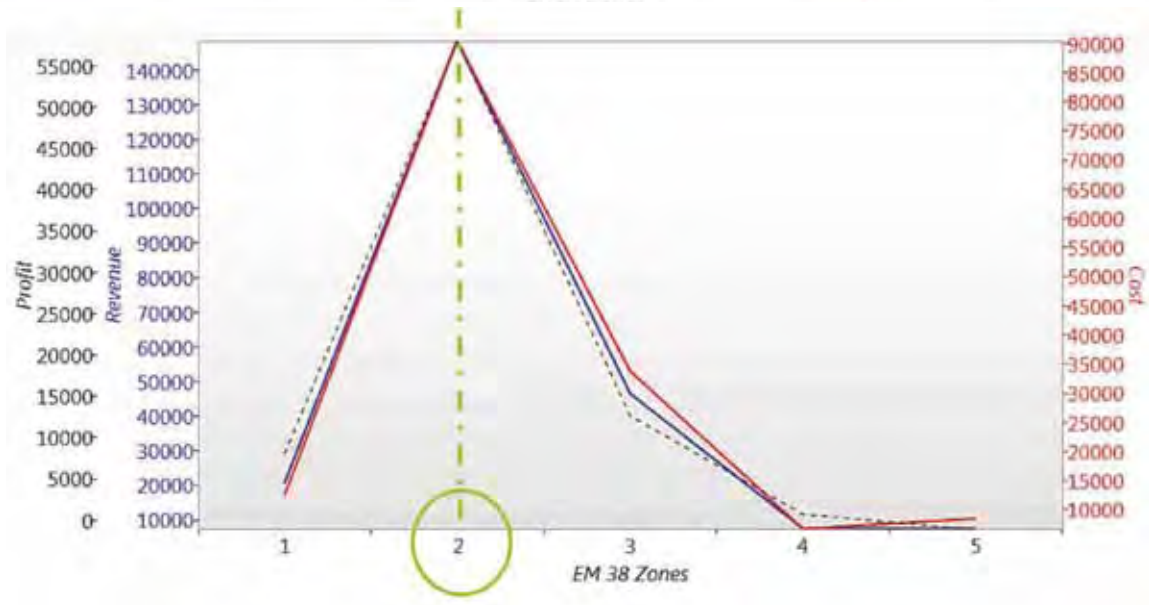
A



B



C



Efficient Spray Application For Cotton

By **BILL GORDON & GRAHAM BETTS**

Achieving the best outcome from spray application requires the careful consideration of many factors. The aim of spray application is to transfer active ingredients through the atmosphere to the target in an effective manner with minimal off-target losses. Application technique needs to be matched to the target and weather conditions. Movement of spray beyond the target area is undesirable as it represents wastage of product and exposure of non-target sensitive areas to potentially damaging materials.

Always read and follow the label when handling and applying chemicals and be aware of federal and state regulations for chemical application. Staff responsible for handling and applying pesticides must be qualified according to relevant state and federal requirements. There may also be workplace health and safety requirements related to storage and use of hazardous chemicals, which require risk assessments to be completed, in addition to maintaining a manifest and Safety Data Sheets for those chemicals deemed to be hazardous. The *myBMP* program can help growers to understand their legal obligations.

Tips to reduce drift

Source: <http://www.cottonmap.com.au>

Spray drift is a major concern in most agricultural areas today. The presence of sensitive areas located within close proximity to the spray target area introduces the possibility of off-target deposition. It is more important than ever that the agricultural industry demonstrates responsible chemical usage to reduce the need for severe application restrictions.

Plan

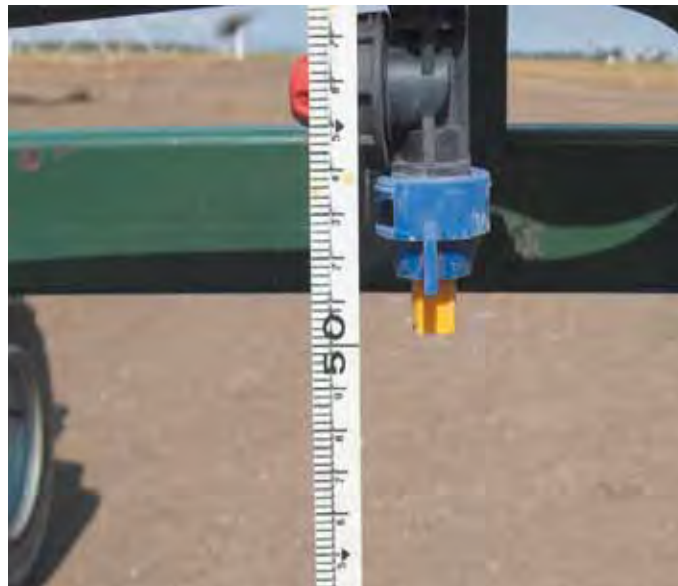
- The development of a comprehensive pesticide application management plan (PAMP) before each season is considered best practice. Having a PAMP in place helps to ensure that everyone involved in pesticide application has a clear understanding of their responsibilities. The PAMP should cover:
 - Farm layout;
 - Identification of sensitive areas, potential hazards and awareness zones;

- Communications procedures;
- Pesticide Management Guidelines; and,
- Accident and emergency procedures.

- Utilise tools such as www.spraywisecisions.com.au to plan the most appropriate application windows.
- Spraying in a cotton area? Check www.cottonmap.com.au for neighbouring fields prior to application.
- Read the product label.
- Communicate with neighbours.
- Upskill by attending a Nufarm Spraywise training course or one run by specialist application consultants such as Bill Gordon, Graham Betts, Craig Day.
- Remember the 6 P's = Perfect Planning Prevents Poor Pesticide Performance.

Boom height/false target

- Boom height needs to be adjusted to the height of the false target (stubble height) or the height of the target – whichever is greater.
- Keep boom height to a minimum (ie 50cm above target/false target for 110o nozzles at 50cm nozzle spacing).
- Increasing the boom height from 50cm to 70cm may increase the amount of driftable fines up to 4 times, and a boom height increase from 50cm to 100cm multiplies them up to 8 times!!



Spray quality

- A COARSE to VERY COARSE spray quality must be used when applying 2,4-D products – EXTREMELY COARSE may be warranted if night spraying.
- Choose the nozzle producing the coarsest spray quality without compromising efficacy. Refer to Nufarm's Boom Spray Application Guide for a full range of recommended water rates and spray qualities for all Nufarm products.
- If needed, include drift-reducing adjuvants such as LI 700®, Activator® or Bonza®.

- Use nozzles at appropriate pressure: conventional nozzles 1.5-3 bar, pre-orifice nozzles 2-4 bar, Low-pressure air induction nozzles 3-5 bar, high-pressure air-induction nozzles 4-8 bar.

Inversions

DANGER – DO NOT spray when a low-level inversion exists.

- During those inversions distinct, isolated layers of air have formed close to the ground. As a result driftable fines are not subject to dilution with the atmosphere.
- Low-level inversions frequently form in the late evening and strengthen overnight - they are strongest near sunrise.
- Use visual indicators such as moisture, smoke or dust to determine if a low-level inversion is present.
- Rule of thumb: the greater the difference between daily maximum and minimum temperatures, the stronger the low-level inversion.

Refer to: **The influence of surface temperature inversions on spray operations.**

Night spraying

- The advent of GPS self-steer and a desire to work within appropriate Delta Ts has seen an increasing trend towards night spraying, particularly during the summer months. Spraying at night dramatically increases the chance of applying product in adverse conditions.
- Night spraying can strongly favour conditions that can trap and move the applied product far from the target area (see inversions). Be particularly vigilant 1 hour either side of sunrise.
- Be aware that the rainfall period will be longer.
- Obtain forecast and monitor for still or low-level inversion conditions.

Wind speed and no-spray (buffer) zones

- It is best to apply pesticides when the wind is blowing away from sensitive areas and crops. Wind speed must be steady between 3 km/hr and 15 km/hr.
- If the wind stops blowing at night – stop spraying immediately (see inversions below).
- Always read the label to see if a mandatory wind speed requirement exists, or if a No-spray zone is required for any of the products you plan to use.
- Rule of thumb: most directional wind changes in Australia will occur in an anti-clockwise direction.

Spray weather summary

- Avoid calm, variable or gusty wind (calm conditions give no positive indication of droplet displacement).
- Be aware of local topographic and convective influences on wind speed and direction.
- At night the cool (heavier) air behaves like water and drains to lower points (waterways, frost-prone paddocks) taking any fine droplets suspended in the air with it as well.
- Record on-site weather conditions at the start and finish of every pesticide application.

The influence of surface temperature inversions on spray operations

Source: GRDC's Surface Temperature Inversions and Spraying Fact Sheet http://www.grdc.com.au/uploads/documents/GRDC_FS_Spray%20drift%20temp%20inversions1.pdf

Acknowledgements: Graeme Tepper, MicroMeteorology Research and Educational Services; Bill Gordon, Bill Gordon Consulting Pty Ltd.

In cooling night conditions airborne pesticides can concentrate near the surface and unpredictable winds can move droplets away from the target. Understanding weather conditions can help spray applicators avoid spray drift

Surface temperature inversions

Inversion conditions can differ significantly from the broader forecast weather patterns. During the night the ground loses heat and the low level air cools (Figure 2). This results in air temperature increasing with height and the temperature profile is said to be inverted. When this occurs close to the ground it is called a surface temperature inversion. In a surface temperature inversion the point where the temperature stops increasing and begins to decrease is the top of the inversion layer. When a strong surface temperature inversion has established, it can act like a barrier, isolating the inversion layer from the normal weather situation, especially the normal wind speed and direction (Figure 3).

During daylight hours the temperature of the soil surface gradually increases. Air in contact with the ground also warms (Figure 2). In this situation the air temperature normally becomes cooler with height. Wind speeds during daylight hours will generally be more than 3 to 4km/h and the air movement across the surface will tend to be turbulent. Turbulence close to the ground causes the air to mix, due to the rolling motion of the air across the ground surface. Mixing is also caused by thermals, which interrupt airflow. This mixing of the air assists in diluting airborne droplets and helps to drive many of them back towards the ground. When this dilution occurs, a safe buffer distance between the sprayed area and potentially sensitive areas downwind from the application site can be estimated.

Surface temperature inversion conditions are unsafe for spraying as the potential for spray drift is high. Under a surface temperature inversion:

- Air movement is much less turbulent so the air does not mix in the same way as during the day;
- Airborne droplets can remain concentrated in the inversion layer for long periods of time;
- The direction and distance pesticides movement is very hard to predict;
- The movement of airborne droplets will vary depending on the landscape; and,

• Droplets or their remnants can move in different ways. Research supported by the GRDC is further investigating the development and implications of temperature inversions in relation to spray application.

When and why do surface temperature inversions occur?

Surface temperature inversions usually develop overnight and can persist well into the next day. They can result from a number of processes that cause the air closest to the ground to become cooler than the air above. The three main reasons experienced in broadacre agriculture are:

1. Radiation inversions (created by radiation cooling)

Radiation inversions can form at any time during the night when wind speed is less than about 11km/h and cloud cover does not severely restrict surface cooling. In calm and clear sky conditions they may form just before sunset. Once the sun has set and has stopped heating the ground, heat radiates back into space, causing the ground to cool. In turn, the air in contact with the ground becomes cooler than the air higher in the atmosphere. This generates the surface temperature inversion. Radiation inversions are the most dangerous for spraying operations as they cause airborne droplets to remain concentrated at a low level for long periods. Winds within the inversion can carry these droplets long distances. On gentle slopes, concentrated droplets can be transported many kilometres by drainage winds towards the lowest point in the catchment. Under an inversion, where water runs from a property, droplets can move.

2. Inversions created by advection (cool or warm air movement)

Cooler, denser air can move into an area and slide under layers of less dense, warm air. This can happen when a cold front moves into an area, or a sea breeze pushes cooler air inland. It can also happen when denser cool air moves down a slope and slides underneath layers of warm air in lower parts of the catchment. If this occurs, the intensity of a radiation inversion increases. Warm air can move over cool surfaces; some of the air closest

FIGURE 1:

Effect of atmospheric stability

Smoke	Condition	Notes	Spray?
	NEUTRAL (e.g. morning)	Cool breeze (4–15 km/h) Optimum spray conditions.	✓
	UNSTABLE (e.g. afternoon)	Hot. Low windspeed, thermal activity. Risk of upward movement of fine droplets.	✗
	INVERSION (e.g. night)	Low windspeed. Hot during day. Risk of significant off-target deposition of fine droplets.	✗
	STABLE (e.g. dusk)	Low windspeed. Risk of off-target spray deposition.	✗

to the ground becomes cooler while the higher air stays warmer.

3. Inversions created by vegetation

Vegetation and crops can shade the ground underneath them. The air in contact with the ground will stay cooler than adjacent areas where there is less groundcover. This often occurs just after sunrise. The air moving above the vegetation or crop may be warmer than the air below the vegetation. This can allow airborne droplets to travel over, rather than through, vegetation. Transpiration from a dense crop canopy on a hot day can form a cool layer of air just above the crop. Later in the day (when wind speeds tend to reduce) this layer of cooler air can act like an inversion over the crop, making penetration of smaller spray droplets into the canopy very difficult and increasing the risk of off-target movement.

Recognising a surface temperature inversion

The scientific method for detecting a surface temperature inversion requires the accurate measurement of the air temperature close to the ground and at a height of at least 10m. On-farm, this is usually not practical, so most spray applicators must rely on visual clues.

Visual clues

A surface temperature inversion is likely to be present if:

- Mist, fog, dew or a frost have occurred;
- Smoke or dust hangs in the air and moves sideways, just above the surface; and
- Cumulus clouds that have built up during the day collapse towards evening.

Other clues

A surface temperature inversion is likely to be present if:

- Wind speed is constantly less than 11km/h in the evening and overnight;
- Cool, off-slope breezes develop during the evening or overnight;

FIGURE 2:

Typical vertical temperature profiles for a point in time during the night and day. At low levels, the day profile typically cools with height and the night profile typically warms with height. Little change occurs at elevated altitudes. (Source Graeme Tepper)

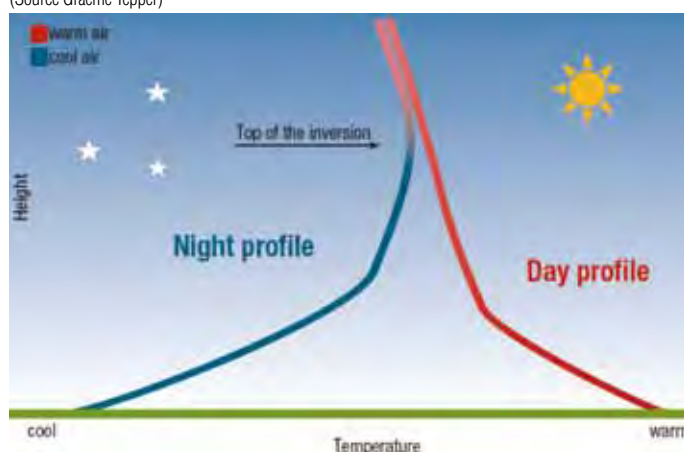
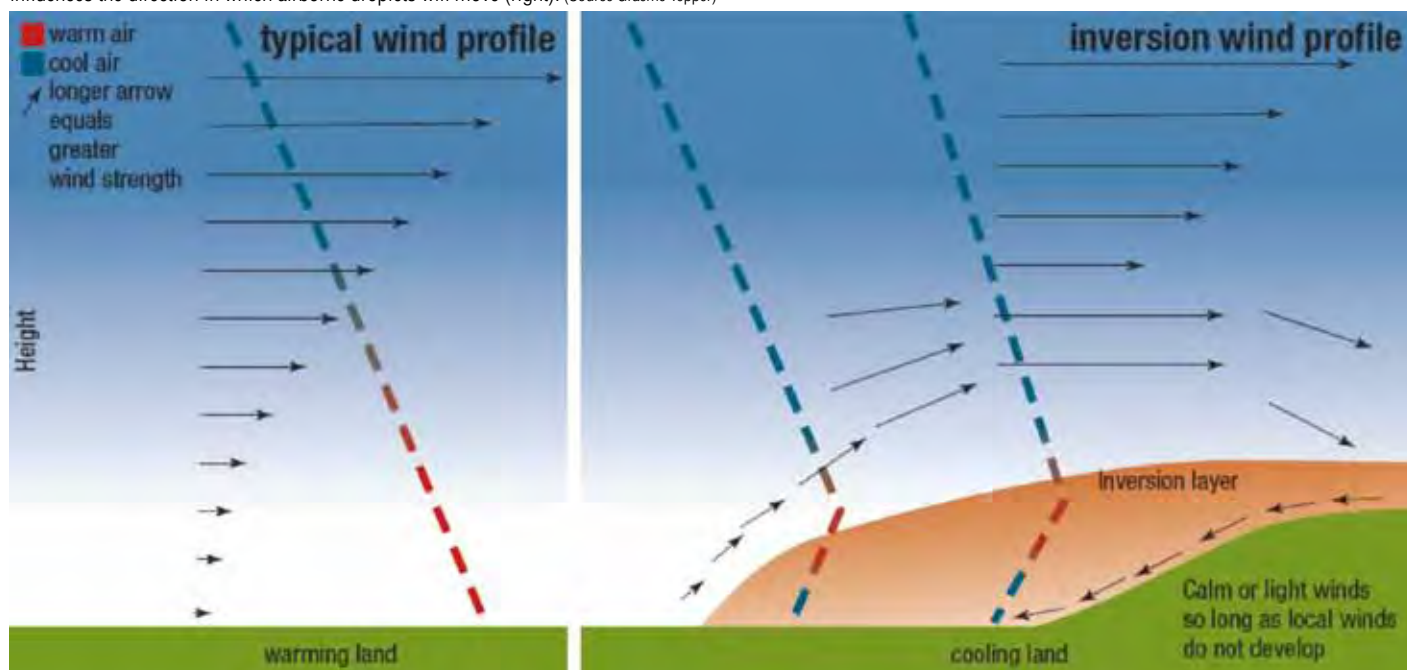


FIGURE 3:

Air movement under a surface temperature inversion differs from a typical wind profile (left). Surface winds de-couple from the surface, accelerate and flow over the inversion. Within the inversion, winds are typically light and often drain down slope, regardless of the overlying wind direction. Under an inversion the shape of the landscape also influences the direction in which airborne droplets will move (right). (Source Graeme Tepper)



- Distant sounds become clearer and easier to hear; and
- Aromas become more distinct during the evening than during the day.

Clues that a surface temperature inversion is unlikely

Applicators should always expect that a surface temperature inversion is most likely to have formed at sunset and will persist for some time after sunrise. However, a surface temperature inversion is unlikely if one or more of the following has occurred:

- Continuous overcast weather, with low and heavy cloud;
- Continuous rain;
- Wind speed remains above 11km/h for the whole* time between sunset and sunrise; and
- After a clear night, cumulus clouds begin to form.

*Sometimes the overnight wind speed can pick up from virtually calm to speeds greater than 11km/h during a surface temperature inversion. This is why the wind speed must be constant all night to ensure the air continues to mix and prevent airborne droplets from becoming concentrated and moving away from the sprayed area.

Further information can be found on the GRDC 2013 Weather Essentials for Pesticide Application booklet www.grdc.com.au/GRDC-FS-SprayInversions

Calculating banded sprays

By **BILL GORDON & GRAHAM BETTS**

Often people want to know the actual application rate and how much chemical to put in the tank (based on green ha or sprayed ha), how far a tank will go (based on paddock ha) and what rate to put in the spray controller. Others want to know what nozzles they should use to achieve a recommendation they have received from their advisor.

The Ispray Banded Spray Calculator for Cotton allows the user to determine suitable nozzle size, flow rates and rate controller settings for banded applications to cotton. Users can adjust speed and application volume to adjust the setup to determine optimum settings for their application. Works for standard booms and banded setups on solid plant or skip row configurations. It is



The Ispray Banded Spray Calculator for Cotton allows the user to determine suitable nozzle size, flow rates and rate controller settings for banded applications to cotton. Users can adjust speed and application volume to adjust the setup to determine optimum settings for their application. Works for standard booms and banded setups on solid plant or skip row configurations. It is available for download as an App on the Google Play Store for Android devices or from the Apple App Store on iPhone and iPad devices.

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– Sean Boland

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There are often big differences between the consultant's recommendation, the applicator's instincts and what the machine can actually do with the nozzles available. The main reason for a banded application is to place the recommended rate of the product onto an area smaller than the whole field (this way we use less chemical over the whole field, but still apply the equivalent rate/ha to the actual target area).

To work out the true application rate we need to know the sprayed width, or average sprayed width for each nozzle, this allows us to calculate the litres per sprayed ha (L/sprayed ha sometimes called L/green ha). Label rates are always given as L/sprayed ha. Advisors should always give recommendations as L/sprayed ha. To apply the correct L/sprayed ha there are two main things to work out:

How much chemical to put in the tank, which is based on L/sprayed ha.

What to put into a controller, which is based on paddock ha per tank, (unless you want to play around with section widths).

Formula

(The following are a selection, there are many that work.)

Band width in metres: **eg 0.7m band** ÷ 1 m row spacing = band width (m) ÷ row spacing (m).

Sprayed width per nozzle (m): = **band width (m)** ÷ **number nozzles per band** (eg 3 nozzles per 70% band of a 1 m row = 0.7 m ÷ 3 = 0.23m).

The application rate = **L/sprayed ha**: **L/sprayed ha** = **L/min/nozzle** x **600** ÷ **speed (km/h)** ÷ **sprayed width per nozzle (m)**.

L/sprayed ha applies to each band (row), whether you spray 1 band (row), or many rows, whether it is a solid plant, single skip or double skip.

Number of sprayed ha per tank = **Tank size (L)** ÷ **L/sprayed ha**.

Amount of chemical to add per tank = **Sprayed ha per tank** x **chemical rate/ha**.

Paddock ha per tank (solid plant): = **Sprayed ha per tank** ÷ **band width (m)**.

Paddock ha per tank (Skip Row Configurations): eg Double Skip on 1m row spacing (only planted 1 out of every 2 rows), this would be the same as only spraying 12 x 1m rows with a 24m boom.

Paddock ha per tank (skip) = **Sprayed ha per tank** ÷ **the band width (m)** x **width of boom** ÷ **row width (m)** ÷ **number of planted rows under the boom**.

Rate to put in the Controller: = **Tank Size (L)** ÷ **Paddock ha per tank**

*this works if you don't want to change the section widths in the controller.

Spraywise Boom Spray Hygiene – Cleaning Procedures

GROUP	CHEMISTRY	PRODUCTS	CLEANING PRODUCT
A	Dims	Sequence	Tank and Equipment Cleaner
	Fops	Nugrass	
B	Imidazolinones	Midas® Arsenal Xpress, Spinnaker Intervix®, Raptor®	Small amount of Tank and Equipment Cleaner or water
	Sulfonyl Ureas	Associate®, Lusta®, Monza® Nugran®, Sempra	Chlorine Bleach
C	Triazines	Nu-Trazine 900 DF Convoy® DF Diuron 900 DF	
		Flowable Diuron, Flowable Simazine	
		Nu-Tron 900 Df, Prometyrn 900 DF, Simazine	
	Benzonitriles	Bromicide 200	
D	Dinitroanilines	TriflurX, Rifle 440	
F	Phenoxynicotinanilides	Paragon, Nugrex	
G	Diphenyl Ethers Triazolones	Striker, Affinity®, Hammer®	Alkaline Detergent 'Omo®' or 'Spree®'
I	Benzoic Acids	Kamba 500, Comet 200, Conqueror	Tank and Equipment Cleaner
		Invader 600	
	Phenoxy Acetic Acids		
	Mcpa (Dimethylamine)	Agritone 750	Cloudy Ammonia followed by Tank and Equipment Cleaner
	Mcpa (Ethyl Hexyl Ester)	Bromicide MA, Nugrex, Paragon	Tank and Equipment Cleaner
	Mcpa (Iso-Octyl Ester)	Broadside, Agritone LVE	
	Mcpa (Potassium Salt)	Trooper®	
	2, 4-Db	Buttress®	Cloudy Ammonia followed by Tank and Equipment Cleaner
	2, 4-D (Dimethylamine And Diethanolamine)	Surpass 475, Amicide 625	
	2, 4-D (Dimethylamine)	Baton®, Kamba M, Surpass 475	
2, 4-D (Ethylhexyl Ester)	Estericide Xtra	Tank and Equipment Cleaner	
Pyridines	Archer		
J	Thiocarbamates	Avadex® Xtra	Small amount of Tank and Equipment Cleaner or water
K	Chloroacetamides	Bouncer	
L	Bipyridils	Revolver, Nuquat 250	
M	Glyphosate	Roundup, Roundup Biactive Roundup CT Roundup PowerMAX®, Roundup Ready Herbicide with PLANTSHIELD, Weedmaster Duo	Water
Q	Triazoles	Amitrole, Illico®	Small amount of Tank and Water Equipment Cleaner or water
Z	Arylamino propionic Acids	Mataven 90	

A first rinse with cloudy ammonia will clean hard deposits in filter and lines. After flushing the tank, a second rinse with Tank and Equipment Cleaner should be used as a follow up.

Selecting the correct nozzle size for a particular job

To work out what size nozzles you need to get a particular L/sprayed ha, you need to know what the required flow rate of each nozzle (L/min/nozzle) should be. If all nozzles are the same size this is relatively easy, as the flow rate will be the same for each nozzle.

For example the average sprayed width per nozzle if you had 5 nozzles per 1 m row at 100% band would be $1\text{m} \div 4 = 0.2\text{m}$.

If you had 4 nozzles per 1m row and a 70% band, then the average sprayed width would be $0.7\text{m} \div 5 = 0.14\text{m}$.

To calculate the required flow rate of each nozzle, the formula you need to use is: **L/min/nozzle = L/sprayed ha \div 600 x speed (km/h) x average width of each nozzle (m)**

If you are using different combinations of nozzle sizes, you can still use the same formula, but it helps to work out the total flow rate for each band (or row), to do this, change the average width per nozzle to the band width or spray width per band (row) to get the total flow required per band (or row) and select nozzles with flow rates that add up to that total (all at the same pressure). Once you have calculated the required L/min/nozzle use a nozzle flow chart to identify appropriate nozzle sizes and pressures, and don't forget to check the spray quality produced to ensure it is consistent with the product label.

Bill Gordon has worked closely with the cotton and grains industry for many years and runs workshops for farmers and trainers. Contact Bill Gordon Consulting 0429 976 565 E:bill.gordon@bigpond.com

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

Cotton pest management guide

GRDC factsheets on:

- Spray Mixing Requirements
- Spray Water Quality
- Preseason check and Controller Settings

Information on weather:

Weather essentials for pesticide application, Graeme Tepper, GRDC.

GRDC Fact Sheet on Weather Monitoring Equipment

Information on weather forecasting tools:

Spraywisedecisions.com.au

– Syngenta.com

– Agricast

Information on pesticide application:

– Spraywise Broadacre Application Handbook, Dr Jorg Kitt, Nufarm Australia

Information on nozzle selection tools:

– Teejet Nozzle Selection App

– Hardi Nozzle App

– Ispray.com.au Nozzle selection tools

– Ispray banded spray calculator for cotton – available on Google Play store for android and the app store for iPhones and iPads.

Better Farming Future

**Integrated Pest Management
Stewardship – Reducing The Risk Of Resistance
Integrated Weed Management
Integrated Disease Management
Field Selection, Preparation & Rotation
Managing Cotton Stubble
Natural Resources**



Integrated Pest Management

By **TRACEY LEVEN (CDRC)**

What is Integrated Pest Management (IPM)?

IPM is the use of all available tactics and resources to reduce the frequency with which pest outbreaks occur on your farm and your reliance on insecticides for their management. IPM is both pre-emptive and responsive. It requires some lateral thinking and some basic knowledge of how insects behave. Upfront tactics work to reduce the incidence of insect pests on your farm. Active tactics enable you to suppress populations in-crop at levels that protect its quality and yield. IPM is a whole year, whole farm approach to managing pests which firstly requires you to devise a plan, taking stock of the resources available to you.

Have a plan

When it comes to pests, fore warned is fore armed. Assess the attributes of your farm and develop an IPM plan as part of your decision to grow cotton. Your plan will become a good reference point during the growing season if tough decisions need to be made. A plan can be as simple as setting a budget for expenditure on pest control for the upcoming season, however this may undervalue your farm's potential and your ability as a pest manager. Challenge yourself to set goals in your plan that will be relevant for many seasons and help you work towards your overall goals for the farm business. Working with others, such as those who provide you with advice, to set your goals, can be an excellent way of ensuring everyone is working to the same priorities for

BEST PRACTICE

- Recognise and foster resources that lower the survival of pests on your farm between cotton seasons.
- Know what's going on in your crop – regularly monitor crop growth, insect presence and insect damage.
- Conserve beneficial insects in your crop by avoiding 'insurance sprays' and choosing a selective option when an insecticide is needed.
- Follow the IRMS to protect the value of insecticide technologies for the future.
- Work as part of a team – with others in your farm business and with neighbouring farms – to keep people safe, to protect your environment and to get the greatest value out of the resources you invest in pest management.

the farm business. Some examples of IPM goals that your business may aspire to are:

- Starting each cotton season with low / no pest populations on the farm.
- Avoiding 'insurance' sprays.
- Following the cotton industry's IRMS when an insecticide is required.
- Making non-crop areas of the farm more productive.
- Avoiding pest outbreaks that are generated within the farm.
- Accommodating apiarists' use of the landscape.
- Strengthening relationships with neighbours.
- Recognise Your Resources

Insects and mites move around the landscape for basic reasons – to find food, to find a mate, to find a favourable place for their juveniles to thrive, because they are blown by wind or because they're seeking shelter from harsh weather. Your IPM resources are the attributes of your farm that act to make these basic needs difficult for pests to satisfy, or conversely easier for them to satisfy away from the crop you are aiming to protect. Thinking about IPM in this way, spending money on insecticides during the season isn't the only way to get 'bang for your buck' in pest management. Insecticides have the advantage of being very targeted, but their influence is very short lived compared to investment in tactics that constantly suppress pests' capacity to thrive.

Veg is valuable

Insect pests live a life of chance. Their short lifecycles and impressive reproductive capacities are essential for them to survive given the equally impressive number of ways they meet their death. Complex vegetation, that is, vegetation made up of lots of plant types, rarely experiences insect outbreaks. In complex veg, the forces working against insect pests are either superior to or in balance with the forces working in their favour. Crops, by their definition lose the advantages inherent in complex veg, but can benefit significantly from having it nearby.

Insect predators – include birds and bats but are mostly other insects and spiders – prefer to live in complex vegetation. This is in part due to its permanence. Perennial native vegetation connects insect predators to crops – both in space and time. The role predators can play in pest suppression in crops is dictated by their ability to persist within a landscape and to move between habitats across the landscape. The following principles can be used to guide you in managing complex vegetation to lower the incidence of insect pests on your farm and enable you to start the season with low pest risk.

Manage for groundcover and diversity

Predators will keep pace with prey / pest populations where vegetation is complex. Complex vegetation has many layers (i.e. trees, shrubs, grasses and herbs) and a range of different plant species in each layer. The

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understory layer of grasses and herbs is most easily changed through management and season. The presence of livestock can result in simplification of the species if grazing periods are too long or there are too few watering points. In time, allowing stock to graze selectively can not only result in loss of the best species, but bare areas will also occur. Drought can result in similar degradations or exacerbate the impacts of grazing management over time.

Loss of groundcover and species diversity favours the establishment of weeds. Many of the annual broadleaf weeds of cropping, such as marshmallow (*Malva parviflora*), milk/sowthistle (*Sonchus oleraceus*), in winter and bladder ketmia (*Hibiscus trionum*) and thornapples (*Datura spp.*) in summer, are better hosts for pests than they are for their predators. When weeds take over beneath trees and shrubs, these areas can become net exporters of pests rather than net exporters of predators.

When planning revegetation, either to rejuvenate areas that are run down or to return a strategic area of crop or pasture to complex, perennial vegetation, prioritise the incorporation of trees and shrubs that flower prolifically. Eucalypts and melaleucas attract feeding insects that are not pests of cotton, which in turn attract a broad range of predator insects that will move into cotton. If seeding of ground species is possible, look to establish a mix of tussocky and sprawling grass together with a mix of winter and summer active legumes. Leaving logs, dead trees and litter where they fall will enhance the habitat for a range of predators.

Prioritise connectivity

The size and configuration of native vegetation in the landscape is important. Small, isolated remnants provide 'stepping stones' across the landscape, but the most effective natural pest control is attained from well-connected areas of native vegetation located nearby the crop. Native vegetation corridors or 'bridges' between remnants facilitate the dispersal of beneficial insects through the landscape and provide local habitat when crops aren't present.



Manage grazing to preserve species diversity. (Photo: Tracey Leven, CRDC)



Prioritise connectivity – insects live in the landscape not on farms. (Photo: Guy Roth)

Where there is little remnant vegetation in an area, focus revegetation efforts on the creation of corridors that link areas together. Fence line plantings, wind breaks and roadside verges can provide effective habitat for beneficials and facilitate movement into and between crops. Plant species diversity and perenniality is as important in corridors as it is in larger areas of vegetation to favour predators over pests.

Enhance habitat with water

More insect species will inhabit vegetation located near a water source. Semi-permanent or permanent water increases and stabilises vegetation condition, especially during drought. Selecting sites for revegetation that incorporate water sources, e.g. channels, storages, or table drains along road sides, will increase the role of vegetation in your farm's natural suppression of pests.

Most irrigation farms growing cotton are designed to retain some storm water runoff on the farm. In addition to the value of the water itself, this attribute of farm design significantly reduces risks to the environment from pesticide residues that move in water. Closed water systems have in the past enabled cotton growers to retain regulatory access to pesticides.

Channels that are nude of vegetation maximise the reticulation capacity of the system in major events. However, establishing perennial vegetation such as cumbungi and grasses on some channel areas, significantly improves the capacity of the system to breakdown pesticide residues on farm. Where water flows more slowly, residues are filtered out by the vegetation and broken down by the enhanced microbial activity associated with vegetated areas. Vegetating distances of 100-200 metres of channel can link habitats for insect movement, reduce erosion risk and protect the environment beyond your farm from pesticide residues.

Different pesticides breakdown in different ways. Strategically combining vegetation on some channels flowing into non-vegetated storage areas means the

system will be efficient at both microbial and UV degradation of pesticides.

Riparian vegetation is highly valuable habitat for insect predators. Floodplain woodlands such as those dominated by river red gum, coolibah and black box rely on floodwater to persist and remain in good condition in semi-arid environments.

For more information:

Pest and Beneficial Insects in Australian Cotton Landscapes, 2011

Growing Trees on Cotton Farms: A Guide to Assist Cotton Farmers to Decide How, When, Where and Why to Plant Trees – available from CRDC, Narrabri

Managing Riparian Lands in the Cotton Industry – available from CRDC, Narrabri

Your neighbours

Insects live in landscapes, not on farms. Area Wide Management (AWM) acknowledges that insects are mobile, and that the management regimes used on one farm have implications for the surrounding locality. By sharing your strategies and coordinating tactics, neighbouring cotton growers have in the past increased their success in implementing IPM.

AWM is relevant when neighbours have identified that they have goals in common. These may be the aim to reduce the early season build-up of pests on a regional/district scale, reduce the mid-season population pressure on susceptible crops or to prevent pest carryover from the end of one cotton season to the start of the next. Tactics that are more effective when implemented in concert with neighbours are weed management, planting windows, selecting insecticides in line with the industry IRMS and post season cultivation of diapausing *Helicoverpa* pupae (Bollgard II Resistance Management Plan). In many neighbourhoods farmers also need to work together towards longer term projects such as to connect areas of remnant vegetation across the landscape. A critical aspect of AWM is to bring together farmers based upon geography, even if from a range of different enterprises, including cotton and other dryland crops.

A key element of most groups that have worked well has been regular meetings before and during the season to share information, discuss strategies and their knowledge of pest presence.

For more information:

IPM Guidelines for Cotton Production Systems in Australia and Cotton Pest Management Guide

Rotation crops

A monoculture of cotton over a wide area reduces the opportunity for insect predators to persist in the landscape beyond the life of the crop. While complex, perennial vegetation offers the most stable habitat for predators, rotation crops also play a key role in linking areas of habitat – perennial veg and cotton – through time and space.

Rotation crops are hosts for a range of pests, some in common with the pests of cotton. Crop selection is based on markets and seasonal outlook, but consequences

for pest management should be factored into decision making, particularly the use of insecticides. The same principles of IPM apply in all crops. Many crops have strong capacity to grow more leaf or fruiting sites to compensate for pest damage. Base spray decisions on recommended thresholds because these take into account the capacity for compensation. If an insecticide is needed, judge the value of selective options not just on their price but flow on effects for other crops on the farm. The lower your farm's total use of insecticides, the greater the local persistence of insect predators.

Where rotation crops are grown at the same time as cotton, try to align insecticide selections with the Cotton IRMS.

For more information: Refer the Crop Rotations Chapter 17.

Varietal tolerances

Select a variety that suits the growing region in terms of season length. Early vigour is an important characteristic. A number of pests, such as thrips and symphyla can only cause economic damage to cotton when vigour is lacking and early growth is slow. Choosing variety characters and growing conditions that favour vigorous establishment can reduce the need to use insecticidal seed treatments and protect the crop from pests to which no effective insecticidal options are available.

Another plant characteristic that lowers the ability for pests to thrive on cotton is leaf shape. The okra leaf shape reduces the rate at which silverleaf whitefly, cotton aphid and two-spotted mite populations are able to increase in cotton.

The Bollgard II trait is ideally suited to IPM as the level of control of *Helicoverpa* spp. provided by the plant reduces the need to spray for these pests, which in turn lowers the need to spray for other pests. Without the primary disruption of from larval sprays, insect predators are able to establish and build over successive generations, keeping their prey populations in check.

Upfront tactics

Weed management

Weed management is perhaps the most undervalued tactic in IPM. Many cotton pests rely on volunteer cotton plants and weed hosts prior to migrating into cotton fields. Pests that gain the greatest advantage from weeds are those that can't hibernate when conditions are unfavourable. Cotton aphids, mirids and silverleaf whitefly are pests that have to constantly find host plants to survive.

Mild, wet winters create the highest risk of pest carryover from one cotton season to the next mainly because of the abundance of host plants in these conditions.

For pest suppression leading into each cotton season, weeds need to be managed in fallow fields, along field borders and irrigation channels and in perennial vegetation and pastures. Control with herbicides can provide robust, fast solutions, but in non-crop areas

costs are difficult to justify and conditions do not always favour their application. Over time, aim to vegetate non-crop areas with perennial, non-host species. Summer growing species that produce a bulk of growth in late summer will suppress the emergence and establishment of winter weeds much more effectively than bare ground. Take care in autumn to manage grazing pressure in pastures to maintain groundcover for winter.

In areas where herbicides are used, winter weed control should begin in late autumn and continue through winter and into spring. Combinations of herbicide and tillage, such as in a double knock, can increase the control of species with tolerance or resistance to herbicides.

Cotton volunteers are the worst weed in terms of pest risk. A 'zero tolerance' approach to cotton volunteers between crops will yield benefits to the farm in pest suppression, lower risks of insecticide and Bt resistance carryover, significantly lower risks of virus outbreak in the next crop and lower likelihood of new or exotic pests getting established.

Field selection

When selecting fields for planting cotton, consider the proximity to sensitive areas – such as watercourses, pastures and buildings – relative to the prevailing wind direction. The Bollgard II trait maybe most appropriate for fields adjacent to sensitive areas. Conventional cotton may be best placed embedded amongst Bollgard II cotton and rotation crops, where pest loads are diluted across all the crop area. When spraying is required for larvae control, the surrounding crops will also act as sources for rapid re-entry of insect predators.

As part of field selection, stubble loads and soil pest activity should be monitored in the lead up to planting. The presence/absence of soil pests can have a strong bearing on crop establishment, particularly if there's high probability that soil moisture conditions and average daily temperatures will be variable. There are no insecticidal control options for symphyla or nematodes – field selection is an important component of managing the rare but serious risks associated with these pests.

Also worthy of consideration is whether the intended location of cotton fields creates 'stepping stone' linkages between areas of crops and vegetation to enable movement of insect predators through the landscape.

Seed bed preparation

As an IPM tactic, seed bed preparation has become increasingly important in recent seasons. The small seed size of the high yielding Sicot 74 varieties demands specific attention at planting. Vigorous, healthy, early growth enables crops to recover from what can at the time appear to be significant early season damage from soil dwelling pests such as wireworm, mealy bug and symphyla. When plant vigour is strong and growth is rapid, cotton can fully recover without reduction in yield or delay in maturity.

For more information: Refer to Crop Establishment Chapter 4.

Planting time

In each cotton region there is a period when soil temperatures become optimal for cotton germination, 14°C, at planting depth at 9:00 am for three consecutive days and forecast temperatures are rising. Planting in these conditions reduce the need for prophylactic insecticidal seed treatments. By limiting the risk of cold shock (minimum temperature $\leq 11^\circ\text{C}$), plant growth rates will be such that seedlings outgrow pest damage. These conditions also increase seedling immunity to diseases and herbicides. However the planting decision is often a compromise to balance other limitations in the system, such as availability of planting moisture and the occurrence of these weather conditions relative to the overall length of the season.

Very late planted cotton has less yield potential and is more susceptible to pests such as whitefly which can be difficult and expensive to control. In areas susceptible to whitefly, coordinated planting windows can provide a period free from host crops to reduce population build up as well as preventing late crops from being inundated by mass movements of adults from senescing, defoliated or harvested crops.

Create a diversion

Trap cropping can assist in resistance management, as well as IPM, depending on the pests targeted and the timing of their use. Trap cropping aims to concentrate a pest population into a smaller area that is costs less to manage by providing the pest with an area of host crop that is more highly preferred and attractive than the crop you are aiming to protect. It is an IPM tactic that can be utilised on a farm level or area wide basis, either way it requires strategic planning and management to be effective.

Lucerne can be used as an effective trap crop for green mirids and aphids, as these insects prefers lucerne over cotton. Planted in strips within fields or along field edges, or in a field adjacent to a cotton fields, lucerne can effectively serve as a trap for mirids and aphids as well as enhancing the build-up of beneficial insects.

For strip configurations, strips at least 8 metres wide are required for every 300 rows of cotton. The configuration should be chosen to fit in with machinery and equate to about 2.0-2.5% of the field area. Alternatively, lucerne can be grown on the borders of a field, using an area equivalent to 5% of the field, or can be planted in a field adjacent to cotton.

In Central Queensland cotton growers use summer trap crops of pigeon pea as part of the RMP for Bollgard II cotton. A summer trap crop aims to draw *Helicoverpa* spp. away from the Bollgard II crop and concentrate them in a small area where they are controlled. In the RMP the trap crop is destroyed with slashing and cultivation.

For more information:

Agronomic management of lucerne in cotton systems, refer to cotton's Weedpak publication, Section 14.

Communicate responsibilities and expectations

While IPM aims to reduce the farm's reliance on insecticides, they inevitably still play a role. Risks associated with their use need to be actively managed. The core best management practice for safe and responsible pesticide use is to develop a pesticide application management plan (PAMP). Developing a PAMP helps identify the risks associated with pesticide applications specific to your farm situation and the practices that are to be put in place to minimise the risks. Implementing a PAMP makes everyone involved in a pesticide application aware of and understanding of their responsibilities.

A PAMP has two essential functions:

- Establishes good communication with all involved in the application of pesticides. This communication is required both pre-season and during the season. It should exist between the grower, the applicator, the consultant, farm employees and neighbours.
- Establishes the application techniques and procedures that are to be used on your farm.

Good record keeping is essential for demonstrating the implementation of your PAMP. Records enable farm management to check the effectiveness pesticide applications, to comply with regulatory requirements and to demonstrate due diligence.

For more information;

Refer to the Pesticide Management module in *myBMP*.

Monitoring

There are several important purposes of crop monitoring:

- Determining whether the crop is growing optimally.
- Detecting the presence of insects – pests and predators – through the field.
- Finding evidence of insect damage to the crop

Monitoring data provides the basis on which tactical decisions about pest management can be made in-crop.

Making well informed and rational pest management decisions will provide the best opportunity to protect yield and minimise the need to spray and incur further pest control costs.

Check frequently

Crops should be checked at least twice weekly, with different emphasis depending on the time of the season.

Early season emphasis should be on plant growth and signs of damage.

Once squaring commences, emphasis is across plant growth, fruit retention, insect presence and signs of damage.

Once the economic yield of the crop is set (cutout), emphasis is on insect presence and signs of damage.

It is generally not possible to make a decision about whether insect control is needed based on just one check. Good decision making requires the use of time series data so that rates of pest population development and



Industry training in sampling techniques is available. (Photo: Paul Grundy)

movement can be compared with both changes in insect predator numbers and the time remaining in the season during which the crop is susceptible to damage.

Determining whether crop growth is optimal

Cotton development can be predicted using daily temperature data (day degrees). The CottASSIST Crop Development Tool (CDT) uses this knowledge to enable crop managers to check the vegetative and reproductive development of their cotton crops compared to a

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potential rate of growth and development. A crop manager can use this information as a prompt to further explore why the crop may not be on track, and manage the crop accordingly.

Finding evidence of insect damage

Damage monitoring includes; leaf loss (important from establishment up to the 6 true leaf growth stage), growing point damage; loss of squares/flowers and boll damage. The type of damage encountered will provide clues as to which insects are responsible – which can help to target monitoring for pest presence. The type of damage inflicted by each of cotton's main insect pests is described in the Insects Chapter of the Cotton Pest Management Guide.

Detecting the presence of insects – pests and predators

There are a number of sampling techniques that have been thoroughly evaluated by industry research and are associated with the thresholds for insecticide intervention. Visual and Beat Sheet sampling are the most commonly used techniques – each has different strengths – meaning it is optimal to use a combination of both techniques.

Beat sheet sampling: A sheet of yellow canvas 1.5 m × 2 m in size is placed in the furrow and extended up and over the adjacent row of cotton. A metre stick is used to beat the plants 10 times against the beat sheet, moving from the base to the tops of the plants. Insects are dislodged from the plants onto the canvas and are quickly recorded. This method is excellent for detecting nymph and adult beetles and bugs – some of which are pests while others are beneficial.



A yellow nightstalker eating a mirid. (Photo: Mary Whitehouse, CSIRO)

Visual sampling: Involves systematically looking at upper and lower surfaces of leaves, along stems and inside squares, flowers and bolls. This method is excellent for detecting the eggs of pest and predator species as well as small sucking/rasping pests such as thrips, aphids, mites and silverleaf whitefly.

Insect numbers should be recorded either as numbers per metre or as a percentage of plants infested to easily compare numbers with the appropriate industry threshold and to allow a predator to prey (pest) ratio to be determined.

For more information:

Collecting and recording data about insect pests is described in the Insects Chapter of the Cotton Pest Management Guide.

Active tactics

Build bigger populations of beneficial insects

Predatory insects, parasitic insects and spiders consume pests. Collectively they are known as 'beneficials'. When abundant, beneficials considerably reduce pest numbers preventing the need for insecticides. The abundance of beneficial insects in a cotton crop is affected by food resources, mating partners, proximity to other sources of habitat, climatic conditions and insecticide sprays. For an IPM system to work effectively, both the attraction and conservation of beneficial insects is critical.

In cotton, lag phases in the build-up of beneficial populations reduce the ability for pest managers to utilise their services. Lags occur when the rate at which the pest population increases is initially faster than the rate at which the beneficial population increases. During the lag period, the crop may suffer economic damage from the pest. Lags are minimised where nearby habitat – rotation crops and perennial vegetation – creates higher starting populations of beneficials, where prophylactic application of insecticide can be avoided and where any insecticides that are needed are highly selective.

The abundance of some beneficial species can be increased through mass releases. Beneficials can be purchased for release in the crop. Lacewings and lady beetles are predators of a range of insect pests and are good candidates for mass releases in cotton. Both lacewings and lady beetles will preferentially feed on aphids. (A common spotted ladybird can consume up to 2,400 aphids in her lifespan!) When aphids are not available, they will feed on other small insects such as mites, moth eggs and mealy bug. For pests such as mealy bug, where there are no effective insecticidal options, beneficials play a particularly critical role and releases can offer significant value for money.

For more information:

Visit the website: the Association of Beneficial Arthropod Producers Inc (ABC Inc) – www.goobugs.org.au

Download: Pests and Beneficials in Australian Cotton Landscapes – www.crdc.com.au

Browse: Spotlight, "Buying in Bugs," Spring 2012 Edition – www.crdc.com.au

Choose insecticides wisely

When choosing an insecticide, in addition to the efficacy against the target pest, it is very important to consider its selectivity. Some insecticides have very little impact on beneficial insects while others are highly disruptive. The relative selectivity of all insecticides available for use in cotton is tabulated in the Insects Chapter of the Cotton Pest Management Guide.

The selectivity of the insecticide helps to assess the risk that following its use, populations of other pests may 'flare' (increase rapidly). For example, where a mirid population has increased above threshold during flowering and an insecticide is required, the best choice depends not only on your budget, but the product's selectivity relative to the types of beneficials you have

and want to conserve. Within the IRMS there are several options available at this time with differing selectivity profiles. The newer neonicotinoid product, clothianidin (tradename Shield), will reduce populations of lady beetles (aphid predators) and Eretmocerus wasps (whitefly parasitoids) but conserve predatory bugs and thrips (mite predators). In contrast fipronil (multiple tradenames such as Regent) will reduce predatory bug populations, conserve lady beetles and thrips, but have an unknown impact on the key wasp parasitoids of whitefly.

Increases in populations of non-target pests such as aphid, mite and whitefly may follow insecticide applications if the beneficial populations keeping them in check are disrupted. Also consider the use of reduced rates of synthetic insecticides mixed with either salt or spray oils. In some instances this will provide greater selectivity and better efficacy.

Ensure spray applications are accurate, timely and triggered by pest thresholds.

Pests such as aphids and mites often infest the edges of a field, not the entire field area. Discuss with your consultant whether it is possible to manage this type of infestation by only spraying the field borders. This may enable beneficial populations to keep pace with the remainder of the pest population in the field.

Be kind to bees

Bees collect nectar from cotton's extrafloral nectaries (under leaves) as well as from the flowers so they may forage throughout much of the season. Insecticide use makes cotton crops a high risk environment for bees. Bees are particularly susceptible to insecticides such as fipronil, abamectin, indoxacarb and pyrethroids. The productivity of hives can be damaged if direct contact with foraging bees occurs during the application, if foraging bees carry residual insecticide back to the hive after the application and when insecticide drifts over hives or over neighbouring vegetation that is being foraged by bees.

The annual Cotton Pest Management Guide provides additional information about insecticide risks to bees. The relative toxicities of cotton insecticides to bees are tabulated in the Insects Chapter and residual toxicity risks for bees are identified in the Spray Application chapter.


With good communication and good will, it is possible for apiarists and cotton growers to work together to minimise risks to bees, as both the honey industry and cotton industry are important to regional development.

The pesticide risk to bees can be reduced by:

- Applying pesticides toxic to bees in the evening when bees are not foraging;
- Notifying the apiarist when beehives are in the vicinity of crops to be sprayed to allow removal of the hives before spraying. Beekeepers require as much notice possible, preferably 48 hours, to move an apiary;
- Avoiding micro-encapsulated formulations such as that



Coolibah trees (*Eucalyptus microtheca*) are a primary source of nectar and pollen for honey bees. These trees grow on the black soil plains along many of the river courses in the cotton growing areas. When heavy budding occurs, beekeepers often move large numbers of hives into cotton growing areas for honey production. Budding and flowering only occurs in response to good spring rains meaning the timing is likely to coincide with the time when insecticides are used in cotton. In northern NSW the buds appear in November and the trees begin to flower mid-late December finishing about the end of January. Budding and flowering times vary by a few weeks in southern and central Qld areas.



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<p>Paul Kelly Moree Real Estate MOREE Ph: (02) 6751 1100</p>	

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used for lambda-cyhalothrin. These are particularly hazardous because the micro-capsules can be transported back to the hive along with the pollen;

- Inform contract pesticide applicators operating on the property of the locations of apiaries;
- Paying particular attention to windspeed and direction, air temperature and time of day before applying pesticides;
- Using buffer zones as a mechanism to reduce the impact of spray drift or overspray in vegetation used by bees; and,
- Avoiding drift and contamination of surface waters where bees may drink.

Communicate with neighbours

During the season, active communication between neighbours, farm employees, your consultant and the applicator is essential to successfully implement your Pesticide Application Management Plan (PAMP) and achieve your IPM goals.

Follow the IRMS when selecting pest control options

Resistance occurs when application of insecticide removes susceptible insects from the population leaving those individuals that are resistant. Mating between these resistant individuals or cloning of the resistant individual, gradually increases the proportion of resistance in the pest population as a whole. Eventually this can render an insecticide ineffective, leading to field control failures. Resistance can be due to a specific trait that is already present in a small portion of the pest population or due to enhancement of the insect's natural defence mechanisms.

Management of resistance is essential to ensure that valuable insecticides remain effective. The Australian cotton industry has developed an Insecticide Resistance Management Strategy (IRMS) for this purpose. The IRMS is designed to both delay resistance development and to manage existing resistance. Some core principles used in the IRMS include:

- Rotation between chemical groups with different modes of action.
- Limiting the time period during which an insecticide can be used. This restricts the number of generations of a pest that can be exposed to selection in each season.
- Limiting the number of applications, thereby restricting the number of selection events.

Spraying for one pest can simultaneously select resistance in another pest that is present, even though that pest may only be present at sub-threshold levels and not be specifically targeted. For example, if dimethoate is used to control mirids, aphids present at low levels are also being selected for resistance. Resistance is selected very quickly in aphids because they reproduce by cloning. In this instance, dimethoate not only selects for resistance to this chemical but also selects for a cross resistance to pirimicarb, even though it is from a different group of chemicals. The decision to use dimethoate for

mirids, leaves few options available for reliable aphid control. Hence the IRMS windows dimethoate for use late in the season and recommends not using dimethoate and pirimicarb in the same field.

Selective insecticide use is consistent with the IRMS, as this helps conserve beneficial insects. Insecticides appear in the IRMS in order of their selectivity – the most selective at the top of the chart available for use early season and the least selective at the bottom available for use at the end of the season.

For more information:

Go to the Stewardship chapter in this Manual.

View the Cotton IRMS in the annual Cotton Pest Management Guide – www.crdc.com.au

Resistance monitoring

Resistance monitoring for *Helicoverpa* spp., two-spotted spider mites, aphids and silverleaf whitefly, is conducted each year by the cotton industry and provides the foundation for annual review and updating of the IRMS. All growers and consultants have access to this industry service to investigate suspected cases of resistance.

For more information:

Aphids, mites and mirids: Dr Grant Herron, NSW DPI, 02 4640 6471

Silverleaf Whitefly: Dr Jamie Hopkinson, QDAAF, 07 4688 1152

***Helicoverpa* spp.:** Dr Lisa Bird, NSW DPI, 02 6799 2428 & Dr Sharon Downes, CSIRO, 02 6799 1576

Resistance management for Bollgard II cotton

Resistance management for Bollgard II cotton is critical due to the season long selection of *Helicoverpa* spp. to the Bt toxins produced by Bollgard II. Since commercial use of the first Bt toxin, Cry1Ac, began in Australia in 1996, there has been over 2,500 days of selection across 3,050,000 hectares. Such prolonged, intense selection creates enormous opportunity for resistance to become common in the population. To counter this, a proactive Resistance Management Plan (RMP) is in use to preserve the effective life of Bollgard II. The RMP requires the use of planting windows to limit the duration of selection each season, refuges to dilute resistance that is selected during the season and pupae busting or trap crops to destroy resistant individuals at the end of each season. Each of the elements of the RMP is highly compatible with IPM and their implementation should be of high priority in the farm's IPM plan.

For more information:

Refer to the Stewardship chapter in this manual.

Defoliation

The timing of defoliation can be an important IPM tool. Late pest infestation problems can sometimes be avoided by a successful defoliation. The Silverleaf Whitefly Threshold Matrix illustrates that control of whitefly to protect crop yield and quality is required between peak flowering and 60% open bolls. As the crop approaches the point where it can be defoliated, the reliance on insecticide intervention declines.

Pupae busting

In NSW and southern Queensland, *Helicoverpa* spp. spend the winter in the soil as pupae and emerge as moths in spring to mate and lay eggs. Pupae under cotton at the end of the season have a higher probability of carrying insecticide and Bt resistance. Their destruction has proven to assist in the management of resistance.

Pupae busting is required following harvest of Bollgard II cotton and is recommended in the industry's IRMS for all cotton.

For more information:

Refer to the Stewardship chapter of this manual and to the Insects chapter of the Cotton Pest Management Guide.

Zero tolerance for regrowth and volunteer cotton plants

Regrowth of cotton after harvest (ratoon cotton) provides habitat for nearly all cotton pests – *Helicoverpa* spp., spider mites, green mirids, mealy bug and aphids. Regrowth should be controlled by slashing, root pulling and/or mulching to prevent pests being carried between

seasons. Control around field edges, along roadways and in irrigation channels is as important as control within cropping fields. In areas with low accessibility this will require hand chipping.

While weather doesn't always permit, prioritise 'zero tolerance' throughout winter right up until cotton planting. Regrowth cotton is also the major risk for carry-over of Cotton Bunchy Top (CBT) disease. Cotton aphids feeding on infected plants through winter can spread CBT to adjacent cotton crops in the spring. However without a source of infected plant material, aphids will not continue to be infected and lose the ability to transmit the disease as they move around.

The Technology User Agreement for Bollgard II cotton requires the control of cotton regrowth.

For more information:

Requirements for managing Bollgard II volunteers are described in the Insects chapter of the Cotton Pest Management Guide.

Options for managing cotton volunteers and ratoons are described in cotton's Weedpak.



Maintain a zero tolerance for regrowth and volunteer cotton. (Photo: Lewis Wilson)

Stewardship – Reducing The Risk Of Resistance

By **SALLY CEENEY** (CottonInfo Team)

Insecticide stewardship refers to protecting the efficacy and longevity of biotechnology traits and insecticides used to control pests in the Australian cotton industry.

Resistance is an outcome of exposing pest populations to a strong selection pressure, such as an insecticide. Genes for resistance usually naturally occur at very low frequencies in insect populations. They remain rare until they are selected for with exposure to a toxin, either from an applied pesticide or from a biotechnology trait, such as the Bt toxins within Bollgard II. Once a selection pressure is applied, resistance genes can increase in frequency because the insects that carry them are more likely to survive and produce offspring. If selection continues, the proportion of resistant insects relative to susceptible insects may continue to increase until reduced effectiveness of the toxin is observed in the field.

Insecticide stewardship

The use of pesticides can select for resistance in pest populations. The cotton industry has implemented an Insecticide Resistance Management Strategy (IRMS) to manage the risk of resistance in aphids, mites and *Helicoverpa* spp. both in conventional and Bollgard II cotton.

The evolution of the IRMS is driven by the Transgenic and Insect Management Strategies (TIMS) Committee. TIMS is an industry committee facilitated by Cotton Australia. The results from the insecticide and miticide resistance monitoring programs, carried out each season, are used to inform the committee of any field scale changes in resistance levels. TIMS consults extensively with cotton growers and consultants in all cotton regions as part of finalising the IRMS each season. The IRMS is updated annually and printed in the Cotton Pest Management Guide.

The IRMS aims to minimise selection across consecutive generations of the pest. The way in which this can be practically achieved, depends on the lifecycle of the pest species, as the life cycles of *Helicoverpa* spp. and the sucking pests are very different, the IRMS recommends different use patterns for different chemistries.

The life cycle of the *Helicoverpa* spp. is 42 days (average). To minimise selection pressure across consecutive generations most chemicals that target *Helicoverpa* spp. are restricted to windows of between one and two generations. The life cycle of mites and aphids is much shorter than that of *Helicoverpa* spp. The resistance strategy for these sucking pests depends on rotation and non-consecutive use of chemistries. There are also restrictions on the maximum number of uses for individual products and chemical groups to further encourage rotation of chemistries. Non-consecutive use of chemistries is particularly important for aphids because they reproduce asexually, which means that all offspring from a resistant aphid will also be resistant.

The IRMS is split into two regions: Northern and Central/Southern. This delineation reflects the different growing seasons from central Queensland through to southern NSW. Since *Helicoverpa* spp. and mirids are capable of travelling long distances, the delineation is also designed to reduce the chance that pests moving between regions would be reselected repeatedly by the same insecticide group by limiting the time period in which most insecticides are available.

Pupae busting is an important tool in the IRMS. It is an effective, non-chemical method of preventing resistance carryover from one season to the next. The guidelines for performing pupae busting in sprayed conventional cotton are based on the likelihood that larvae will enter diapause before a certain date. This means that in specific field situations pupae busting is not necessary. The estimated commencement date of diapause is based on the model which drives the *Helicoverpa* Diapause and Emergence Tool on the Cotassist website. The web

Cotton IRMS:

The FIRST place to go when selecting a spray

Cotton IRMS

INSECTICIDE RESISTANCE MANAGEMENT STRATEGY 2013/14

BEST PRACTICE PRODUCT WINDOWS AND USE RESTRICTIONS TO MANAGE INSECTICIDE RESISTANCE IN APHIDS, SILVERLEAF WHITEFLY, MITES AND HELICOVERPA SPECIES.

2 - What stage are you in?

Central & Southern Regions: Balonne, Bourke, Darling Downs, Gwydir, Lachlan, Lower & Upper Namoi, Macintyre, Macquarie, Murrumbidgee

1 - Find your region

	STAGE 1 15 Dec 2012	STAGE 2 15 Jan 2013	STAGE 3 15 Jan 2013	STAGE 4 15 Feb 2013	WHICH PRODUCT FOR WHICH PEST? Refer to Tables 2-16, pages 8-xx.
SELECTIVITY	Foliar Bacillus thuringiensis (Dipel)				Excludes Bollgard II refuges.
	Foliar Bacillus thuringiensis (Gentrol, Viradip)				Avoid season long use of low ratios.
	Pyrimicarb				NON CONSECUTIVE APPLICATIONS.
	Parathion DM (Kancopy, Bioprest)				No restrictions.
	Cyfluthrin (Zelta)				After 1625 DD in a salvage situation, a knockdown is required before use.*
	Cyfluthrin (Zelta)				Note*
	Chlorantraniliprole (Alacor)				Note**
	Dicofol				Ground only, NSW only.
	Amorphous silica (Abrade)				No restrictions.
	Diatomaceous earth (Diatom)				NON CONSECUTIVE APPLICATIONS*
DOWNY MITE	Pyrimicarb (Eufit)				NON CONSECUTIVE APPLICATIONS*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
DOWNY MITE	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*
	Cyfluthrin (Zelta)				Note*

3 - What's the softest option?

4 - Have you reached the maximum number of applications?

5 - Have you met your other requirements?

STOP OVERWINTERING OF RESISTANT POPULATIONS BY PRACTISING GOOD FARM HYGIENE AND CONTROLLING WINTER HOSTS, PUPAE BUST AFTER HARVEST.

RESTRICTIONS AND NOTES DESCRIBE ALL USE RESTRICTIONS

NO MORE THAN ONE APPLICATION PER SEASON NO MORE THAN THREE APPLICATIONS PER SEASON

NO MORE THAN TWO APPLICATIONS PER SEASON NO MORE THAN FOUR APPLICATIONS PER SEASON

Note 1: If a non-chemical dressing is used instead of a neonicotinoid seed dressing then do not use pyrimicarb or dimethoate/omethoate. First foliar spray as there is cross resistance between them. All Dimethoate/omethoate use will select catastrophic pyrimicarb resistance in aphids so do not use pyrimicarb and dimethoate/omethoate in the same field.

Note 2: Failures of neonicotinoids against aphids have been confirmed. DO NOT follow a seed treatment with a foliar neonicotinoid when aphids are present.

Note 3: Cross check with the Silverleaf Whitefly Threshold Matrix, page xx.

Note 4: Maximum 2 consecutive sprays, alone or in mixtures.

Note 5: Additional applications can be made if targeting *Helicoverpa* moths using Magret.

Note 6: Sprayed conventional cotton crops defoliated after March 9 are more likely to harbour resistant diapausing *Helicoverpa* and should be pupae bused as soon as possible after harvest and no later than the end of August.

Note 7: Observe Withholding Periods, page 158. Products in this group have WHP 28 days or longer.

Note 8: High resistance is present in *Helicoverpa* *armigera* populations. Expect field failures.

tool uses long term average weather data to predict the timing of diapause.

Adherence to the IRMS is an important tool in pest management, particularly in Bollgard II cotton. Infestations of aphids, mites, mirids and silverleaf whitefly often require intervention with foliar insecticides to protect cotton yield and quality and as such there is a risk of resistance developing in these populations. The IRMS chart seeks to directly manage the risk of resistance in pests as well as reduce risk of inadvertent selection of pests that are not the primary target of the insecticide.

Large areas of Bollgard II will not change the frequencies of resistant genes being carried by *H. armigera* moths. The same proportion of resistant and susceptible moths will continue to lay eggs in cotton – be it conventional or Bollgard II. Hence the likelihood of resistance developing to foliar and soil applied insecticide remains the same, even if the overall size of the *H. armigera* population is reduced. Continuing to follow the IRMS will ensure that the industry retains the ability to control *H. armigera* effectively with the insecticides on cotton both now and in the future. The IRMS should always be consulted when making a spray decision, even in Bollgard II cotton.

Stewardship of Bollgard II cotton

The introduction and adoption of biotechnology traits has delivered significant benefits for Australian cotton growers and cotton production systems. Following the introduction of the first biotechnology trait (INGARD® cotton in 1996), biotechnology has today become a very important feature of cotton production and a key component in cotton breeding programs. In 2012, approximately 98% of the cotton planted in Australia contained at least one biotech trait which underlines the importance of the technology to Australian cotton growers.

Biotechnology has delivered real benefits to cotton growers and has significantly reduced some of the production risks associated with the crop. This has directly enabled growers to focus on key management strategies to drive yield and fibre quality outcomes. The technology has also allowed growers in non-traditional growing areas to explore cotton as a mainstream cropping option and adapt their farming system (irrigated or dryland) to benefit from cotton as part of their rotation.

Currently there are two broad classes of cotton biotechnology traits which are approved and available in Australian cotton varieties providing either insect protection, herbicide tolerance or in varieties which are 'stacked' with a combination of both traits.

The herbicide tolerant varieties are discussed in more detail in chapter 15. For more information on obtaining access to these biotechnologies please refer to chapter 3 of the Production Manual. This chapter will focus on the stewardship of biotechnologies that provide insect protection.

Bollgard II

Bollgard II cotton was introduced to the Australian market in 2005. It contains two genes derived from the common soil bacterium *Bacillus thuringiensis* (Bt). These bacteria produce a large array of crystalline proteins, two of which are produced in Bollgard II cotton, Cry1Ac and Cry2Ab. Cry 1Ac is specific to Lepidoptera (moths, including our major pests, *Helicoverpa* spp.) and Cry2Ab to Diptera (flies) and Lepidoptera, giving inbuilt protection against the larvae of *Helicoverpa* spp. (source: Monsanto).

The introduction of insecticidal transgenic varieties into the Australian cotton market has allowed the industry to reduce its pesticide use by more than 90% and is arguably the most important technology the industry uses. However, resistance is a great threat to the continued availability and efficacy of Bollgard II cotton in Australia. Even though the Bt proteins are derived from plant tissues, they still select for survival of resistant individuals. The Resistance Management Plan (RMP) for Bollgard II was established by regulatory authorities to mitigate the risks of resistance developing to either of the proteins contained in Bollgard II cotton.

When the RMP for Bollgard II was developed the frequency of resistance to both of the toxins that it expresses (Cry1Ac and Cry2Ab) was expected to be low. Screening for resistance in *H. armigera* and *H. punctigera* began around the time that Bollgard II was commercially released, revealing that baseline frequencies were much higher than anticipated.

While in both *H. armigera* and *H. punctigera* the first isolations of alleles conferring resistance to Cry1Ac were recently detected, these alleles remain rare (< 1 in 1,000). But, since developing the RMP for Bollgard II, CSIRO's monitoring has shown that in both of the main target species resistance to Cry2Ab is present, is higher than expected, and is probably increasing.

This is the case not only for *H. armigera* which has a track record of developing resistance to conventional insecticides, but also for *H. punctigera* which has shown limited ability of evolving resistance to conventional insecticide sprays. The continued efficacy of Bollgard II cotton is therefore dependent on the effective implementation of the RMP.

The Bollgard II RMP

The RMP is based around 5 key elements that impose limitations and requirements for management on farms that grow Bollgard II. These are mandatory growing of refuges; control of volunteer and ratoon plants; a defined planting window; restrictions on the use of foliar Bt; and pupae destruction. In theory the interaction of all these elements should effectively slow the evolution of resistance.

Planting windows

The purpose of planting windows is to confine crop development and maturity to limit the number of

generations of *Helicoverpa* spp. exposed to Bollgard II cotton each season. This measure effectively restricts the selection pressure on key pests to develop resistance to Bollgard II.

The planting window concept was originally part of the voluntary Insecticide Resistance Management Strategy (IRMS) and was based on a scientific understanding of the ecology of *Helicoverpa* spp. The start date of the planting window is based on the date that moths are likely to emerge in a region using long term temperature data and the window length is one lifecycle of the pest, based on daily temperatures around the start date, which is about 42 days. Imposing a start date is especially important in warmer regions where pupae do not necessarily enter a diapause over the winter and where there is no climatically driven restriction on when planting can begin.

There are usually 3-4 generations of *Helicoverpa* spp. in a cotton growing season, depending on temperatures for that year, so the risk strategies around the RMP have been developed based on these numbers. In warmer cotton growing regions there is not always a climatic limit on how long crops can be grown, so the RMP includes an end date for crops in Central Queensland, and all Bollgard II and associated trap crops must be destroyed by July 31.

Mandatory refuges

The aim of a refuge crop is to generate significant numbers of susceptible moths that have not been exposed to the Bt proteins in Bollgard II. Moths produced in the refuge will disperse to form part of the local mating population where they may mate with any resistant moths emerging from Bollgard II crops, delaying the development of resistance. This strategy works because resistance to the Bt proteins has so far been found to be recessive, so if a resistant moth (rr) from the Bollgard II crop mates with a susceptible moth (ss) from the refuge, the offspring they produce (rs) are also killed by the Bt toxins.

The current RMP options for irrigated Bollgard II refuges are 100% sprayed cotton, 10% unsprayed cotton or 5% pigeon pea (relative to the area of Bollgard II cotton grown) with almost 70% of refuges grown being pigeon pea. No matter which refuge is grown, it is critical that they are managed to be most attractive to *Helicoverpa* moths when Bt cotton is also most attractive.

It is a requirement of the RMP for growers to ensure that their refuge crops receive adequate nutrition, irrigation (for irrigated refuges), and weed and pest management (excluding *Helicoverpa* sprays) so that they remain attractive while Bollgard II is grown. An important characteristic of mandatory refuges is their synchronicity with the corresponding Bollgard II crop. The timing of refuge planting is dependent on the timing of Bollgard II cotton planting so that the refuge is flowering (both pigeon pea and cotton refuges) at the same time as the Bollgard II. Ideally, refuges should be as or more attractive to *Helicoverpa* than the corresponding Bollgard II crop to attract females to lay eggs in the refuge.

Role of non-mandatory refuges

Helicoverpa are polyphagous which means that they feed on a wide range of host crops and vegetation, including cotton. Bt cotton dominates the total area of cotton grown in Australia but at a landscape scale it often forms part of a mosaic of other crops and vegetation. Non-cotton crops and natural vegetation are known to be important for Bt resistance management by providing alternative sources of Bt susceptible moths apart from those produced by the mandatory refuges. But we cannot confidently rely on these unstructured refuges to produce moths because their effectiveness and distribution is highly variable between seasons and regions.

Control of volunteer and ratoon plants

The presence of volunteers within a refuge diminishes the value of a refuge, as some of the moths emerging from that refuge have had some exposure to the Bollgard II proteins. Larvae that carry the gene for resistance, Heterozygous (RS) individuals, may emerge and develop on the refuge (conventional cotton or pigeon peas) crop before moving onto a Bollgard II volunteer within the refuge. In this way, the RS larvae become exposed to the Bt proteins at a later growth stage when they can survive to produce offspring. This will lead to an increase in the frequency of resistant individuals in the population.

The same risk to resistance from increasing exposure to the Bollgard II technology applies not only to Bollgard II volunteers within refuge areas but also in fallow fields and non-cropping areas. The good farm hygiene practice of removing all volunteers in and around cropping areas is not only important in removing disease and pest carryover hosts but also in reducing the resistance risk to Bollgard II technologies.

Restrictions on use of foliar Bt sprays

Sprayed cotton refuges are grown for commercial cotton yields, requiring active control of *Helicoverpa* with foliar insecticides. To ensure that no selection for Bt resistance can take place in this type of refuge, the use of foliar Bt insecticide is excluded. Sprayed cotton refuges are much larger than unsprayed refuge types because of the lower rates of *Helicoverpa* survival.

In unsprayed cotton and pigeon pea refuges, 'unsprayed' is in reference to insecticides which control *Helicoverpa* species. In these refuges, all foliar applied insecticides with activity against *Helicoverpa* species are excluded. These refuges are able to produce high numbers of *Helicoverpa* moths from much smaller areas.

Pupae destruction

Helicoverpa larvae enter a diapause phase in the soil as temperatures begin to cool and daylength decreases in early autumn. This dormancy strategy allows the pest to survive the winter months in temperate regions when host plants are scarce and temperatures are generally too low to allow successful development.

Cultivation of the soil between seasons, during the

dormancy phase, is an effective way of preventing any moths that developed resistance in the previous year from contributing to the population in the following year. In Central Queensland, due to the warmer temperatures and smaller changes in daylength, *Helicoverpa* pupae produced late in the season do not remain in the soil but emerge within 15 days of pupating, making pupae busting ineffective. Late season trap crops are used as an alternative. Trap crops of pigeon peas are timed to be at their most attractive after the cotton has cut out. Moths emerging from the Bollgard II fields late in the season should be attracted to the pigeon peas to lay their eggs. Once the cotton has been harvested the trap crops are destroyed and cultivated to kill the larvae and pupae.



Pupae destruction is an important part of the RMP. (Photo: Trudy Staines)

Evaluating the effectiveness of the RMP

To evaluate the effectiveness of the RMP the CRDC funds a program that monitors field populations of moths for resistance to Cry1Ac and Cry2Ab. Monsanto Australia operates a separate but complimentary monitoring program. The data provides an early warning to the industry of the onset of resistance to Bollgard II. The results are used to make decisions about the need to modify the RMP from one season to the next to ensure its ongoing effectiveness at managing resistance. Any changes to the RMP are put forward by Monsanto to the Australian Pesticides and Veterinary Medicines Authority. Industry is given an opportunity to have input into these changes via the TIMS Committee.

The full details of the RMP are published annually in the Cotton Pest Management Guide along with the latest annual results from the resistance monitoring program.

The future – third generation Bt technology

The industry's third generation Bt technology is being developed. It is based on the same platform as Bollgard II but with a new protein (Vip3A) added.

CSIRO has begun performing screens against the new protein in Bollgard III (Vip3A) and found that in *H.*

armigera the frequency of genes conferring resistance is around 1 in 20 moths. Not only is this higher than expected, it is much greater than the starting frequencies for Cry2Ab. Vip3A resistance genes have also been detected in *H. punctigera* at a frequency that is higher than expected and higher than the starting frequencies for Cry2Ab.

Work is underway to characterize this Vip3A resistance. This information, along with data on the efficacy of Bollgard III against *Helicoverpa* (also underway), will be used with information on the frequencies of Cry1Ac, Cry2Ab and Vip3A to determine the RMP for Bollgard III. At this stage it is almost certain that we will not be developing a RMP with a clean resistance slate.

Managing resistance to Bollgard II is critical in the lead up to the introduction of Bollgard III to ensure the efficacy of this technology is maintained, both now and into the future.

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

- Cotton Pest Management Guide
- Biotechnology Module

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By **IAN TAYLOR** (CottonInfo Team)

Acknowledgements: James Hill, Graham Charles (NSW DPI), Tracey Leven (CRDC), Jeff Werth and David Thornby (DAFFQ)

What is IWM?

Integrated Weed Management (IWM) is the planned implementation of diverse weed management tactics aimed at rapidly depleting the soil seedbank and preventing further seed set/recruitment. IWM aims to manage today's weed problems in a manner that reduces the potential for weed problems in the future. There are five key principles in developing an IWM plan:

- Know the weed spectrum and aim for maximum weed control.
- Stop seed set, actively manage the seedbank and control survivors to prevent replenishment.
- Monitor and respond to the success of your control tactics.
- Treat weed flushes with a diversity of in-crop and fallow management tactics.
- Don't automatically reach for glyphosate – think longer term.

An IWM program uses a range of weed control tactics in combination, so that ALL weeds are controlled by at least one tactic in the weed management system. In short, IWM is about NOT relying on only one or two methods of weed control alone, and in particular it does

not involve relying only on herbicides. When developing an IWM program, think strategically about how you can best utilise all available weed control methods in cotton, in rotation crops and in fallows. A short term approach to weed management may reduce costs for the immediate crop or fallow, but may not be cost effective over a five or ten year cropping plan. Over this duration, problems with species shift and the development of herbicide resistant weed populations are likely to occur where weed control has not been part of an integrated plan. Herbicide resistant weed populations are becoming increasingly common in NSW and Queensland.

Why use IWM in cotton systems?

Effectively managing weeds using an integrated weed management program for the entirety of the cropping rotation will reduce:

- Rate of shift in weed spectrum towards more herbicide tolerant weeds.
- Risk of selecting herbicide resistant weeds and so prolong the useful life of each herbicide.
- Future weed control costs by reducing the number of weed seeds in the soil seed bank.
- Competitiveness of weeds and improve crop productivity each year.

Although all of these outcomes are important, reducing the risk of developing herbicide resistant weeds is critical. Throughout the world 185 weed species have developed resistance to different herbicides. Thirty-six weeds have developed resistance to herbicides in Australia. In northern NSW populations of 4 common grass weeds – awnless barnyard grass, liverseed grass, windmill grass and annual ryegrass (also occurring in southern NSW) – and one broad leaf species, flax-leaf fleabane have developed resistance to glyphosate. Weeds with resistance to multiple herbicide modes of action are also occurring more frequently. The following tactics should be used to develop an integrated weed management strategy for your farm to help prevent the development of herbicide resistance.

IWM tactics in cotton

Key weeds are identified

Ensure that weeds are correctly identified before deciding upon a response. Refer to Weed Identification Tool.

Monitoring

Monitoring fields before weed control is implemented, enables the best control option to be used. Scouting should be repeated to assess efficacy post-treatment.

For IWM strategies to be effective in preventing resistance, weeds that survive an herbicide must be controlled by another method before they set seed. Weeds may need to be closely examined, as some are capable of setting seed while very small. For information on key weeds refer to the Weed Growth and Development Guide in WEEDpak.

BEST PRACTICE

- Herbicides are applied according to label directions and the pesticides act.
- Good farm hygiene is practised to minimise entry of new weeds.
- Key weeds identified and weed burden assessed annually. Weed strategies are targeted to managing problem weeds.
- Fields scouted regularly to assess weed pressure and efficacy of control measures.
- Herbicides are applied at the ideal weed and crop growth stages.
- Weeds that survive a herbicide application are controlled using an alternative mode of action prior to seed set.
- Key weeds and management practices that are at risk of glyphosate resistance are identified through use of a risk assessment tool.

Identify and closely monitor areas where machinery such as pickers and headers breakdown. Weed seeds are often inadvertently released when panels are removed from machines for repairs.

Weed scouting in non-crop areas of the farm is a valuable source of information for planning future weed management strategies.

Field records

For all fields, maintain records of weed control methods and their effectiveness after every operation. Consider the records from past years in this year's decisions, particularly in relation to rotating herbicide modes of action. Repetitive use of the same mode of action group over time is closely associated with the evolution of herbicide resistance. In addition, records are useful in terms of crop rotations and plant back periods.

The spring tickle

The spring tickle uses shallow cultivation in combination with a non-selective, knockdown herbicide. The aim of the spring tickle is to promote early and uniform germination of weeds prior to sowing to ease weed pressure in-crop. Some weed species are more responsive to the spring tickle than others. Highly responsive weeds include bellvine and annual grasses such as liverseed grass and the barnyard grasses.

The spring tickle may be used in conjunction with pre-irrigating to maximise the emergence and control of weeds prior to crop emergence.

Double knock

The double-knock technique is a fallow weed control tactic that is being used widely in southern states to manage hard to control weeds such as herbicide resistant annual ryegrass. When executed well, the double-knock tactic will provide 100% control. In cotton systems there are several ways the technique can be applied to improve control of weeds such as flaxleaf fleabane and simultaneously reduce the risk of resistance developing in other key weed species such as liverseed grass and awnless barnyard grass. More recently the term double-knock has evolved to include the sequential application of two herbicides with different modes of action in a narrow time frame (3–14 days). When using two herbicides, the basis of the double-knock is to apply a systemic herbicide, allowing sufficient time for it to be fully translocated through the weeds, then return and apply a contact herbicide, from a different mode of action group, that will rapidly desiccate all of the above ground material, leaving the systemic product to completely kill the root system. Most commonly glyphosate is followed with a Group L product. The optimum time between the treatments is dependent on the weed targets. Small, rapidly growing grasses respond best when the second application occurs 3–5 days after the first. When slightly larger fleabane is the target, separate the applications by 7–10 days.

Herbicide tolerant crops are grown according to licence requirements

Herbicide tolerant cottons allow the use of non-selective herbicides for summer weed control in-crop. Incorporating this tactic into the IWM strategy allows for more responsive, flexible weed management. Weeds need only be controlled if and when germinations occur, meaning herbicide application can be timed to have maximum impact on weed populations. In relatively clean fields the reliance on residual herbicides for in-crop management is reduced. In fields known to have heavy weed burdens, using the non-selective together with residual herbicides can achieve very high levels of control. Avoid using the same herbicide to control successive generations of weeds. Use the weed control threshold calculation tool to assist with timing of Roundup Ready application.

Prevent weed establishment

Where cotton is grown in rotation with crops such as winter cereals or maize, retain stubble cover from these rotation crops for as long as possible. Stubble cover reduces weed establishment and encourages more rapid breakdown of weed seed on the soil surface.

Protect yield potential

Young cotton is not a strong competitor with weeds. The critical times when weed competition can cause yield loss are provided in the Cotton Pest Management Guide for a range of weed densities and weed types. Irrespective of the type of weeds, early season control is critical to prevent yield loss. The higher the weed population and the more competitive the weed, the longer into the season weed control is required.

Control survivors and late germinations

Use a range of selective controls – inter-row cultivation, lay-by herbicides, chipping and spot spraying – to prevent seed set in weeds that survived early season tactics or have germinated later in the season.

For a range of reasons, situations will occur when some weeds escape control by herbicides:

- Some tap-rooted annual and perennial weeds, such as fleabane and bindweed may have relatively little leaf area and survive most herbicide applications;
- Stressed weeds are much harder to kill with herbicides;
- Missed strips due to nozzle blockages or equipment failure;
- Insufficient coverage due to high weed numbers;
- Applying the incorrect rate; and
- Interruptions by rainfall are just a few reasons why weeds escape control.

If herbicide resistant individuals are present, they are likely to be among the survivors. It is critical to the longer term success of any IWM strategy that survivors not set seed.

Inter-row cultivation

Inter-row cultivation can be used to prevent successive generations of weeds from being targeted by post-emergent herbicides. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the soil damage caused by tractor compaction and soil smearing from tillage implements.

Manual chipping

Manual chipping is ideally suited to dealing with low densities of weeds, especially those that occur within the crop row. Whilst this is an expensive option, perhaps it should be costed not just to this crop, yet also to subsequent crops.

Spot spraying

Spot sprayers may be used as a cheaper alternative to manual chipping for controlling low densities of weeds in crop. Ideally, weeds should be sprayed with a relatively high rate of herbicide from a different herbicide group to the herbicides previously used to ensure that all weeds are controlled.

Crop rotations

Rotation crops enhance IWM by:

- Introducing herbicide options not available in cotton.
- Producing stubble loads that reduce subsequent weed germinations (it is important to remember stubble loads and their impact on emerging cotton plants).
- Varying the time of year non-selective measures can be used and the time of year that crop competition suppresses weed growth.
- Rotation between summer and winter cropping provides opportunities to use cultivation and knockdown herbicides in-fallow at all times of the year.

Bury seed of surface-germinating species

Use strategic cultivation to bury weed seeds and prevent their germination. Some weed species, such as common sowthistle (milk thistle) and flaxleaf fleabane, are only able to germinate from on or near the soil surface (top 20 mm).

Good farm hygiene is practiced

To minimise the entry of new weeds into fields, clean down boots, vehicles, and equipment between fields and between properties. Pickers and headers require special attention. Eradicate any new weeds that appear while they are still in small patches. Monitor patches frequently for new emergences.

Irrigation water can be a source of weed infestation with weed seeds being carried in the water. While it is not practical to filter seeds from the water, growers should be on the look out for weeds that gain entry to fields via irrigation. Control weeds that establish on irrigation storages, supply channels and head ditches.

Critical success factors in IWM

Timely implementation of tactics

Often the timeliness of a weed control operation has the largest single impact on its effectiveness. Herbicides are far more effective on rapidly growing small weeds, and may be quite ineffective in controlling large or stressed weeds. Cultivation may be a more cost-effective option to control large or stressed weeds, but additional costs can be avoided through being prepared and implementing controls at the optimum time.

Rotate herbicide groups

All herbicides are classified into groups based on their mode of action in killing weeds. Rotate herbicide groups whenever possible to avoid using the same group on consecutive generations of weeds. When this is unavoidable, use other methods of weed control in combination with the herbicide and ensure no weeds survive to set seed. The cotton industry is very fortunate to have registered herbicides in the majority of the mode of action groups.

Herbicides applied according to label directions

Herbicides are a principal component of most IWM strategies so it is important that they are used in the most effective manner possible. When reading the herbicide label check:

- That the Rate you are about to use is right for the growth stage of the target weeds Always use a robust rate and aim for maximum control of the weeds present.
- Whether a wetter or crop oil is required to maximise herbicide performance.
- That your Application set up is consistent with the label – water volume, droplet spectrums, operating pressure.
- For additional, specific information regarding appropriate weather conditions for spraying.

Consider other aspects of crop agronomy

Most agronomic decisions for cotton have some impact on weed management. Decisions such as cotton planting time, pre-irrigation versus watering-up, methods of fertiliser application, stubble retention and in-crop irrigation management all have an impact on weed emergence and growth. The influence of these decisions should be considered as part of the IWM program.

Resistance

Resistance is now a real issue for the cotton industry with glyphosate resistant weeds being detected in both irrigated and dryland cotton situations. Cotton growers and managers now more than ever need to ensure that they have sound IWM strategies in place to manage the risk of herbicide resistance especially given the reliance of the industry on Roundup Ready Flex® technology for weed control in-crop as well as, the high reliance on

glyphosate for fallow weed management. The cotton growing regions are closely aligned with the northern grains region. Across this area, there are 18 weed species that have developed resistance to at least one herbicide mode of action. Most recently, liverseed grass, windmill grass, awnless barnyard grass and fleabane have been confirmed as being glyphosate resistant, while feathertop Rhodes grass is very difficult to control with standard rates of glyphosate.

Development of herbicide resistant weed populations has been most strongly associated with cropping systems where there is minimal or no use of tillage and where there is only limited rotation between summer and winter cropping. It is essential that growers follow the industry's best management practices and are proactive in preventing the development of herbicide resistance.

Refer to www.myBMP.com.au

Looking for the early signs of resistance

Resistance genes can be present at very low frequencies in weed populations before the herbicide is first applied. Using the herbicide creates the selection pressure that increases the resistant individuals' likelihood of survival. The underlying frequency of resistant individuals within a population will vary greatly with weed species and herbicide mode of action. Resistance can begin with the survival of one plant and the seed that it produces.

Early in the development of a resistant population, resistant plants are likely to occur only in small patches. This is the critical time to identify the problem. Options are much more limited if resistance is first diagnosed over large areas.

Many of the symptoms of herbicide resistance can also be explained by other causes of spray failure. Evaluate the likelihood of other possible causes of herbicide failure. Start by taking the self assessment (see table). The more questions to which you have confidently answered 'Yes', the more a further investigation of possible resistance is warranted. If you have answered 'Yes' to most of these questions, including questions 9–11 on field history, take action;

- Collect samples and send for testing.
- Remove surviving plants from the field to limit the amount of seed going into the soil seed bank.
- Develop a management plan for continued monitoring of the sites and the use of alternative weed control strategies.

Phenoxy

Cotton is extremely sensitive to phenoxy and other Group I herbicides via off target application and through poorly decontaminated booms. To help reduce off target drift damage it is essential that you identify your cotton fields on the cottonmap website. This map will be used by spray contractors, resellers, agronomist and neighbours to identify crops.

Decontaminating spray rigs and tanks is VERY important for cotton.

Self assessment – for possible herbicide resistance: Y/N

1.	Was the rate of herbicide applied appropriate for the growth stage of the target weed?
2.	Are you confident you were targeting a single germination of weeds?
3.	Were the weeds actively growing at the time of application?
4.	Having referred to your spray log book, were weather conditions optimal at the time of spraying so that herbicide efficacy was not compromised?
5.	Can the weed patch be related to a previous machinery breakdown (such as a header) or the introduction of weed seeds from a source such as hay?
6.	Are you confident the suspect plants haven't emerged soon after the herbicide application?
7.	Is the pattern of surviving plants different from what you associate with a spray application problem?
8.	Are the weeds that survived in distinct patches in the field?
9.	Was the level of control generally good on the other target species that were present?
10.	Has this herbicide or herbicides with the same mode of action been used in the field several times before?
11.	Have results with the herbicide in question for the control of the suspect plants been disappointing before?

If you suspect herbicide resistance and require further information please refer to the *Cotton Pest Management Guide*, available on the Cotton CRC website or discuss with your agronomist.

These guidelines are a brief version of the Integrated Weed Management Guidelines for Australian Cotton II.

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

- WEEDpak
 - Weed Identification Web Tool
 - Herbicide Damage ID Web Tool
 - Herbicide Resistance Risk Assessment Tool
- Cotton Map – <http://www.cottonmap.com.au/>



Look for the early signs of resistance. (Photo: Graham Charles, NSW DPI)

Integrated Disease Management

By **SUSAN MAAS** (CRDC)

Acknowledgements: Stephen Allen (CSD); Karen Kirkby, Peter Lonergan (NSW DPI); Linda Smith, Linda Scheikowski, Cherie Gambley, Murray Sharman (Qld DAFF)

Developing an Integrated Disease Management (IDM) strategy for your farm

Effective disease management must be integrated with management of the whole farm. Basic strategies should be implemented regardless of whether or not a significant disease problem is evident. These basic strategies should focus on the host, the pathogen and the environment.

Pathogen

Impact from disease can be reduced and even avoided if pathogen is prevented from building up in an area.

Conduct your own field disease survey

It is important to be aware of what diseases are present and where they occur. Conduct an early and late season disease surveys and record findings to allow comparison over time. See below for in season troubleshooting. In addition train farm staff to look for and report unusual symptoms. If a suspect cotton plant is located, submit suspect plant samples and healthy comparison plant samples to a plant pathologist for diagnosis/confirmation. Refer to the 'Cotton Symptoms Guide' or the Cotton Pest Management Guide for instructions on how to send a sample.

Come Clean Go Clean

Minimise the risk of moving diseases onto or off your farm or from one field to another by considering machinery movements within the farm and having a

strategy for ensuring clean movement of machinery onto and around the farm.

Minimise spillage and loss when transporting modules, hulls, cotton seed or gin trash.

Ensure all staff and visitors are aware of the requirements to 'Come Clean-Go Clean' (See page 96).

Control alternative hosts and volunteers

Having a host free period prevents buildup of disease inoculum and carryover of disease from one season to the next. The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, Tobacco Streak Virus and Alternaria leaf spot can also infect common weeds found in cotton growing areas.

Having a host free period is particularly important for diseases such as Cotton Bunchy Top, that can only survive in living plants. Controlling alternative hosts, especially cotton volunteers and ratoons will help reduce the risk of yield damage from cotton bunchy top.

Crop residues are managed to minimise carryover of pathogens into subsequent crops

The pathogens that cause Verticillium wilt, Fusarium wilt, Black root rot, boll rots, seedling disease and Alternaria leaf spot can all survive in association with cotton and some rotation crop residues. Manage crop residues to minimise carryover of pathogens into subsequent crops. Incorporate cotton crop residues as soon as possible after harvest, except where Fusarium wilt is present.

Where Fusarium wilt is present residues should be slashed and retained on the surface for at least one month prior to incorporation. The Fusarium wilt pathogen can also survive and multiply on the residues of non-host crops such as cereals. Currently recommendations are that residues should be incorporated or removed as soon as possible after harvest.

Crop rotations are utilised to assist in disease management

Use rotation crops that are not hosts for the pathogens present. The Verticillium wilt pathogen has a large host range and most legume crops are hosts of the Black root rot pathogen. Legumes such as mungbeans and soy beans also increase the Fusarium wilt pathogen. Disease risks can be higher for back to back cotton fields.

In addition to fixing substantial quantities of nitrogen, alternative crops such as vetch, canola and mustards can provide a biofumigation effect against Black root rot under specific management regimes.

Cotton is highly dependent on mycorrhiza, specialised fungi which form beneficial associations with plant roots, and can act as agents in nutrient exchange. Bare fallow for more than 3 to 4 seasons or removal of top-soil (especially more than 40cm) may result in a severe lack of mycorrhiza; a cereal or green-manure crop may restore sufficient mycorrhizal fungi for cotton.

The Cotton Rotation Finder can assist with developing a rotation strategy.

BEST PRACTICE

- Control volunteer and ratoon cotton throughout the year.
- Ensure vehicles, equipment and people have followed Come Clean, Go Clean.
- Where pathogens are known to be present, plant resistant varieties as late as possible in the window.
- Monitor crops throughout the season for disease.
- Manage crop residues and consider crop rotations based on best practice for diseases present in the field.
- Utilise industry pathology services where unusual symptoms or new diseases are present.

Fungicides

All cotton seed sold in Australia for planting is treated with a standard fungicide treatment. A protective fungicide is registered for the control of *Alternaria* leaf spot on Pima cotton only.

Control of insect vectors

Diseases caused by a virus or phytoplasma can often be prevented by controlling the vector that carries the pathogen. Cotton bunchy top (CBT) can be transmitted by aphids feeding on infected plants then migrating to healthy plants. Transmission of Tobacco streak virus (TSV) to plants relies on the virus from infected pollen entering plant cells through the feeding injury caused by thrips. Control of insect vectors should be considered IPM principles and resistance risks (See IPM chapter).

Viruses can only survive in living plants. Control of cotton ratoons and volunteers throughout winter will reduce pathogen levels and also lower vector insect populations, drastically reducing disease risk.

Host

A particular plant may be immune, resistant or susceptible. Breeders also use the term 'tolerance' to imply good performance (yield) despite the presence of disease.

Plant resistant varieties

For back to back fields, disease risks can be higher, increasing the importance of planting resistant varieties and using other IDM strategies. Levels of resistance to *Verticillium* wilt and *Fusarium* wilt are indicated by higher V Rank and F Rank respectively. Bacterial Blight can still be a problem in some old Pima varieties. New blight resistant varieties of Pima are available. In addition to resistance, consider the seedling vigour of a variety particularly when watering up or planting early. Refer to CSD variety notes for more information.

Grow a healthy crop

A healthy crop is more able to express its natural resistance to disease. Adopt a balanced approach to crop nutrition, especially with nitrogen and potassium. Both deficiencies and excesses provide better conditions for the development of diseases such as *Verticillium* wilt and *Alternaria* leaf spot. Excess nitrogen greatly increases the risk of boll rot particularly in fully irrigated situations.

Replanting

Replanting decisions should be made on the basis of stand losses, not on the size of the seedlings. For more information refer to Chapter 18a.

Environment

Pathogens have optimum environmental requirements for infection to occur and for the disease to spread and multiply in the host plant. It may appear difficult to manipulate the environment but it can be achieved by altering row or plant spacing, irrigation method or frequency or by changing the sowing date.

Preparing optimal seed bed conditions

Plant into well prepared, firm, high beds to optimise stand establishment and seedling vigour. Carefully position fertiliser and herbicides in the bed to prevent damage to the roots. Fields should have good drainage and not allow water to back-up and inundate plants.

Irrigation scheduling

Applying water prior to planting provides better conditions for seedling emergence than watering after planting. Watch for signs of water stress early in the season if the root system has been weakened by disease (eg. Black root rot) and irrigate accordingly. Avoid waterlogging at all times, but especially late in the season when temperatures have cooled. Irrigations late in the season can result in a higher incidence of *Verticillium* wilt. Tail water should also be managed to minimise the risk of disease spread.

Agronomic management

High planting rates can compensate for seedling mortality however a dense canopy favours development of bacterial blight, *Alternaria* leaf spot and boll rots. Provide balanced crop nutrition to assist the plants' natural resistance to disease. Avoid rank growth and a dense canopy with optimised nitrogen and water and with the use of growth regulators where required.

If Black root rot is present, either manage for earliness to get the crop in on time (in short season areas) or manage for delayed harvest to allow catch up (in longer season areas).

When *Verticillium* wilt is a concern, plan for an earlier finish to avoid cool conditions later in the season.

In fields where *Fusarium* wilt is present avoid inter row cultivations after seedling stage as mechanical damage to the roots provide a site for infection by the pathogen.

Sowing date

Delay sowing as late as possible within the planting window to avoid cool, wet conditions that favour disease. Aim to sow when the soil temperature is 16°C and rising.



Monitor for plants with unusual symptoms. (Photo: Jamie Iker)

In season disease trouble shooting

Early season

Compare number of plants established per metre with number of seeds planted per metre. Refer to section 9C for further information about crop establishment and replanting decisions.

Walk the field and look for plants that show signs of poor vigour or unusual symptoms.

Examine seedling roots.

During and late season

Walk field and look for plants that are dead, show signs of poor vigour or have unusual symptoms.

Cut stems and examine for discoloration.

Where disease is detected in new fields, or if unsure about diagnosis, contact the cotton pathologists in your state:

QLD DAFF pathologist – 07 3255 4356. NSW DPI pathologist – 02 6799 2454
Exotic Plant Pest Hotline 1800 084 881

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

- Cotton Pest Management Guide
- Cotton Symptoms Guide
- Rotation Crop Comparison Tool

COME CLEAN. GO CLEAN.

Practicing good farm hygiene will help prevent the entry and spread of diseases, weeds and pests onto your farm. These pests will impact on your business so you need to make sure that Come Clean Go Clean is part of your business.

Step 1: Wash down



Park on a clean wash down pad where contaminants can be trapped.

Apply high pressure water to all surfaces to remove all trash and mud, being sure to get into crevices where residual mud or trash might be trapped.

Don't forget to clean out the inside of the cab and vehicle foot pedals and other surfaces that have come into contact with dirty footwear.

Step 2: Decontaminate



Apply decontaminant (e.g. 10% water dilution of Castrol Farmcleanse or equivalent) liberally to all surfaces especially areas that were dirty. Also decontaminant mats, tools and footwear. Leave the decontaminant to work for 10

minutes unless directed otherwise by the label.

Step 3: Final Rinse



Rinse decontaminant. Clean all mud off the pad with high pressure water so it is clean for the next person and that mud & debris isn't picked up by wet tyres. Where equipment has not been cleaned down on farm,

thoroughly inspect to ensure cleanliness.

MAKE COME CLEAN GO CLEAN A PRIORITY

Come clean Go clean takes commitment especially during busy

periods such as harvesting. The risks are real, so ensure that all equipment and people stop and clean down.

INFORM PEOPLE

Well designed signage informs visitors that Come Clean Go Clean is important and they share responsibility for protecting the farm from risk.

Signs should be placed at all external entrances, directing visitors to have clean vehicles and to contact the farm office before entering.

Come Clean Go Clean requirements should be communicated with contractors and consultants well in advance.

WASHDOWN FACILITIES

On farm facilities allow farm employees, contractors and visitors to clean their vehicle and equipment in an easy to manage area where waste water can be contained. Facilities should be readily accessible, have sealed or packed gravel surface, access to high pressure water, washdown product and power, and be away from production areas and not drain into waterways or cropping areas.

For more information go to www.mybmp.com.au or please contact D&D team disease & biosecurity lead Susan Maas susan.maas@crdc.com.au 0477344214

Stop the spread of diseases, weeds & pests on this farm.

**Come
clean.
Go
clean.**

Please contact farm office before entering:

Tel: _____

UHF: _____



This message is proudly sponsored by AgriRisk to promote best practice production in the Australian Cotton industry.

Field Selection, Preparation & Rotation

By **DALLAS KING, NILANTHA HULUGALLE** (DPI NSW) & **TRACEY LEVEN** (CRDC)

Cotton soils

Soils that are relatively fertile, with good internal drainage and reasonably high water holding capacity are preferred for cotton. Crops are more likely to produce high yields when their roots are able to grow freely. Understanding the soils into which the cotton will be planted is important for many management decisions.

The soils on which cotton is grown in Australia are inherently fertile. They are dominated by cracking clays (Vertosols) which are naturally fertile, alkaline, with high clay content and high organic matter as they initially supported brigalow/belah associations. Other soil types on which cotton is grown include red-brown earths (in the Macquarie, Namoi and Gwydir valleys) and in many of the Queensland districts Solodic and Solodised-Solonetz form a part of the soil.

Large values of Plant Available Water Capacity (PAWC), which are found in some clay-rich alluvial soil types and deep black earths, allow a longer interval between furrow irrigations. Under dryland conditions, if the profile starts out full, large values of PAWC delay the onset of moisture stress in crops.

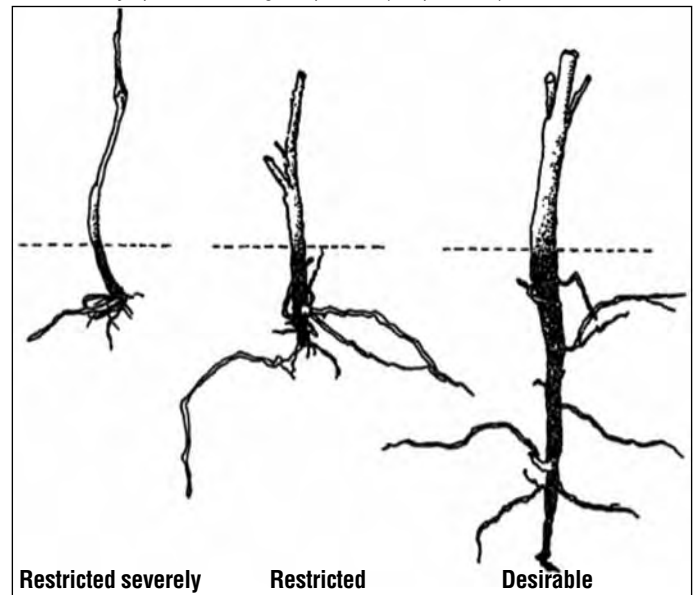
Cotton has poor tolerance of water logging. To allow adequate water entry, and to encourage root exploration by quickly re-establishing aeration after irrigation and

BEST PRACTICE

- Crop growth will be easier to manage in a field with a uniform soil type.
- Fix problems associated with land forming before planting cotton
- Favour fields that have most recently grown a crop other than cotton, where stubble has been retained and there is low risk of herbicide residues
- Consider alternative irrigation systems i.e. would lateral moves or pivots be more appropriate on lighter soils than flood irrigation.
- Consider suitable run lengths not just for cotton but possible rotation crops.

FIGURE 1:

Cotton root symptoms following compaction. (Soilpak C4-1)



rainfall, cotton soil needs to have good porosity for infiltration and internal drainage.

Soil types with dense, sodic subsoils have poor profile permeability (the ability of water to move through the soil), and hence limit root development.

Compaction (Structural damage), may create large platy clods. Such damage restricts permeability and will also affect plant growth. Root growth is retarded by the same factors that restrict water entry and seedling growth. Subsoil sodicity tends, however, to cause water logging by the process of excessive swelling rather than dispersion of clay particles.

While the root zone should be permeable, the deep subsoil should be slow draining; excessive deep drainage may cause water tables to rise. Irrigation management and crop rotation should aim to minimise the amount of water draining to the deep subsoil.

Soil properties within a field are variable, and good quality soil survey information provides the opportunity to minimise the impact of soil variation within each management unit. refer to Chapter 11 for more information about mapping variation.

Land forming

An appropriate slope and field length, in combination with furrows and hills/beds, will ensure good surface drainage and reduce water logging. Land forming using laser grading usually is needed to provide the required slope across all parts of a field, particularly under irrigation.

Surface drainage and tail drains must be designed to minimise flooding during heavy rain, the consequences of which may be disastrous during the seedling stage. Furrow-edge compaction and water application rates need to be matched so that the root zone does not become waterlogged due to excessive water intake. Slopes that are too steep create erosion hazards.

Land forming of cotton fields can create soil problems that should be dealt with before cotton is grown. The main issue is the exposure and spreading of unstable subsoil.

Subsoil exposure is usually unavoidable because of the need to provide an even slope in irrigated fields. Even drip irrigated fields have to be land formed because of the need to quickly dispose of runoff water after heavy rain. At best, the exposed subsoil will have inadequate organic matter. At worst, it will be sodic, depleted of mycorrhiza, have a high pH and perhaps be saline.

Where sodic subsoil is exposed, the scraped material also has poor physical properties. It may be spread thinly over low lying areas which previously had a favourable soil structure. Therefore it is desirable to stockpile the original topsoil, landform the subsoil, and then replace the topsoil.

If stockpiling and replacement of the topsoil is not possible, the exposed sodic soil will have to be reclaimed by the use of gypsum, and perhaps by the growth of a well-fertilised cereal crop (e.g. Barley). Zinc fertiliser may need to be added.

Due to the tight schedules of land forming contractors, it is difficult to reshape fields at the recommended soil water content, particularly when there is a mix of grey and red soil. Nevertheless, a well fertilised crop such as wheat should be grown just before land forming to maximise the chances of the soil being dry enough.

For more information on soil constraints refer to Chapter 7.

Rotation & previous crop history

A vital component of any farming system is the inclusion of a rotation phase. Planning should take into account a range of issues, including weed, insect, diseases, water use, and soil structural issues, to maximise the advantages and minimise the disadvantage at a field and whole of farm basis. Rotation crops can be used as a tool within the farming system. For example there is evidence of improved cotton yields after a corn crop which is most likely due to increased organic matter and better soil structure.

Crop rotations and fallow can be an important part of an integrated weed management system, providing the opportunity to use different groups of herbicides, as well as incorporate other measures such as strategic cultivation and crop competition. Refer to the IWM Chapter 15 for more information.

One of the difficulties with the use of alternative herbicides however is that residual properties may be toxic on following crops. Keep good records and always check the label for plant back periods. Consider the following two crops you may plant when planning rotations as some residual herbicides have very long (>18month) plant back periods.

Rotations and fallows can also be an important consideration in disease management, because they affect



Rotation crops are an important part of a farming system, with each crop providing benefits such as an opportunity to rotate herbicide groups as well as risks and management considerations such as impacting disease inoculum levels.

the survival and reproduction of plant pathogens, as well as the biology and quality of the soil. Using rotation crops that are not hosts will usually help in preventing the amount of pathogen in the soil from building up. Crop residues should be managed based on best practice for the diseases present, and be aware that some crop residues may also have allopathic effect on cotton. Disease risks are generally higher in back to back cotton fields. Refer to Chapter 16 for more information.

The Cotton rotation finder, provides a comprehensive matrix as to the different rotation crops available and their positive and negative impacts.

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

- ASPX
- Rotation Crops Comparison Tool
- Cotton Symptoms Guide
- Herbicide Damage ID Web Tool
- Cotton Pest Management Guide



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Managing Cotton Stubble/Residues

By IAN ROCHESTER (CSIRO) & DALLAS KING

Returning cotton stubble to the soil provides a source of energy for the microbial organism, which in turn helps the breakdown of stubble. This maintains the supply of nutrients to the crop. Organic matter enhances the health of the soil, as higher organic matter drives better water infiltration and internal drainage.

An experiment was conducted at Narrabri over three seasons (1992–95) to investigate stubble management systems in relation to cotton growth, lint yield and fertiliser N recovery.

The experiment indicated that removing cotton stubble caused a reduction in lint yield and profitability over time. Compared with the lint yield of the stubble-retained treatment, the yield of the stubble-removed treatment was reduced by 3 and 9% respectively, in the second and third years of the experiment.

The experiment also revealed that the N fertiliser recovery was reduced by 10% where the stubble was removed compared to the retained plots, ie more N fertiliser was lost from the soil where stubble was removed.

A number of growers still pull cotton plants after harvest, but the stalks are then mulched using a conventional mulcher. This process allows the stubble to be returned into the soil profile during cultivation operations

BEST PRACTICE

- Where possible; harvest, in crop operations with heavy machinery and all tillage operations should be performed when soil is dry to reduce compaction risk
- Post-harvest crop management includes the destruction of plants and incorporation of crop residues, generally through performing a root cut and mulch operation followed by tillage to incorporate crop residues.
- Pupae destruction must be performed post-harvest by July 31 in Bollgard II crops and should be performed prior to August 30 in conventional cotton. Tillage is required to a depth of 10cm across the whole bed and furrow.
- The removal of cotton volunteers and ratoon plants from all cropping and non-cropping areas reduces carryover of pests and diseases and is a component of the Bollgard II RMP to reduce resistance risk.

Avoiding soil compaction

Cotton pickers are very heavy, with front axle loads as great as 14 t for conventional pickers and about 40t for round module pickers. However, when the soil profile is dry at harvest, their impact on soil structure is less than when the soil is moist, although wide tyres or dual front wheels will compact loose beds.

It must be remembered, that serious soil compaction may have occurred earlier in the season (due to operations such as fertiliser application and weed control), or remain from previous seasons when the soil has had insufficient time to restore its structure. Soils may take years to recover from structural damage and many wetting and drying cycles assist this process.

A big advantage of a dry harvest is that it gives you the widest possible range of options for preparation and improvement of cracking clay soils, provided that heavy rain does not follow soon afterwards. Cultivation, and particularly deep tillage should only be attempted when the soil is either at plastic limit or drier than plastic limit. Clay soils may be cultivated when dry, however non-swelling soils containing higher amounts of loam or sand can be damaged if cultivated when too dry as the soil structure is more easily broken down. Refer to figure 1 for tillage and rotation options after a dry harvest.

Pupae control

Pupae destruction is a mandatory requirement of the Bollgard II Resistance Management Plan (RMP) and a key recommendation for conventional cotton under the Insecticide Resistance Management Strategy (IRMS). Cultivation of the soil after harvest is an effective way of controlling *Helicoverpa* spp. pupae that may carry resistance to the toxins contained in Bollgard II or to conventional insecticides. In Bollgard II cotton, pupae destruction must be completed prior to July 31 and in conventional cotton it is recommended that the operation be completed prior to the end of August. This ensures that pupae are destroyed prior to the following spring and do not emerge as moths that are potentially carrying resistant genes.

Tillage to a depth of at least 10 cm is needed to kill overwintering *Helicoverpa* pupae, if all of the very large clods (more than 50 mm wide) in the topsoil have been broken down and rearranged. However, care should be taken on silty soil where aggressive dry cultivation will create dust and destroy soil structure.

For further information on pupae control refer to the Stewardship chapter.

'Volunteer' and 'ratoon' cotton

Due to the advent of herbicide tolerant cotton cultivars in the past decade, cotton residue management has become an extremely important consideration for cotton producers utilising the technologies.

'Volunteer' or 'ratoon' cotton provide an excellent host (green bridge) for diseases such as Cotton Bunchy Top



(CBT) and pests such as whitefly, aphids, mites and mealy bugs to survive on-farm from one season to the next. Therefore the need to provide a high level of control has never been more pertinent.

The presence of volunteer and ratoon Bollgard II cotton also poses a resistance risk. It is a requirement of the RMP that all Bollgard II volunteers and ratoon plants are removed as soon as possible from all fields and fallow areas including refuge areas. Refer to Chapter 14.

Good farm hygiene practices of removing all volunteers and ratoon plants in and around cropping areas is not only important in removing disease and pest carryover hosts but also in reducing the resistance risk to BGII technologies.

Effective post-harvest management of crop residues reduces the risk of volunteer and ratoon cotton becoming a problem in the following season. There are several factors which will determine the choice of operation to eliminate the current crop residue effectively (see Residue Management Options below) including equipment availability and the moisture status of the soil.

Post harvest crop residue management

It is a requirement of the Bollgard II RMP that Bollgard II cotton crops must be destroyed by cultivation or herbicide as soon as practical after harvest so that they do not continue to act as hosts for *Helicoverpa* spp. As well as this requirement, there are a number of advantages to effective management of crop residues.

Crop residues can carry disease, clog tail drains, and interfere with herbicide incorporation and with planting operations. Incorporation of stubble will improve these issues and may improve the amount and quality of soil organic matter.



Photo 1 (top) – how a field's trash content should look like after only 2 workings (once mulched they were centre busted and then trace listed). Photo 2 (bottom) – large piles of trash left on the field can cause blockages and other management issues.

Methods for crop residue control have changed greatly since the late 1990's when 'pull, rake & burn' was a common option.

The main processes currently promoted in the industry include:

- Mulching of stalk above the ground and cutting the root below cotyledon height (performed in the one operation).
- Incorporating the residues into the surface soil.

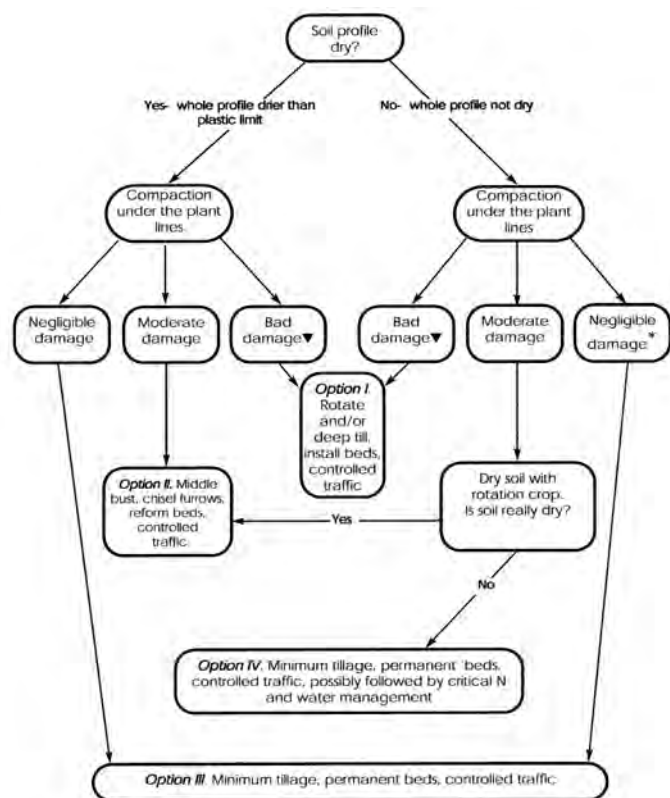
Mulching and root cutting

The Australian cotton industry has moved away from the practices of stubble removal and burning, and now promotes the practices of slashing and incorporating stubble. Some of the positives of the mulch and root cut approach are:

- Speedy operation.
- Root and sub section is cut in half reducing cultivation problems.
- System has been widely proven and is available in a variety of configurations.
- Residue is more easily broken down and incorporated than slashing.
- Weather conditions have less of an impact than on rake & burn operations.
- Depending on depth of root cut, some preliminary pupae control is achieved.

FIGURE 1:

Tillage and rotation options after a dry harvest.



* Bad damage – severe compaction in the bed subsoil, sub-surface and/or surface (SOLpak score less than 0.5)
 Moderate damage – moderate compaction in the bed subsoil, sub-surface, and/or surface (SOLpak score between 0.5 and 1.5)
 Negligible damage – absence of compaction problems (SOLpak score greater than 1.5)
 † If economically necessary to grow cotton immediately, apply critical N and water management (see Chapter 66)



- Residues are mulched back into the soil as opposed to being burnt.

Some of the negatives of the mulch and root cut approach are:

- Unless the machine is set up properly 'ratoon' plants can become an issue if roots are not cut below cotyledon level. GPS systems have helped to reduce this.
- With moist conditions trash and soil surface can build up and hamper following fertiliser applications.
- Machines are generally heavy and horsepower intensive.
- There can be more expense with maintaining machinery due to the extra components.
- Generally speaking, the cutting operation requires a much greater speed to achieve maximum efficiency.

Soon after harvest the stalks should be cut finely enough to avoid immediate management problems such as implement blockage. However if the trash is broken down too finely, decomposition and nutrient release may occur too quickly – this can lead to loss of nutrients such as nitrogen.

If the cotton disease Fusarium wilt is known to be present, it may be necessary to at least partially, disinfect the stalks by leaving them exposed to UV light on the soil surface for several weeks – immediate stubble incorporation is likely to aggravate the fusarium problem. Refer to Chapter 16.

It is important that mulchers and slashers are working effectively. With high yielding varieties, good water availability and stable cotton prices, a large percentage of the Australian cotton crop over the last 3 years has been planted on back to back fields rather than fallow. Good cotton stalk management on these back to back fields is important to ensure a suitable seedbed to optimise germination and establishment.

Systems that work very well include mulchers operated at a slower speed with extra flails added (used in photo 1) and the use of rotary hoe machines either before centre/side busting operations or after the fertiliser operations have been completed. This has been shown to further increase the soil tilth and ensure a good seed bed prior to planting.

Standard slashing

This operation focuses on slashing of the crop residue and allowing other operations to take care of the cotton stub and root system below the ground. This practice is no longer common within the industry due to the issues associated with 'ratoon' cotton.

Pull, rake and burn

The pull, rake and burn process is rarely used throughout the industry as a mainstay for crop residue control. This option is only generally used when growers are looking to re-laser fields and due to minimal cuts are seeking to avoid stubble becoming an issue with the laser buckets. Burning of cotton stalks should be avoided as nutrients will be lost and soil carbon levels will decline quickly.

Management of compacted soils

Compaction in clay soils may be remediated by subsequent crops. Cycles of wetting and drying during the growing period and deep drying by the crop after the last irrigation can crack the soil and improve structure to a point where deep tillage may not be necessary. However, residual compaction may remain; and cracking by rotation crops, and/or deep tillage, may be required to improve yields and profits of subsequent crops.

Full land preparation (ploughing the old hills and forming new ones) gives you the opportunity to 'tidy up' a field: removing hollows, straightening crooked rows, adjusting guess row spacing, and controlling weeds.

After examining the soil structure, assess soil moisture to determine to what depth tillage would be beneficial. The soil profile may not be at a uniform moisture content. It may be possible to till the upper, dry part of a compacted layer and leave the deeper, moist soil untouched (and unsmearred).

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

- SOILpak
- Cotton Pest Management Guide

Reasons why ratoon and volunteer cotton must go

- Mealybugs survive from one season to the next on these food sources, infesting crops earlier in the following season.
- Cotton aphids with resistance to neonicotinoids survive between seasons on these plants, reducing insecticide effectiveness.
- Bunchy top disease can be transmitted by cotton aphids from infected ratoons to new cotton crops.
- Silverleaf whitefly survive between seasons on these plants, resulting in earlier infestation in the following season.
- They provide a winter host for pale cotton stainers and solenopsis mealybugs.
- Inoculum of soil-borne diseases such as black root rot, Fusarium and Verticillium builds up in ratoons.
- Ratoon plants place extra selection pressure on Bt
- Ratoon cotton can be used as a host by the earliest and latest *Helicoverpa* generations.
- Ratoon plants may only express sub-lethal doses of the Bt proteins, therefore increasing resistance selection pressure.
- Fields with ratoons from Bt cotton are unsuitable for planting refuge crops, as the refuges cannot be effective if contaminated with Bt cotton plants.
- Removing ratoons may be a costly exercise, but it is cheaper than the costs of dealing with the problems resulting from not removing them.
- They are a biosecurity risk. Ratoons harbour pests and are a potential point of establishment for exotic pests.

Natural Resources

Sustainable cotton landscapes

By JANE TRINDALL

Natural areas on and surrounding cotton farms provide ecosystem services which can benefit the farming enterprise. Beneficial insects live in natural vegetation which provides resources otherwise not found in cropping fields especially when in fallow. Native vegetation can increase natural pest control early in the growing season in adjacent fields and may keep your pest insect thresholds lower for longer. Riparian vegetation prevents erosion along waterways and provides a natural filter for farming inputs protecting soil, nutrients and chemicals from entering rivers and protecting fish and their habitats. Healthy soils on the natural areas on your farm can sequester carbon and improve nutrient cycling.

Three key principles below are listed below to assist you better understand and manage the natural assets on your farm for both environmental and production benefits.

Healthy landscapes

Improving the health of individual stands of natural vegetation and linking them together on your farm and in the district will improve the numbers and diversity of plants and animals on your farm, including beneficial insects, bats and birds which provide natural pest control.

What to do:

- Map areas of natural vegetation, weeds and pests on your farm.
- With your neighbours map areas of natural vegetation, weeds and pests in your district.
- Investigate the plants and animals in your natural vegetation.
- Graze areas of natural vegetation sustainably.
- Leave logs, rocks, dead trees and litter in natural areas where ever you can.
- Work with your neighbours to control weeds and pests in the natural areas in the district.
- If you would like to revegetate areas on your farm, think about linking corridors between natural areas and use local species to improve natural pest control and increase the numbers of plants and animals on your farm.

Healthy rivers

Across the country, cotton farms are located along the rivers in the northern Murray Darling basin and the



Cotton farmers are custodians for an average of nine kilometres riparian land of which more than 85% is actively managed (2012 Cotton Industry Survey). (Photo: Cotton Australia: Greg Kauter)

reef catchments of the Fitzroy. On many cotton farms rivers, wetlands and billabongs are lined with majestic River Red Gums and iconic Coolibahs that define rural Australia. Many studies have shown that these areas are in good condition (as in 'near natural') and harbour many species of birds. The riparian zone also provides an important buffer between agricultural activity and the waterway, helping to maintain water quality and protect aquatic habitats

What to do along waterways:

- Be extra careful when spraying and farming.
- Reduce or prevent traffic access to prevent erosion.
- Work with neighbours upstream and across the river to control weeds and pests.
- Leave logs, rocks, dead trees and litter.
- Allow understorey shrubs and young trees to regrow.
- Protect existing trees and revegetate.
- Retain or replace natural snags in the river.
- Work with your local catchment body to secure eroded river banks.
- Leave a grassy buffer zone between your fields and waterway.
- Graze sustainably.
- Enter into your local Carp Muster!

Healthy soils

Whether in your field or in the natural areas of your farm, healthy soil can make farming a whole lot easier. Without the insurance of healthy soil issues like salinity, sodicity and erosion are can require an ongoing investment of time and money to restore. Simple practises to maintain soil biology, structure, organic matter and carbon will protect your farm for the long haul.

What to do:

- Manage irrigations to minimise deep drainage and salinity risks (see Chapter 8 and Water Quality Section below)

- Manage traffic
- Maintain groundcover
- Graze sustainably
- Match Landuse with Land capability
- Benchmark % groundcover based on soil type/capability

Water quality for sustainable irrigation

By PETER VERWEY

Irrigating with poor quality water, can result in soil salinisation, sodification and nutritional stress. Crop production can decline if the salts in irrigation water exceed certain levels. It may be difficult to recognise salinity problems in the paddock because there can be a significant yield decline before the signs of salinity are obvious. There may be no obvious plant symptoms or signs of salt on the surface. Cotton is reasonably tolerant to salinity in the later stages of development but very sensitive during the early stages (see WATERpak Chapter 5.4 for details). Water quality can also impact on irrigation equipment and spray quality.

Resource condition and management of groundwater aquifers is an important factor to consider. Groundwater levels can change over time, where an aquifer may either gain or lose water. Groundwater can also be susceptible to contamination, for example with an increase in salinity. It is important to note that once there is an impact detected at the point of use then significant zones of the aquifer will already have undergone an irreversible deterioration in water quality

By regularly monitoring your water quality and keeping records of test results, a baseline condition can be established and any trends or changes in water quality and availability can be acted upon and considered in the farm management plan to both maximise crop yield and to ensure the long term viability of the farm water resources

TOLERANCES

pH Reference Data		
	Lower Boundary	Upper Boundary
Corrosive to pumps	0	6.5
Low corrosive nature	6.5	9
SAR Reference Data		
	Lower Boundary	Upper Boundary
No problems likely	0	2
Suits most crops and conditions	2	8
Sensitive crops and soils affected	8	18
Fully evaluate before use!	18	46
General Water Quality Benchmarks		
	EC (dS/m)	
Rainwater	0.00	
Desirable limit for people	0.83	
Environmental impacts may occur	1.50	
Safe limit for people	1.56	
Limit for mixing herbicides	4.70	
Seawater	> 55	

For more information go to Cottassist website (<http://www.cottassist.cottoncrc.org.au>)

WATER SALINITY LIMITS FOR SURFACE IRRIGATION (in dS/m)

Soil type	Well drained		Moderate to slow draining		Very slow draining soils	
	Yield reduction	25%	Yield reduction	25%	Yield reduction	25%
Cotton	7.7	12.5	5.1	8.3	2.5	4.2

More EC reference data for other crops can be found in WATERpak Section 5.3, pg 240-241.

Water quality monitoring

What to test:

- As a minimum test EC, pH and SAR, and for bores, the groundwater level should be monitored.
- A wider range of baseline water quality parameters such as hardness, turbidity, nutrients, organics, and trace metals can also be assessed. This not only provides useful information for on farm use of irrigation water, but helps to build a profile of the surrounding landscape resource condition.

For further information on what tests to conduct contact your nearest NATA accredited water testing laboratory.



Consider the impact of water quality on irrigation equipment as well as soils. (Photo: Cotton Australia: Tim Haffey)

When to test:

- Water quality testing should be done at least once every year, preferably more often.
- The groundwater level should be measured at least at the start and end of every irrigation season. Data loggers to measure groundwater level are available and can provide the best information on the rise and fall of the aquifer throughout the year, clearly showing the effects of pumping and recharge.

How to test:

- To reduce risk of contaminating sample discuss water sampling protocols with the laboratory prior to sampling. Records such as time, GPS coordinates, ambient temperature and notes about recent local weather and other visual signs (look/smell of water).
- For groundwater, it is important to purge the bore before collecting any water sample for testing to ensure that the water being tested is representative of the aquifer and not the water that has been sitting in the bore casing between pumping. To do this, start the pump and allow it to run for at least half an hour before collecting the water sample. This will guarantee that the sample is taken from the aquifer water supply and will give accurate results of the groundwater quality.



The other side of the farm. (Photo: Cotton Australia: Irene Fletcher)

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Who can analyse:

- The full range of recommended tests can only be done in a laboratory and these tests for water quality should be performed by a NATA (National Association of Testing Authorities) accredited laboratory to ensure the accuracy and reliability of the test results.
- pH and EC tests as well as some nutrients/chemicals can be conducted on farm by growers using inexpensive and easy to operate equipment/dip tests. The quality of the results using this equipment might not match laboratory results, however these on-farm tests are well suited to continued in-season testing and monitoring changes throughout the irrigation season between laboratory tests..
- The groundwater level can be tested using a measuring tape and 'dipper' device, alternatively a commercial dip meter designed to measure the groundwater level will provide a more accurate result.

Water quality tool

A Water Quality Tool is available on the CottASSIST website (<http://www.cottassist.cottoncrc.org.au>) to assist landholders assess suitability of water for irrigation. The tool can also help growers make water shandyng decisions to dilute the impacts of poorer quality bore water.

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

- The Australian Cotton Water Story
- WATERpak
- CottASSIST Water Quality Tool
- DIY Groundwater Monitoring Fact Sheet
- Ecosystem Services Fact Sheet
- www.mybmp.com.au Natural Assets Module

You local NRM groups or CMA may be able to provide additional advice and resources.



Delivering Cotton For The Customer

Managing For Fibre Quality
Preparing For Harvest
Harvesting
Beyond The Farm Gate

Managing For Fibre Quality

By **MICHAEL BANGE (CSIRO)**

Acknowledgements: Greg Constable, Stuart Gordon, Robert Long, Geoff Naylor & Rene van der Sluijs (CSIRO)

Importance of Quality Fibre

Producing a quality fibre is important. Not only because Australian cotton holds a reputation of being purchased for a premium, but because the consequences of producing poor fibre quality is substantial (See table 1).

In ensuring that fibre quality is maintained, it is important to understand the nature of fibre and the interacting factors that affect its quality.

Optimising fibre quality starts with good crop management and selecting the right variety is a good start.

Crop management for improved fibre quality

Fortunately the majority of crop management factors which increase/optimize yield will also increase/optimize fibre quality. One exception may be instances of high yielding crops with undesirable high micronaire cotton.

Fibre length and micronaire are significantly affected by agronomic and climate effects, however Fibre strength is more influenced by variety choice. Fibre growth and development is affected by most factors which influence plant growth. Since the fibre is primarily cellulose, any influence on plant photosynthesis and production of carbohydrate will have a similar influence on fibre growth. Cell expansion during growth is strongly driven by turgor (the pressure of fluid in the plant cell), so plant water relations will also affect fibre elongation in the period immediately following flowering. Thus in terms of primary (direct) responses, water status (irrigation) strongly influences fibre growth and ultimately final fibre length. Fibre elongation will also be affected by temperature and carbohydrate limitations.

Here fibre elongation refers specifically to the elongation of a fibre in length during its growth. In terms of fibre quality, fibre elongation also refers to the elongation in a fibre before it breaks in a strength test.

Fibre thickening are also affected by temperature and radiation effects on photosynthesis with large reductions in fibre thickening leading to low fibre Micronaire following long periods of low temperatures or cloudy weather. Delayed sowing may expose more of the fibre thickening phase to lower temperatures and reduce Micronaire. Potassium deficiency can have a significant

impact on fibre length because of the role of potassium in maintenance of cell turgor by osmotic regulation. Other nutrient deficiencies can also reduce fibre length. However where nutrient deficiencies are not the major factor in a production system, nitrogen or potassium fertiliser treatments will not necessarily improve fibre length. Early crop defoliation or leaf removal can cause substantial reductions in fibre Micronaire due to the cessation in carbohydrate supply for fibre thickening. Few agronomic or climatic conditions have been shown to consistently affect fibre bundle strength.

Severe weed competition in cotton can have strong effects on fibre properties as well as trash contamination. High density and narrow row cotton production systems have variable effects on fibre quality: from no impact to significant reductions. This varied response can be explained by the specific combination of negative direct and positive indirect effects – e.g. negative impacts of competition on fibre quality may be balanced by positive effects of avoiding later unfavorable conditions. One aim of high density narrow row systems is to compress fruiting and fibre development to a shorter time period and avoid later cool or stress conditions – to at least achieve more uniform crop fibre properties.

Cotton's indeterminate growth habit also leads to many secondary (indirect) impacts of climate and management on fibre properties. Any management which delays crop maturity can lead to reduced Micronaire due to exposure of a greater proportion of a crop to unfavorable conditions such as cooler or cloudy weather. Early stress with subsequent recovery, or higher nitrogen fertility and different tillage or rotation systems and insect damage causing compensation and later fruit production are examples. Therefore adoption of appropriate and efficient management (both strategic and tactical) for improving yield will also contribute to improved fibre quality. The issues to consider for each crop management phase are summarised in the following Tables.

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

• FIBREpak Chapters 7 to 11

Put your best foot forward...



Come Clean Go Clean



TABLE 1:
Consequences of poor fibre quality

Fibre trait	Trait description	Ideal range	Consequences of poor fibre quality – cotton price	Consequences of poor fibre quality – spinning
Length	Fibre length varies with variety. Length and length distribution are also affected by stress during fibre development, and mechanical processes at and after harvest.	UHML in excess of 1.125 inch or 36/32nds. For premium fibre 1.250 or 40/32nds.	Premiums can be gained for long staple length. Significant price discounts below 33/32nds.	Fibre length determines the settings of spinning machines. Longer fibres can be spun at higher processing speeds and allow for lower twist levels and increased yarn strength.
Short fibre content	Short fibre content (SFC) is the proportion by weight of fibre shorter than 0.5 inch or 12.7mm.	< 8%	No premiums or discounts apply.	The presence of short fibre in cotton causes increases in processing waste, fly generation and uneven and weaker yarns.
Uniformity	Length uniformity or uniformity index (UI), is the ratio between the mean length and the UHML expressed as a percentage.	> 80%	Small price discounts at values less than 78. No premiums apply.	Variations in length can lead to an increase in waste, deterioration in processing performance and yarn quality.
Micronaire	Micronaire is a combination of fibre linear density and fibre maturity. The test measures the resistance offered by a weighed plug of fibres in a chamber of fixed volume to a metered airflow.	Micronaire values between 3.8 and 4.5 are desirable. Maturity ratio >0.85 and linear density < 220 mtex Premium range is considered to be 3.8 to 4.2. (linear density < 180 mtex	Significant price discounts below 3.5 and above 4.9.	Linear density determines the number of fibres needed in a yarn cross-section, and hence the yarn count that can be spun. Cotton with a low Micronaire may have immature fibre. High Micronaire is considered coarse (high linear density) and provides fewer fibres in cross section.
Strength	The strength of cotton fibres is usually defined as the breaking force required for a bundle of fibres of a given weight and fineness.	> 29 grams/tex. For premium fibre > 34 grams/tex.	Small premiums for values above 29 g/tex. Discounts appear for values below 27 g/tex.	The ability of cotton to withstand tensile force is fundamentally important in spinning. Yarn and fabric strength correlates with fibre strength.
Grade	Grade describes the colour and 'preparation' of cotton. Under this system colour has traditionally been related to physical cotton standards although it is now measured with a colorimeter.	> MID 31	Small premiums for good grades. Significant discounts for poor grades.	Aside from cases of severe staining the colour of cotton and the level of 'preparation' have no direct bearing on processing ability. Significant differences in colour can lead to dyeing problems.
Trash/dust	Trash refers to plant parts incorporated during harvests, which are then broken down into smaller pieces during ginning.	Low trash levels of < 5%	High levels of trash and the occurrence of grass and bark incur large price discounts.	Whilst large trash particles are easily removed in the spinning mill too much trash results in increased waste. High dust levels affect open end spinning efficiency and product quality. Bark and grass are difficult to separate from cotton fibre in the mill because of their fibrous nature.
Stickiness	Contamination of cotton from the exudates of the silverleaf whitefly and the cotton aphid.	Low/none	High levels of contamination incur significant price discounts and can lead to rejection by the buyer.	Sugar contamination leads to the build-up of sticky residues on textile machinery, which affects yarn evenness and results in process stoppages.
Seed – coat fragments	In dry crop conditions seed-coat fragments may contribute to the formation of a (seed-coat) nep.	Low/none	Moderate price discounts.	Seed-coat fragments do not absorb dye and appear as 'flecks' on finished fabrics.
Neps	Neps are fibre entanglements that have a hard central knot. Harvesting and ginning affect the amount of nep.	< 250 neps/gram. For premium fibre <200	Moderate price discounts.	Neps typically absorb less dye and reflect light differently and appear as 'flecks' on finished fabrics.
Contamination	Contamination of cotton by foreign materials such as woven plastic, plastic film, jute/hessian, leaves, feathers, paper, leather, sand, dust, rust, metal, grease and oil, rubber and tar.	Low/none	A reputation for contamination has a negative impact on sales and future exports.	Contamination can lead to the downgrading of yarn, fabric or garments to second quality or even the total rejection of an entire batch.



TABLE 2: Key in-field management considerations for optimising fibre quality.

Objectives	Pre planting	Sowing to first flower	First flower to open boll	Open boll to harvest	Harvest to gin
Realising the genetic potential for fibre length	Variety selection. Strategic planning for irrigation availability. Consider skip row for dryland.	Monitor soil moisture and schedule irrigation to optimise plant vegetative size.	Monitor soil moisture schedule irrigation to optimise plant vegetative size and to avoid stress on developing fibres.		
Maintaining fibre strength	Variety selection.		Maintain healthy crop.		
Producing fibre with mid range micronaire to avoid fibres that have too high linear density or are immature	Variety selection.	Monitor soil moisture and schedule irrigation to optimise plant vegetative size. Sow at appropriate date for the region to avoid early crops in hot areas or late crops in cool areas.	Management of plant vegetative size, structure and balance with boll setting pattern. Uniform boll set is achieved by having the appropriate plant type for the variety, region and climate. Optimise agronomic management such as water, fertiliser and growth regulators. Adopt IPM to protect fruit, and leaves.	Timely harvest to avoid bad weather. Use appropriate nitrogen fertiliser rates to match crop requirements and assist cut out. Schedule last irrigation to leave soil at refill point at defoliation. Use appropriate timing, product and rate for defoliation.	
Reducing the incidence of neps	Variety selection.				Spindles and doffers maintained daily. Reduce spindle twist by not picking too wet.
Delivering clean white cotton with no stickiness	Weed management.	Weed management.		Fertiliser, irrigation and defoliant management as above. Refer to IPM guidelines for aphid and whitefly management.	Picker setup – avoid pin trash and bark. Follow guidelines for module placement, construction, tarping and transport. Keep good module records.
Preventing contamination	Farm hygiene to avoid contamination during harvest later. Weed management.	Weed management.			Farm hygiene. Picking height. Hydraulics on pickers and builders checked and maintained.

Preparing For Harvest

By Michael Bange (CSIRO)

Acknowledgements: Sandra Williams, Greg Constable, Stuart Gordon, Rob Long, Geoff Naylor and Rene van der Sluijs (CSIRO)

The key to effective defoliation

Effective cutout

Cutout is when the crop ceases to produce new fruiting sites. Timing of cutout must consider opportunity for further fruit production (yield) and potential losses in fibre quality and harvesting difficulties. The cutout date should aim to optimise yield and quality allowing squares and bolls on the plant to mature and open, enabling harvest prior to cool/wet weather.

Management tips

During flowering monitor cutout at least weekly using the Nodes Above White Flower (NAWF) technique. NAWF = 4 is generally the accepted time of cutout.

Use the CottASSIST Crop Development Tool to assist you to track your crop's rate of cutout compared with the optimal rate.

Crops approaching cutout too rapidly are stressed (either not enough water or nutrition or carrying a very high fruit load). So use a strategy to provide new growth such as irrigation or nutrition.

Consider how much time is left in the season. This can be done by estimating the date of the last effective flower (See Table 1). This can be determined through the CottASSIST Last Effective Flower Tool. This tool can be used to select your own data using your nearest weather station.

Crops approaching cutout too slowly can indicate that there has been a loss of fruit and/or plenty of water and nutrition. These crops should be monitored to determine if a growth regulant is necessary. Use the CottASSIST Crop Development Tool to check your VGR (Vegetative Growth Rate). Refer to Chapter 6 – Using Mepiquat Chloride.

BEST PRACTICE

- The key management considerations for optimising fibre quality are variety selection and avoiding crop stress. So good water and fertiliser management is critical. Producing poor quality fibre can lead to significant price discounts.
- Any management which delays maturity can lead to reduced fibre micronaire, and should be avoided where possible.

TABLE 1:

Average dates for the last effective flower for various locations for different times when crops are expected to finish. These have been calculated by the CottASSIST Last Effective Flower Tool (www.CottASSIST.cottoncrc.org.au) using historical climate data since 1957.

Town	Average target date of your last effective flower				
	Date when you want your crop to be finished (date of last harvestable boll)				
	1st Mar	15th Mar	1st Apr	15th Apr	1st May
Jerilderie	30th Dec	11th Jan	22nd Jan	30th Jan	5th Feb
Griffith	31st Dec	12th Jan	24th Jan	31st Jan	7th Feb
Hillston	5th Jan	17th Jan	29th Jan	5th Feb	12th Feb
Warren	6th Jan	18th Jan	29th Jan	6th Feb	13th Feb
Bourke	13th Jan	25th Jan	6th Feb	15th Feb	22nd Feb
Walgett	11th Jan	22nd Jan	4th Feb	13th Feb	20th Feb
Wee Waa	8th Jan	20th Jan	2nd Feb	10th Feb	18th Feb
Gunnedah	4th Jan	16th Jan	29th Jan	6th Feb	14th Feb
Spring Ridge	31st Dec	12th Jan	24th Jan	1st Feb	9th Feb
Moree	8th Jan	20th Jan	2nd Feb	11th Feb	20th Feb
Mungindi	11th Jan	23rd Jan	5th Feb	14th Feb	22nd Feb
St George	12th Jan	24th Jan	6th Feb	15th Feb	23rd Feb
Goondiwindi	8th Jan	20th Jan	2nd Feb	11th Feb	19th Feb
Dalby	2nd Jan	14th Jan	28th Jan	6th Feb	15th Feb
Theodore	9th Jan	21st Jan	5th Feb	15th Feb	25th Feb
Emerald	11th Jan	24th Jan	7th Feb	18th Feb	28th Feb

Season length

Season length is another consideration that effects defoliation and harvest. Short growing seasons as experienced in southern & eastern growing regions should consider sowing as early as feasibly possible to avoid crops maturing and being harvested in cold and wet conditions. Sowing too early can however increase risk of poor seed germination and crop establishment.

Ceasing crop growth for a timely harvest

Late flowering and especially regrowth will cause fibre quality problems directly which will be reflected in reduced micronaire and increased neps, and indirectly with poorer grades. Delayed harvests also expose clean lint to increased chances of weathering. Humid conditions or rainfall increases microbial damage thereby potentially reducing colour grades. Poor and untimely defoliation can have a significant impact on fibre maturity as well as the amount of leaf trash.

- Management considerations from open boll to harvest include:
- Appropriate irrigation management for finishing the crop and avoiding regrowth.
- Managing aphid and whitefly infestations to avoid sticky cotton.

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Preparing For Harvest

- Accurately determining crop maturity.
- Ensuring timeliness of harvest operations to avoid wet weather.
- Effective application of harvest aids.

A perfect system to attain the highest quality cotton would be to have a field with 70-80% mature bolls, generated from uniform flowering and boll retention resulting in an abrupt cutout that had ample water and nutrition to meet only those requirements of the fruit present at cutout. Leaves would have matured naturally and allowed for easy defoliation at an appropriate time when temperatures were warm. The crop would be ready to harvest when the chances of rainfall were small.

Irrigation management for finishing the crop

Crop management to synchronise crop maturity dates and harvesting operations with climate and weather is one aspect of timeliness. Excess nitrogen rates (see sowing to first flower chapter of FibrePAK) or events which cause late regrowth (e.g. excess soil moisture at harvest) can interfere with defoliation practices and picking. Delayed growth may also mean that fibre development may also occur in cooler weather (reducing fibre maturity, lowering micronaire and increasing neps).

Unnecessary and late season growth also supports late season insects which can damage yield and quality. In wet or humid weather leafy crops may also contribute to boll rot.

Timing of last irrigation is a balance between ensuring (1) there is enough moisture to allow the growth and maturity of harvestable bolls, and (2) fields are dry enough to assist defoliation, limit regrowth, and minimise picking delays and soil compaction. The moisture required for late crop growth is related to the time of defoliation. The broad aim is to plan to manage irrigations effectively to finish the crop and to limit regrowth by having soil moisture levels to refill points by defoliation.

Determining end of season crop water requirements (taken from IPM guidelines)

End of season water requirements can be estimated from the date of the last effective flower (which is when the Nodes Above White Flower (NAWF) measurement is equal to 4). The last harvestable bolls take 600 to 650 degree days to reach crop maturity. Therefore for crops to be defoliated towards the end of March, the last effective flower needs to occur in the last week of January. Crop water use needs to be considered for this period. At the time of first open boll, crop water use may be 5-7 mm per day and may decline to around 4 mm per day prior to defoliation.

Factors to consider:

- Days to defoliation;
- Boll maturity;
- Crop water use;
- Plant available water – ability to extract water below normal refill point; and,
- Soil moisture objective at defoliation.

Days to defoliation

(General example – need to generate values for your own district)

- Defoliate when Nodes Above Cracked Boll (NACB) is equal to 4.
- Takes 42 degree days, around 3 days (up to 4 days in cooler regions) for each new boll to open on each fruiting branch.
- $(\text{Total NACB} - 4) \times 3 = \text{days to defoliation}$.
- Aim to be at or close to refill point at time of defoliation.

Crop maturity is monitored to avoid early crop cessation

To determine crop maturity monitor plants that are representative of the crop.

Methods include:

- **% bolls open** – Crops can be safely defoliated after 60-65% of the bolls are open. This method is simple and works well in crops with regular distribution of fruit.
- **NACB (Nodes above cracked boll)** – In most situations 4 NACB equates to the time when the crop has 60% bolls open. This is a useful methodology on crops that are uniform in growth, and is less time consuming than % open bolls.
- **Boll cutting** – The easiest and probably the most effective method to determine if bolls are mature or immature. It can be used effectively even when crops are not uniform (e.g. tipped out plant, gappy stands). Bolls are mature when: they become difficult to cut with a knife; the seed is well developed (not gelatinous) and the seed coat has turned brown (see Figure 1); and when the fibre is pulled from the boll it is stringy (moist but not watery).

See also timing of harvest aids following.

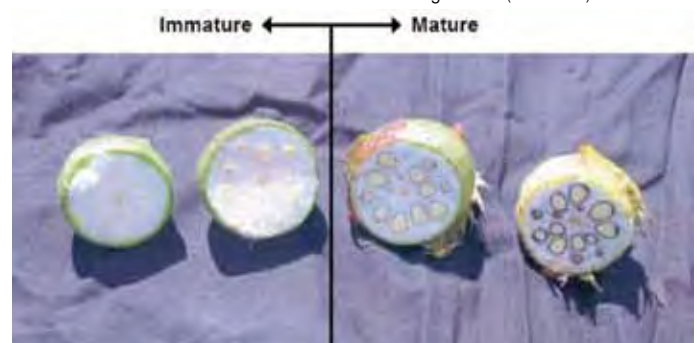
Whitefly and aphid infestations are monitored and managed to avoid sticky cotton

A significant proportion of all cases of stickiness are attributable to honeydew exudates of the silverleaf whitefly (*Bemisia tabaci* B-biotype) (SLW) and the cotton aphid (*Aphis gossypii*). The sugar exudates from these insects lead to significant problems in the spinning mill.

Presence of honeydew on the surface of cotton late in the

FIGURE 1:

Bolls that are mature have seed coats that are turning brown. (Photo: CSD)



season can also contribute to reductions in grade as it provides a substrate for sooty moulds and other fungal growth. In humid conditions the growth of fungal spores along with honeydew can increase the grey colour of the lint.

SLW and aphids prefer to feed on the under surface of the leaf allowing the small transparent droplets of honeydew to fall to leaves and open bolls below. The level of contamination by honeydew is directly dependant on the numbers and species of insects present. Control of these pests is especially important once bolls start to open.

For more information on managing these pests see the Cotton Pest Management Guide.

Timeliness of harvest operation

Cotton that is severely damaged from weather is also undesirable in textile production because the lint surface has deteriorated and this is perceived to have dye uptake problems. It also can increase the roughness of the fibre which alters its frictional properties and thus how the fibre performs in the spinning mill.

As cotton weathers it loses reflectance, becoming grey due to moisture from both humidity and rain, exposure to ultraviolet radiation (UV) and from fungi and microbes that grow on the lint or wash off the leaves. Damage to the fibre will reduce micronaire as the fibre surface becomes rough retarding air movement in the micronaire chamber. Weathering will also reduce fibre strength making fibres susceptible to breakage during the ginning process, reducing length and increasing short fibre content leading to issues in yarn production.

When a boll opens under humid conditions microbes begin to feed on the sugars on the surface of the fibre and stain the lint. Under very humid conditions fungi can multiply on the lint causing 'hard' or 'grey locked' bolls which can reduce both quality and yield.

If bolls are opened prematurely by frost often it has a yellow colour that varies with intensity of the frost. Injury to moist boll walls as a result of frost damage releases gossypol which stains the cotton yellow.

A grower should examine their harvest capacity, regional weather patterns, and have monitored their crop development to avoid excessive weathering.

Specific considerations include:

- Time harvest to avoid excessive rainfall once bolls are open. Tools to assess rainfall frequency include: Rainman (<http://www.daff.qld.gov.au/26-15734.htm>) <http://www.bom.gov.au/climate/averages/>
- Plan to have the crop defoliated before first frost. See Table 2 or use the last effective flower tool on the CottASSIST website which can be used to identify the timing of first frost for your locality.

Effective application of harvest aids

Defoliation induces leaf abscission which is the formation of a break in the cellular structure joining the leaf to

TABLE 2:

Dates of first and last frost for cotton production
(Source: <http://www.longpaddock.qld.gov.au/silo/>)

Region	Years of climate data	Average date of first frost	Date of earliest frost recorded
Emerald	111	9 Jun	23 Apr
Dalby	111	26 May	17 Apr
St George	43	7 Jun	7 May
Goondiwindi	107	2 Jun	23 Apr
Moree	111	28 May	12 Apr
Narrabri	43	25 May	27 Apr
Gunnedah	62	22 May	11 Mar
Bourke	43	12 Jun	10 May
Warren	43	27 May	27 Apr
Hillston	43	17 May	1 Apr

the stem allowing the leaf to fall off. Leaf removal is critical for reducing the amount of leaf trash in machine harvesters. These chemicals allow timely and efficient harvest of the lint to reduce quality losses from weathering and leaf stain from excess leaf trash. Boll opening is also accelerated by defoliation as removal of leaves exposes bolls to more direct sunlight, promoting increase temperatures for maturation, and drying and cracking of the boll walls.

Application of harvest aids are determined by: the timing, the type of chemical used, and the rates applied. The effectiveness of harvest aids is dependent on: uniformity of plant growth, weather conditions, spray coverage, and adsorption and translocation of the chemical by the plant. Optimum timing of harvest aids must strike a balance between further boll development and potential losses from adverse weather and the inclusion of immature fibre which can lower micronaire and increase neps (Figure 2). Avoiding regrowth resulting from residual nitrogen and moisture in the soil will also contribute to harvest aid effectiveness, as regrowth plants have high levels of hormones that can interfere with defoliation.

Types of harvest aids

The categories of harvest-aid chemicals include herbicidal and hormonal defoliants, boll openers, and desiccants each with a different mode of action:

Defoliants (Thidiazuron, Diuron, Dimethipin) – All defoliants have a common mode of action to remove leaves. They increase the ethylene concentration in leaves by reducing the hormone auxin and/or enhancing ethylene production. Dimethipin alters the concentration of ethylene by reducing the amount of water in the leaf stimulating ethylene production. This change in ethylene concentration triggers separation in the abscission zone at the base of the petiole (leaf stalk). Chemical defoliant



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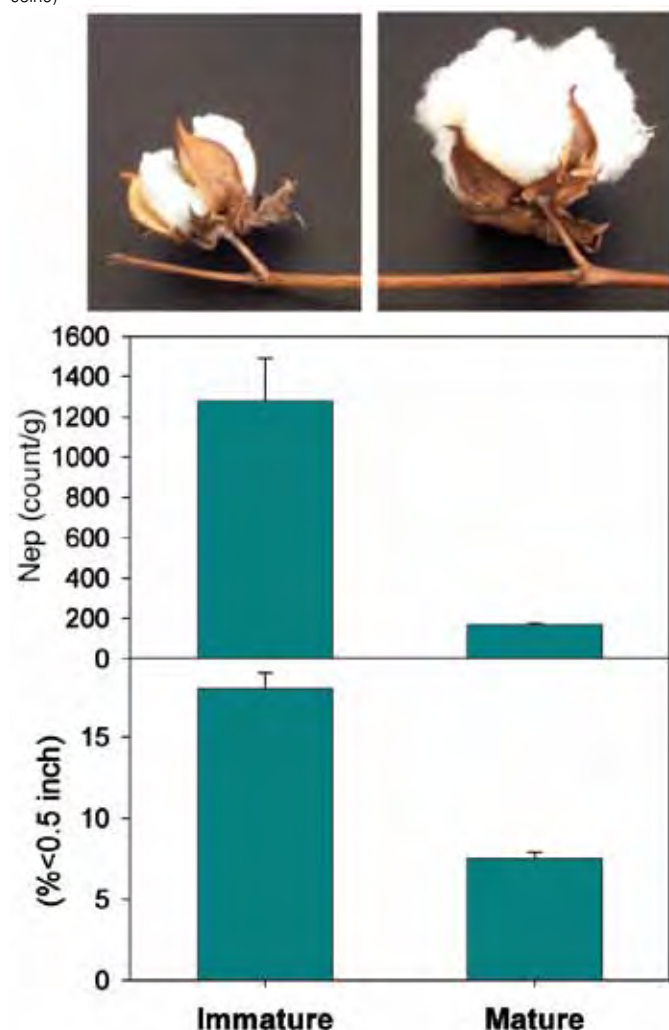
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FIGURE 2:

Pursuing late bolls may put fibre quality at risk. Un-fluffed immature bolls contribute little to yield but significantly increase neps and short fibres. (Rob Long, CSIRO)



enters leaves through the stomates (minor route) or through the leaf cuticle (major route). Hormonal defoliants are applied to reduce auxin and/or enhance ethylene production, while herbicide defoliants injure or stress the plant into increasing ethylene production (similar to waterlogging or drought effects). If herbicide defoliants are applied at too high rates the plant material may die before releasing enough ethylene to cause defoliation resulting instead in leaf desiccation (leaf death).

Boll openers/conditioners (Ethephon, Cyclanillide, Aminomethane Dihydrogen Textraoxosulfate) – These chemicals specifically enhance ethylene production by providing a chemical precursor for the production of ethylene, which leads to quicker separation of boll walls (carpels).

Desiccants and herbicides (Sodium Chlorate, Magnesium Chlorate, Glyphosate, Diquat, Paraquat) – Desiccants are contact chemicals that cause disruption of leaf membrane integrity, leading to rapid loss of moisture, which produces a desiccated leaf. Desiccants should be avoided as they dry all plant parts (including

stems) which can increase the trash content of harvested lint. Sometimes it is necessary to use desiccants if conditions do not enable the effective use of defoliants (e.g. very cold weather). Desiccants are also a reliable method to reduce leaf regrowth. High rates of some defoliants can act as desiccants.

Timing of the application of harvest aids

The type of defoliation product is unlikely to impact on fibre quality if timing is correct however, early defoliation can cause a significant reduction in all desirable fibre properties. Too early defoliation will increase the number of bolls (often from the top of the plant) harvested that have immature fibre with reduced fibre strength and micronaire. This may cause fibres to break during ginning lowering fibre length and uniformity and increasing short fibre content and neps. It is important to note that immature fibre will not allow for correct assessments of fibre strength using HVI.

Application of defoliations earlier than 60% of bolls open will reduce micronaire and increase neps. In crops that have non-uniform maturity it is advisable that there be no more than 29% immature bolls (of total boll number) that are defined as immature bolls using the boll cutting technique to avoid increasing neps.

Key issues for use of defoliants

- Ensure defoliation practices occur before the onset of frost.
- Aim to have soil moisture at refill points at defoliation. Severely water stressed crops will not allow defoliants to act effectively.
- If boll openers/conditioners are applied prior to boll maturation they may cause bolls to shed and reduce yield.
- The use of boll opener/conditioners should only be considered if the bolls that will be forced open are mature.
- Avoid application of defoliants when there is a risk of rainfall shortly after. Some defoliants are taken up slowly by the leaves and will wash off by rain, resulting in incomplete defoliation.
- To avoid regrowth issues it is prudent not to defoliate an area bigger than can confidently be harvested within 2 weeks.

Rate and chemical selection issues

- Varieties can sometimes differ in the needs for defoliation as they can differ in the quantity of wax on the leaf surface which affects harvest aid uptake, and plant hormone concentrations.
- Leaves most susceptible to defoliant are older leaves. Higher rates of defoliant will be needed for young healthy leaves. However, there is a chance that young leaves may 'freeze' on the plant if defoliant is applied in too warm weather.
- Cool temperatures, low humidity and water stress prior to defoliant application can increase the waxiness

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and thickness of the leaf cuticle reducing the efficiency of chemical uptake. Wetting agents or spray adjuvants can assist with this problem.

- Because leaf drop requires production of enzymes, the speed with which a leaf falls off is highly dependant on temperature. There are different optimal temperatures for defoliant performance. Hormonal defoliants and boll conditioners have a higher optimal minimum temperature of around 18°C compared with herbicide defoliants that have optimal minimum temperatures ranging from 13 to 16°C. Higher rates are often needed to offset the effects of low temperatures.
- The defoliating effects of a chemical are usually complete 7 days after application.

Application issues

- Low humidity during application decreases uptake because chemicals dry rapidly on the leaf.
- For penetration of defoliants lower into the canopy consider using larger droplet size or directed sprays in the case of ground rig use. Use of spray adjuvants may decrease droplet sizes and this may work against chemical penetrating deeper into the canopy.
- Many growers use combinations of defoliants with different modes of action and multiple applications to enhance defoliation. Multiple applications are beneficial because leaves deep in the canopy can be covered fully.
- If increased waxiness of the leaves is suspected, applying the defoliant in warmer conditions can assist chemical penetration as the waxy layer is more pliable.

Refer to the Cotton Pest Management Guide and manufacturers details for specific chemical defoliation options and rates.

These guidelines have been extracted from FIBREpak – A Guide to Improving Australian Cotton Fibre Quality.

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

- FIBREpak
- CottASSIST
- Cotton Pest Management Guide
- myBMP

Harvesting & Delivering Uncontaminated Cotton

By **RENE VAN DER SLUIJS (CSIRO)**

Acknowledgements: Sandra Williams, Greg Constable, Stuart Gordon, Rob Long and Geoff Naylor (CSIRO)

OH & S at harvest

It is vital that all contractors and farm staff go through a safety induction in 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. This process is equally important for contractors as well as farm staff.

Developing a set of procedures of how you would like the picking operation to progress will ensure that all involved are aware of correct and safe operation of equipment. The following are examples of procedures:

- Read and understand the operation manual and the basic safety procedures which are provided with the picker.
- Establish procedures and picking patterns and then train and re-train all staff/contractors on how picking machinery will be serviced and operated.
- Wearing appropriate clothing and using protective equipment where necessary can reduce the risk of an accident occurring.
- Keep windows and mirrors clean for good visibility.
- Keep all lights and alarms in proper working order.
- Ensure walkways and platforms are free of tools, debris or mud.
- Travel at safe speeds around ground staff and

BEST PRACTICE

- Regular maintenance and correct set up of pickers must be conducted for a clean and effective harvest.
- Check tarp quality.
- Check moisture levels in modules.
- Come Clean Go Clean - Ensure farm hygiene practices are in place to avoid contamination, especially when constructing modules.

equipment and limit unnecessary traffic around pickers and builders

- Ensure everyone is out of danger way before emptying or moving a picker or plant.
- Emphasise 'look up and live' to avoid contact with overhead obstacles such as powerlines, trees or sheds.
- If work continues during the night, workers must take extra care and be aware of the position of other workers. Workers should wear reflective clothes or safety vests and audible warning sounds on machinery should be activated.

For further information on OH & S please refer to Chapter 26.

Use of a properly maintained picker that is setup correctly

The two types of mechanical harvesting equipment are the Spindle picker, which is used to pick the bulk of the Australian crop, is a selective type harvester that uses rotating tapered, barbed spindles (Figure 1) to pull seedcotton from opened bolls into the machine. The other type of harvesting machine is the cotton stripper which is a non-selective, that uses brushes and bats to strip seed cotton from bolls. These harvesters are predominately used to harvest seed cotton from rain fed (dryland) cotton with shorter plant heights and lower yields but removes not only the well opened bolls but also the cracked, immature and unopened bolls along with the burrs (carpel walls), plant sticks, bark and other foreign matter. Stripper harvested seed cotton often increases ginning costs and results in lower turnout as well as lower grades.

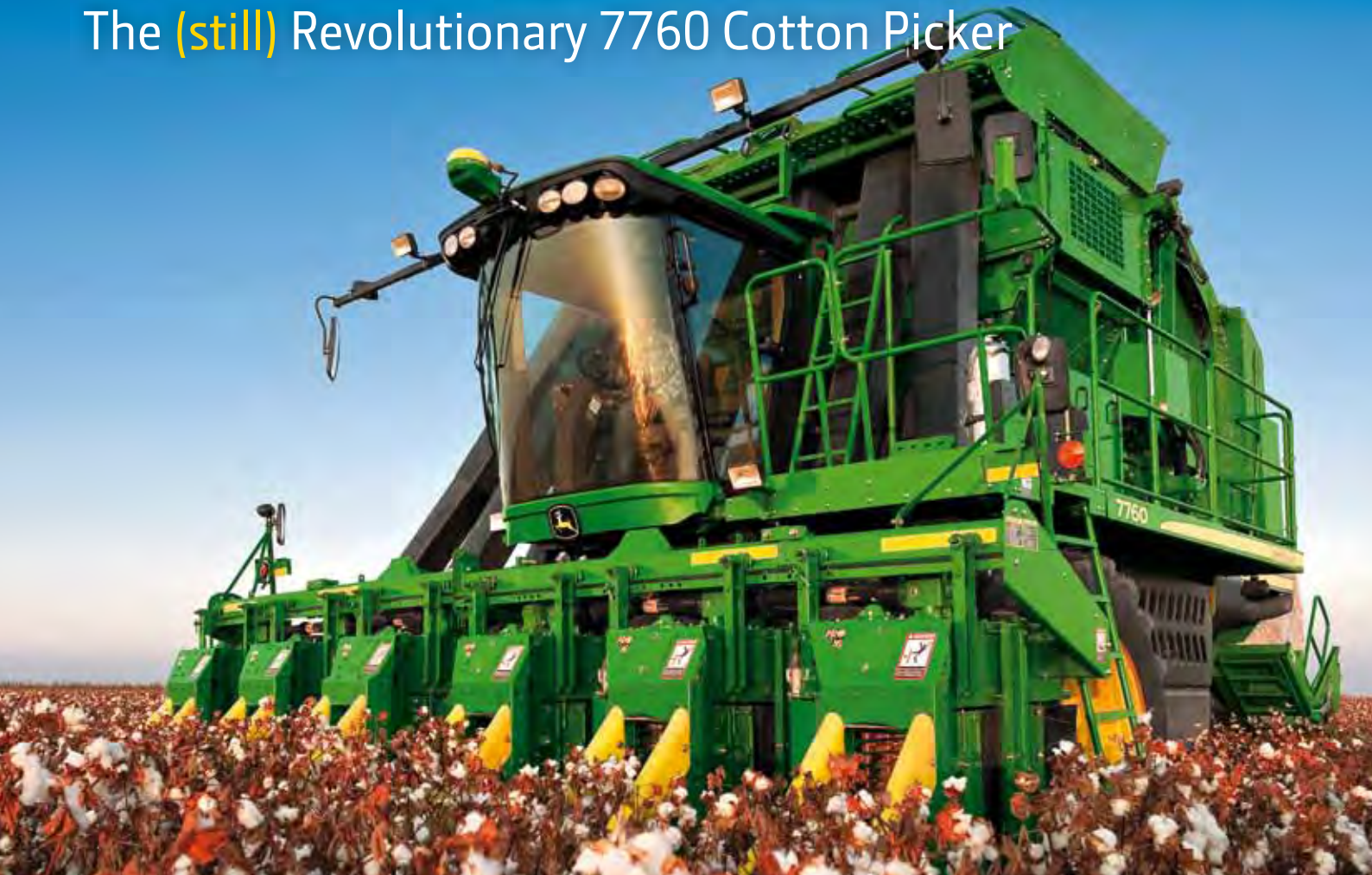
Generally agronomic practices that produce high quality uniform crops contribute to harvesting efficiency. Soil

FIGURE 1:

Spindle pickers require regular maintenance to operate at high efficiency.



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should be relatively dry in order to support the weight of the harvesting machinery and avoid unnecessary soil compaction. Row ends should be free of weeds and grass and should have a field border for turning and aligning the harvesters with the rows. Banks in drains should not be too steep an angle. Plant height should not exceed about 1.2 m for cotton that is to be picked and about 0.8 m for cotton that is to be stripped.

Spindle pickers are large and complex machines that are expensive to purchase costly to maintain and require precise setup, adjustment and trained and skilful operators to obtain the maximum yield and value per acre possible. Special care should be given to the spindles, moistener pads, doffers, bearings, bushings, and the cam track. Proper maintenance and correct setup of pickers will help to ensure a clean and effective pick. Your best source of information about picker maintenance and setup is your picker operator's manual.

Moisture is added to the spindles to keep them clean and to enhance the adherence of the fibre to the spindle and allow for its removal by the doffer. Spindles generally require less moisture in the morning than in the afternoon.

As Australian cotton is mainly picked by means of the spindle harvester, this chapter will focus mainly on this system. Many issues will however apply to both picked and stripped cotton harvesting systems.

Pre season maintenance includes:

A successful harvest requires a cotton harvester that is in good condition; even old harvesters can do an efficient job if they are in good mechanical condition. Special care should be given to the spindles, moistener pads, doffers, bearings, spindle bushings, and the cam track. Your best source of information about maintenance and setup is the operator's manual.

- Check and replace damaged tyres.
- Inflate tyres to the pressure specified before making any field adjustments.
- Ensure that row units are tilted as specified by machinery manufacturer.
- Replace bent, broken or worn spindles and ensure that all spindles are sharp and free of rust.
- Check spindle bushes for excessive wear.
- Ensure all spindles have similar length and diameter.
- Ensure all spindles turn when the row unit is rotating.
- Doffers need to be ground and reset properly as required. Replace when damaged.
- Check moisture pads, bar heights and grid bars. Moisture pads should wipe each spindle clean to remove plant juices (sap) that may cause spindle twist.
- Check cam track, roller, drum head and bar pivot stud for excessive wear.
- Check pressure doors for wear, bends, gap and alignment.
- Clean basket pre cleaners and picker basket top.



(Photo: Cotton Australia: Joanne Ambrose)

- Check hydraulic lines, components and air hoses for leaks.
- Ensure drive belts are adjusted correctly and universal joints in the drive train are lubricated and in good condition.
- Check condition of steps and handrails on harvester.

Daily setup and checks include:

Proper cleaning and servicing of the harvester before, during and after harvesting has been completed will result in better performance and lower the potential of fire.

- Check engine oil and coolant levels before starting engine of harvester for the first time in the morning.
- Picker heads should be greased when they are warm. Some systems also require light greasing every two to four hours throughout the day. Spin heads to remove excess grease and wash down if excess still remains.
- Ensure head heights are set correctly (too high and bolls are not harvested, too low and soil is collected).
- Ensure correct setting of pressure doors for crop conditions. Dented or worn doors cause inefficient picking. Adjust doors to allow efficient removal of lint but avoid excessive green boll and stem bark removal.
- Doffers need to be checked daily and throughout operation. Too much clearance leads to improper doffing and spindle twist in the lint while lack of adequate clearance leads to rapid abrasion of doffer plates by the spindles leading to presence of doffer pad specks (often not detected until textile manufacture).
- Spindles and bushes should be regularly checked for wear, especially the ones near the ground. Worn parts should be replaced.
- Spindles should be kept clean as dirty spindles cause spindle twist (wrap) and incomplete doffing resulting in excessive accumulation causing the unit air system to choke.
- Use a recommended spindle cleaner in conjunction with the correct nozzle output determined by existing conditions (especially if there is green leaf present on the plants).



- Perform regular cleaning, either using a broom, your hands or compressed air, of the picking air suction doors, basket or bale chamber. Dispose of fly cotton where it cannot contaminate the module.
- Adjust water volume correctly according to the time of day and picking conditions. Higher rates are usually needed in the middle of the day when conditions are drier.
- To avoid harvesting green bolls, pressure doors should be set to light to medium and all grid bars should be in position.

Templates are available in the Fibre Quality module in *myBMP* to help with pre-season and daily picker checks.

Guidelines for module placement, construction, tarping and transport

Key considerations for module production to maintain quality are module placement, construction, tarping, storage and transportation to the gin. Another important consideration is ensuring personnel involved in module building are instructed and observe a sanitary workplace in terms of contamination. Workers should abide by the dictum that no unworn clothing, rags, papers, tools, non-cotton ropes, tarps (with exception of the module tarp), lunch bags etc. be left in and around the module making work site. In addition cotton is highly flammable and it is essential that workers do not smoke near cotton modules. Typically harvesters with basket systems require module builders to produce conventional (traditional) modules that have a maximum size of 2.4 x 3.0 x 12 metres. These modules can weigh 12-16,000 kg which produce an average of 24 bales. In contrast harvesters that can build modules on board builds modules which weigh 2,000-2,600 kg which produce an average of 4 bales.

Module placement

Incorrect placement of modules has the potential to contribute to significant losses caused by moisture damage as well as contributing to contamination. The following guidelines should be considered when choosing a site for module placement:

- Module pads should have enough space to allow easy access for the equipment and trucks.
- Located on a well-drained field road and avoiding areas where water accumulates.
- Surface of site free from gravel, rocks, stalks, and debris such as long grass or cotton stalks.
- Smooth, even and firm compacted surface that allows water to drain away.
- Accessible to transport and inspection in wet weather.
- Away from heavily travelled and dusty roads, and other possible sources of fire and vandalism.
- Clear of overhead obstructions, especially power lines.
- Build modules in a straight line which will assist the carrier to avoid misalignment of modules on the trailer that could cause an over-width load, breakage of the module and lost cotton.

- Ensure ample space around the module builder so that harvesting equipment, trucks and infield loaders have easy access.
- Module builders should not be elevated with blocks as this can create oversized and overweight modules.
- Only build module weights which are appropriate to the transportation system. Do not exceed 16 tons if chain beds are to be used, with flat top trucks able to handle more weight.

Module construction

A module builder compacts seed-cotton to a density of about 190 kg/cubic m. A tighter module better sheds rainfall on the sides and less cotton is lost during storage, loading and hauling. The top of the module should be rounded to allow the top of the module when covered to shed water. In addition a well compacted module will help reduce freight costs to the gin.

Good communication is needed between module-builder operators, picker and boll buggy drivers to allow appropriate time for modules to be built and to avoid spillages. Cotton that is spilled from modules should be carefully added back into the module avoiding contamination whilst following strict OH & S guidelines.

A constant lookout for oil leaks on both cotton pickers and the module builders is needed to prevent contamination. Oil leaks on builders should be repaired as soon as they are noticed. Oil contaminated cotton needs to be removed from the module as soon as it is identified.

Module tarping

Use of a high quality tarpaulin on modules is important to avoid moisture affecting quality as well as avoiding significant contamination of the cotton from the tarpaulin itself. Before using tarpaulins inspect them for holes, tears and frayed edges and that they repel water.

Tarpaulins should be chosen considering their tensile strength to avoid tearing, resisting puncturing and abrasion, adhesion of coatings, UV resistance, and cold crack temperature. If tarpaulins have seams they should be double stitched, with a minimum number of stitches. Centre seams (unless heat sealed) should be avoided as it is a potential weak point to allow water to enter the module. All these factors should be weighed up in light of the overall cost of the tarpaulin and its life expectancy. The tarpaulins should be kept in a dry, vermin free store to ensure their quality and longer life expectancy.

To avoid contamination and fibre quality losses tarpaulins need to be securely fastened to the module. For best performance of tie-down type module covers use all loops and grommets provided. Cotton rope is the most appropriate fastener to limit contamination and synthetic rope should never be used. Ensure rope has enough strength to endure strong winds. Belly ropes should be avoided if possible as they may break. A tarp should be large enough to cover at least half to two thirds of the modules on the ends.

Module transportation

- Locate module tickets in the same location on each tarp, this will help when loading and allow for easy checking that each module has been tagged.
- Truck and trailer beds need to be cleaned prior to picking up the module (A rake should be provided).
- No loose cotton to be added to module when loading.
- All loads to be properly covered.
- Truck beds to be cleaned down after unloading (Come Clean – Go Clean).
- For specific details on regulations for module transportation go to www.cottonaustralia.com.au for the latest information.

Keeping good module records

Identifying when and where each module is produced can help with producing better fibre quality outcomes as the grower can discuss with the ginner the quality of the cotton of each module and thus tailor the ginning process to suit. The grower can also use these records to better understand the variability that exists in fields to refine management practices for that particular field in subsequent seasons.

Each module should have a record (with a duplicate kept in a safe place), which includes the date and weather conditions when picked. Any records or numbers assigned to modules should be as permanent as possible. Permanent marker pens should be used on cards attached to modules in a sealable plastic bag.

If a module is suspected of having a contaminant, clearly identify it, and notify the gin when delivering the module of the potential problem.

Round module pickers

The introduction of on board module building capacity on pickers (Figure 2) has offered opportunities to growers to undertake non-stop harvesting and eliminate in-field unloading to boll buggies and processing in module builders. This picking process may potentially save time, fuel, and labour and may allow simpler segregation of cotton of differing quality.

The round modules are covered with an engineered polyethylene film that both protects the seed cotton and provides compressive force to maintain the module density. As this harvester can harvest without stopping to unload the operator needs to decide where and when to drop the module that has been completed and being carried. Typically, the finished module is carried until it can be dropped on a turn-row. However if the yield is very high, or the row lengths are long, it may be necessary to drop the modules anywhere within the field. This action has no impact on the operation of the harvester, but stalks may puncture or tear the plastic wrap.

While management processes using these systems will differ and alleviate some of the issues discussed below many of the principles will, however, still apply.

Module staging

As is the case with conventional modules incorrect placement of modules can contribute to losses caused by moisture damage as well as contributing to contamination. The modules must be picked up from where they were dropped in the field, and staged together for pickup. The most common system is a mast-type tractor mounted implement that holds the module with the axis parallel to the tractor rear axle. Because the round modules can weigh up to 2,600 kg's, a large tractor is required for staging.

- Transport speed of the tractor with a module on the handler should be kept to a safe speed to suit current conditions and not exceed 16 km/h (10 mph).
- When transporting modules through harvested rows, the module should be carried high enough to minimize contact with those rows.
- Gap between the underside of the module and the ground should be sufficient and never be less than 15 cm during module staging to prevent drag and tearing of underside of wrap.
- Modules should be staged only in well drained areas of bare soil, such as turn-rows. If the soil is wet, wheel slip by the truck can cause the loading chains to tear the plastic wrap.
- Modules should be staged on a high flat surface. Staging on well defined flat driveways or a flat disked surface is optimal. Modules will take the shape of the surface they are placed on. Setting on beds or uneven surfaces requires digging into the ground with the module truck chain to safely get under the entire surface of the module.
- Avoid placing the module on cotton stalks, as the movement of the modules on the stalks can puncture the plastic wrap. If possible, avoid staging in areas where the truck cannot access the modules if rain occurs.
- When staging round modules together for transport or for storage at the gin, lift the module 30 cm or more above the ground. A lower position can result in stalks tearing the exposed wrap on the bottom.
- When placing modules together for transport, a gap should be left between each module.
- Do not allow module ends to touch, as this will cause water to enter the modules rather than to run off down the ends. The modules should be aligned so that the centrelines are within a +/- 13 cm band. If not properly aligned, the wrap may be damaged by the sidewalls of the module truck.
- Stage round modules for transport as per transport operators required method. The two typical staging types are "Sausage" (end to end) and "Wagon Wheel" (at 90 deg from end to end). The "Wagon Wheel" is more common for loading by articulated loaders and transport by flat top trucks. The "Sausage" staging is for the more specialised self loading chain-bed trailers. However development of a self loading



trailer for Wagon Wheel loading is being pursued. Modules staged for sausage chain-bed module truck pickup must have gaps between 102 mm and 203 mm at module cores. Too little gap can cause tearing as modules travel up module truck incline due to interference with adjacent modules. Also, having module ends contacting each other during long-term storage can increase chances of mold growth. Gaps between modules allow ventilation.

- Significant wrap tears must be repaired in the field before module truck pickup to prevent further wrap damage and ginning problems.
- Loose outer tails must be secured with a high strength spray adhesive (3M 90) or lint bale repair tape.

Round module transportation

The Load Restraint Guide requires each module to be individually restrained.

On open sided semi-trailers, the round bale modules can be loaded either 'wagon wheel' or 'sausage' configuration. From the point of view of managing the risk that the sides of individual round bale modules may bulge beyond the statutory load width of 2.5 metres once restraint straps are tensioned, the 'wagon wheel' option is the preferred loading configuration.

Caution: Round bale modules loaded on open sided flat-top trailers in the 'sausage' configuration are much more likely to expand beyond the trailer sides once restraint straps are tensioned.

If any section of a round bale module extends beyond the statutory maximum width of 2.5 metres when loaded on a flat-top trailer, then the entire load is deemed to be over-width. In this situation you may not be legally able to operate under an over-width notice due to the multiple number of round bales on the trailer determined as a 'divisible' load.

Quality Issues

Moistures considerations

Cotton that is picked wet will result in cotton being twisted on the spindle (spindle twist – roping that occurs when spindles are partially doffed) which may lead to seed cotton being more difficult to process in the gin. Moist cotton during the ginning process can also mean that excessive drying is needed which also causes fibre damage. The harvesting operation itself is also interrupted as picker doors are blocked more often when cotton is too moist and efficiency declines as a result of poor doffing efficiency, i.e. no flow out of the basket. Doffers and moisture pads on pickers can also be damaged.

Typically cotton is too moist for harvest at dawn in Australia but cotton can be picked well into the night provided relative humidity remains low. Moisture monitoring using moisture meters or dew point charts/calculators need to be used more frequently at each end of the day as the change in moisture can be quite abrupt,

e.g. moisture can increase abruptly from 4% to 6% within 10 minutes as night and dew point temperature fall rapidly. Harvesting seed-cotton in excess of 12% moisture is not recommended. Note: hand held moisture meters are usually $\pm 1\%$ accurate.

If wet cotton is processed into a module in the field it will also increase the risk of the module self combusting or lowering the grade due to yellowing or spotting associated with fungal contamination.

Modules during storage on-farm and in the gin should be monitored every five to seven days for temperature rises. A rapid temperature rise of approximately 8 to 11 degrees Celsius or more in 5 to 7 days signifies a high moisture problem and that module should be ginned as soon as possible. Modules that have temperatures rising to 43 degrees Celsius need to be ginned immediately. The temperature of modules harvested at safe storage moistures will not increase more than 5.5 to 8 degrees in 5 to 7 days and will level off and cool down as storage period is extended.

Assessing moisture content

Some rules of thumb to consider relating to moisture on cotton to be harvested include:

- If moisture is present on vehicles while harvesting it is most likely that the cotton is too wet.
- The seed should feel hard (cracks in your teeth)
- When a handful of cotton collected in the palm of your hand is squeezed into a ball and then released, the moisture content is acceptable if the seed cotton springs back to near its original size.
- If you can feel moisture on the cotton it is too wet. Seed cotton measured on a moisture meter should be less than 12%.
- Consider that machine picking can also add 2% moisture to seed cotton.
- The addition of green leaf will add moisture.
- A symptom of moist cotton is frequent blocked doors, throwing cotton out the front of the picking heads.
- If cotton is being expelled into the basket in dense blobs and is not fluffy it may be too moist.
- Suitable picking conditions late into the night are rare.
- Notify your ginner of modules that may be moist so that they may be ginned first, or at least monitored in the module yard.

FIGURE 2.

Round modules and small modules automatically made and discharged from pickers avoid to a large extent the problem of contamination, although contamination from tarps and coverings, which need to be removed before ginning, remains an issue. (Photo: John Deere)



Round modules

Seed cotton moisture has always been an issue; however, there are some characteristics of round modules which highlight the need for diligent monitoring of seed cotton moisture:

- Round modules are smaller in size in comparison traditional modules which means that there will be less dilution of the cotton from across different picking times and moistures. The last round module picked each night will have significantly higher moisture than those picked in the middle of the day. From a ginners perspective this is an issue as they are unable to respond to rapidly changing moisture levels to gin efficiently.
- As there is less surface on each round module exposed to the air to allow for moisture to evaporate and round module covers are also difficult to remove and replace to assist with drying. Round modules clumped tight in sausage formation will also limit airflow between modules.
- Isolation for express ginning of high moisture round modules can be difficult, as they can be lost in the multitude of modules produced in a shift. Cartage of several (5–6) round modules can also make isolation of these modules at the gin difficult.

Contamination

Contamination of cotton with foreign substances lowers the value of the product and often causes problems and increased costs for those processing the cotton at both the gin and the spinning mill. Australian cotton is recognised as one of the least contaminated cotton's in the world and receives a premium. Any contaminants lower the value of the final product and can potentially damage Australia's reputation as a supplier of quality cotton. This standard must be maintained and the responsibility for keeping

Australian cotton clean and contamination free rests with everyone involved in growing the crop, preparing it for harvest, harvesting and module construction, transport to the gin, ginning and shipping to the mill. By far the largest contribution to contamination occurs at harvesting and module building time.

There are two types of contamination:

- **Natural** – Such as the likes of rocks, wood, leaf, bracts, bark, green leaf, burrs and grass. As well as honey dew which are produced by aphid/whitefly which cause a sticky sugary substance which causes problems in ginning and spinning. Many of these natural contaminants can be avoided with careful management and good agricultural practices both prior to and during harvest.
- **Man made contaminants** – Synthetics such as plastic and twine, oil, hydraulic oil, grease, pieces of metal and equipment as well as food wrappers, drink bottles, mobile phones, cleaning rags can also find their way into a grower's module. Mostly these man made contaminants can be eliminated. Trial markers (pink tape etc) are a source of contamination and should be removed prior to harvest.

A site inspection before putting down a module can prove very useful. Rocks and dirty and discarded cotton is a common form of contamination and can be avoided if an inspection is carried out. All workers should be trained to watch out for contaminants. Make them aware of the potential problems and provide them with the facility to clean up and isolate rubbish, for example provide garbage bins in which all waste is thrown and use only white cleaning rags.

These guidelines have been extracted from the Draft BMP for Harvesting and FIBREpak – A Guide to Improving Australian Cotton Fibre Quality.

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

- FIBREpak
- An example module information form can be found in the Fibre Quality module in *myBMP*.

<http://www.cottonaustralia.com.au/library/publications/bb-safe-picking-transport.pdf>

Pick N Match – Cotton Australia website if in need of a contractor

To register as a contractor email Cotton Australia on talktous@cotton.org.au

Beyond The Farm Gate

Ginning

By **RENE VAN DER SLUIJS** (CSIRO)

Acknowledgements: Michael Bange, Greg Constable, Stuart Gordon, Robert Long and Geoff Naylor (CSIRO)

The ginning industry in Australia is relatively modern, with higher throughput gins compared with other countries. The principal function of the cotton gin is to separate lint from seed and produce the highest total monetary return for the resulting lint and seed, under prevailing marketing conditions. Current marketing quality standards most often reward cleaner cotton and a certain traditional appearance of the lint.

A ginner has two objectives:

- To produce lint of satisfactory quality for the grower's classing and market system; and,
- To gin the cotton with minimum reduction in fibre spinning quality so the cotton will meet the demands of its ultimate users, the spinner and the consumer. The spinner would prefer fibre without trash, neps and short fibres. Unfortunately, the highly mechanised (and productive) harvesting and ginning processes used today, mean that removing trash is difficult without introducing some neps and increasing short fibre content.

The challenge for the ginner is therefore to balance the amount of cotton produced (turn-out), the speed at which it is ginned and the effects that the various cleaning and ginning components have on the fibre quality. Particular settings in a gin for speed or heat can exacerbate nep and short fibre content. The use of lint cleaners, while removing trash, also increases the number of neps and short fibres. Whilst not included in existing classification

BEST PRACTICE

- The main concerns during the ginning process are to maintain quality, optimise lint yield and contain the costs of ginning.
- Appropriate ginning and handling practices post-harvest are important to maximise returns for growers and maintain the industry's reputation for high quality cotton.
- Good communication between growers and ginner is a key factor in assisting this process (see Table 1).

TABLE 1:

Summary of key post harvest decisions for optimising fibre quality.

Objectives	At the gin
Maintaining fibre length	In the gin, fibre length can be preserved and short fibre contents reduced, by reducing the number of lint cleaner passages (depending on quality of seed cotton) and ensuring fibre moisture at the gin and lint cleaner should be closer to 7% than 5%; however, fibre moisture at either point should not exceed 7%. Lower combing ratios between feed rollers and the saw of lint cleaners also reduces the amount of fibre breakage.
Reducing the incidence of neps	Lint cleaners are responsible for most of the neps found in baled cotton. Reducing the number of lint cleaners reduces neps. Maintenance of prescribed setting distances, e.g. feed and grid bar distances to the lint cleaner saw reduces fibre loss and nep creation, as does close and proper setting of the doffing brush to the saw. Preservation of fibre moisture as prescribed for length preservation also helps reduce nep creation.
Preventing contamination	Clean gravelled module storage yards. Frequent inspection of tarps on modules. Appropriate bale covering/wrap. Storage and handling to avoid damage.

systems for cotton, the presence of neps and short fibre seriously affect the marketing ability. The ginner must also consider the weight loss that occurs in the various cleaning machines. Often the weight loss to achieve higher grade results in greater removal of lint as well, which results in a lower total monetary return to growers and ginner as they are both paid on a per bale basis.

Cotton quality after ginning is a function of the initial quality of the cotton, and the degree of cleaning and drying it receives during ginning; the exact balance between turn-out and grade will depend upon the particular premium-and-discount (P&D) sheet applied to the cotton in question. For every P&D sheet there will be a point in the balance between turn-out and grade that maximises the return to the grower.

Given this need to balance competing considerations, it is essential that growers seek to:

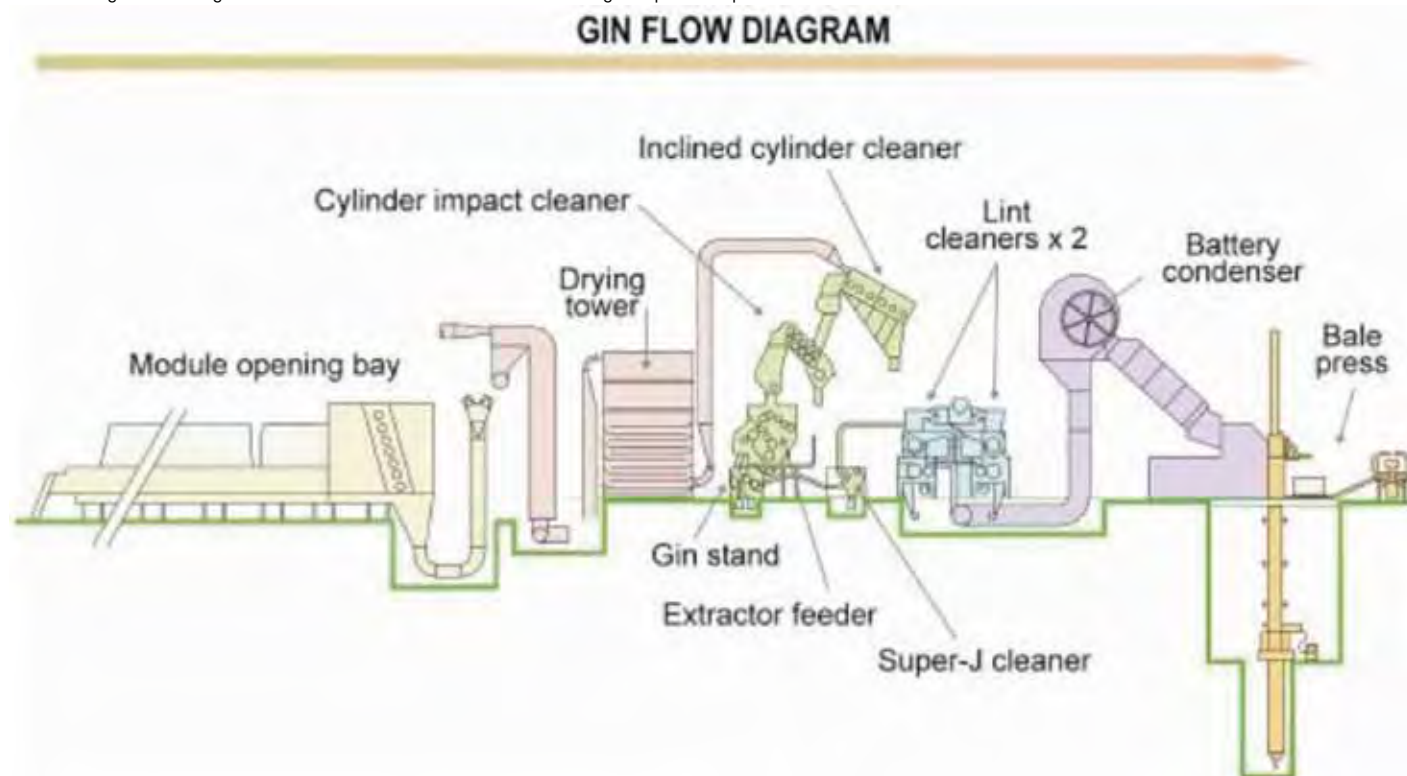
- Ensure defoliation and harvest practices limit trash;
- Contamination is limited; and,
- The size and moisture of the module are appropriate.

Ultimately it is important that growers communicate with ginner these aspects of their harvest prior to the start of the ginning season. An understanding of the issues that were faced in the field may give the ginner insights on how the cotton can be handled to optimise turn-out and quality together.

Modern gins are highly automated and productive systems that incorporate many processing stages. Gins must be equipped to remove large percentages of plant matter from the cotton that would significantly reduce the value of the ginned lint, according to the classing grade standards. Figure 1 shows the cross-section of a gin with machines that are typical of those found in a modern gin, although it is noted that most Australian

FIGURE 1.

Gin flow diagram showing cross-sections of machines used in a modern gin to process spindle harvested cotton.



gins typically have more pre-cleaning stages. This gives them the flexibility to process both spindle harvested cotton and stripper harvested, which requires more pre-cleaning.

At ginning the lint is separated from the seed. Moisture can be added to dry cotton prior to the gin stand at either the pre-cleaning stage or after the conveyor distributor above the gin stand. However, in Australia the moisture addition at these points is not common. After ginning, fibre travels by air to one or two lint cleaners for further cleaning and preparation. At the lint cleaners, moisture content is critical to prevent cotton from significant damage (neps and short fibres). Cotton that is too dry (< 5.5% moisture content) will be damaged to a greater degree during the lint cleaning process.

This information has been adapted from FIBREpak chapter 13 – post harvest management.

Classing

Acknowledgements: Helen Dugdale (CRDC); John Stanley (UNE, Australian Classing Services)

The quality of cotton can be expressed by a number of different measurements which are performed by cotton classers. These measurements are described in a wide range of grades (Figure 1), and affect the final price that is paid for a bale of cotton.

Once cotton is ginned, and while it is being baled, a sample (of 120g – 170 g) is taken from both sides of every bale and bulked together and sent to the classing facility for classification.

Historically, the cotton industry has employed both visual and mechanical methods to determine quality. Most aspects of visual cotton classing are gradually being replaced as they are considered to be subjective, by the HVI (High Volume Instrument) instrument which is able to assess various important textile quality related fibre properties by objective measurement.

Visual methods are based on the United States Department of Agriculture (USDA) standard grade boxes for Upland and Pima cottons of colour and foreign matter, and then assigning such cotton to a certain

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- Classing is a complex process, whilst this chapter gives an overview, a more detailed understanding can be gained from visiting your nearest classing facility.

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FIGURE 1:
Interpretation of Base Grade: 31–3–36, G5

BASE GRADE: 31		–	3	–	36,	G5		
Colour		–	Leaf	–	Staple Length,	Micronaire		
Descriptor	Code	Colour	Descriptor	Code	Measurement	Code	Measurement	Code
Good Middling (GM)	1	White	1	Level 1 (least)	1 inch	32	2.4 and below	G0
Strict Middling (SM)	2	Light Spotted	2	Level 2	1 1/32"	33	2.5 through 2.6	G1
Middling (MID)	3	Spotted	3	Level 3	1 1/16"	34	2.7 through 2.9	G2
Strict Low Middling (SLM)	4	Tinged	4	Level 4	1 3/32"	35	3.0 through 3.2	G3
Low Middling (LM)	5	Yellow Stained	5	Level 5	1 1/8"	36	3.3 through 3.4	G4
Strict Good Ordinary (SGO)	6				1 5/32"	37	3.5 through 4.9	G5
Good Ordinary (GO)	7				1 3/16"	38	5.0 through 5.2	G6
Below Grade (BG)	8				1 7/32"	39	5.3 and above	G7

Actual length applies so this table is just an example of possible staple lengths

established standard grade. This will be to describe cotton for buying and selling. Cotton classers are skilled in determining those grades visually. Currently in Australia classer's grade is still used to describe colour, leaf and preparation, with moves underway to replace this with HVI colour.

The price received for cotton is dependent on the quality of each bale of cotton. Cotton prices are quoted for 'base grade' 31-3-36, G5 (see Figure 1). Premiums and discounts apply for higher and lower grades respectively. These pricing adjustments reflect the change in suitability for the spinning and dyeing process (see Chapter 20, Table 1 'Consequences of poor fibre quality' right column). For this reason, variability in any quality characteristic may influence the price. Some of the key quality characteristics are outlined below:

- Colour
- Leaf
- Preparation
- Staple Length
- Micronaire
- Strength

Colour

The colour of a sample is currently measured visually by a trained cotton classer. The true colour can only be assessed under specific light conditions and via comparison to a 'standard' sample of universal standards provided by the USDA.

Also known as 'trash' is a measure of the amount of leaf material (from the cotton plant) remaining in the cotton sample. Whilst the gin removes the majority of trash, some remains in the sample which is removed in the

spinning process resulting in a reduction in lint yield and increases cost. Hence, cotton with high levels of trash attract a discount. Leaf grades range from 1 (lowest) to 5 (highest), with level 3 as 'base grade'.

Staple length

Length is measured on a sample of fibres known as a 'pull' when hand classing, and is measured to the nearest 1/32 inch. HVI determine length in 100ths and in 32nds of an inch or on a 'beard' or tuft of lint formed by grasping fibres with a clamp. Australian cotton is all classed using HVI measurements. Under raingrown conditions, staple length tends to range from similar to irrigated cotton (1 1/8 inches) down to very short (1 inch or less). Base grade is 36 or (1 1/8").

UPLAND LENGTH CONVERSION CHART

Length (32nds)	Length (inches)	Length (32nds)	Length (inches)
24	0.79 & shorter	36	1.11 – 1.13
26	0.80 – 0.85	37	1.14 – 1.17
28	0.86 – 0.89	38	1.18 – 1.20
29	0.90 – 0.92	39	1.21 – 1.23
30	0.93 – 0.95	40	1.24 – 1.26
31	0.96 – 0.98	41	1.27 – 1.29
32	0.99 – 1.01	42	1.30 – 1.32
33	1.02 – 1.04	43	1.33 – 1.35
34	1.05 – 1.07	44 & +	1.36 & +
35	1.08 – 1.10		



Micronaire

Micronaire is measured by placing lint in a chamber, compressing it to a set volume and subjecting it to a set pressure. The reading, when related to a variety, is an approximate guide to fibre thickness and has been used as a measure of fibre maturity. Other, more accurate, fibre maturity testing methods and devices are being tested and may soon be introduced but for now the general guidelines below still apply:

- Low (<3.5) Micronaire indicates fine (immature) lint.
- High (>4.9) Micronaire indicates coarse lint.

The desired range is 3.5 to 4.9 (G5) and discounts apply for micronaires outside that range. Discounts for low Micronaire can be substantial. Micronaire results are grouped on the schedule for premiums and discounts.

Common causes of low Micronaire include:

- Cool temperatures during fibre wall development;
- Potassium deficiency;
- Dense plant stands;
- High nitrogen;
- Excess irrigation/rainfall;
- Favourable fruit set and high boll retention; and,
- Early cut-out due to frost, hail, disease or early defoliation.

The most common causes of high Micronaire include:

- Poor boll set;
- Small boll size due to hot weather or water stress; and,
- Variety.

Ginning has little or no effect on Micronaire although low Micronaire cotton is more susceptible to buckling and entanglement which creates neps which can effect preparation and subsequently grade.

Raingrown cotton normally falls into the acceptable Micronaire range, however under hot, dry conditions some varieties are prone to produce high Micronaire. Late planted crops are susceptible to low Micronaire and heavy discounts sometimes apply.

Management practices that open immature bolls such as pre-mature defoliation can contribute to the inclusion of immature fibres and an increase in neps. Experiments conducted at the Australian Cotton Research Institute confirmed that defoliating before 60% bolls open lowers micronaire (reduced fibre maturity) and increases neps. (Bange et al. 2009)

Fibre strength

Fibre strength is highly dependant by variety although environmental conditions can have a small effect. Raingrown cotton strength is usually not adversely affected by growing conditions. Most Australian varieties are of high strength and local plant breeders have agreed to eliminate varieties that do not meet a minimum standard, thus keeping Australian cotton highly competitive in the world market. Fibre strength is measured by clamping a bundle of fibres between a pair of jaws and increasing the separation force until the

bundle breaks.

Strength is expressed in terms of grams force per tex with the following classifications:

- ≤ 23 , weak;
- 24 – 25, medium strong;
- 26 – 28, average
- 29 –30, strong (most current Australian varieties); and,
- ≥ 31 , very strong.

Preparation

Preparation (often referred to as ‘prep’) relates to the evenness and orientation of the lint in the sample. Factors contributing to poor preparation include spindle twist or wrapping during picking or roping or knotting (neps) of immature or very fine fibres in the ginning process.

Other quality characteristics

Pricing adjustments (premiums or discounts) may be made for other undesirable quality characteristics including (but not limited to):

- Grass or bark in the sample;
- An un-uniform sample;
- Sugars (honeydew);
- Neps; and,
- Short fibre (fibres shorter than 0.5 inch).

A number of other fibre characteristics measured in HVI testing which, whilst of increasing importance to



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spinners, currently do not have a direct impact on price , include:

- Uniformity Ratio (UR);
- Elongation (EL);
- Short Fibre Index (SFI);
- Maturity;

Cotton grade and price

The price received for cotton is dependent on the quality of each bale. Cotton prices are quoted for 'base grade' 31-3-36, G5 (see Figure 1). Premiums and discounts apply for higher and lower grades respectively.

Cotton merchants generally present actual classing results in an easy to read report displaying the AUD \$/ bale premiums or discounts.

These pricing adjustments are calculated using their 'Premiums and Discount (P&D) Schedules' or 'Differential Sheets'. Australian merchants P&D schedules are formatted similarly and the adjustments are generally quite similar, however there may be some differences. P&D schedules often change between seasons and sometimes within the season, the merchant will generally set the seasons P&D around ginning time. From this time they can be requested from your merchant.

Premiums or discounts may be displayed in either USD \$/lb or USD points/lb. There is 100 points in a cent. For example a 300 point discount is equivalent to -\$0.03. To convert from per pound to per bale, multiply by 500. To convert into Australian dollars, divide by the USD/AUD exchange rate (ask your merchant the exact exchange rate which is applicable).

For example: A total discount of 800pts/lb = $-\$0.08/\text{lb}$
 $= \frac{-\$0.08 \times 500}{.85}$
 $= \text{AUD } -\$47.06/\text{bale}$

Multiple adjustments may apply to one bale of cotton. One adjustment for colour – leaf – staple length, while all other characteristics have their own adjustments

For more information talk to your merchant or their classing facility look at the following websites:

Australian Cotton Shippers association:
<http://www.austcottonshippers.com.au/>

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

- FIBREpak

The Business Of Cotton

Cotton Economics & Marketing
Insurance
Safe People Management



(Photo: Cotton Australia: Ailyse Morris)

Cotton Economics & Marketing

By JANINE POWELL

The information in this chapter has been prepared for general circulation and does not have regard to the particular circumstances or needs of any specific business or person. For financial advice see your accountant or agribusiness manager.

This chapter covers some of the key business aspects of growing cotton, including: budgeting, marketing, finance

Gross margin budgets

A gross margin represents the difference between gross income and the variable costs of producing the crop. Gross margin budgets provide a guide to the relative profitability and an indication of the management operations involved in different enterprises.

Gross margins do not take into account risk, overhead costs or farm profit:

Risk

Gross margins can show the proportion of costs in relation to income, but don't consider price and yield risk. The following sensitivity charts help to illustrate the effect that changes in yield and cotton lint prices have on gross margins.

These sensitivity charts reflect the resulting changes to crop gross margins from a 20% change in both typical yields and long term average prices. **The charts emphasise that the profitability of a cotton crop is highly sensitive to both changes in yield and the cotton lint price, highlighting the importance of using achievable figures in the budgeting process.** The range of potential yields and prices is much wider than depicted, however it is the relationship between yield, price and the effect they have on gross margins which is

BEST PRACTICE

- Prepare a gross margin budget using published budgets as a guide only.
- Seek advice from a reputable cotton merchant to understand your marketing options for both cotton lint and seed
- Take the time to consider risk and insurance options. Seek insurance advice from reputable insurance providers/specialist and talk to established cotton growers about their past insurance experiences.

FIGURE 1: Sensitivity analysis – yield & \$/bale – dryland cotton (approx \$1200/ha costs).

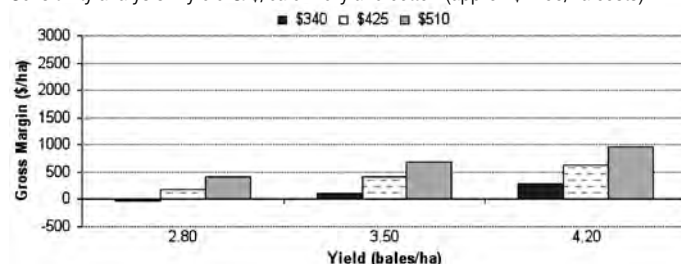
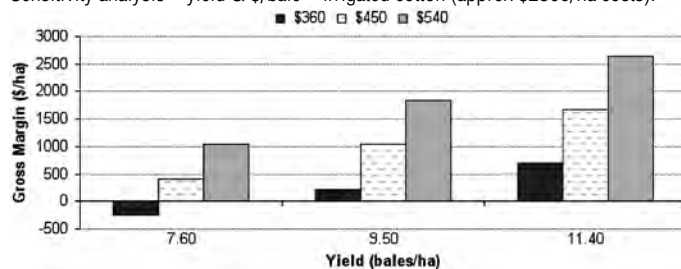


FIGURE 2: Sensitivity analysis – yield & \$/bale – irrigated cotton (approx \$2800/ha costs).



important.

Gross margin budgets do not show gross farm profit because they do not include fixed or overhead expenses such as depreciation on machinery and buildings, interest or insurance payments, rates, taxes or permanent labour which have to be met regardless of crop type. The amount of fixed costs per hectare varies considerably between properties, making it difficult to provide useful representative estimates of such costs.

You can use published budgets as a guide when initially developing your own gross margin budgets, altering costs and operations as necessary. The Department of Primary Industries NSW develop gross margin budgets for crops, vegetables and livestock annually at <http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets>

Individual budgets are provided in Portable Document Format (PDF). To read these files you need to have Adobe Acrobat Reader installed on your computer. These budgets are calculated using crop yields for the region that are consistent with the operations given, current commodity and input prices and technical information provided by agronomists and cotton industry development officers.

The degree to which these budgets reflect actual crop returns will be influenced not only by general factors common to all farms, such as prices and season conditions, but also by the individual farm characteristics such as soil type, crop rotation, and management.

Consequently, it is strongly recommended that published gross margin budgets be used as a GUIDE ONLY and should be changed to take account of movements in crop prices, changes in seasonal conditions and individual farm characteristics.

Refer to the NSW Primary Industries website (<http://www.dpi.nsw.gov.au/agriculture/farm-business/>)



budgets Download: 'Farm forms – crop') for downloadable specialised cotton budget forms in Excel format.

Gross margins need to be used carefully when using them as a guide to deciding on the farms overall enterprise mix. Because overhead costs are excluded, it is advisable to only make comparisons of gross margins between enterprises which use similar resources (i.e labour).

TABLE 1:

Example summary gross margin @ \$450/bale. Use this Gross Margin budget as a guide to create your own budget reflecting your operations, yield estimates and current pricing.

IRRIGATED COTTON (Roundup Ready Flex™ Bollgard II)	
Income	\$/ha
9 bales/ha @ \$450/bale	\$4050
2.61 t/ha seed @ \$130/tonne	\$339
TOTAL INCOME (A)	\$4389
Variable Costs	
Cultivation/Farming	\$ 98
Seed and sowing	\$ 113
Fertilisers & Application	\$ 499
Herbicides & Application (incl defoliation)	\$ 217
Insecticides & Application	\$ 114
Irrigation 7ML (C)	\$ 311
Insurance	\$ 55
Consultant	\$ 60
Licence fees	\$ 390
Contract harvesting	\$ 317
Module lifting & Cartage	\$ 106
Ginning	\$ 495
Levies	\$ 41
Refuge (Pigeon Pea 5% of costs below)	\$ 23
TOTAL VARIABLE COSTS (B)	\$2837
GROSS MARGIN/HA (=A-B)	\$1552
GROSS MARGIN/ML (=A-B)/C)	\$222
Pigeon Pea Refuge Crop (assumed costs)	
Seed & Sowing	\$ 76
Herbicides & Application	\$ 160
Irrigation	\$ 112
Slashing	\$ 12
Cultivation	\$ 107
Cultivation	\$107.00
Variable Costs per ha of pigeon pea	\$467.00

If major changes are being considered, more comprehensive budgeting techniques (that include overhead costs) are required to indicate the real profitability situation.

Some assumptions used for the NSW Primary Industries gross margins include:

- Average cotton yields from the previous season.
- An average to high number of insecticide applications using a soft approach to maintain predators (Listing of brand or chemical names in the budgets does not imply a recommendation of those brands/ chemicals).
- Selection of pesticide varies markedly depending on pest species and season. Rotation of insecticides should be followed as per industry strategy, which changes each year due to changes in insect resistance to chemicals (see pest management guide for details).
- Source of water is from the river using a diesel pump.
- 7ML of irrigation water is the volume applied to the crop in field (system losses & tail water not accounted for).
- Machinery costs refer to the variable costs of fuel, oil, repairs and maintenance for both the tractor and the implement. For details on variable and overhead cost calculations refer to NSW Primary Industries Guide to machinery and water costs at <http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets> and the 'Guide to machinery costs and contract rates' (Primefact 913) on the same site.

All prices are those estimated in the August prior to planting.

Table 1 is an example of a simple gross margin. The budget lists income sources, cost items and totals, with gross margin calculated as the total income less total costs. These figures are an indication only, and may not reflect your business. For more detailed cotton budgets, see the following websites;

Department of Primary Industries NSW:

PDF Summer Gross Margins: <http://www.dpi.nsw.gov.au/agriculture/farm-business/budgets/summer-crops>

Downloadable Gross Margin template: http://www.dpi.nsw.gov.au/__data/assets/file/0008/195641/FF-crop2009.xls

Cotton Seed Distributors:

Gross Margin Analysis: <http://www.csd.net.au/page/show/21113/>

Dryland cotton overview (including gross margin comparisons for various row configurations)

<http://www.csd.net.au/asset/send/2283/inline/original/>

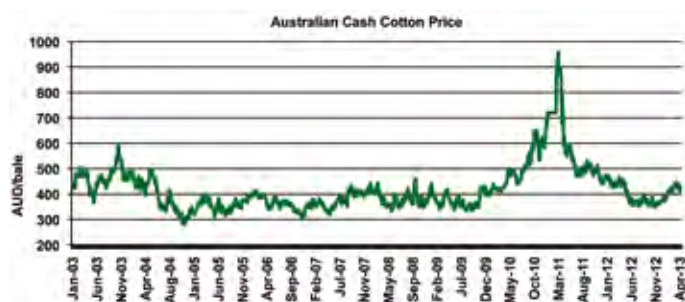
Marketing

Acknowledgements: Namoi Cotton Cooperative

The aim of this section is to give a general overview of the cotton pricing components and marketing alternatives available to Australian cotton growers. It is strongly recommended that growers seek advice from a reputable merchant about the alternatives suitable for their specific situation.

Variability in the Australian cotton price is caused by fluctuations in the underlying futures prices, currency rates and basis levels. This variability can create major

FIGURE 3:



uncertainties (or risk) for cotton growers when deciding if to plant cotton and when to sell. It is important that growers understand the components of the cotton price, associated risks and available marketing options before they begin marketing their crop.

The ability to 'lock in' a commodity price for some or all of a crop before harvest can be a major advantage for cotton growers. However, fixing prices before harvest can be risky, due to uncertain production levels. To understand the different marketing alternatives it is necessary to understand the risks.

Risk

A definition of risk: *Effect of uncertainty on objectives*. In this case returning a profit from the cotton crop is the objective and the primary areas of uncertainty (or risk) include; production (quality and quantity of the cotton produced) and price (the movement of prices before they are set i.e adverse movements include an increase in input costs and decrease in commodity prices). These risks are complex and vary between growers and over time, however marketing is one method for managing these risks.

Production risk is separated into quantity (yield and area) and quality. With the ability to enter into forward contracts before the crop is planted, there is uncertainty with both the area to be planted (due to seasonal conditions) and the yield that will be achieved. Yield risk also exists when a contract is entered into after planting, but before harvest. Variable yields may result in a grower under or over producing against contracted commitments. If production exceeds commitments made and the contract price is higher than the spot or market cotton price, then the grower has an opportunity loss. If the grower under produced a fixed bale contract, then the grower may be obligated to fill the contract at market rates, which could result in a financial loss to the grower.

Varying quality is managed by merchants with all forward contracts priced on 'base grade'. Once the cotton is ginned and classed, the final price paid to the grower is adjusted with a premium when the grade is higher than 'base', or a discount in price when the grade is inferior. These pricing adjustments can be found on a merchants corresponding premium & discount sheet (for more information about quality see chapters: ginning, classing, quality).

Price risk, in relation to a cotton grower, is when all or a

portion of the crop is not priced and the value is reduced due to decreases in the cotton price. Price variability is due to fluctuations in the three components of the Australian dollar cash price: ICE cotton futures, basis and the AUD/USD exchange rate.

Cotton is internationally traded and priced in USD, using the Intercontinental exchange (ICE) Cotton No2 contract (previously managed by the New York Board of Trade).

Basis can be broadly defined as the difference in value (or price) between a physical bale and the futures contract price. Basis accounts for location, grade and local supply and demand conditions.

Australian growers generally receive their income in Australian dollars, so the USD price is converted into local currency using the AUD/USD exchange rate. This may not be the spot exchange rate, rather the relevant forward rate for any forward contracts.

All three price elements can and do change on a daily basis. The price of cotton in Australian dollar terms is therefore subject to daily volatility. The major merchants in Australia publish their daily prices on-line or communicate their prices via fax, e-mail and text message. To be kept up to date with pricing movements contact the merchants and ask to be added to their daily price lists.

Marketing options

Australian cotton growers are well serviced by several cotton merchants who buy cotton from growers to sell in the international market. Due to the relatively small size of the Australian cotton market, it is often the cotton merchants approaching growers to buy cotton, thus creating a price competitive market.

Merchants involved in the cotton market tend to build robust relationships with clients and may contract cotton with these growers up to 4 years into the future, using forward contracts. A forward cotton contract is a customised agreement between two parties to deliver cotton on an agreed future date for an agreed price. Price will be determined in reference to the other terms of the contract — quality, quantity, and the time and place of delivery or the buyer may require a guarantee of a specific grade or quality of the commodity from the seller. From a growers perspective this may mean selling the cotton before it has been harvested or even planted.

The most commonly utilised forward marketing options are:

- **AUD Fixed cash price** – Generally known as the 'cash' price, this is a forward contract for delivery after ginning of the season specified (i.e 2013-14). Growers accept a certain fixed price and a fixed number of bales are agreed upon in the contract; thus, there is a fixed commitment to deliver.
- **Fixed bale pool** – a commitment to deliver a specified number of bales to a 'pool' of bales with a particular marketing organisation. Both price risk and yield risk are borne by the grower, but the price risk is managed



by the marketing organisation. Most pools have an indicative price attached and often once that price is no longer achievable, the pool will be closed. As with all pools, payment is spread over a period of time as delivery of cotton from growers, and sales to mills proceed.

- **Other pools** may be offered by merchants with varying conditions. Some characteristics of a pool (or other customised contract) may include;
- **Hectare contract** where the grower commits a particular acreage, all cotton produced from that area is covered by the contract. The contract may have a maximum yield deliverable to it (i.e up to 10 bales/ha). Downside yield risk is managed by the merchant.
- Some pool contracts may have a **guaranteed minimum price (GMP)**, with potential (but limited) upside. For these contracts the grower bears production risk and some price risk. Due to the hedging requirements for the merchant to guarantee a certain minimum return, these contracts usually come at a discount to the cash market.
- **Balance of crop (BOC)** is a contract where the grower commits their remaining unpriced bales. These contracts are generally available towards the end of the season when the grower can make a reasonable estimate of their yield.
- **Force majeure (FM)** – ‘compelling force, unavoidable circumstances’. When an FM clause is attached to a cotton contract it generally means that a production shortfall in the nominated bales set out in the contract need not be delivered. This variation is borne by the merchant.

Cotton seed

The value of cotton seed can be a significant component of the income from a cotton crop. Cotton seed is priced through the ginning company which may not be the same merchant the cotton is sold through. Cotton seed is usually priced in bales (based on the amount of seed that is produced in the ginning process of one bale, this is approximately 290kg of seed). The price of cotton seed is strongly correlated with feed grains and fluctuates with supply and demand. Cotton seed has been worth up to \$120/bale, and as little as \$30/bale (which is not enough to cover ginning costs), however a price closer to \$60/bale has been more common. The ginning organisation may quote the seed price as ‘ginning plus seed’ (i.e \$60/bale, may be quoted ‘ginning plus \$5/bale’, indicating that the seed price covers the ginning price of \$55/bale, with \$5 paid back to the grower). Talk to your preferred ginning organisation about current cotton seed pricing. For further information on marketing your cotton, talk to a merchant or you can find comprehensive marketing notes on the following websites:

Australian Cotton Shippers Association:

http://www.austcottonshippers.com.au/downloads/Grower_Marketing_Risk_Handbook.pdf

Finance

Financing the crop is a major consideration. As well as the traditional banking finance options, credit and loans may be available through some of the agribusinesses you deal with.

Crop credit is available through some agricultural resellers (i.e chemical resellers) and allows growers the option of deferring costs until after picking. Interest is charged at current short term money market rates, e.g bank bill rates.

At picking pre-ginning loans (module advances) are available from most ginners and merchants. Details can be discussed with your merchant.

Timing of payment for cotton lint depends on the type of contract. Cash contracts are generally paid within 14 days of ginning, whilst ‘Pool’ contracts may pay up to 75 percent in July (after ginning) with further payments in September and December. Confirm with your accountant and merchant about the best payment structure for your business prior to entering into any contracts.

Most cotton growers have debt. Whether it is a seasonal overdraft or a long-term loan, it is important to understand the capability of your business to repay the loaned amount.

There are many ways to assess the financial sustainability of a business. The five indicators below are a good place to start, as these are some of the indicators that a financial institution will assess in a loan application.

- Debt levels;
- Ability to service interest;
- Net operating expenses;
- Interest expense; and,
- Equity.

Looking at one indicator on its own may give a false impression of a business’s financial health. To get the whole picture, it is important to consider all financial aspects of the business, if you are unsure on how to calculate any of these five financial measurements or have any other questions, it is recommended that you speak to a financial advisor for more information and advice on how these measurements impact your individual businesses financial assessment.

Hail Insurance

By **DAVID BLACKETT**
(Innovative Risk Transfer)

Deciding on whether and how to insure is an important decision requiring a clear understanding of the risks and impacts that hail can have on your business. Cotton hail insurance is more complicated than winter crop insurance as you are planting into the hail risk period rather than harvesting out of it.

This fundamental difference changes the whole structure of cotton hail insurance because the hail events are happening at the beginning of crop growth rather than at the end. This means if you have a loss early in the season there is the potential to re-plant. If hail damage comes later, partially damaged crops will be grown out and the loss assessed by reference to a suitable undamaged control crop. If there is a total loss, the claim payment must be adjusted to take account of variable production costs not incurred due to the early loss of the crop. None of these factors need to be considered when structuring winter crop insurance.

All policies aim to put you in the same position after a loss as you would have been had the loss not occurred, subject to the excess and the adequacy of the sum insured you nominated.

Differences between policies

The main differences between policies, and the complication when comparing them, relates to total loss claims and how the variable cost savings are defined and treated. Although the different policies define and treat variable costs differently, if the same total figures are used and apportioned properly, the differences in total claim outcome are minimal and should be easily explained to you.

The way cotton hail claims are dealt with should be considered in comparing insurance policies. One of two different methods are usual: insurers will either engage Loss Assessors or Loss Adjusters.

Loss Assessors inspect the crop to assess the damage and how the crop is being managed after the loss. Follow-up inspections are conducted and ongoing advice about crop management and picking is provided. After each inspection, the Loss Assessor reports back to the insurer who determines your payout.

Loss Adjusters also inspect and assess the damage, but then go further and negotiate a claim settlement with

BEST PRACTICE

- Allow yourself enough time to consider your business needs as well as the details of the policies on offer.

you. They present the negotiated settlement to the insurer for approval.

Once you have determined your specific needs you should then talk to hail insurance providers and specialists for more advice and information.

For more information please contact your preferred crop insurance specialist.

New Risk Management Tools

By **JOHN VAN DER VEGT** (AGRIRISK)

Weather derivatives

Over the last few years a number of international reinsurers have become more interested in products that are based on weather statistics rather than historical losses — these are called weather derivatives, and they are not an insurance product.

The reason for their growing popularity is that they can be priced based on weather data that is readily available over an extended time period. Weather derivatives are simple contracts that respond when specific weather triggers are recorded at a specified meteorological station. As a consequence weather derivatives create a basis risk as losses are determined at the meteorological station rather than on farm.

Weather derivatives could be structured to financially protect a farm business from

- Insufficient rainfall during the planting window or growing season.
- Excessive rainfall at harvest
- Temperature extremes such as frost at flowering or excessive heat at critical stages of crop growth
- Lack of heat units during the vital growth stages of the crop
- Excessive wind

Index products

Index products are not an insurance product. They are based on an available independent index generally of yield or weather data. With Index products losses are determined by changes in the index which creates a basis risk as losses are determined according to the index rather than on farm.

While Weather Derivatives and Index Products are relatively new to the Australian Agribusiness sector, it's still early days but growers need to be aware of these risk management tools as they may well provide a far better option than having no financial safeguards at all.

Please note that Weather Derivatives and Index products are not insurance products and special licencing is required to provide advice in this area. If you are interested please seek professional advice from an appropriately licenced organisation.



Matching cover to your risk profile



Helping you carry on when nature does its worst



Working for a 'fair go' from insurers

Agricultural Insurance Services

AgInsure, the agricultural insurance specialists, provide what we think is the best value cotton hail insurance available.

We take time to understand your business so we can match cover to your agronomic practices and risk preference.

And when destructive hail comes, we'll act as your advocate and negotiate with the insurer to promote a fair and timely claim outcome.

We'll stand by you, so you can carry on when nature does its worst.

For further information call 1800 648 794 or visit www.aginsure.com.au/manual



...standing by you



Safe People Management

Workplace Health & Safety (WHS)

By **JOHN TEMPERLEY** (Australian Centre for Agricultural Health and Safety, The University of Sydney)

While many accept that the most valuable asset for a business is its people, the question that should still be considered is “are we paying sufficient attention to the management of our human resources?” At least, in terms of meeting relevant legal compliance and optimising the value that our employees contribute to the farm business.

This section is focused on just one critical aspect of human resource management for cotton growers; that is ‘workplace health and safety’, (WHS). It aims to provide a quick overview of key legal requirements and advice on practical support being made available for growers to manage their WHS responsibilities by Cotton Australia and through *myBMP*.

Work health and safety law

The Work Health and Safety Act and Regulations outline the responsibilities of key parties involved in managing health and safety risks associated with workplaces and work activities.

Current WHS legislation refers to a person who conducts a business or undertaking (or a PCBU). The term PCBU includes employers, farm owners, growers and managers of cotton farms, cotton gins and all other work places.

The PCBU’s legal responsibilities for WHS include:

- Ensuring a safe workplace and the health and safety of workers;
- Involving (consulting) with workers to establish and maintain the WHS plans;
- Organising safe systems of work, including the use of safety equipment;

BEST PRACTICE

- Make sure you are aware of your WHS legal responsibilities and maintain an effective WHS program, that is integrated into all aspects of the cotton business.

- Maintaining work areas, machinery and equipment in a safe condition;
- Ensuring safe use, handling, and storage of plant and dangerous substances;
- Providing information, instruction, training and supervision to workers;
- Providing adequate facilities for the welfare of workers (eating, toileting, washing and storing personal belongings; and,
- Ensuring Workers Compensation for injured workers and assistance with injury management, rehabilitation and their early return to work.

The definition of ‘Worker’ has also been extended and now includes contractors and contract workers as well as the PCBU’s own employees. Others who can be deemed to be workers, include labour hire workers, students and in some cases volunteers.

Workers also have WHS legal responsibilities. Workers must:

- Comply with any reasonable health and safety instructions of the PCBU;
- Take reasonable care of the health and safety of themselves and others; and,
- Cooperate with reasonable health and safety policy and procedures of the PCBU (the farm owner, manager or employer) in managing safety at work.

Safety – a core business value

Managing safety must be accepted as an integral part of the way that we manage our cotton farm businesses. The cost of accidents is not only felt in terms of pain and suffering, but can also result in significant financial loss to growers personally and the farm enterprise. The cost of poor WHS performance may also include:

Reduced productivity

Equipment damage, downtime and replacement of injured workers; and,

Civil claims, prosecutions and the associated legal costs and time spent off farm attending to business with solicitors and/or in courts defending litigation.

WHS risk management

Contemporary WHS legislation in Australia has moved from being over prescriptive to a requirement for workplaces to demonstrate a risk management approach to WHS issues. The key steps to WHS risk management on cotton farms include:

- **Seeing** or identifying safety hazards on farms and related workplaces;
- **Assessing** the nature and severity of risks;
- **Fixing** or controlling those risks to manage safety;
- **Evaluate** and check the effectiveness of safety controls; and,
- **Record** or documenting the safety control/s taken or planned.

Employee Relations

By **BOB KELLOW**

The working arrangements you agree to with your employees are an integral part of the overall operations of your business. Getting it right is not only important to good employee relationship and effective management but also a legal requirement with its many consequences.

Employment conditions

It is important to know what the minimum employment conditions are and how they apply to your particular employees. These minimum conditions are generally found in awards and the Fair Work Act including the National Employment Standards (a set of 10 minimum conditions that apply to all employees)

The Cotton Industry is principally serviced by two Modern Awards, The Pastoral Award 2010 and the Cotton Ginning Award 2010. Other awards may apply and it is important to seek advice if unsure how your particular employee fits in to these awards.

The awards together with the National Employment Standards set minimum conditions that all employers must observe. These include such entitlements as:

- Minimum rates of pay;
- Hours of work, including overtime;
- Penalties and allowances;
- Leave entitlements such as annual leave, sick leave, compassionate leave etc;
- Termination provisions including redundancy;
- Types of employment, eg. full time, part time, casual; and,
- Classification structures.

Further information:

Employers can access the following government websites for copies of awards and/or a range of industrial relations matters:

Fair Work Commission, www.fwc.gov.au

or the Fair Work Ombudsman – www.fwo.gov.au.

Employers also have access to the *myBMP* management tool that provides general HR (Human Resources) information.

For further information please contact Bob Kellow, Industrial Mediation Services, 0427 667 344.

For cotton growers, farm managers and workers a helpful acronym to remember those 5 key safety risk management steps is:

S-A-F-E-R, representing **See it, Assess it, Fix it, Evaluate and Record it**.

Growers safety priority in controlling hazards must be to eliminate hazards where it is reasonably practicable.

WHS Regulations provide information to a PCBU on what is required to meet their safety obligations. Codes of Practice, Australian Standards and Safety Guides provide more information on how to comply with their obligations and determine minimum health and safety performance, or what is considered as reasonably practicable.

What help is available to manage WHS on cotton farms?

Under the banner of CottonSafe, Cotton Australia is promoting an increased awareness of relevant WHS issues for the cotton growing industry. Delivering to growers and cotton farm workers up-to-date evidence based guidelines, tools and other resources to assist in managing WHS responsibilities and to mitigate injury, legal and financial risks known to be associated with poor WHS performance.

Access to the cotton WHS risk management resources will be available through the Cotton Australia website and through the *myBMP* 'Human Resource' module.

Growers are encouraged to visit the the Cotton Australia website and CottonSafe section and to utilise the information and resources available on that site.

For further information on:

CottonSafe program (Cotton Australia website) www.cottonaustralia.com.au

myBMP 'Human Resource': website www.myBMP.com.au

QLD WHS Law: website www.deir.qld.gov.au/workplace/index.htm

NSW WHS Law: website www.workcover.nsw.gov.au

BEST PRACTICE

- Understand the appropriate award, the correct classification level of the employee, the status of the employee (full time, casual etc), the hours required to be worked and the relevant rate of pay including additional payments for overtime, allowances etc.



Glossary & Acronyms

Glossary

Alluvium Refers to sediment that has been deposited by flowing water, such as a flood plain.

AM Arbuscular Mycorrhiza: was called VAM. A partnership between soil borne fungi and most crop plants, including cotton (but not brassicas). AM fungi colonise the roots of the plant without causing disease. AM fungi act as an extension of the root system and transfer extra nutrients, especially phosphorus, from the soil to the plant. In return the plant provides the fungi with sugars as a food source.

Aphid colony 4 or more aphids within 2 cm on a leaf or terminal.

Area Wide Management (AWM) Growers working together in a region to manage pest populations. AWM is a cotton industry vehicle driving adoption of on-farm IPM.

At-planting insecticide Insecticides applied in the seed furrow with the seed during planting. The insecticide may be applied as a granule or as a spray into the seed furrow.

Australian Rainman StreamFlow A computer program for PC/Windows which analyses rainfall information and can forecast seasonal rainfall.

BDI Beneficial Disruption Index – Is a score for each insecticide for the entire cotton season, of the impact of each insecticide on beneficial insect populations. The BDI helps benchmark the 'softness' or 'hardness' of an individual fields' insecticide spray regime.

Beat sheet A sheet of yellow canvas 1.5 m x 2 m in size, placed in the furrow and extended up and over the adjacent row of cotton. A metre stick is used to beat the plants against the beat sheet. Insects are dislodged from the plants onto the canvas and are quickly counted.

Beneficial insects Predators and parasitoids of pests.

Biological insecticides Insecticides based on living entomopathogenic (infecting insects) organisms, usually bacteria, fungi or viruses, or containing entomopathogenic products from such organisms i.e. Gemstar, Vivus and Dipel (BT).

Biomass Plant biomass is the total dry weight of the crop.

Boll Cotton fruit after the flower has opened and fertilisation has occurred (after the flower has turned pink). Bolls typically have four or five segments, known as locks, each containing about 6–10 seeds. The lint, or cotton fibre, is produced by elongated cells that grow from the surface of the seed coat, hence the 'seed cotton' in the boll is a mixture of seed and lint.

Bollgard II® cotton Genetically modified cotton variety containing the insecticidal proteins Cry1Ac and Cry2Ab which provides control of *Helicoverpa* spp., rough bollworm, cotton tipworm and cotton looper under field conditions.

Broad spectrum insecticide Insecticides that kill a wide range of insects, including both pest and beneficial species. Use of broad spectrum insecticides usually reduces numbers of beneficials (predators and parasites) leading to pest resurgence (see below) and outbreaks of secondary pests.

Bt The *Bacillus thuringiensis* protein which is toxic to *Helicoverpa* spp.

Buffer zone A boundary of land or crop set up within or outside the cotton farm to collect spray droplets that may otherwise drift onto sensitive areas, such as rivers or pasture.

Calendar sprays Insecticides sprayed on a calendar basis, e.g. every Friday, regardless of pest density or the actual need for pest control.

Cold shock Is when the daily minimum temperatures fall below 11°C. When this occurs, cotton growth and development the following day can be reduced regardless of the maximum temperature reached. Cold shocks have greatest impact on early plant development and will delay the timing of emergence, squaring and flowering and increase the susceptibility of plants to diseases.

Consecutive checks Refers to successive insect checks taken from the same field or management unit.

Conventional cotton Strictly a cotton variety that does not contain transgenes (genes from other species), but used in this guide to indicate varieties that do not include genes to produce insecticidal proteins (i.e. Bollgard II®) but which may include herbicide resistance genes i.e. Round-up Ready®).

CottASSIST A group of web tools developed by CSIRO, Cotton CRC and CRDC designed to deliver the latest cotton research and integrate up-to-date information and assist with cotton management decisions.

Cotton bunched top (CBT) A relatively new disease spread by the cotton aphid (*Aphis gossypii*, Glover). Symptoms of CBT include reduced plant height, leaf surface area, petiole length and internode length. Pale angular mottling of the leaf margins is the most reliable diagnostic feature.

Cotyledons Paired first leaves that emerge from the soil when the seed germinates.

Crazy cotton Multi-branched cotton caused by excessive and repeated tipping out.

Crop compensation The capacity for a cotton plant to 'catch-up' after insect damage without affecting yield or maturity.

Crop Development Tool A web tool which allows crop managers to monitor both vegetative and reproductive growth of their crops compared to potential rates of development.

Crop maturity This usually occurs when 60–65% of bolls are mature and open. Cotton bolls are mature when the fibre is well developed, the seeds are firm and the seed coats are turning brown in colour.

Cut-out As the cotton plant continues to develop bolls, the demand for carbohydrates that are produced in the leaves increases. Eventually the demand by the bolls exceeds supply, resulting in the production of new fruiting nodes ceasing and the shedding of excess bolls, less than 14 days old. This point is known as 'cut-out'. An approximation of the timing of cutout is when a crop has reached on average 4 nodes above white flower (NAWF).

Damage threshold The level of damage from which the crop will not recover completely and which will cause some economic loss of yield or delay in maturity. Damage thresholds are usually applied in conjunction with pest thresholds to account for both pest numbers and plant growth. For instance a plant which has very high fruit retention (see below) may be able to tolerate a higher pest threshold (see below) than a crop with poor fruit retention.

Day Degrees (DD) A unit combining temperature and time, useful for monitoring and comparing crop development. To calculate your DD visit the Australian Cotton CRC website.



- Deep drainage** Water from rainfall or irrigation that has drained below the root zone of the crop. A certain amount of deep drainage helps flush salts from the soil, but excess deep drainage means water and nutrients are being wasted.
- Defoliation** The removal of leaves from the cotton plant in preparation for harvest. This is done by artificially enhancing the natural process of senescence and abscission with the use of specific chemicals.
- Denitrification** A biological process encouraged by high soil temperatures. Denitrification occurs when there is waterlogging, such as during and after flood irrigation and/or heavy rainfall. The process converts plant available N (nitrate) back to nitrogen gases which are lost from the system.
- Dessicant** A chemical used as a harvest aid that damages the leaf membrane causing loss of moisture in the leaf producing a desiccated leaf.
- Determinate/Indeterminate** Cotton is an indeterminate species which is capable of continuing to grow after a period of stress. Although short season varieties are considered determinate, which terminate reproductive development comparatively abruptly.
- Diapause** A period of physiologically controlled dormancy in insects. For *Helicoverpa armigera*, diapause occurs at the pupal stage in the soil.
- Doffer** Doffers unwind and remove the cotton from the spindle so that it can be transported to the basket in an airstream.
- Double knock** Is the sequential application of two weed control options with different modes of action in a short time-frame.
- Double skip** A row configuration used in dryland/semi irrigated situations to conserve soil moisture.
- D-vac** A small portable suction sampler or blower/vacuum machine used to suck insects from the cotton plants into a fine mesh bag. D-vac samples are collected by passing the tube of the vacuum sampler across the plants in 20 m of row. When plants are small this may be a single pass, but when plants are bigger a zig zag pattern from the bottom to the top of the crop with each step of the operator may be required to sample the canopy more effectively. Samples from the d-vac bag are transferred into a plastic bag and counted.
- Earliness** Minimising the number of days between sowing and crop maturity. Within a cotton variety earliness usually involves some sacrifice of yield.
- Efficacy** The effectiveness of a product against pests or beneficial insects (predators or parasites).
- Egg parasitoids** They are parasitoids that specifically attack insect eggs. E.g. *Trichogramma pretiosum* attacks the egg stage of *Helicoverpa*. The wasp lays its eggs in the egg, and the wasp larvae which hatch consume the contents of the host egg. Instead of a small *Helicoverpa* larva hatching, up to four wasps may emerge from each host egg. Thus the host is killed before causing damage.
- Flat fan nozzle** A spray nozzle with an outlet that produces spray droplet distribution that spreads out of the nozzle in one direction but which is thin in the other direction, much like the shape of a Chinese or Japanese hand fan.
- Flush** A high volume irrigation carried out in minimal time.
- Food sprays** They are natural food products sprayed onto cotton crops to attract and hold beneficial insects, particularly predators, in cotton crops so they can help control pests. Two types of food sprays are available for pest management. They are the yeast based food sprays which attract beneficial insects and the sugar based ones which retain predators which are already in the crop.
- F Rank** A rank that each cotton variety is given in accordance with its resistance to the cotton disease Fusarium Wilt.
- Fruit load** Refers to the number of fruit (squares or bolls) on a cotton plant.
- Fruit retention** Refers to the percentage of fruit (squares or bolls) that the cotton plant or crop has maintained compared with number it produced.
- Fruiting branch** Grows laterally from the main stem in a series of segments. Each segment finishes at a node at which there is a square and a leaf. At the base of the square the next segment originates, and so on.
- Fruiting factor** Is a measure of the number of fruit per fruiting branch. A method to check if the total fruit number produced by the crop is on track. Fruiting factors which are too high or too low can indicate problems with agronomy or pest management which may need to be acted on. To calculate the fruiting factor divide the fruit count made in 1 metre of cotton row by the number of fruiting branches in that area.
- Gilgai micro relief** is formed due to clay horizons shrinking and swelling with alternate drying and wetting cycles. This forces 'blocks' of subsoil material gradually upwards to form mounds.
- Habitat diversity** A mixture of crops, trees and natural vegetation on the farm rather than just limited or single crop type (monoculture).
- Hill** Refers to the risen bed where the crop is planted in a furrow irrigated field.
- Honeydew** A sticky sugar rich waste excreted by feeding aphids or whiteflies. It can interfere with photosynthesis, affect fibre quality and cause problems with fibre processing.
- HVI** High Volume Instrument that is able to quickly and accurately determine the fibre properties of a large volume of cotton.
- Irrigation deficit** Readily available water capacity.
- In-furrow insecticide** Insecticides applied in the seed furrow with the seed during planting. The insecticide may be applied as a granule or as a spray into the seed furrow.
- Insecticide resistance** Where a pest develops resistance to an insecticide, the insecticide will no longer kill those individuals that are resistant. This usually results in poor control and may lead to failure of control with the insecticide in the worst cases. The resistant insects develop a mechanism for dealing with the insecticide, such as production of enzymes which break the insecticide down quickly before it kills the pest.
- Insecticide Resistance Management Strategy (IRMS)** An industry regulated strategy that sets limits on which insecticides can be used, when they can be used and how many times they can be used. This helps prevent the development of insecticide resistance.
- IPM** Integrated Pest Management.
- Labile P/non-labile P** There are a few Phosphorus fractions within the soil including labile (available) P and non-labile (slow release) P.
- Lay-by herbicide** A residual herbicide used to control weeds in-crop or during the growth of the cotton crop.
- Larval parasitoids** A wasp that lays their egg on or in a larva and use the lifecycle of the larva in order to reproduce. Parasitoids usually cause the death of their host whereas parasites do not.
- Leaf crumpling** Leaves that are wrinkled, cupped and smaller than normal. This can be caused by thrips.
- Lint** Cotton fibres. These are elongated cells growing from the surface of the cotton seed coat. See also 'Bolls'.



- Listing Rig** A cultivator used to form cotton beds.
- Lodging** Towards the end of the season cotton plants with large and heavy boll loads will often fall into each other which is known as lodging.
- Main stem node** A point on the main stem from which a new leaf grows. At these points there may also be fruiting or vegetative branches produced.
- Management unit** An area on the farm that is managed in the same way i.e. same variety, sowing date, insect management.
- Micronaire** Measurement of specific surface area based on the pressure difference obtained when air is passed through a plug of cotton fibres. This reflects fineness and maturity.
- Mycorrhiza** Specialised fungi which form beneficial associations with plant roots and can act as an agent for nutrient exchange.
- NACB** The number of main stem Nodes Above the first position Cracked Boll. This is an indication of the maturity of the plant and can be used in making decisions about the final irrigation or defoliation.
- Natural enemies** Predators and parasitoids of pests.
- Natural mortality** The expected death rate of insects in the field mainly due to climatic and other environmental factors including natural enemies.
- NAWF** The number of main stem Nodes Above the first position White Flower that is closest to the plant terminal.
- Neutron probe** An instrument used to measure soil moisture.
- Node** A leaf bearing joint of a stem, an important character for plant mapping in cotton where nodes refer to the leaves or abscised leaf scars on the main stem.
- Normalised Difference Vegetation Index** Is an indicator used to analyse remote sensing measurements to assess whether the observed target contains live green vegetation.
- Nursery** A crop or vegetational habitat which attracts and sustains an insect (pest or beneficial) through multiple generations.
- NutriLOGIC** Nitrogen fertiliser management web tool in CottASSIST (www.cottassist.cottoncrc.org.au).
- NUTRIpak** An information resource for cotton nutrition, including critical levels for soil tests, and interactions between different nutrients.
- Nymph** The immature stage of insects which looks like the adult but without wings. Eg. nymphs of mirids. Nymphs gradually acquire adult form through a series of moults and do not pass through a pupal stage. In contrast, 'larvae' are immature stages of insects, such as the *Helicoverpa* caterpillars, that look quite different to the adults, which in this case is a moth.
- Okra leaf type** Cotton varieties with deeply lobed leaves that look very similar to the leaves on the Okra (*Abelmoschus esculentus*) plant, which is related to cotton and hibiscus.
- OZCOT model** A cotton crop simulation model that will predict cotton growth, yield and maturity given basic weather, agronomic and varietal data.
- Partial root zone drying** The creation of simultaneous wet and dry areas within the root zone. Only part of the root zone is irrigated and kept moist at any one time.
- Pest flaring** An increase in a pest population following a pesticide application intended to control another species. This usually occurs with species that have very fast life cycles such as spider mites, aphids or whitefly. It occurs following the use of broader spectrum insecticides which control the target pest but also reduce the numbers of predators and parasites. This allows these 'secondary' or non-target pests to increase unchecked, often reaching damaging levels and requiring control.
- Peak flowering** The period of crop development where the plant has the highest numbers of flowers opening per day.
- Pest damage** Damage to the cotton plant caused by pests. This can be either damage to the growing terminals (known as tipping out), the leaves, or the fruit (including squares or bolls).
- Pest resurgence** An increase in a pest population following a pesticide application intended to reduce it. This usually occurs because the insecticide has reduced the numbers of beneficials, which normally help control the pest, thereby allowing subsequent generations of the pest to increase without this source of control.
- Pest threshold** The level of pest population at which a pesticide or other control measure is needed to prevent eventual economic loss to the crop. See also 'Damage threshold'.
- Petiole** The stalk that attaches the leaf to the stem.
- Phase 1** The period between planting and the start of flowering (one flower per metre).
- Phase 2** The period between flowering to first open boll.
- Phase 3** The period between first open boll to harvest.
- Pima cotton** Is of the *Gossypium barbadense* species. It has an extra long staple and its growth is limited to regions with long growing seasons. Normal cotton is of the species *Gossypium hirsutum*.
- Pix** Mepiquat chloride, cotton growth regulator.
- Plant Available Water Capacity (PAWC)** The amount of water in the soil that can be extracted by plants, usually full point (when the soil can hold no more water) minus wilting point (point at which the plant can no longer extract sufficient water from the soil and begins to wilt).
- Plant cell density** A term used in precision agriculture which is a ratio of infra-red to red reflectance produced from digital imagery.
- Plant growth regulator** Chemicals which can be applied to the plant to reduce growth rate (see also 'Rank crop').
- Plant mapping** A method used to record the fruiting dynamics of a cotton plant. This can be useful for understanding where the plant has held or is holding the most fruit in order to interpret the effects of factors that may affect fruit load such as pest damage, water stress, heat.
- Plant stand** The number of established cotton plants per metre of row.
- Planting window** Is a period of time in which you need to plant your cotton. Bollgard II® cotton has a planting window which is a strategy used to restrict the number of generations of *Helicoverpa* spp. exposed to Bollgard II® in a region.
- Plastic limit** The water content where soil starts to exhibit plastic behaviour.
- Post-emergent knockdown herbicide** A herbicide used to rapidly control weeds after they emerge.
- Predator to pest ratio** A ratio used to incorporate the activity of the predatory insects into the pest management decisions. It is calculated as total number of predators per metre divided by the total number of *Helicoverpa* spp. eggs plus very small and small larvae per metre.
- Premature cut-out** Premature cut-out is when the production of bolls exceeds the supply of carbohydrates too early in the crops development and therefore the production of new fruiting nodes stops. This results in a less than ideal boll load.
- Pre-plant knockdown herbicide** A herbicide used to rapidly control weeds prior to planting.



- Presence/absence** The binomial insect sampling technique that records the presence or absence of a pest rather than absolute numbers on plant terminals or leaves, depending on the pest species being sampled.
- Prophylactic** Refers to regular insecticide sprays applied in anticipation of a potential pest problem. Spraying on a prophylactic basis runs the risk of spraying to prevent pest damage that would not have occurred anyway, thereby increasing costs, selection for insecticide resistance and the risk of causing secondary pest outbreaks due to reductions in predator and parasite numbers.
- PSO** Petroleum Spray Oil – Is a petroleum derived oil commonly used to control insect pests such as *Helicoverpa* spp., mirids, mealy bugs, aphids, thrips, scales and mites. PSOs can also be used to deter egg lay of some pests such as *Helicoverpa* spp.
- Pupae** Once larvae of *Helicoverpa* have progressed through the larval (caterpillar) stages they will move to the soil and burrow below the surface. Here they will change into a pupae (similar to a butterfly chrysalis). In this stage they undergo the change from a caterpillar to a moth.
- Pupae busting** Effective tillage to reduce the survival of the overwintering pupal stage of *Helicoverpa*. Pupae busting is an important tool in reducing the proportion of the *Helicoverpa* population carrying insecticide resistance from one season to the next.
- Rank crop** A rank crop is usually very tall (long internode lengths) with excessive vegetative plant structures. This can be caused by a number of factors including excessive fertiliser use, pest damage and crop responses to ideal growing conditions especially hot weather. Rank crops can be difficult to spray and to harvest and may have delayed maturity or reduced yield. Seed company web sites detail methods to assess plant growth to test if a plant growth regulator might be needed to prevent such rank growth.
- Ratoon cotton** A cotton crop in which the stalks are cut down after harvest, but the crown and rootstock are left in the ground to regrow the following season. For pest and disease reasons, this form of cropping is not used in Australia.
- Refuge** This term is used to refer to crops grown specifically as a requirement of the Bollgard II® licence to produce *Bacillus thuringiensis* (Bt) susceptible *Helicoverpa* spp.
- Rotation crops** Other crop types grown before or after the cotton is grown.
- Scouting** Checking crops (e.g. for insects, damage, weeds, growth etc).
- Secondary pests** Pests such as spider mites, aphids or whiteflies which do not usually become a problem unless their natural enemies (predators or parasites) are reduced in number by insecticides. See also 'Pest Flaring'.
- Seed bed** A type of mound on which furrow irrigated cotton is grown.
- Seed treatment** An insecticide/fungicide used to coat cotton seeds to offer a period of protection during germination and establishment against some ground dwelling pests eg. wireworm and some early fo
- Selection pressure** The number of times insecticides from a particular chemical group are sprayed onto a cotton crop. Each of these spray events will control susceptible individuals, leaving behind those that are resistant. More selection events means that there is greater 'pressure' or chance of selecting a resistant population.
- Side-dressing** Normally refers to adding an in-crop fertiliser.
- Single skip** A row configuration used in dryland/semi irrigated situations to conserve soil moisture.
- Sodicity** A measure of exchangeable sodium in relation to other exchangeable cations. A sodic soil contains sufficient exchangeable sodium to interfere with the growth of plants.
- 'Soft' approach** Managing insect and mite pests using pesticides and other approaches that have limited effect on beneficial insect populations.
- SOILpak** Information about cotton soils.
- Soil water deficit** The difference between a full soil moisture profile and the current soil moisture level.
- Solid plant** A row configuration generally used in irrigated cropping and is normally 1m row spacing.
- Solodic soils** Are typical in semi-arid and subhumid climatic zones and tend to be very dense soils with low permeability. The difference between solodic soils and solodized solonetz soils occurs in the structure of the B horizon: solodics have a medium to coarse blocky structure whereas solodized solonetz soils have a coarse columnar structure with clearly defined domes on the tops of the columns.
- Spray adjuvant** A substance added to the spray tank that will improve the performance of the chemical.
- Spring tickle** Uses shallow cultivation to promote early germination of weeds prior to sowing. These weeds can then be controlled with a non-selective knockdown herbicide.
- Square** Cotton flower bud.
- Squaring nodes** A node at which a fruiting branch is produced, which is defined as a branch with a square which has a subtending leaf that is fully unfurled and on which all central veins are visible.
- Standing stubble** Stalks from a crop that has been harvested or sprayed out and left to stand in the field.
- Subbing up** An irrigation term referring to the wetting process of the cotton beds.
- Sucking pests** Usually from the group of insects known as hemiptera or bugs which have piercing tubular mouthparts which they insert into plant parts to obtain nutrition. Key among these are green mirids, which feed on cotton terminals, and young squares and bolls. Some bugs inject toxins into the plant when they feed, which if bolls are fed on, may cause seed damage and staining of lint.
- Sweep net** A large cloth net (approximately 60 cm deep) attached to a round aluminium frame which is about 40 cm in diameter with a handle (1 m in length) used to sample insects.
- Synthetic insecticides** Non-biological insecticides. They may be man made versions of natural insecticides (i.e. pyrethroids are synthetic, light stable versions of naturally occurring pyrethrum) or they may simply be man made molecules with insecticidal or miticidal (controls mites) activity. In this manual we have used the term to encompass most insecticides with the exception of Bt sprays, virus sprays, food sprays and petroleum spray oils (PSOs).
- Terminal** The growing tip of a cotton stem, particularly the main stem.
- Tip damage** When the plant terminal has been damaged, also known as tipping out.



Top 5 retention The percentage of first position fruit maintained on the top 5 fruiting branches.

Trap crop – last generation A crop grown to concentrate *Helicoverpa* moths emerging late in the cotton season from the non-diapausing component of pupae from the last generation in autumn. These pupae are likely to be more abundant under conventional cotton and will have had intense insecticide resistance selection. The aim is to have these moths lay their eggs in the trap crop where the resulting pupae can be controlled by cultivation.

Trap crop – Spring A crop grown to concentrate *Helicoverpa armigera* moths emerging from diapause, usually between September and October. These moths will establish the first generation of larvae in these crops, where they can be killed using biological insecticides (ie. virus sprays) or by cultivation to kill the resulting pupae.

Trap crop – Summer A crop grown to draw *Helicoverpa armigera* away from a susceptible crop like cotton, and which can also produce large numbers of beneficial insects. The aim is to have these moths lay their eggs in the trap crop where the resulting larvae can be controlled using biological insecticides (i.e. virus) or the pupae controlled by cultivation.

True leaves Any leaf produced after the cotyledons.

VAM Vesicular Arbuscular Mycorrhiza: now called AM. (see above)

Vegetative growth The roots, stems and leaves as distinct from the reproductive growth of flowers and bolls.

Vertisols Clay-rich soils that shrink and swell with changes in moisture content.

Visual sampling Sampling insects in the field with the naked eye without the use of other equipment. See also 'Beat sheets', 'Sweep net' and 'D-vac'.

V Rank A rank that each cotton variety is given in accordance with its resistance to the cotton disease Verticillium Wilt.

Water stress When the demand for water to maintain plant function exceeds the amount available to the plant from the soil.

Waterlogging When the plant roots endure a prolonged period under water, the lack of oxygen impairs water and nutrient uptake, both of which will have a direct effect on growth and yield.

WATERpak An information resource for cotton water use and management.

Acronyms used in the cotton industry

AAAA – Aerial Agricultural Association of Australia

ACPA – Australian Cotton Pickers Association

ACRI – Australian Cotton Research Institute Narrabri

ACSA – Australian Cotton Shippers association

AIRAC – Avcare Insecticides Resistance Action Committee

APSRU – Agricultural Production Systems Research Unit

APVMA – Agricultural Pesticides and Veterinary Medicines Authority

AWM – Area Wide Management

CCA – Crop Consultants Australia Inc.

CGA – Cotton Growers Association

CA – Cotton Australia

CRDC – Cotton Research & Development Corporation Cotton

CRC – Cotton Catchment Communities Cooperative Research Centre

CSD – Cotton Seed Distributors

CSIRO – Commonwealth Scientific & Industrial Research Organisation

DAFF – Department Agriculture Fisheries and Forestry

EC – Electrical Conductivity

EM Survey – Electromagnetic Survey

EPA – Environmental Protection Authority (NSW/QLD)

ESP – Exchangeable Sodium Percentage

GPS – Global Positioning System

GVB – Green Vegetable Bug

ICAC – International Cotton Advisory Committee

ICE – Intercontinental Exchange

IPM – Integrated Pest Management

IRMS – Insecticide Resistance Management Strategy

IWM – Integrated Weed Management

MIS – Multispectral Imaging System

NSW DPI – New South Wales Department of Primary Industries

OGTR – Office of the Gene Technology Regulator

Qld DAFF – Queensland Department of Agriculture, Fishery & Forestry

RCMAC – Raw Cotton Marketing & Advisory Committee

SLW – Silver Leaf Whitefly

TIMS – Transgenic & Insect Management Strategy (Committee)

TRC – Cotton CRC Technology Resource Centre

TSP – Technical Service Provider

TSV – Tobacco Streak Virus

TUA – Technology User Agreement

ULV – Ultra Low Volume

VGR – Vegetative Growth Rate

WUE – Water Use Efficiency

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The Cotton Industry Development and Delivery Team recognises and appreciates all contributors to the third Australian Cotton Production Manual





CANOPY. THE SIMPLE SOLUTION.



Managing early season sucking pests just got a whole lot simpler. That's because Canopy® has added yet another string to its bow with registration for suppression of silverleaf whitefly in cotton.

So give your resistance-risky insecticides a break, dodge secondary pest flaring, and maybe avoid an expensive late season clean-up spray by using Canopy® at every early season spray opportunity.

This way you'll keep on top of aphids, green mirids, and now silverleaf whitefly all at the same time.

With registered uses through the whole cotton season and beyond into winter cropping, **Canopy® is clearly the simple solution.**



Download a free QR Code reader App from your App store and scan this QR Code with your smartphone. This will take you directly to the most up-to-date information about Canopy® for cotton.



PRECISION
SPRAY OILS