During my travels under the Nuffield scholarship, I sought to develop a blueprint for the cotton industry in northern Australia, but through various meetings with Brazilian farmers, agronomists and researchers, it became clear that a rigid year-on-year production plan in these climatic conditions doesn’t exist. There are so many variables at play in the tropics, it is vital to retain as much flexibility as possible for when the unexpected situation invariably arises.

A holistic approach, which assesses major crop indicators, varying climatic influences and uses area wide management systems, is necessary.

Northern Australia is broadly defined as all country North of the tropic of Capricorn, as shown in Figure 1.

**FIGURE 1**

Northern Australia differs from the traditional cotton growing areas because the crop is planted when temperatures and daylight hours are decreasing. Previous attempts at Ord cotton production involved planting during April and May, at the beginning of the dry season, which meant the crop was flowering and filling bolls during the shortest and coolest days of the year.

The optimum time for flowering and boll fill in the Ord is April-May, which means crops need to be planted from mid-January through until the end of February to take full advantage. But this meant exposing the crop to the peak season for Spodoptera litura.

The commercial introduction of Bollgard 3 to the Australian cotton industry provided northern Australia with the opportunity to re-assess wet season cotton, because Bollgard 3 is effective against Spodoptera litura (cluster caterpillar).

After visiting farmers and researchers from around the world, as well as using some of my own experiences trialling cotton in the ORIA in 2018, I gained insight into what the key factors are for producing cotton in the north. The factors are complex, and Eduardo Kawakami of TMG in Brazil summarised the approach.

“Everyone wants to know the cake mix for tropical cotton – there isn’t one. You must be in the crop assessing what it is telling you, what the weather is going to do, then make a decision on what to do next.”

Research, development and experience have provided a production blueprint for how to best manage cotton crops in June–July 2020

**AT A GLANCE…**

In 2012, Kimberley Agricultural Investment (KAI) was named as preferred proponent to develop Stage Two in the Ord River Irrigation Area (ORIA). Since 2012 KAI has assembled approximately 27,000 hectares in various land parcels with the aim of developing a fully integrated agricultural operation in the East Kimberley.

KAI’s initial focus had been on high value grains such as chia and quinoa as well as maize, chickpeas and sorghum, but with the rate of development and size of the eventual operation, a crop that can be grown on an extensive scale has been sought.

Trials of Bollgard 3 cotton varieties in the ORIA from 2013–16 and in larger trials in 2016–17 showed promising results. But while providing a potential option for extensive production, the introduction of cotton back to the region has raised plenty of questions. It was these questions that led Luke to apply for and receive a Nuffield Scholarship with the support of Cotton Australia and Cotton Research and Development Corporation (CRDC).

As KIA was moving toward cotton production, Dr Stephen Yeates of the CSIRO advised Luke that if he wanted to understand tropical cotton, he should go to Brazil. Stephen put him in touch with Eduardo Kawakami of seed company TMG in Brazil. Eduardo hosted Luke for nearly two weeks, showing him cotton all over Brazil from Sapezal in north western Mato Grosso to Barreiras in the State of Bahia and everywhere in between.

The initial research focus was weighted towards setting up the farm to adapt to cotton, specifically double cropping, rotation crops, irrigation methods, staff requirements, machinery requirements, resource and environmental management.

Attempts at cotton production in the Ord had always concentrated on dry season crops, but during 2018, KAI planted the first commercial wet season cotton crop since the 1970s. Luke’s experience with this crop, along with lessons learnt in Brazil and elsewhere, have greatly influenced his approach to cotton production in tropical Australia.

Northern Australia currently lacks production scale, ginning, processing and logistics infrastructure. These factors are dependent on each other in a ‘horse and cart’ scenario that has been a constant feature of northern development to date. Recent developments in the tropics may enable investment decisions in production capacity and infrastructure to be made with more certainty and a viable cotton industry in northern Australia established.
temperate Australia. My initial focus was to develop a similar blueprint for northern Australia, but the focus has shifted to better understanding crop growth responses in the tropics and being prepared with flexible agronomic management tactics when required.

Management of cotton in the tropics does not stop after picking or at the farm gate. There is sufficient temperature, and in an irrigation system adequate moisture, for the crop to persist year-round. This extends exposure to the Bt toxins as well as creating a ‘green bridge’ for pests to survive the off-season and immediately move into a crop the following year.

Control of ratoon and volunteer cotton post-harvest is important everywhere, but in the tropics it is vital. Double cropping becomes an option in tropical areas, but continuous 12-month cropping, whether cotton or a combination of other crops, is the fastest way to build up pest populations and select for resistance in northern Australia.

This risk is not limited to pests controlled by the Bt toxins. Solenopsis mealybug provides a good example of why creating a fallow period free of hosts is important. Mealybug currently has limited chemical control options with the most effective control method being to encourage and preserve beneficial insect predators and enact strict on farm hygiene with a host free break of at least three months. This challenge of controlling volunteer cotton will extend to any cotton seed used as a feed source in northern Australia to ensure it does not germinate and become a host for pests within the landscape over time.
In-crop management

What can the plant tell you?

Heat units rapidly accumulate in the tropics and when combined with unlimited moisture and potentially high N the cotton plant can enter periods of extremely fast growth. If a stress occurs the plant will shed fruit but because of the rapid growth, one week of cloudy weather could affect up to four nodes and maybe 25 per cent of the crop.

The start of flowering signals the beginning of a complex period for cotton management in the tropics. The plant must balance concurrent growth as it continues to both develop a canopy while retaining bolls in a tropical environment where photosynthesis may be impacted by variable radiation, hot night temperatures and changes to nitrogen availability in the soil due to rainfall.

Figure 2 shows a cotton crop at Narrabri, NSW against a crop in the Burdekin region of North Queensland, both at first flower. Accepting that cotton grows differently to what most producers expect is the first step in preparing to manage the crop in the tropics. Both these crops had a similar yield of 12 bales per hectare.

Nutrition

Difficulties emerge in the tropics with managing availability of nutrients as rainfall can cause both nutrient loss and make application of artificial nutrients difficult.

Research by Dr Stephen Yeates has shown that nitrogen uptake can be as low as 13 per cent on clay soils during the wet season, when applied before, or at planting, when using urea.

While the plant may be showing signs of N deficiency, a flexible management strategy to limit losses and maximise uptake must be in place, because weather conditions may not allow timely applications.

Fruit retention

Temperate environment crops are managed to maintain retention at or above 60 per cent during squaring and peak flowering. Crops in northern Australia have more ability to compensate for early fruit losses, but this does not mean that crop growth can be extended without consequence. Pushing maturity later into cooler weather may still have detrimental effects for yield potential, lint quality and increase crop exposure to pest insects.

Canopy

Row closure in the tropics is much earlier in the season and this can reduce light penetration to the lower canopy and effect boll retention and growth. This rapid growth may promote fruit shedding and lead to later boll set, causing a ‘top crop,’ and a delay in crop maturity. Figures 3 and 4 show cotton plants from Sapezal in Mato Grosso (Figure 3) and Bahia (Figure 4) in Brazil. Both show the plants’ preference to set a top crop as opposed to bottom fruit traditionally seen in southern Australia.

In the photo from Bahia (Figure 4), the plant the author is holding was cut off around 70 cm from the ground. There were four small bolls below that point, and the nine nodes above it held 24 bolls.

This farm was owned by Grupo Horita where the average yield for the season was 9.25 bales per hectare, all rain fed. Brazilian farmers allow the crop to grow to 1.3 metres tall to maximise node production and top crop potential, and are not worried if the crop is up to 1.5 metres tall.
Roots

Root development reflects the location of moisture available to the plant. If continued wet weather is experienced, the plant has no need to extend roots down to find moisture. In extremely wet weather, roots have been observed developing sideways into a bed in an effort to get away from waterlogged furrows. The roots give an indication of the soil water conditions that the plant has been exposed to, which the crop manager can use to predict how the crop might respond to irrigation or future weather conditions.

Nodes Above White Flower

Nodes Above White Flower (NAWF) is a measurement to show whether the crop is still actively growing during flowering. There is a risk when transitioning from wet to dry season conditions that the plant can cut out prematurely particularly when large plants have poorly developed root systems that rapidly become stranded in the drying upper soil profile. Measuring NAWF weekly can detect plant stress that is curtailing growth in time to make management adjustments for irrigation or nutrition.

Weather and climate influence

While growers have no control over the climate it is important to understand what different conditions can do to the plant so that decisions can be made to minimise risk or to quickly react to changing conditions. It is easy to view northern Australia as having ideal weather conditions for cotton production, but the intensity and variability of conditions have major impacts on crop growth, and on the partitioning of that growth into vegetative and reproductive components.

Figure 5 shows the average half-month rainfall for the ORIA, but most telling is the extreme variation from the average that can be experienced. Late March for example has an average of 27 mm but a range from 0–150 mm. This illustrates the difficulty in planning operations in the tropics and shows why plans must remain flexible to meet varying conditions.

Management strategies – how do you plan and react?

Individual managers will have different risk appetites but clearly establishing and understanding what you are prepared to sacrifice or lose going into the season is a key step and first in the decision-making process.

Once decisions are made on row spacing, planting rate, variety and sowing date there are three tools available to manage the crop:

- **Nitrogen**;
- **Irrigation**.

Excessive N available to the crop early, combined with moist sunny conditions, can encourage the plant to perennate, because it has it ‘too good’ and sees no need to reproduce until conditions change.

There are various agronomic options available to limit the excess uptake of N.

In Brazil I saw a trial using the legume crotalaria as a cover crop before cotton. Crotalaria can reduce nematodes and also fix nitrogen – with up to 60 kg of N available to the following cotton crop.

Another management tool available is the use of delayed-release N products.

**Growth regulator management**

Based on Burdekin research, Paul Grundy says there are three key principles to using Mepiquat chloride (Pix) successfully in the tropics:

- Do not apply it to stressed plants or when an immediate stress is likely;
- Check what the goal is in applying Pix and ask: “Is it the answer?” and,
- Think about the future – What will the weather be like in the coming week? Is my irrigation on schedule and what is my fruit load? You can only impact tomorrow’s growth; if you have a tall plant in front of you, you can’t change that.

The rates and uses are different in the tropics compared to temperate growing regions. Bom Futuro agronomists in Sapezal used a total of two litres per hectare of Pix in the 2018 season over eight applications. One of these applications was 800 ml per hectare at cut out and as little as 150 ml per hectare during earlier crop growth.

**Irrigation**

A tropical crop may be set up for irrigation, but high and continued rainfall may mean the first irrigation may not be until 60 days after planting for a mid-January planted crop. A crop in this situation is likely to have a small root system relative to the large canopy. Irrigation needs to be scheduled to give the plant time to adapt to the changing conditions.

After receiving weeks of rain and a full soil profile it is easy to under-estimate the moisture requirements of the plant. Irrigations may need to be as soon as five days after the previous rainfall event and scheduling should take into account the ability to irrigate the entire program soon after the last effective rainfall has occurred.

Alternatively, a low rainfall season may require earlier irrigation and combined with warm sunny days and high nutrition can send the plant into excessive vegetative growth. Fruit counts to establish total fruit per metre is the best indicator of the need for irrigation at this stage. Placing moisture stress on the plant at this point could be beneficial to encourage it to produce more fruit. Once there is fruit on the plant, the moisture demand changes and irrigation is needed to hold and mature that fruit, or to develop more, to achieve the yield target.

**Making effective decisions in-crop**

Defining a manager’s appetite for risk is a key point in the decision-making process. The next key point is setting a yield target and knowing how many bolls per metre are needed to achieve this. It is not suitable for the target to be ‘as high as possible.’ Decisions to push the plant above the initial target

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**FIGURE 5: The average half-month rainfall for the Ord River Irrigation Area**

![Image showing average half-month rainfall for the Ord River Irrigation Area](image-url)
Applied in-furrow at planting, Yara Liquids FLOWPHOS fertilisers deliver a concentrated band of water-soluble, readily-accessible nitrogen, phosphorus, potassium, sulphur and zinc directly to where it’s needed most. Made from the highest quality ingredients and to guaranteed specification, FLOWPHOS liquid fertilisers offer unbeatable accuracy and the convenience of constant or variable rate application. Contact Yara and find out how Yara Liquids FLOWPHOS can give your cotton the best start.
should be assessed against the impact on the whole cropping system.

**The case for Area-Wide Management**

As part of the northern RMP (Northern Resistance Management Plan), all Bollgard 3 crops must be slashed or mulched and controlled to prevent regrowth within four weeks of harvesting.

Northern Australia does not have the benefit of a cold winter and frosts to assist in killing survivors, but effective crop destruction and control of ratoon and volunteer cotton has benefits beyond the risk reduction for Bt.

Positive outcomes can be achieved from a coordinated, unified industry-wide approach to a problem.

For example, in Brazil there is no industry-wide approach to boll weevil control and some farmers are spraying up to 18 times a season and spending over USD $200 per hectare to control the pest – around 10 per cent of total production costs. We shouldn’t forget how the Ord cotton industry was shut down in the 1970s, when farmers were using a similar number of applications for caterpillars.

Control of boll weevil requires the use of broad-spectrum insecticides, meaning a reduction of beneficial predators of sucking pests like whitefly, with some severe honeydew problems.

In contrast, the Texas Boll Weevil Eradication Foundation (TBWEF) was established in 1993 to eliminate boll weevil from cotton fields in Texas using cooperative area-wide control. Once they started the eradication, growers started to see the ‘top crop’ set fruit and contribute yield. No one thought that cotton could grow like that on the plains, such was the influence of the boll weevil. The program’s success depends on the involvement of every cotton grower.

**Lessons for northern Australia**

Mealybug was first identified in the Ord in 2004 and then identified in Queensland cotton crops in 2009 before moving south.

There are currently only limited chemical controls available for mealybug, so Integrated Pest Management (IPM) is the most effective method available.

The key method in IPM for mealybug in northern Australia will be to maximise host-free periods between crops and deny the pest a food source. In just about every case of mealybug outbreak encountered in commercial cotton fields, there has been a ratoon or volunteer plant nearby.

The field in Figure 6 was twice offset ploughed post-harvest, but ratoon cotton is seen here persisting in a strip along the head ditch in January 2019, four months after harvest. Ultimately multiple herbicide passes killed the plants but this was only possible because the plants were reachable from a trafficable area. When this photo was taken the rest of the paddock was too wet to access with machinery.

If this survival rate was widespread the only effective solution would be tillage, difficult during the wet season in the ORIA.

**Conclusion**

Cotton can be grown successfully in northern Australia, but differences between tropical and temperate environments and the implications for the crop, pests and diseases need to be considered.

The speed at which the crop develops and at which conditions change mean that managers need to be constantly assessing the crop and tweaking their management to suit the conditions. As discovered in Brazil, there is no recipe for tropical cotton production. Most farmers and pastoralists in northern Australia will tell you no two wet seasons are the same, so it makes sense that a production plan will differ year to year to match this variability.

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**Figure 6:** Ratoon cotton in the Ord (left) and mealybug found on these plants (right).